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ILCA

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Livestock systems research manual

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Preface

In its research work ILCA has always used and continues to use a farming systems approach. At the same time both in its mandate and as one of its operational goals ILCA seeks to improve the capacity of Africa's national agricultural research systems. This manual presents the fruits of both ILCA's own long experience of livestock systems research and of the expertise and efforts of others in this field.

The intended audience are primarily African scientists who are working for national research organisations and who are in need of reference materials and of practical examples of livestock systems research. The manual may also be of use to a wider audience, including those who need to study livestock systems in Africa in the context of development activities rather than research.

The manual has been produced as an ILCA Working Paper (in two volumes) for a number of reasons. One of these is that there will never be a 'final word' in livestock systems research, because new techniques will be continually invented and old ones adapted. At its first appearance there are parts of this manual which are already in need of updating.

Another reason is that the manual as a whole has not been formally reviewed as have other ILCA official publications and manuals, in an external peer review process. Of course, individual modules have been extensively reviewed both internally within ILCA and externally. But if anyone indeed existed who had the breadth of experience and knowledge to be able to review the manual as a whole, that person would be in such demand that he or she would not have the time to do the review.

ILCA has therefore decided to circulate this manual as a Working Paper, initially in a limited edition to a number of people from different backgrounds but who are known to be most active and most interested in livestock systems research. You are one of these. We should be most grateful for your comments, your proposals for amendment, and your suggestions about how it might be made more sound and more useful. We shall then, unless you tell us otherwise, present it to a wider audience.

All comments on the manual should be sent to ILCA marked 'For the attention of the Head of Livestock Economics Division'.

Acknowledgements

Work on the *Livestock systems research manual* started in 1986 and has been conducted under the supervision of a Steering Committee of ILCA staff. The work was executed within the programme of the Livestock Policy and Resource Use Thrust.

The manual is primarily the product of Martin Doran who worked at it in stretches over a period of two years. He drew so much on the knowledge, skills and assistance of ILCA scientists that authorship has been attributed to ILCA as a whole rather than to any one individual. Nevertheless, Martin Doran drafted almost every word of the manual. He did so with the general support of Stephen Sandford who, as coordinator of the Livestock Policy and Resource Use Thrust, reviewed and commented repeatedly on almost every part of the manual. The third major contributor was Inca Alipui. She was instrumental in adding clarity and precision, and in making the manual easier to read went far beyond the normal role of a language editor.

Other substantial contributors to Section 1 of the manual were John McIntire, whose constructive comments shaped Module 3, and Barbara Grandin who helped with data and reference material; Trevor Wilson who provided data and extensive reference material for Module 5; John Tothill who was most helpful in the writing up of Module 6; Jess Reed and Douglas Little who commented on Module 7; and Brian Perry of ILRAD, Nairobi, without whose substantial input in the form of data and references Module 8 would have been incomplete.

Comments on the first draft were given by Ralph von Kaufmann (Module 3); Barbara Grandin and Solomon Bekure (Module 4); Ray Brokken (Module 5); Pieter de Leeuw and Pierre Hiernaux (Module 6); Michael Goe (Module 7); and Olajide Kasali and Eddie Mukasa-Mugerwa (Module 8). In addition to commenting on range resource evaluation, Pieter de Leeuw read the whole Section 1 of the manual for technical accuracy.

John Sherrington, ILCA's biometrician, rewrote the greater part of Module 11 in Section 1 and commented on the statistics in Section 2. Credit for the contents of the main statistical module (number 2) in Section 2 goes to Robin Sayers, his predecessor. Brian Perry's substantial contribution to the Animal Health Appendix to Module 2 is also gratefully acknowledged.

SECTION 1

INTRODUCTION

INTRODUCTION

This manual has been written for people working in national agricultural research systems (NARS) in sub-Saharan Africa. It is also relevant to those involved in training and programme planning for the livestock sectors in the region.

The manual assumes a basic understanding of the farming systems research[1] approach and provides a comprehensive bibliography on the subject.[2] It draws mainly, but not exclusively, on the research experiences of the International Livestock Centre for Africa (ILCA) and emphasises those areas in which particular expertise has been developed.

A discussion of on-station research methodology is not included, since this subject is dealt with elsewhere in the literature (e.g. Little and Hills, 1978), but the importance of maintaining strong links between on-farm and on-station research is emphasised (Module 2, Section 2). The focus is on the principles of livestock systems research which are generally applicable to the different types of production system (pastoral, agropastoral and mixed) in Africa, and when differences occur, they are given specific attention.

Part A of this Introduction gives a brief outline of the theory and practice of livestock systems research for those who wish to refresh their minds about the basic concepts and stages involved in this type of research. Part B shows how ILCA has been involved in systems research, and Part C outlines the structure of the manual by section and module to facilitate its use.

PART A: FUNDAMENTAL CONSIDERATIONS IN LIVESTOCK SYSTEMS RESEARCH

The system perspective

Over the last two decades, the performance of the livestock sector in Africa has been poor: output has grown at a low rate; per caput consumption and self-sufficiency rates have declined; imports of the major livestock commodities have risen; and environmental degradation is apparent (Sandford, 1983). The reasons for this poor performance reflect inappropriate policies, institutional deficiencies, resource constraints and a failure to design projects and technologies which are widely applicable to the problems commonly confronted.

Failures in technology development have stemmed from:

- weak links between agencies involved in research and those involved with the traditional farm sector. Technologies have therefore tended to be either irrelevant or only partially relevant to the producer.
- emphasis given to technologies and criteria of performance developed in high-income countries (Behnke, 1984; de Ridder and Wagenaar, 1986a, b).
- failure to understand the situation of the small farmer/pastoralist. In general, the knowledge of the factors which influence production decisions at the farm level has been inadequate (Anderson, 1979; Byerlee and Collinson, 1980; Gilbert et al, 1980). A 'systems approach' to research is now generally recognised as the most appropriate means of gaining such knowledge.

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1 In the context of the terminology used at the farming systems research conference held at ICRISAT in India in 1986, the manual concentrates on'adaptive systems research methodology'. However, in order to maintain consistency with ILCA's literature on the subject, the term 'livestock systems research' (LSR) is used throughout.

2 The bibliography provides references on crop and livestock systems research within the region.

A properly applied farming systems approach should:

- begin ***without pre-conceptions*** about the nature of the system
- be ***improvement-oriented***
- ***examine interactions/relationships*** between the internal (endogenous) and external (exogenous) factors affecting household production goals, decisions and levels of performance, and, from this information, attempt to identify constraints to production at the household level
- be ***multidisciplinary in approach***. This is necessary if interactions are to be adequately understood and constraints to production correctly identified.
- ***involve the farmer/pastoralist*** in the process of system description and diagnosis and the development of solutions, and
- ***evaluate 'solutions'*** in terms of their effects on the productivity, equity, stability and sustainability of the system.

Note: While the need for an appropriate policy and institutional framework is indisputable, emphasis is given to improving productivity and/or reducing risk through the development of new technologies.[3] Issues such as stability, sustainability and equity have been given little attention to date, and conflicts between private and social goals have been difficult to resolve (Byerlee and Collinson, 1980; Gilbert et al, 1980; Caldwell, 1984; Conway, 1985; Norman and Collinson, 1985; Bawden et al, 1985; Caldwell and Walecka, 1986; IARCs, 1987).

Livestock systems research

Livestock production systems in Africa have a number of distinguishing features which can influence the methods of livestock systems research. They are:

- **livestock mobility**

  For instance, pastoral herds are highly mobile, and this affects the manner in which data can be collected and trials conducted.

- **producer attitudes**

  Because of the value attached to livestock, particularly cattle, producers tend to be unwilling to divulge information about the livestock they own or hold and to participate in trials.

- **multiple outputs**

  Livestock in Africa produce meat, milk, draught power, manure and other commodities. Some of these outputs are difficult to measure and value.

- **communal land tenure systems**

  Communal grazing of livestock poses problems for on-farm/ on-range trials and limits the scope for technological improvement.

- **life-cycle duration**

  The life cycle of cattle is relatively long, thereby increasing the cost of research and reducing the chances of long-term participation by farmers and pastoralists in trials.

- **life-cycle synchronisation**

  This can pose a problem when collecting production data or for on-farm trials, since in some systems, it is extremely difficult to obtain enough animals of the same age, sex and parity.

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3 The significance of an appropriate policy and institutional framework must be recognised at the outset. Inappropriate policies can, for example, restrict the uptake of new technology and may, therefore, have to be corrected before innovations can be widely adopted. Alternatively, livestock systems research may, by its findings, provide the basis for policy reform (CIMMYT, 1985).

These problems are discussed in greater detail in Module 1 (Section 2). They are elaborated in the literature by Bernsten et al (1984) and Gryseels (1986) and debated by McIntire (1986).

Sequencing livestock systems research

While the characteristics of particular livestock systems may influence the methodology of livestock systems research, the terminology used and the sequencing of activities into phases is similar for all types of farming systems research (Zandstra, 1980; Byerlee and Collinson, 1980; Flora, 1984; Norman and Collinson, 1985; Caldwell and Walecka, 1986). The phases commonly identified[4] are:

- **the descriptive/diagnostic phase**
- **the design phase**
- **the testing phase**, and
- **the extension phase.**

The main objectives of the ***DESCRIPTIVE/DIAGNOSTIC PHASE*** are to:

- ***Describe the production system*** of each identified target group, using secondary data and informal surveys.

  This involves a preliminary analysis of the internal and external factors which influence household production decisions and goals (Module 1, Section 1) (Butler, 1984; CIMMYT, 1985; Grandin, 1988).

  A proper understanding and interpretation of these wider features of the system is critical to technological design. The adoption of technology at a later stage will often be dependent on correct initial interpretation of the general characteristics of a system – a fact which is often ignored or given inadequate attention (Barlow et al, 1986).

- ***Identify the target group*** for which intervention is intended.

  The aim at this stage is to divide farmers or pastoralists into relatively homogeneous groups ('recommendation domains') on the basis of socio-cultural, environmental, institutional and economic characteristics, assuming that decisions about production and technology adoption within each group will be guided by similar considerations (Module 1 and Appendix 1, Section 1). More than one group may be identified. Secondary data sources and informal surveys are initially used for the purpose of group identification, but refinements resulting from the findings of formal diagnostic surveys and/or on-farm trials will often be required.

- ***Identify the factors which constrain or limit production and income*** within each target group by examining the existing relationships/linkages.

  Constraints can sometimes be identified by reference to secondary data sources and/or through informal contacts with farmers and other informed people within the target area (Module 1, Section 1). At other times, further in-depth analyses of the system based on formal diagnostic survey techniques may be required.

  Such analyses may be of a general nature (Module 2, Section 1), or they may be confined to specific issues (e.g. labour resources, animal health, nutrition – Modules 3–10, Section 1). For the general type of study, low-cost, rapid survey techniques using once-off questionnaires are normally sufficient (CIMMYT, 1985), but for the more in-depth study, repeat visits will often be required.

4 The phases described are not always as distinct as might be implied in the literature. In practice, different LSR activities will overlap during the 'testing phase', for example, and system diagnosis and description may have to be continued as new insights emerge.

- ***Determine*** whether there is ***scope for improvement*** within the system being analysed, so as to decide on an appropriate course of action.

  Available technologies should be 'pre-screened' for their suitability to the environment and the particular social and economic circumstances in each target area (Module 1, Section 1; Module 1, Section 2). A multidisciplinary team approach to problem identification and evaluation of alternative 'solutions' are strongly recommended.[5]

  During the *DESIGN PHASE*, the focus is on technologies which are compatible with the resources and objectives of the producer and consistent with the system features identified during the descriptive/diagnostic phase. The two major rules are:

- ***Adaptation of technologies already developed*** by commodity research programmes will normally be given priority. Research institutions and extension agents should therefore be consulted to determine the suitability of these technologies to the circumstances of the target group.

- ***All feasible options*** should be evaluated, using technical, economic and institutional criteria and a multidisciplinary team approach. Technologies tested during the on-farm trial phase may be commodity specific or they may need to be addressed to whole-farm issues which limit production and income (Norman and Collinson, 1985).

  Another good rule is to determine whether the technologies identified or developed should actually aim to overcome constraints or to work within them, by exploiting the possibilities in the system. The decision will depend mainly on the types of technology currently available for adaptation, the degree of flexibility within the system itself, and the severity of the constraints encountered.

  In the short term, significant improvements will often be achieved through technologies which exploit the existing options, but major long-term increases can only be obtained by overcoming constraints to production. Part B of Module 6 (Section 1) gives examples.

  When selecting among existing technologies for improvement and designing new ones, the economic implications of adoption need to be carefully considered. This is done using prices and costs appropriate to the circumstances of the farmer or pastoralist. Given the normal time-lag between design, testing and extension of new technologies, prices and costs should be based on future trend estimates (Barlow et al, 1986).

During the *TESTING PHASE*, the objective is to test, by on-farm trials, the solutions proposed during design. Initial assumptions about the characteristics of producers and the environment in which they operate, should also be re-assessed. Modifications to design will often be necessary as new information comes to light during the trial period. Access to research station facilities is therefore advantageous, since refinements are often best carried out under controlled conditions which allow careful monitoring of interactions and responses (Module 2, Section 2).

The following general principles apply for this phase:

- ***Farmers should be involved*** in the trial process and in the evaluation of technologies (Harrington, 1980; Norman and Collinson, 1985). They should, where possible, be representative[6] of the target area or group (Gilbert et al, 1980).

- ***Levels of farmer/researcher involvement*** need to be carefully defined at the outset and should take into account the characteristics and objectives of the trial. Trials should be planned in accordance with the financial and manpower resources available to the research team.

5 The composition of the team will depend on financial and manpower resources. It will largely determine the type of research to be conducted and may need to be altered as new priorities emerge or as new insights are obtained.

6 Logistical considerations may prevent selection of representative participants, particularly when they are widely dispersed within the target area.

- ***Experiments should be simple***, the number and complexity of the treatments declining as the level of farmer involvement in the management of the trial increases. (Module 2 in Section 2 gives guidelines on the type and complexity of treatments used under different levels of trial management.)
- ***Results need to be evaluated*** on the basis of several criteria, including statistical significance, financial and economic performance, farmer assessment, environmental and equity considerations.
- ***Replication of experiments over time*** is generally necessary. This is because satisfactory initial results will often be followed by disappointing later outcomes (Price, 1983).
- ***The transferability of tested technologies to farmers outside the target area*** should be assessed. To a large extent, this will depend on the flexibility of the technologies and on the particular characteristics of the target area.

For livestock on-farm trials, the following additional points apply:

- ***Often, it is more appropriate to conduct trials aimed at monitoring farmers' reactions*** to the innovation, rather than attempting to obtain statistically analysable results, since obtaining the sample size required to conduct the latter type of trial is extremely difficult. This is particularly the case when the animals need to be grouped or 'blocked' on the basis of like characteristics, such as age, sex and parity.
- ***Adequate supervision*** is a must particularly in trials conducted for the purpose of statistical analysis. Trial supervision can be extremely difficult when livestock are involved. Often, selected animals are dispersed over a wide area, making adequate supervision logistically impossible. At other times, participating farmers 'switch' animals between treatments if one group is observed to perform better than another. Module 2 in Section 2 outlines these problems and the ways in which they can be overcome.

The objective of the *EXTENSION PHASE* is to assess the impact of new technology in the wider community, not only the target area, by monitoring its uptake and examining its interactions with:

- production levels and the use of inputs
- resource allocation (e.g. in terms of changing land-use patterns)
- institutions (e.g. markets and credit), and
- different social groups (i.e. who benefits from the improvement?).

The extension phase is when the real testing takes place and causes for success or failure are carefully assessed to ensure that the adaptive research process continues. This requires that contact with farmers, extension agents and researchers is maintained and feedback is ensured (von Kaufmann, 1986).

On-going monitoring and evaluation of technological impact should provide the basis for improving designs and developing new strategies to fit changing circumstances. In practice, however, this phase of systems research has been the most neglected (Barlow et al, 1986).

Practical considerations in livestock systems research

The practical aspects of operation need to be carefully considered both at the beginning and during the implementation of any systems research programme, since they will often determine the success or failure of work carried out during the first three stages of livestock systems research and, consequently, the long- term impact of the programme.

Among these operational aspects are institutional support, resource availability and time required to complete each phase of the research.

- cultural divisions (e.g. on the basis of ethnic differences)
- logistic considerations (distance or a lack of infrastructure may set limits on the size of the area), and
- the manpower and/or financial resources of the research team.

Each of these aspects should be carefully considered prior to determining the boundaries of the target area. The area eventually selected may incorporate several of these considerations - e.g. it may be within one agro-ecological zone, confined to one district and limited in area (within that district) because of manpower, financial and/or logistic reasons.[1] Since circumstances differ between and within countries, it is impossible to give general rules for the selection of study areas but the reasons for their selection should be clearly stated.

Characteristics of the study area. Once the boundaries of the study area have been defined, the features of that area which influence the production patterns of farmers and pastoralists should be described. Such features include:

- political structure
- institutional structure
- historical background
- socio-cultural characteristics
- agro-economic conditions, and
- infrastructural developments.

The links between these factors[2] should be specified and, where possible, the different farming subsystems within the area should be identified and their characteristics broadly defined.[3] Factors outside the boundaries of the area which have a direct influence on its structure and activities should also be recognised and their effects stated (see footnote 1 below).

Target groups. Having obtained a broad overview of the study area, the focus narrows to **preliminary** selection of the target group (or groups) for which research is specifically intended.[4] By focusing on a particular group of farmers or pastoralists, livestock systems research is said to become 'domain specific' in its emphasis.

The conventional farming systems research approach involves **subjective** grouping of farmers/pastoralists into relatively homogeneous strata or 'recommendation domains' on the basis of their socio-cultural, agro-economic and/or institutional/infrastructural characteristics. This assumes that decisions about production and adoption of technological innovations within each identified stratum of farmers/pastoralists will be based on similar considerations and that the research approach used and the recommendations made will be uniform for each group (Gilbert et al, 1980; CIMMYT, 1985, p. 15).[5]

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1 The area selected is likely to be part of a broader system and to be influenced by factors outside its own boundaries. An essential aspect of the descriptive stage of systems research is to define these influences and to understand their effects within the boundaries of the research area as a whole and, ultimately, on the target group(s) selected. A system is defined by Conway (1986) as "an assemblage of elements contained within a boundary such that the elements have strong functional relationships with each other but limited, weak or non-existent relationships with elements in other assemblages".

2 The relationship between different system components (e.g. between agricultural practices and agro-climatic conditions, culture, infrastructure and/or services, such as extension, education and health) can sometimes be more clearly identified by examining the effects of change over time (e.g. the effect of infrastructure on the marketed output of agricultural commodities).

3 In this context, performance should be considered with respect to the productivity, sustainability and equity of the existing farming systems. However, data on these issues are scarce and often unreliable and may need to be verified during the diagnostic stage, after the target group(s) have been selected.

4 Initial target groups may need to be adjusted as new information comes to light during constraint diagnosis or on-farm trials, e.g. if important variations in management within a group are observed.

5 A recommendation domain is a concept which explicitly takes account of socio-economic factors in the definition of groups within a community or area (Harrington and Tripp, n.d.).

However, this approach has been criticised on two grounds:

- Problems can occur if farming practices within the target area are highly variable and if groups are delineated using only one or two criteria (e.g. soil type and climate). The groups so identified may not be as uniform as first thought and the results of the research may have limited applicability. Rigid adherence to groups defined on the basis of one or two criteria may foreclose a wide range of research opportunities (Cornick and Alberti, 1986).

- The initial identification of groups tends to be based on a subjective evaluation of information obtained from secondary data sources or informal interviews, which can be highly inaccurate. Jolly (1986) recommends the use of objective criteria, such as actual production levels, measured levels of input use, household structure and proximity of off-farm employment opportunities,[6] which requires fairly comprehensive formal surveys (Module 2, Section 1). Target groups should, therefore, be identified only tentatively at the descriptive stage.

Producers' circumstances and constraints. This involves collecting information about the factors which influence the production decisions of farmers/pastoralists within each target group. Some of these factors may be external and largely beyond the control of the producer (i.e. **exogenous factors**) or, they may be internal and controlled by the producer or household (i.e. **endogenous factors**). In systems research literature, they are termed as farmer/pastoralist **circumstances** (CIMMYT, 1985, p. 19).

The information obtained about producers should be used to:

- improve understanding about the overall system and management strategies
- identify critical problem areas at the farmer/pastoral level, and
- provide directions for further research (e.g. diagnostic surveys) at the household level.

Understanding the manner in which external and internal factors interact and affect management practices will often point to constraints and indicate pathways for improvement via technological, policy or institutional change. An examination of management practices may provide insights about the constraints, priorities and attitudes which affect the potential for change. Understanding why a particular practice is not adopted can also be informative (data on herd structure can, for instance, provide useful information about management aspirations and performance levels - see Module 5, Part A).

An understanding of farmer/pastoralist circumstances is thus an essential starting point in livestock systems research. It implies the need to examine relationships/linkages at the farm level, which is usually not possible at the descriptive stage. However, simple intuitive assessments based on information gleaned from secondary data and/or informal interviews will often point to specific issues which can be examined in greater detail by using the diagnostic techniques outlined in Modules 2–10 of Section 1.

Technology pre-screening. Screening of potentially suitable technologies at the descriptive stage involves an initial identification of existing technologies which might be appropriate for a particular target group.[7] It involves the isolation of constraints thought to affect production and income, followed by the selection of technologies which could be used to overcome these constraints or to exploit possibilities for improvement (Gilbert et al, 1980).

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6 Sometimes, one single factor can be found which provides sufficient basis for initial (or even subsequent) identification of target groups. Categorising stock owners on the basis of recognised wealth ranking criteria is one of such factors which may incorporate socio-cultural, political, historical, infrastructural, institutional and economic characteristics of a target group. Wealth ranking is particularly applicable to African production systems in which livestock constitute the major part of a producer's assets (Grandin, 1983; de Haan, 1983) (Appendix).

7 Existing technologies may be considered appropriate without adaptation or they may need to be altered by adaptive research to suit particular circumstances. The reasons for non-adoption or partial adoption should always be identified: for instance, a technology is technically feasible, but its wide adoption will depend on institutional and/or policy reforms. They can sometimes be isolated during the descriptive stage but usually further research will be required (e.g. by diagnosis and on-farm trials).

For each technological possibility, the chances, rate and effects of adoption should be assessed.

When assessing the *chances of adoption,* it should be determined whether:

- The farmer/pastoralist can, in fact, adopt the new technology. This is known as the necessary condition of adoption and will involve the consideration of such aspects as infrastructural support, accessibility of inputs etc.
- The farmer/pastoralist will adopt the new technology. This is known as the sufficient condition of adoption and will involve the consideration of social and economic factors influencing farmer/pastoralist decisions (Caldwell, 1984).

When assessing the *rate of adoption,* it should be borne in mind that the credibility of the research largely depends on how fast it produces results. For this reason, it is often better to opt for technologies which have the potential to achieve modest gains in production quickly, rather than for those which might achieve larger gains over a longer time period. Furthermore, the early introduction of some improvements, even if they are modest, can help to sustain the interest in and support of the research by governments, donors and/or producers, while more long-term and possibly more important improvements are still being worked on (Sandford et al, 1983).

When assessing the *effects of adoption,* one should consider:

- **Effects at the producer level**

  For instance, production effects, income effects, the risks of adoption, and effects at the household level in terms of resource control.

- **Effects on the whole community**

  For instance, the effects of adoption on the environment, on social structure and the distribution of wealth (i.e. who benefits from the technology?)

At both levels, adoption can have both **direct** and **indirect** effects. While the direct effects may be fairly obvious (e.g. an increase in production), indirect effects are often unforeseen, unintended and difficult to measure. Each will determine the potential for and desirability of technological adoption on a wide scale.

In general, the technologies recommended should be compatible with both individual and social objectives but this can be difficult to achieve in practice (Sandford et al, 1983).

> For instance, artificial insemination of dairy cows is likely to result in increased milk production. However, if only the larger, more progressive producers can afford to adopt the technology, income disparity within the target group may widen as a result of its use. Indirect effects may thus outweigh the direct effects of adoption.

PART B: TYPES OF DATA

In order to meet the objectives of the descriptive stage of livestock systems research, three types of data will need to be collected (CIMMYT, 1985). They include data on:

- **the general characteristics of the study area**
- **the specific characteristics of farmers/pastoralists within each target group, and**
- **available technologies which might be applicable to the problems identified.**

General characteristics of the study area

The information gathered about the study area will include:

- political information

- institutional information
- historical information
- socio-cultural information
- information on infrastructure development, and
- data on agro-economic conditions.

Political information. Background information about the organisational structure of government is useful because the formal political hierarchy affects the manner in which government policies are implemented.[8] The policies of government can, in turn, have important effects on the socio-economic characteristics of the study area and the producers within it.

The broad objectives of government at the national, regional, subregional and the relevant subsector levels (e.g. the livestock subsector) should also be recognised at the outset. These objectives are not always explicitly stated (e.g. in policy documents) but can often be gleaned from statements made by politicians or by the priorities evident in development and/or individual sector policies. Apparent conflicts or inconsistencies in government objectives should also be noted.

Institutional information. Background information on the following types of institutional arrangements and structures should be collected:

- land tenure regulations, both formal and informal/traditional
- agricultural institutions such as the extension service (structure, farmer contact/coverage, emphasis), animal health services, credit, cooperative and marketing agencies, farmer organisations, development programmes, and
- other institutions affecting agriculture, e.g. local governments, water development, land development, education and health agencies.

Historical information. Historical events in the study area often determine its present production patterns and socio-cultural characteristics. Interest should focus on the effects of change over time in:

- political and institutional structures
- government policies/priorities
- land tenure arrangements
- infrastructures (markets, roads etc.)
- agricultural production and land use patterns
- off-farm economic developments (e.g. off-farm employment)
- population density and distribution, and
- ethnic/cultural groupings.

Socio-cultural information. Background information about the characteristics of individual cultural groupings within the study area can be obtained from sociological survey reports or by interviewing people from the different groups about their:

- attitudes, preferences and beliefs, e.g. with respect to ownership of livestock, land, trees and grazing rights and the control of social and household resources.

8 A distinction between formal and informal (traditional) types of government may also need to be made. Often, it is the traditional political hierarchy which has the most significant impact on producer decisions. If so, background information about, for instance, the chiefdom, headman and lower levels of this hierarchy would need to be obtained.

- social obligations and linkages, e.g. with respect to different social units within the same cultural group and between different groups.

Infrastructure development. Since availability or lack of particular infrastructure may affect production patterns and attitudes to technological adoption in traditional agriculture, information should be obtained about the following types of infrastructure within the study area:

- marketing facilities/outlets (type and frequency of use)
- road network (condition, accessibility, relationship to markets and other facilities)
- water (dams, stock watering points, their number and dispersion, communities serviced)
- research facilities (type, location, emphasis)
- educational facilities (type, number and dispersion, groups serviced)
- health facilities (type, number and dispersion, groups serviced)
- other rural facilities (e.g. electricity, post, telecommunications, private businesses), and
- urban centres (location, employment, support services, industries).

Agro-economic conditions. Under this category, three types of data should be collected:

- physical data
- biological data, and
- economic data.

Physical data include data on climatic conditions and ecological zones, particularly:

- *rainfall* (total, seasonal[9] and regional distribution patterns, effects on stock movement, crops grown and other agricultural practices)
- *temperature* (maximum, mean, minimum, by ecological region, effects on agricultural practices)
- *topography and geology,* and
- *soils* (types, distribution, effects on agricultural practices).

Biological data include data on:

- *livestock* (species, numbers, management practices, production performance, trends in numbers and production)
- *crops* (types, areas, management practices, yields, trends in production)
- *diseases* (of economic importance for livestock and crops, incidence, effects on agricultural practices[10])
- *pests* (for livestock and crops, incidence, effects on agricultural practices), and
- *nutrition* (feed quality and quantity over the year, alternative sources of feed, effects on management practices; soil fertility and availability of fertiliser).

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9 Variability in climate, prices, costs etc. should be carefully considered because variation introduces risk and this can have important effects on production practices and attitudes to new technologies.

10 The often strong linkages between crop and livestock production can only be understood if some attention is given to the collection of background data on the agro-economic characteristics of the study area during the initial stages of systems research.

Economic data include data on:

- *livestock outputs* (for the different species, sales and offtake rates, purchases, prices by grade, seasonal variations and trends in these variables)
- *crop outputs* (for the different species, sales, prices, seasonal variations and trends)
- *livestock inputs* (inputs used, costs, availability, seasonal variations and trends)
- *crop inputs* (inputs used, costs, availability, seasonal variations and trends), and
- *off-farm data* (employment, wages, seasonal variations and trends; the effect of off-farm employment opportunities on the allocation of resources in agriculture, e.g. on the use of farm labour and inputs).

Specific characteristics of farmers/pastoralists

The opinions of farmers/pastoralists about their environment and the constraints which they face must be taken into account in systems research. This fundamental principle has often been ignored in the past, and technologies developed have tended to be inappropriate as a result (Introduction to this Manual) (Behnke, 1984; Bernsten et al, 1984; de Ridder and Wagenaar, 1986).

Within each selected target group, farmers/pastoralists should specifically be questioned about:

- Their **major farm and non-farm activities** (e.g. livestock and crop enterprises, other farm activities, off-farm employment). Information about yields, the relative importance of different enterprises/activities and the timing of farm/pastoral operations throughout the production year should be obtained.
- **Current practices/technologies**, reasons for their use and reasons for change over time.
- **Perceptions of the system** in which the farmers/pastoralists operate. The exogenous factors (i.e. political, historical, institutional, infrastructural, socio-cultural and economic) which influence production patterns and the links between them should be considered in this context.
- **Endogenous factors** which influence production decisions at the household level (e.g. household resources and decisions, production aspirations or preferences) and the manner in which each affects the other. Reasons for the allocation of land, labour, capital and management resources to different activities should be determined. How household priorities are decided in terms of resource use should also be specified.
- **The constraints** which they perceive to be important and their attitudes to risk, particularly with respect to the adoption of new technologies.
- The manner in which each of the above affects **individual objectives** in respect to production, income and the adoption of new technologies. Such information will enable the researcher to form a preliminary idea of the **objective function** of farmers or pastoralists within each target group (Gilbert et al, 1980).

Available technology

Information needs to be collected about the technologies available to meet the problems initially identified as important. An initial screening as to their applicability can then be carried out by contacting research stations, extension officers and farmers.

PART C: METHODS OF DATA COLLECTION

At all stages in livestock systems research, it is important to ensure that the data collection method adopted is as practical and inexpensive as possible. The need to obtain reliable and useful information should be balanced against the need to complete operations in the shortest possible time. The following types of questions should always be asked before starting any data collection (Gilbert et al, 1980; Butler, 1984; Hart and Calixte, 1984):

What are the objectives of data collection?

Which types of data are needed and why are they needed?

Does the information required already exist?

Which data collection method is the most appropriate?

What quality of data is required?

How long[11] will it take to obtain the information required?

During the descriptive stage of livestock systems research, **rapid survey techniques** are normally used to obtain information from the producers and much of the data gathered is qualitative in nature. The techniques applied thus tend to be less rigorous than those used later in the LSR process. They should nevertheless be based on clearly defined principles relating to the:

- **use of secondary data**
- **types of informal surveys, and**
- **pre-screening of technologies**.

Use of secondary data

When using secondary data to obtain background information on the study area, one should be selective and check all data for accuracy.

Be selective. To ensure that only relevant data are used, a table should be compiled for each type of data needed which lists its source(s), the reason(s) for collection and the level of detail required (see example below). The responsibility for each type of data should be allocated to the team member most familiar with the topic concerned (e.g. livestock production data to a livestock specialist).

Example:

Type of data:	cattle production data
Sources:	annual reports of the Ministry of Agriculture, farm-management survey reports, project documents, extension officers
Detail required:	specific data on herd structures, reproduction rates, mortality rates, offtake rates etc
Reasons for collection:	to obtain livestock performance indicators for the study area
Researcher(s) responsible:	livestock specialist and agricultural economist

11 Drafting a timetable of expected operations (e.g. in the form of a simple bar chart) reinforces the need to continually consider the timing and efficiency of different activities at all stages in the LSR process. Collinson (1972) gives an example of this for a cropping systems research programme. The bar chart used separates the main activities and assigns a period for their completion. Adjustments can be made to the scheduling of operations as the need arises.

Check the data. Secondary data in the Third World are notoriously unreliable (Cornick and Alberti, 1986) and should therefore be checked for **accuracy**. This can often be done by cross-checking information from different sources. Errors can, however, be compounded if one inaccurate report quotes another or if data are used in the wrong context.

It is always useful to cross-check secondary data with people who are familiar with the subject being researched, even if they were not involved in the preparation of reports/statistics.

> For instance, extension officers can be interviewed to cross- check production statistics for an area; because of their experience, their information is often more reliable than that given in official reports. For socio-economic data, the most recent reports should be used as the socio-economic circumstances of an area can change significantly over a period of, say, five years. Reports which are more than five years old should be verified (CIMMYT, 1985).

Secondary data should also be checked for their **adequacy** - i.e. do they provide the level of detail required?

Types of informal survey

Informal interviews are used to confirm or complement the information obtained from secondary data sources and to get insights from producers and community members who are directly involved. They fall into three main categories:

- **Individual interviews** in which a small (non-random) sample of producers within each target group is selected for questioning.

  Individual interviews are relatively informal, the questions being specific for each respondent.[12] Usually, several members of the multidisciplinary team will be involved in an interview, so that observations about the producer and the farming system can be compared.

- **Group interviews** are used to broaden perspectives about the farming system or to obtain insights about the farm/pastoral community itself.

  Group interviews are informal and respondents are encouraged to participate in debates on particular issues affecting the members of the community (e.g. government policies, land tenure issues).

- **Key informant interviews** are directed towards individuals knowledgeable about particular subjects (e.g. the socio-economic characteristics of the target group, the activities of extension staff etc.).

The individuals chosen for this type of interview may be farmers, extension staff, district administrators, traditional leaders (e.g. chiefs, headmen) and traders. Key informant interviews can provide high-quality information on a wide range of topics in a relatively short time. The information obtained should always be cross-checked by interviewing more than one informant on the same subject or by comparing informants' responses with information from other sources (e.g. secondary data).

Principles

For each type of interview, it is necessary to make sure that:

- the right people are selected for the interview
- the right language is used, and

12 This does not imply that only one individual should be interviewed in each selected household (e.g. the household head). Short interviews with several different individuals are often preferable, particularly when operations are allocated to specific sex or age groups (e.g. in pastoral communities, women may be questioned about milking; in mixed farming systems, women may be questioned about cropping practices).

- the right questions are asked so that the right information is obtained (for further details see CIMMYT, 1985, pp. 29–59).

The farmers or pastoralists selected for an interview should be representative of the target group. If selected by an extension officer or senior government official in the area, it is likely that the more progressive producers will be chosen and that the information obtained will not reflect the characteristics of the target group as a whole. Since general impressions of the target group are required at the descriptive stage, it is particularly important to obtain unbiased information about the subsystem and choose representative producers to interview (CIMMYT, 1985).

For group discussions, producers should be drawn from different segments of the target group and all should be encouraged to take part in the debate. Often, the most influential members of the community will dominate the discussion, giving information that is not representative of the views of the entire community. In such cases, the information obtained should be cross-checked by interviewing selected individuals privately or by conducting other group meetings with a different set of people.

For key-informant surveys, one should decide first which information is desired before selecting suitable individuals. If, for example, a farmer is chosen to discuss the farming system of the target group as a whole (not his own farm), then it is important to ensure that he has lived in the area for a number of years, is in farming at present, is knowledgeable about other farms in the area and is willing to give information.

The language and terminology used in informal interviews should be understood and correctly interpreted by all participants. Interviews should be conducted in the respondents' native language and if an interpreter is used, he/she must be fluent in that language and familiar with local concepts and terms.

For all types of informal interview, it is useful to draw up guidelines for discussion beforehand. The CIMMYT (1985) manual, which deals with the diagnosis of farming systems, provides an example of guidelines for cropping systems research in eastern and southern Africa.

Frankenberger and Lichte (1985) give another example of guidelines prepared for reconnaissance surveys in Liberia. The guidelines consisted of sets (categories) of specific topics and were called 'topics of enquiry'. Subtopics were identified within each set of topics to ensure that all necessary information is obtained.

Example: Set A may be concerned with the general characteristics of a production system and the subtopics to be covered may be:

- enterprises/activities on and off the farm
- the relative importance of different enterprises/activities, as indicated by the respondents, and
- changing patterns of production (crops, livestock) and reasons for change over time.

Interviews should normally last between 45 and 60 minutes and may be longer if the interviewed farmer/pastoralist is willing to continue. If the person is not cooperative, he may be interviewed for different information at a later date or, alternatively, a new interviewee may be chosen. At the end of each interview, the information obtained should be summarised in roughly the same format as the guideline itself. It should then be evaluated and gaps in knowledge should be identified to determine whether additional interviews are needed.

Guidelines will vary with the purpose of the interview, the system being studied, and the quantity and quality of information available from other sources. They will only be useful if different members of the multidisciplinary team contribute to their compilation and if there is already some background knowledge of the system.

Technology pre-screening

Pre-screening of technologies during the descriptive stage is likely to consist of two steps:

1. constraint identification, and
2. selection of 'best-bet' technologies.

Step 1. Critical problems[13]and constraints can be identified from secondary data and qualitative information obtained in informal surveys. A matrix or 'checklist table' which relates current management practices to the endogenous and exogenous factors thought to influence or to have the most profound effect on management and production is a useful graphical aid (Byerlee and Collinson, 1980).

> For instance, the researcher may want to find out why farmers in the target group started ploughing operations later than expected. The factors indicated by respondents to be most important were availability of household labour for ploughing and herd structure (i.e. the number of oxen in the herd), but rainfall and land tenure also had an effect. The first two factors are endogenous and because of their major effect on ploughing, they can be marked on the matrix with a double asterisk (**). The symbol for the two exogenous factors (rainfall and land tenure) could be one asterisk (*) to denote that they are thought to influence ploughing time to some extent.

Step 2. After the problems and constraints have been identified, technologies thought to be appropriate to deal with them are listed and the 'best-bet' technological options are selected. Reasons for their selection should be stated (Zandstra, 1980; Byerlee and Collinson, 1980; Gilbert et al, 1980; Bernsten et al, 1984), taking into account:

- the nature of the problem(s)/constraint(s) identified
- the suitability of the technology for the problem(s)/constraint(s) identified
- the compatibility of the technology with farmers' or pastoralists' circumstances and priorities
- the likely social effects of adoption
- the likely speed of adoption, and
- the resources of the research team itself (skills, time and finances).

Byerlee and Collinson (1980, p. 64) suggest that a table should be constructed which relates. The different characteristics of the technology to farmer/pastoralist circumstances which either favour or do not favour each technology characteristic.

13 The problem identified may, for instance, be a low-calving or kidding percentage and the constraints which affect performance may be lack of disease control measures, poor grazing conditions and limited genetic potential of breeding stock.

Example: Assume that introduction of exotic breeds of cattle is identified as a possible technological intervention for an agropastoral community in a semi-arid region. The effects/characteristics of this technological change can then be related to farmer circumstances to help researchers in the pre-screening process. A table similar to the one which follows might be drawn up:

Assumed characteristic of technology	Farmer's circumstances	
	favouring	not favouring
Improved weight gain and carcass quality	Inferior-grade animals usually sold now	Long trekking distance to markets; over-grazing on communal lands
Improved milk production	Low levels of human nutrition	Overgrazing on communal lands; lack of education
Improved calving rates	Low calving and weaning rates	Overgrazing on communal lands; disease problems

Alternatively, a **decision matrix** can be constructed relating the different technologies available to various criteria thought to influence adoption (Steiner, 1987). An example of a decision matrix and the criteria likely to affect technological adoption is given in Module 1 of Section 2, where screening during the design phase of livestock systems research is discussed. For the financial assessment of the different options, simple techniques such as partial budgeting and gross margin analysis can be used (Module 3, Section 2).

Two sets of hypotheses can be expected to result from the pre-screening process at the descriptive stage (Byerlee and Collinson, 1980). They will relate to:

- the reasons for the adoption of present practices, and
- the likely acceptability of changed practices.

Such hypotheses can be tested by examining the kinds of relationship discussed in Modules 2–10 of this Section or by conducting on-farm trials (Section 2).

APPENDIX
Wealth ranking as a method for the identification of target groups or recommendation domains[14]

Introduction

Wealth ranking is a simple field research technique used to classify households within a community on the basis of their relative wealth or economic status. For a community of up to 100 households, this could be done in less than a day. The method requires only one assistant (who is fluent in the local language) and three or four villagers for the interviews. It has been used in Kenya for systems research work among the Maasai pastoralists.

Why wealth ranking is used

Inequality exists in every human society, but the degree of inequality and the attributes upon which it is based may vary considerably. The most common and important inequalities are based on attributes such as race, religion, ethnic group, caste and **wealth**. They apply to both family units and individuals in society.

Wealth is defined in terms of **access** to or **control over** important economic resources and is often **reflected** in higher levels of income and expenditure. It is, however, more than an economic attribute, particularly in smallholder communities, where it has important social and political connotations. The relative wealth status of an individual or household will often determine vulnerability to famine, disease, political/social exploitation and access to government services (Chambers, 1983), and is, therefore, a very important determinant of producer behaviour and family well-being.

In terms of agricultural production, relative wealth status will, to a large extent, determine enterprise combinations, livestock ownership, management practices, overall levels of production and technologies adopted. Farmers and pastoralists in different wealth strata will therefore tend to have different needs and aspirations and will respond differently to technological proposals made by research and extension agencies.

The division of communities into wealth strata thus provides a sound basis for the identification of recommendation domains or target groups in livestock systems research. The following discussion shows how the wealth ranking method is used.

Procedure involved in wealth ranking:

Step 1: Obtain background information

Step 2: Select communities

Step 3: Select informants

Step 4: Define basic terms

Step 5: Obtain a list of household heads within each selected community

Step 6: Rank the community using wealth criteria.

14 This appendix is an abbreviation of the manual entitled *Wealth ranking in smallholder communities: A field manual* written by Grandin (1988). Minor changes in text order have been made, but the content remains essentially the same.

1. Background information

While wealth ranking ensures that a representative sample is chosen within a given community, this is of little value if the community or communities chosen are themselves not representative of the wider target area. The method therefore begins with the choice of a target area and a review of available secondary data on it. Key informants can also be used to provide background information. From this information, it is normally possible to identify the production systems which exist in the area. Differences between neighbouring communities are likely to result from such things as:

- *accessibility,* i.e. distance to towns and markets, roads and other forms of communication
- *population density*
- *land tenure*, including size of land holdings, rights of use, settlement distribution, and
- *Ethnic and historical origins,* which can have marked effects on social structure and agricultural production practices.

2. Selection of communities

Once the major differences have been identified, local people can be asked whether and how these correspond with overall wealth differences between communities. On the basis of this information, and taking into account the resources of the research team, a number of representative communities within the target area can be chosen for wealth ranking.

In the early stages of exploratory research it is preferable to have as many communities as can reasonably be covered. Later, when research is narrowed to specific target groups and on-farm trials are conducted, the number of groups may have to be reduced due to financial, manpower and/or logistic considerations. The reasons for selecting particular communities for research should be recorded, since this may help to explain the results obtained during diagnostic research or on-farm trials.

In most areas, there are several levels of organisation from smaller to larger groups. Usually there are households, often residing jointly with other households which, in turn, are grouped into neighbourhoods, wards, villages, chiefdoms etc. The unit chosen in any given research site will depend on the number of households it contains.

Groups of 100 households or less are desirable for wealth ranking purposes, because the method relies on the use of informants with an intimate knowledge of all households within the community. If the selected community has too many households, the next level in the social hierarchy should be chosen (e.g. a neighbourhood within a ward, rather than the ward itself). The social unit finally chosen should always be representative of the community as a whole. If there is no recognised division into wards, neighbourhoods etc, an arbitrary division may need to be made on the basis of geographical location etc. The unit chosen should not be too small either, since this will result in a sampling bias in the results obtained.

Once the community has (or communities have) been identified, the ranking or grouping of individual households on the basis of wealth criteria can begin. To do this, however, it is necessary to select informants from each community.

3. Selection of informants

The informants should be long-standing members of the community, who are trustworthy and have a good general knowledge of the area. They should be ordinary producers who represent a cross- section of the community. Community leaders and/or extension agents can often be used to suggest likely candidates. For a community of approximately 100 households, between three and five informants will need to be selected.[15]

15 Agreement between informants in community wealth ranking has been shown to be remarkably high, and this reduces the need to use large numbers of informants for the exercise (Grandin, 1983, p. 249; 1988, p. 10).

The chosen informants can then be asked to define important local terms and concepts and to draw up a list of households resident in the area.

4. Definition of basic terms

The concept of wealth. If households are to be ranked (grouped) on the basis of wealth, it is imperative that the concept of wealth be clearly defined at the very beginning.

Most communities have a clear concept of wealth which should be used as the basis for ranking. It should be defined by the assistant(s) working with the research team and checked with local informants. Local terms should always be used, and the important components of the definition should be stated (e.g. land holdings, livestock holdings, wage employment etc). It should also be ascertained whether the concept of wealth can be applied to individuals as well as to households.

Because livestock constitute the single most important indicator of wealth in many African societies, informants will often opt to rank on the basis of livestock holdings alone. In the Maasai pastoral community, for example, the word used for wealth *-emali* – is a term most commonly applied to a household's holding of livestock (Grandin, 1983).

In mixed cropping situations, livestock holdings are also likely to be regarded as the key indicator of wealth, as the size and structure of the livestock enterprise may influence the ownership of crop assets, cropping practices, areas cropped, total crop production and yield (Gryseels and Anderson, 1983).

The definition of a household. A household is often defined as a group of people (normally related to one another) who live together and share the same resources and tasks of production (agricultural and non-agricultural). The output produced is also normally shared between its members.

It is not always easy to identify households precisely, particularly in societies where extended families are common. Nevertheless, through discussion with people familiar with the language and local concepts, it is generally possible to find a word or phrase which defines the term adequately and to get an idea of the different forms it may take.

The wealth ranking of households is normally possible, even when individual economic roles and/or control over resources are not clearly defined. Thus, in most livestock systems research, and in wealth ranking, it is normal to use the household as the basic unit for research.[16]

5. List of household heads

To be able to rank households on the basis of wealth, a complete listing of all households within a community must be obtained. This task is rarely as simple as it seems. Sometimes land registration, taxation or census lists can be used, but because these are often incomplete and inaccurate, checks with community members will generally be needed. The reliability of these checks will depend on the nature of the system being studied.

> **Example:** Once the boundaries of a sedentary community have properly been defined by the research team, it is usually easy to sit with a few people and have them "mentally walk through the area", giving names of household heads. Checks with other people familiar with the area should also be made.
>
> **Continued...**

16 Intra-household differences in wealth (e.g. between men and women or between the head and other members of the unit) can also be explored with the wealth ranking technique.

Example continued...

In more mobile communities, obtaining a complete list of households tends to be more difficult. One could make a list of all households using a particular watering point, if these are not too many in the area. If, as is the case with the Kenya Maasai, household heads have a neighbourhood which they consider to be 'home' (whether they are present or not), their names can be elicited from a few residents. Some members of a household living in the area may consider that they belong elsewhere, but they should still be included in the list. In an ILCA Maasai study site of 1350 km^2, for instance, a neighbourhood interview elicited the names of 206 household heads in less than 1 week.

When the list has been checked, the name of each household head should be written on a small card (about 8 x 13 cm). Each name should also be given a number for subsequent ease of reference.[17]

6. Community ranking by wealth

Informants are generally willing to rank community members on the basis of wealth, provided that sensitive information about individual assets (e.g. the number of cattle owned or held) is not required. The wealth ranking technique, therefore, emphasises the ranking or grouping of households only, not the provision of specific details. If an informant shows unwillingness to do even this, it is better to select a new one to ensure that the information obtained is reliable. The purposes of the survey should be explained to all informants before starting the exercise.

To ensure that the results are consistent, each informant should be asked to give examples of rich and poor households in the community and to define, in their own words, what wealth actually means in the local context. When the researcher is satisfied that there is consistency in the use of the concept and that all informants are happy to participate, actual ranking can commence. This involves:

- *Card sorting*

  Card sorting should be done in a quiet place. A table can be used but this is not necessary. Card sorting is quicker, if it is done by each informant separately. However, it is acceptable and very often informative, if two work together, provided that at least three different rankings are obtained. Before being distributed, cards should be shuffled so that they are again in random order.

  Each informant is then asked to take a card and place it in a pile, each pile representing a household group in which wealth status is thought to be similar. The informant should decide on the number of piles he/she wants to use, but not less than three piles should be made (e.g. upper, middle and lower groups) to ensure accuracy in ranking.

  At any point during this process, the informant can increase the number of piles by starting a new pile. Most informants appear to use four or five piles but some will use more. If there is some hesitation in placing a card, it is best for the informant to put that card aside and make the decision later. The researcher supervising the ranking should always be willing to answer questions during card sorting.

- *Verification of the ranks made*

  After the cards have been sorted, each pile should be carefully reviewed. The informant should be told that this is necessary in order to double-check his or her groupings. A pile at the upper or lower end of the grouping should be selected and each name read again to test the ranking given. This process should then be repeated for each pile, and the informant should be encouraged to re-rank individual households, if this is thought to be necessary.

17 Households in most African societies are normally named after the head. Therefore, the name of the household head is used for identification purposes in wealth ranking.

Occasionally, even when an informant has used several piles, most households will be placed in one particular pile. As a rule of thumb, it is suggested that no more than 40% of the households should be in one group (Grandin, 1988). If more than 40% are grouped in one category, the informant should be asked if there are differences between those households, and if the answer is affirmative, he/she should be encouraged to subdivide the group into two or more piles (see example below).

Verification encourages informants to think about differences between households, so that, by the end of the exercise, they would have a clear picture of the nature of these differences and be able to define them precisely. The focus should always be on group differences, not on the differences of individual household within any group.

- *Specification of group differences*

  To assist in the clear specification of group differences, the researcher should begin with the wealthiest group and ask the informant to specify what it is that all producers in the group have in common (e.g. large holdings of livestock). The characteristics of the group should then be noted down and another pile of households selected for discussion. At the end of the discussion, the researcher should have a clear picture of the factor (or one outstanding factor) which defines wealth within that community.

  At this stage, informants may also be asked questions relating to the specific interests of the research unit. For instance, if animal health problems have been identified as important, it will be useful to ask whether obvious differences occur in animal health, and whether veterinary drugs are being used by the different groups.

- *Recording the information obtained*

  Both actual rankings and comments about individuals or groups should be recorded (see example on page 25 from Grandin, 1988).

- *Computation of average scores and grouping*

  The above procedure should be repeated for all informants used in the ranking exercise. Their individual scores should then be combined to obtain an average wealth rank score for each household. From the averages calculated, households can then be re-grouped into categories which reflect the overall opinions of all the informants selected.

  The simplest way to obtain an informant's score for each household is to divide the pile number given by an informant by the total number of piles he/she has nominated. For ease of calculation, this number is then multiplied by 100 (see practical example on next page).

Example: If a household is in the first (wealthiest) pile and six piles have been nominated by the informant, then the score given to a household in that group is 1/6 x 100 or 17. If the household is in the fifth pile, the score given is 5/6 x 100 or 84. Wealthier households thus get a lower score than poorer households.

Since each informant gives a ranking for each household, several scores for each household are calculated. To obtain the average score for a household, the scores are added and then divided by the total number of informants used. Thus, if three informants have been used for ranking and their scores for a household have been calculated as 25 (1/4 x 100), 17 (1/6 x 100) and 20 (1/5 x 100), the overall weighted average score for that household will be (25 + 17 + 20)/ 3 = 20.67.[18]

18 A household consistently ranked by all informants in the poorest group will have an average score of 100.

Example:

ACTUAL INFORMANT RANKING

Wealth ranking - Olkarkar group ranch, Kenya

Informant: PARMUS Ho (#39) Date: Jan 18, 1982

Age: Iseuri age-set Assistant: f ole Simba

Neighbourhood: ORPAIPE

		Score
1. Richest	11(B), 12, 14, 16, 18, 21, 24 (30), 28, 33(A,B), 39, 40, 46	25
2.	8, 9, 11A (C), 15 (A), 17, 20, 22, 23 (36), 27, 31, 37, 41, 42, 47	50
3.	4, 6, 7, 19, 25, 27A, 32 (36), 43	75
4.	1, 2, 3, 5, 10, 13, 26, 28A, 29, 34, 44, 45, 48	100
5.		
6.		
7.		
8.		
9.		
10.		

Unknown 38

Comments 11 A+C are completely independent of 11 + 11 B now, but not from each other. Brothers who have never separated and can't be ranked separately 24+30, 23+36, 32+36. Category 4 people cannot support their families. They need help from other people. Category 3 people can just support their families. They have nothing to spare to help others. 28A was separated from his father, then lost his animals and is now largely dependent on his father.

Source: Grandin (1988).

When calculating informants' scores, the data should be scanned to check for obvious inconsistencies, and the reasons for them should be determined. After all average scores have been computed, households can be grouped into different wealth strata which can then be used as a basis for the identification of target groups or recommendation domains.

As a rule of thumb, Grandin (1988) suggests that the number of groups should not be more than the average number of piles used by the informants and not less than three. In practice, the number finally identified will depend on the particular objectives of the research team. Normally, for ease of comparison, groups should be roughly equal in size. Natural breaks in the scores listed will often provide a basis for grouping.

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SECTION 1

MODULE 2

DIAGNOSTIC SURVEYS IN LIVESTOCK SYSTEMS RESEARCH

MODULE 2

Diagnostic surveys in livestock systems research

Diagnostic surveys are conducted if the need for further systems research is indicated during the descriptive stage. This module outlines some of the principles of conducting diagnostic surveys and lays the foundation for Modules 3–10. It deals with some of the more practical issues applicable to diagnostic survey, including selection of samples, training of enumerators, designing questionnaires etc., which often determine the success of such surveys.

Diagnostic research may not always be necessary. It can be expensive and time consuming, and scarce resources should not be wasted in collecting unnecessary information. This can be prevented by stating at the start which information is not desired, so that research priorities are clearly understood (Gilbert et al, 1980, p. 50).

PART A: PURPOSES

Diagnostic surveys are formal and structured. They are conducted with a randomly selected group or farmers or pastoralists to provide a **quantitative basis** for conclusions drawn during the descriptive stage. Enumerators are normally used to conduct interviews and collect data on particular aspects of the production system.

Diagnostic surveys can also be used to:

- redefine target groups
- test hypotheses made about relationships/linkages
- identify further relationships/linkages, and
- identify priorities for research.

Redefinition of target groups. When recommendation domains are identified during the descriptive stage, farmers/pastoralists are broken into groups based on one or two characteristics (e.g. access to inputs, wealth etc.). Because diagnostic surveys use random sample methods, variability in these characteristics within a target group can be re-examined and quantified, and the initial groupings can be refined or modified.

Testing of hypotheses. For example, initial exploratory surveys may have suggested that the time of planting was related to the number of oxen in households. This hypothesis could be verified by conducting diagnostic surveys.

Identification of other relationships. Often, relationships/linkages not specifically recognised during the descriptive stage are found during diagnosis. For example, a diagnostic survey of cattle herd size and household size in Matabeleland, Zimbabwe, in 1982 indicated that household size increased with

Table 1. Relationship between household size and herd size, Matabeleland, Zimbabwe, 1982.

Household size	Herd size	Standard error
1–7	'9.6	1.2
8–20	21.7	2.8

Source: Doran (1982).

increasing herd size (Table 1). Relationships like this can have a major effect on production and should be carefully examined and tested for statistical significance.

Identification of research priorities. It is not always easy to identify research priorities with any confidence during the descriptive phase of livestock systems research. The pre-screening of technologies is only tentative, and quantitative data are required to continue the process of priority selection/identification. The options for further research can be narrowed and priorities can be more clearly defined through diagnostic surveys. Techniques such as partial budgeting can, for example, be used to examine the financial implications of making a change at the farm level (Module 3, Section 2).

Quantitative information collected during the diagnostic stage of livestock systems research may be helpful in the design and interpretation of on-farm experiments by specifying management practices (e.g. the timing of different operations) and the criteria used by farmers/pastoralists to evaluate different technological options (CIMMYT, 1985). The farmers or pastoralists in the target group can also be selected to take part in future trials.

PART B: TYPES OF SURVEY

The type of survey used in diagnostic research will largely depend on the:

- type of data to be collected
- degree of accuracy required
- manpower and financial resources available
- logistical considerations, and
- availability of complementary data.

Since each situation is different, only general guidelines can be given which should then be adapted to the prevailing circumstances and the research requirements. There are essentially four types of survey used in diagnostic research:[1]

- **single-visit, single-subject surveys**
- **single-visit, multiple-subject surveys**
- **multiple-visit, single-subject surveys, and**
- **multiple-visit, multiple-subject surveys.**

Single-visit, single-subject surveys

In this type of survey, one particular issue is identified for research (e.g. herd or flock structure, household assets, herd/flock numbers etc.) and data are collected from all sample households on that issue alone.

The main advantage of single-visit, single-subject surveys is that data on particular subjects can be collected in a relatively short time and at a low cost. Many farmers or pastoralists can normally be included in the sample to improve the chances of obtaining representative results. In addition, the supervision of enumerators tends to be minimal.[2]

1 Surveys are sometimes classified on the basis of whether data are obtained by recall or by observation or direct measurement. When data are collected by recall, the information derives from the respondent's memory, while actual measurements are taken at the time of data collection (e.g. when measuring animal liveweight gains).

2 However, this is not always the case. When, for instance, average weight gain (Module 5) is being estimated by once-off surveys, close supervision of measurements is required, but less when collecting data on assets, herd/flock structure etc.

Single-visit, single-subject surveys cannot be used when observation and measurement over prolonged periods are required (e.g. for estimating **individual** animal weight gain performance - see Module 5). Since they are confined to the study of one issue only, they are also unsuitable for the study of relationships or linkages.

Single-visit, multiple-subject surveys

This type of survey is used to collect data on **several** subjects/issues during one visit. These data can then be used to establish **relationships/linkages** between different variables, such as livestock holdings and cultivated area; household size and the marketed offtake of cattle; or livestock holdings and off-farm remittances.

Single-visit, multiple-subject surveys largely rely on recall by the respondent. If the periods of recall are long (e.g. 1 year), data collected on farm activities/transactions performed regularly throughout the year will tend to be unreliable (Module 4), while less regular operations (e.g. cattle sales) are recalled more reliably over relatively long periods of time (see example below). Frequent but irregular events (e.g. expenditures on food, labour inputs) are usually very difficult to recall (Solomon Bekure, 1983; Grandin and Solomon Bekure, 1983).

Increased accuracy of results usually implies increased survey costs and/or reduced number of surveyed variables. When accuracy is less important than, for instance, a general description of the system, single-visit surveys will often be preferred to repeated recall or observation (Collinson, 1972; Gilbert et al, 1980, p. 50).

Single-visit surveys of a large number of respondents are commonly conducted in systems research. They are often complemented by more frequent interviews with a smaller, non-random sample of producers, known as case studies,[3] to reduce measurement errors (Gilbert et al, 1980).

Example: In 1982, ILCA conducted two concurrent surveys (one with monthly and one with daily interviews) of household budgets in a non-random sample of households in Kenya's Maasailand. Table 2 shows that the daily and monthly recalls of expenditures on livestock transactions (irregular events) were not much different, but that of expenditures on food (regular and frequent events) differed greatly between the two types of interview.

Table 2. Monthly (M) and daily (D) recalls of cash expenditure in four households, Merueshi Group Ranch, Kenya, October 1982.

	Food		Livestock		Other items		Overall total	
	M	D	M	D	M	D	M	D
Expenditure								
Kenya shillings	1308	3047	1905	1980	1188	1015	4401	6042
Per cent of total	30	50	43	33	27	17	100	100
Monthly: daily recall ratio	0.43		0.96		1.17		0.73	

Notes: M = monthly recall; D = daily recall.

Source: Solomon Bekure (1983, p. 293).

3 Case studies are variants of the informal survey in which a few households are chosen within the sample for intensive study. They may provide data on several household activities, thereby contributing to a better understanding of linkages at the household level (Grandin and Solomon Bekure, 1983).

Multiple-visit, single-subject surveys

If, after the initial enquiry, more detailed information is needed on one particular issue (e.g. individual animal losses or mortalities) over a prolonged period, repeat or 'continuous' surveys are conducted. Such surveys tend to be costly and generally require a high degree of supervision. The data may be obtained by recall or by direct observation and the frequency of data collection will depend on the type of data being collected.

Example: To collect reliable data on liveweight, milk production, labour use and household expenditures in the traditional systems, the frequency of visits required will be as follows:

Cattle liveweight gain:	1st, 3rd, 7th and 18th month after birth
Cow's milk:	four visits/month over 2–3 months
Sheep and goat milk:	once a week over 2–3 months
Labour use and household budget:	very frequent measurements over a year or a season.

Since multiple-visit, single-subject surveys are costly and require considerable supervision, the possibilities of obtaining the same data by other means should be explored. Often it may be better to use less precise methods with larger sample sizes (for details see Part C of Modules 3–6). Collinson (1972) stated that detailed measurement/observation, and the additional costs involved, are justified only if the implied level of accuracy sufficiently and consistently improves the understanding of the issue being researched.

Multiple-visit, multiple-subject surveys

Multiple-visit, multiple-subject surveys include farm management surveys which deal with a wide range of topics over a longer period of time (usually 1 year). They are costly in terms of data collection and handling and involve heavy supervision. Because masses of information are collected, data analysis and reporting are often delayed. In addition, enumerator boredom and respondent fatigue are common, and continual checks for accuracy and consistency must be made. The emphasis in systems research has, therefore, shifted to more 'efficient' (but possibly less accurate) rapid survey methods of data collection (Collinson, 1972; Gilbert et al, 1980).

PART C: METHODS OF DATA COLLECTION

If the data collected in formal surveys are to be of any value, attention should be given to:

- scheduling of survey operations
- design of questionnaires and record sheets
- recruitment and training of enumerators
- pilot testing of questionnaires, and
- sampling methods and sampling error.[4]

4 Much of the discussion in Part C of this module is based on CIMMYT's (1985) manual on diagnostic research and on the field experiences of ILCA staff involved in system diagnosis (e.g. Grandin and Solomon Bekure, 1983).

Scheduling of survey operations

To ensure credibility, the survey method adopted must be practical, efficient and inexpensive, which, in turn, means that operations should be carefully planned in advance and that schedules should be adhered to as closely as possible.

Operations whose starting and ending times need to be scheduled include:

- target group(s) identification
- talks with community leaders and political and government officials about the aims of the survey of each target group
- talks with farmers/pastoralists within each group about the aims of the survey
- questionnaire design
- questionnaire testing and adjustment
- sample selection within each target group
- survey implementation/supervision
- correction of obvious non-sample errors
- data coding, re-checking and entering into the computer
- listing of computer data and re-checking for data entry errors, and
- data analysis for report writing.

Simple bar charts (Table 3) help the research team to think through the processes involved step by step and to determine the expected time of completion of each operation. For some operations (e.g. data coding, re-checking and entry), it is relatively easy to determine the amount of time required, while for others (e.g. selection and training of enumerators), allowance must be made for delays or for overlaps. If the research conducted is to become credible, the data collected must be rapidly analysed and the results published.[5] Sufficient time should always be allocated to these tasks.

Table 3. Schedule of a hypothetical single-visit diagnostic survey.

Operation	Month: 1	2	3	4	5	6	7	8	9	10
Target groups identification	—	—								
Talks with community leaders		—	—							
Talks with target group			—	—						
Questionnaire design		—	—	—						
Questionnaire testing					—					
Sample selection					—					
Survey implementation					—	—				
Data checking and correction					—	—				
Data coding and re-checking								—		
Data analysis and reporting								—	—	—

5 The analysis and presentation of survey results are discussed in detail in Module 11.

Design of questionnaires and record sheets

Questionnaires are prepared to obtain answers to specific questions, while record sheets are used to record observations and/or measurements. To meet the stated objectives of the survey, the content and format (or design) of the forms to be used should be carefully considered at the outset.

Content

Four questions need to be answered regarding the content of a survey form. They are:

- What are the objectives of the survey?
- What information is needed to achieve those objectives?
- How will the data be analysed and processed?

When deciding on the content of the survey form, it is advisable to follow four steps:

- **Define priorities for the survey**

  This should be done on the basis of the findings of initial exploratory surveys or the insights obtained from a review of secondary data sources (see Module 1).

- **List the main categories of data to meet these priorities**
- **List the important components of each main category of data**

  For instance, if information on household structure is needed, data on the age and sex of household members, and their occupations and availability for farm work, should also be obtained. If livestock management is to be related to labour supply, the indicators of management performance, and management practices, which might be affected by labour supply must be identified.

- **Specify methods of presentation and analysis**

  This must be done for each type of data collected and for each type of analysis to be made, and involves such considerations as how the data will be tabulated and what computer programmes will be used to analyse and present the data.

In general, the content of the survey form will vary with each target group, reflecting the different characteristics of that group identified during the descriptive stage (CIMMYT, 1985).

Format

Proper format (or design) will take into account the structure of the survey form and the wording and layout of its questions.

Structure. This includes considerations about the two main parts of any survey form: the *title page* and the part of *specific questions/records.* The title page should give:

- the respondent's name or code number
- the name or code number of the enumerator
- the location of the surveyed household (ward, village etc)
- the date of the survey
- the starting and ending times of the interview, and
- the number of the questionnaire.

This information serves as a general record of the survey conducted, but it is also a means of identifying respondents, should the need arise, and of checking on enumerators if the data entered are suspect.

After the title page, the rest of the questionnaire should be structured using the following guidelines:

- **Order the topics of inquiry into logical sequence and mark them clearly**

  Moving from one topic or category of data to another in a logical manner improves the understanding and cooperation of the respondents and facilitates data analysis. It also helps the enumerator to ascertain whether each category of data has been dealt with exhaustively. Marking each section or group of data with an alphabet (or another distinct marker) is also helpful in that it breaks the questionnaire/record sheet into distinct categories of information.

> **Example:** In a single-visit, multi-subject questionnaire intended for a mixed farming system, the subject categories for data collection might be grouped as follows:
>
> A. Household structure
>
> B. Off-farm employment and non-farm income
>
> C. Assets
>
> D. Cropping activities, and
>
> E. Livestock husbandry.

- **Sequence questions within each category of information specified**

  CIMMYT (1985) gives six generally applicable rules believed to facilitate this task:

– Move from the **general to the specific**

  For instance, find out the size of the household before asking questions about the age and sex of its members.

– Move from the **simple to the complex**

  Questions which require a simple "yes" or "no" should precede those which have multiple choices and require considerable thought on the part of the respondent.

– Maintain a **logical flow** in the questions asked

  Attempt to order questions so that one question leads logically to the next, or helps to elaborate the questions which follow.

– Move from **recent** to more **distant** events

– Sequence **questions about farm activities** in the order the activities are normally performed.

  For instance, questions about ploughing should precede questions about harrowing.

– Leave **opinion** and **sensitive questions** to the end

  Example of an opinion question is, What cattle diseases do you consider most important? A sensitive question is, How many head of cattle do you own/hold?

Questions asked within each subject category should be identified by a number. The instructions for the enumerator should be specific, clearly worded and written in an obvious place so that he/she can find them. Space should be left for the enumerator to make comments about the responses obtained. An example of a questionnaire layout is given in the Appendix.

- **Code all questions**

  Questions should be coded **before** the survey is conducted. Answers to questions may be in numeric form or may be stated in words. If they are in numeric form, sufficient space should be provided for the entry of the maximum possible value. If the answers are not in numerical form, it is usual to group them (ex–post and after the survey is completed) into different categories and to provide a code for each category.

For open-ended questions (see page 51), coding is done after the form has been returned, by grouping the answers given into major response categories and assigning a code number to each category.

Codes should also be provided for missing responses, which may be due to the enumerator failing to ask the relevant question(s) or because the respondent refused to give an answer. The reason for non-response should be clarified. The code used for a missing response is optional, but should be different from the codes given to particular responses (e.g. 101 to 106 in the example below). Often the same number (e.g. 0 or 99) will be used to indicate missing responses throughout the questionnaire.

Example:

Question: Which source of cash do you primarily use to pay for the purchase of food for your household?

(Enter code number) [ ]

Answer: Cash obtained from

101. Sale of cattle

102. Sale of smallstock

103. Sale of crops

104. Sale of handicrafts or home-made beer

105. Off-farm earnings

106. Other sources (specify) ....
....
....

Option 6 is an example of a 'catch-all' data category used for answers thought to be relatively unimportant. If a large proportion of the answers falls into this category, the importance of the other categories must have been misjudged. Additional categories should therefore be identified on the basis of the answers given under option 6 and provided with new codes.

- **Include data cross-checking mechanisms**

  Although well trained enumerators will often detect inconsistencies, subtle cross-checks should be built into the questionnaire to ensure that the data obtained are consistent. Some time should be spent with the enumerator before the survey to explain why and how cross-checks are used. When an inconsistent response is detected, he/she is expected to remind the respondent of an answer given before to a similar question and clarify the issue with him before moving on.

Example:

Q: Do you own/hold cattle?

(Enter code number)

A: 1. yes 2. no [2]

The respondent indicated that he owns/holds no cattle. At a later point in the questionnaire there was a cross-check:

Q: How did you pay for the fertiliser you used on the maize crop this year?

A: *By using cash from the sale of cattle.*

This answer is at variance with the one above where the respondent indicated that he owns/holds no cattle. Having drawn the respondent's attention to the two answers, the enumerator found that the respondent had sold all his cattle before the time of the survey, to purchase fertiliser, food and other household needs. This means that the two answers were consistent with the respondent's circumstances at each point in time.

Cross-check questions can be double-checked during data entry to determine whether the enumerator has been able to detect inconsistencies in the data obtained, thereby also checking on his/her diligence in filling out the questionnaire.

Question types and layout. Whether the researcher obtains the desired information will depend on the type of question he/she asks. Questions can be formulated to obtain facts or opinions.

Factual questions can be 'closed' or 'open-ended' (CIMMYT, 1985, p. 64). A closed question gives the respondent no other options to answer than those specified in the questionnaire. An open-ended question gives the respondent the option to say what he/she wishes in its response. *Opinion questions* are always open-ended.

Each type of question has its place in the survey. When specific information is needed about the household (e.g. number of adult males, number of cattle owned/held, types of other assets owned) or when we wish to find out if a particular practice (e.g. ploughing and weeding) is widely used and how much time is spent on it, then the appropriate type of question to use is the factual question. When, however, the aim is to elicit community views about particular practices/beliefs/cultural obligations etc., then opinion questions should be used.

There are advantages and disadvantages with each type of question. With opinion questions, the danger is that the respondent will give an answer which he/she thinks the researcher (or the enumerator) wants to hear. Therefore, leading questions such as, *Do you think the government should provide a dip-tank service for this area?*, should be avoided. Factual questions lack flexibility, but the answers to them are easy to analyse.

The type of question asked will influence its **layout**. There are essentially four layouts possible (see examples on the next page):

- single-option, closed
- multiple-choice, closed
- tabular, closed, and
- open-ended.

Wording. Each question should be worded clearly so that there is no doubt about its meaning. The aim should always be to:

- tap the precise information required
- enhance recall, and
- minimise 'enumerator effects' by encouraging standardised responses (Grandin and Solomon Bekure, 1983).

Proper wording therefore implies the use of correct terminology and the avoidance of vague terms, jargon and multiple-issue questions.

Examples:

a) Single-option, closed question layout

(Enter code number)

Do you own/hold goats? ☐

(1. yes; 2. no)

b) Multiple-choice, closed question layout

(Enter code number)

Q: How do you plough your fields? ☐

A: By using

1. your own tractor
2. a hired tractor
3. your own oxen
4. hired oxen
5. your own donkeys
6. hired donkeys

c) Tabular, closed question layout

Answer the following questions about land preparation:

	Operation			
	Performed? (yes/no)	When? (month)	Method used ? (animal/tractor)	Is animal or tractor owned or rented? (owned/rented)
Ploughing				
Harrowing				
Seeding				

Source: Adapted from Byerlee and Collinson (1980, p. 35).

d) Open-ended question layout

Why do you keep cattle? ....

....

....

Correct terminology. It is advisable to translate the questionnaire into the local language, particularly when the enumerator's knowledge of English (or French) is limited. The translation should be tested with several enumerators to ensure that the interpretation is correct. Translations by enumerators in the field are likely to result in errors of interpretation (CIMMYT, 1985, p. 68, gives examples of some of the errors involved).

Vague terms. Words such as 'often', 'frequently' and 'always' may be misinterpreted and should be avoided. Words which may have several different meanings in the local language should not be used either.

> For instance, the question 'How often did you dip your cattle last year?' would be more specific if worded as 'How many times did you dip your cattle from May to December last year?'

Jargon. The use of technical agricultural terms such as 'stocking rate', 'carrying capacity' and 'livestock unit' can cause confusion and result in misinterpretation by the respondents. Every-day words which convey the same meaning are therefore preferable, as are local terms for diseases and units of measurement. Abbreviations such as FMD (for foot-and-mouth disease) should be avoided.

Multiple-issue questions. Questions such as, Do you own/hold cattle and smallstock? are confusing and should be broken down into questions dealing with one issue only (e.g. Do you own/hold cattle? and Do you own/hold smallstock?).

Recruitment, training and supervision of enumerators

In surveys based on questionnaires, enumerators are normally used to collect the data. Therefore, a properly designed survey form would not serve its purpose, if the enumerators are not carefully chosen, properly trained and adequately supervised.

Selection and recruitment

Enumerators should have a good educational background to enable them understand the objectives and principles of data collection, communicate these to the interviewees in their own language, and perform basic arithmetic calculations and other functions as required. Fluency in the local language is a must, but if the research team does not speak that language, enumerators should also be bilingual. In addition, they should be familiar with local terms, customs and farming practices, and be open-minded, tactful and flexible.

Extension officers, school teachers and other similarly qualified people resident in the study area should be used to conduct once-off interviews in their spare time. They are normally very effective because while they are familiar with the people and their customs, they are usually also sympathetic to efforts aimed at obtaining information about the community. More often, however, only enumerators from less educated groups in the population are available.

Training

Irrespective of the background of the enumerator, sufficient time should be given to training each time a new questionnaire is used. Training on the use of the interviewing technique selected for the survey, and its merits and demerits, should be emphasised (CIMMYT, 1985).

Orientation. Enumerators should be acquainted with the purposes and principles of data collection and be given a proper background on the target group (farming practices, political and cultural aspects etc.). The orientation sessions with enumerators should include discussions about:

- the timing of operations
- functional support (food, clothing, accommodation, materials, salaries/wages, transport)
- the number of households in the sample and their location
- the division of responsibilities
- who should be interviewed (e.g. household head) and when during the day, and
- the questionnaire itself (its content, layout, cross-checks, consistency of interpretation and interviewing technique).

Interviewing technique. Enumerators should be made aware that the method of interview they use can 'make or break' the survey. Poor technique can mean that the respondent loses interest and becomes uncooperative. The essential principles of a good method are:

- **Stress confidentiality of information**

  Respondents should be assured that the information given will be treated as confidential, particularly in respect of livestock ownership. If a respondent refuses to answer a question, the interviewer should record the fact without further debate.

- **Cooperate with the interviewees**

  The time, place, length and pace of the interview should suit the respondent. An interview should be completed in less than 1 1/2 hours, and the respondent should always be thanked for participating.

- **Adhere to the content of the questionnaire**

  The interviewer should keep the respondent 'on track' and confine his questioning to the survey. He/she should also be alert to inconsistencies in the answers given and avoid suggestive questioning. At the end of the interview, survey forms should be checked to ensure that all questions have been properly answered.

Often it is useful to give a new enumerator an opportunity to practise using the questionnaire, either with a member of the research team or with other, more experienced enumerators.

Supervision

The need to supervise enumerators cannot be overemphasised. Supervision of enumerators will involve checks in the field and in the office.

Field checks. Periodic checks in the field are recommended to ensure that the required data are indeed being collected (instances when enumerators fill questionnaires without ever having visited the interviewees are, unfortunately, common), and that the collection is done properly. A check early in the survey will often prevent mistakes being made throughout the survey. This should be followed by random visits during the survey period to check the data, ensure adequate support for the data collection and prevent enumerators from filling in forms with fictitious information.[6]

Office checks. When completed forms are returned, they should be checked for inconsistencies and missing answers, and then re-checked during data entry on the computer.

Pilot testing of questionnaires

All questionnaires should be pre-tested with a small number of non-randomly selected respondents. The aims of pre-testing are to:

6 Enumerators may skip particular questions either because of embarrassment or because they assume that the answer is self evident and requires no further confirmation.

- isolate inconsistencies and sensitive issues in the questionnaire
- determine whether each question is properly worded and understood by the enumerator as well as the respondent. Enumerators' suggestions for re-wording should be included in the revision
- decide whether all questions are relevant or whether additional ones may be needed
- test the layout of the questionnaire and the coding system, and
- determine expected duration of each interview.

Pre-testing can have a useful training function, though some of its objectives may not be fulfilled if novice enumerators are used (CIMMYT, 1985, p. 85).

Sources of error

There are two potential types of error in sampling: sample and non-sample errors.

Sample errors

Sampling techniques are used when complete enumeration of a population is considered impractical (because of cost, manpower and/or logistical reasons, for instance). Sampling produces errors in estimation because of chance or the sampling method used. The magnitude of sampling errors is normally unknown but can be estimated from the sample data (see page 57).

Non-sample errors

Non-sample errors occur because of incomplete or poor responses, enumerator error or bias and mistakes made during data processing. They can thus occur both when sampling is applied or when complete enumeration is used. Sources of non-sample error commonly encountered during the diagnostic stage of livestock systems research are discussed in detail below (see also CIMMYT, 1985, p. 92).

Respondent error or bias. Such errors will occur if the information given by respondents is incorrect or when questions are asked which cannot be answered. There are six potential sources of respondent error:

- **Refusal of selected respondents to participate in the survey**

  This can result in missing data. For practical purposes, cases of refused participation are treated as 'missing cases'. To compensate for such cases, a larger sample than necessary may be selected (known as oversampling). There will always be some refusals to participate in a survey, but their number can be considerably reduced through preliminary discussions with farmers/pastoralists and community leaders to identify a sample of willing and representative respondents.

- **Refusal to answer particular questions**

  This may happen when questions are asked about household income (Module 4), animal mortality (Module 5), livestock ownership/holdings and the disposal or acquisition of livestock (Module 9).

- **Deliberate provision of misleading information**

  Grandin (1983, p. 282) reported that the Maasai in Kenya dislike talking about livestock acquisition, and because of this, tend to report giving more than they receive (for instance, exchanges of adult steers for young females tend to be understated because such exchanges, though common, are regarded as 'begging'). Deliberate misrepresentation of stock numbers is common in most African societies, and is exacerbated by fears of taxation.

- **Misinterpretation or misunderstanding of questions**

  Errors due to misinterpretation or misunderstanding of questions can be significantly reduced by using appropriate language in the questionnaires, by choosing enumerators familiar with local terminology and, last but not the least, by periodically checking on the progress of the survey.

- **Recall problems**

  These problems are discussed in Part B above (pages 44–46) and in various of the following modules.

- **Inability to answer questions accurately**

  This may occur when questions are asked about measurements (e.g. distance walked when herding) or when the measurement/time standards used by the enumerator differ from those of the respondents. Errors can also arise when the wrong respondent is chosen (for instance, the household head may know little about an operation such as milking which is normally done by women).

- **Respondent fatigue**

  Lengthy interviews lead to loss of concentration on the part of the respondent, which affects the accuracy of the answers given. Respondent fatigue is also common when surveys are complex or when they are conducted over several months (e.g. multiple-visit, multiple-subject surveys; see Part B, p. 46).

Enumerator error or bias. This type of error is commonly due to:

- **Deliberate laziness or dishonesty and boredom** (in multiple-visit surveys)

- **Misunderstanding/misinterpretation of questions and answers**

  Errors of this type can be avoided by selecting enumerators proficient in the language spoken by the interviewees and through practice in the use of questionnaires and relevant interviewing techniques.

- **Incorrect measurements or use of incorrect conversion standards**

  Measurement errors may occur if the enumerators are not familiar with the measurements used or the conversions applied. They can be prevented by proper training of enumerators before they are involved in measurement.

- **Mistakes in data entry**

  Mistakes can be made when filling in questionnaires or entering data into the computer if the enumerators and data coders are inexperienced or unfamiliar with the questionnaire. Data entry can be simplified by using properly designed questionnaires. Regular checking during the survey of responses and adequate practice in the use of questionnaires are also likely to reduce mistakes in data entry.

  Other sources of non-sample error. These include incomplete coverage or listing of sample units, loss of questionnaires and data, incomplete data entry and incorrect data conversions at the office after correct information had been collected in the field.

- **Incomplete coverage**

  Obtaining a complete listing of sample units (e.g. all households in the target group) is a major practical difficulty in livestock systems research, particularly when no supplementary information is available (e.g. census and extension lists) or when populations are dispersed, as in pastoral communities. Specific sampling methods (e.g. cluster sampling) can overcome such problems (see page 60).

If available, census lists should always be checked for reliability, as they may be out of date. Lists made by extension officers are likely to reflect their biases and to be incomplete. The researcher must weigh the time and cost involved in obtaining an accurate listing against possible inaccuracies resulting from the use of easily available, but less accurate, lists (CIMMYT, 1985, p. 76).

- **Incomplete computer data entry**

  This type of error can be checked by listing all computer entries and comparing them with the original data entries in the questionnaires or record sheets.

Sampling methods and errors

It is not possible, in this manual, to explain the theory and practice of sampling adequately to readers not acquainted with it. Such readers should consult one of the standard textbooks such as Cochran (1977), Yates (1981) and Snedecor and Cochran (1984). What follows here is an aid to the memory of those who already have some acquaintance with sampling.

Sampling methods are used when complete enumeration is impractical for financial, manpower or logistic reasons. Sampling is necessary because different units within populations (e.g. households, cattle, smallstock) vary in their individual characteristics. Given this variation, the samples selected for examination must be representative of the entire population.

Because the number of cases studied is less, sampling permits a more detailed study of particular population characteristics than would normally be possible in a census. In addition, non-sample errors tend to be less because sampling permits greater attention to detail during data collection and analysis.

Estimates from samples are subject to sample error, the extent of which can be approximated by statistical formulae. When probability methods of sampling are used (see below) 'confidence intervals' can be established for any given estimate to indicate the reliability of the figure obtained. (See Module 11 for further information on confidence intervals.)

The sampling method used in the field will be influenced by two main concerns - sample selection and estimation.

Sample selection. This involves the manner in which sample units are chosen for study and their definition. In livestock systems research, the unit most commonly chosen is the household, but individuals within a household or individual animals may also be identified as sample units.

Estimation. This involves the manner in which inferences are drawn about the population as a whole and the precision/accuracy of these inferences or estimates.

The objective should always be to select that method which produces results of acceptable precision at the lowest possible cost and in the shortest possible time. This implies an ability to evaluate the level of precision required before diagnostic research begins.

The sampling methods most commonly used in livestock systems research fall into two main categories – the probability and non-probability methods.

Probability methods. These methods make it possible to draw inferences about the population which can be statistically evaluated. Probability methods are used if the probability (or chance) of selection of each unit (e.g. household) in the sample is known.

Non-probability methods. When the probability of selection of each unit is unknown (because complete population lists are not available), 'non-probability samples' are chosen (CIMMYT, 1985). With these methods, inferences about the population can be drawn, but they cannot be statistically evaluated.

> **Examples continued...**
>
> - household size and livestock enterprise composition, i.e. the ratio of cattle to smallstock etc. (Swift, 1985, p. 139).
> - household structure and livestock enterprise composition (Swift, 1985, p. 139).
> - herd size and labour time devoted to livestock management (Bailey, 1982).

Feasibility of new technology

Without a knowledge of labour availability and allocation there is a danger that one may become preoccupied with technologies which may subsequently be found to be unacceptable to the target group (Grandin, 1983, p. 305).

Labour-related constraints on technology development may be determined by culturally accepted ways of doing things. For instance, they may be set by household goals and aspirations or, they may be a function of the amount of labour physically available on the farm at critical times of the year.

Information on the total amount of labour available during a year may not, therefore, be sufficient to determine the potential of a new technology for adoption. Rather, one has to examine how that labour is used throughout the year, and which tasks are allocated to different age and sex groups within the household. It is also necessary to know how households overcome labour shortages (e.g. by cooperative labour sharing or by hiring).

New technologies will often require significant changes in the amount of labour used or the pattern in which it is allocated. Therefore, for each new technology proposed, it will be necessary to determine whether:

- The technology is feasible in terms of the labour it uses, i.e. whether the demand for labour resulting from the use of the technology can be matched by the supply of household labour at the required time.
- The adoption of the technology implies a shift in labour resources from one activity to another, and what are the opportunity costs of that shift (i.e. whether the additional profit resulting from using labour in the new technology is greater than the profit lost as a result of shifting away from the old).
- The proposed pattern of labour use (i.e. adult/child or male/female task allocation) is culturally acceptable.

PART B: TYPES OF DATA

To assess the effect of labour on farm and non-farm activities and on the adoption of new technology, data are required on:

- labour available to the household, and
- labour use over a period of time by age and sex category.

Labour supply

Information on the total amount of labour available to the household is needed to:

- Check the consistency of results of in-depth analyses of labour flows over time.

- Determine whether the amount of labour available corresponds to the amount actually used at different times of the production year. If labour is scarce at particular times of the year, the manner in which households compensate for such shortages should be clarified.
- Test relationships between different variables which may help in the design of technological innovations.

This type of data can be collected during single- or multi-subject, single-visit surveys. To maintain consistency in the interpretation and presentation of results, it is helpful to define, at the outset, what constitutes 'household labour' and in which unit labour is measured.

Household labour. When the intention is to measure labour productivity, a household will generally be defined in terms of those individual members who participate in its productive activities. The available household labour[1] supply may therefore include:

- persons who are part of the family unit, reside at the household site and are actively involved in production[2] (Solomon Bekure et al, 1987)
- persons who live at the household site but are not related to the household members
- household members who are in off-farm employment but work on the farm on an occasional basis (e.g. by returning home to plough).

Measurement unit. Different types of labour make different contributions to production, depending on the nature of the task performed and the age and sex of the person performing it. Thus, before comparisons can be made between households (or between different tasks carried out by members of the same household), labour time must be expressed in terms of a common denominator.

Such a common denominator is the *man-day* equivalent. In general, a man-day of work is defined as the amount of work (of a particular kind) that can be carried out by an adult male in an 8-hour work period. A man-hour is one-eighth of this.[3]

The man-day equivalent is based on the use of standard conversion factors (weights) applied to males and females in different age groups and carrying out different tasks.

> For instance, a conversion factor of 1.0 means that an individual can perform a given task in the same time as a normal adult male, while a factor of 0.5 means that the task would take twice as long to perform as it would if done by an adult male.

Adult males and females are normally assumed to be different in terms of the amount of effective work they can do, though there may be some tasks (e.g. in cropping) where their work output will be equivalent. Children's work output will depend on their age and the nature of the task performed. For some tasks (e.g. herding), a child of 14 years, for example, can perform as effectively as an adult. For other tasks (e.g. weeding and carting water), a reduction should be applied for children.

Example: Let us calculate the total man-hours available for herding in a pastoral household consisting of eight persons belonging to three age categories:

- Two adult males (between 15 and 65 years) for herding cattle

Continued...

1 Focusing on the household as the unit of production may not be always appropriate (Grandin and Solomon Bekure, 1983) because different systems, and even the individuals within a particular production system, will vary in terms of their reliance on household and non-household labour. Pastoralists, for instance, tend to share communal labour more often than farmers

2 Distinction should be made between those who are able to work and those who, although present, can not work because of sickness, old age etc. If any resident member is not available for work at particular times during the year, this should also be taken into account.

3 The use of an 8-hour day to estimate man-day equivalents is only a guide. Different day lengths could be applied to different circumstances.

Example continued ...

- Two adult females (between 15 and 65 years) for herding smallstock and calves, and
- Two children (male and female; between 6 and 14 years) for herding cattle and smallstock.

Assuming that adult males and females contribute an average of 0.5 hours/day to herding, and children an average of 6 hours/day, then total man-hour equivalents are calculated by multiplying total labour days by the amount of time spent on herding and the relevant conversion factor.

Labour category	Number of persons	Labour availability		Conversion factor	Total man-hours/ year
		Total days	Hours/day		
Adult males	2	730	0.5	1.0	365
Adult females	2	730	0.5	1.0	365
Children	2	730	6.0	1.0	4380
Total man-hours/year					5110
Total man-days/year[1]					640

[1]Calculated at 8 hours per average workday.

The above example gives an annual estimate of the labour available for one operation. However, labour shortages are seasonal, and annual estimates of labour supply may conceal them. It is, therefore, often useful to break down labour supply estimates on a seasonal or monthly basis and relate them to the man-day needs of each operation.

The conversion factor used in estimating man-day or man-hour equivalents will vary according to circumstances, and no general standards can be recommended. (An example of age-sex-task conversion factors used in a study of mixed cropping practices in northern Ghana is given in the Appendix.) The same applies to the definition of an 'adult'. Most commonly, adults are defined as those individuals between 15 and 65 years, but this definition will also vary with the circumstances[4] (Swift, 1985; Panin, 1986).

The user of this manual should be very cautious about using conversion coefficients calculated for one task to estimate the amount of work allocated to other tasks.

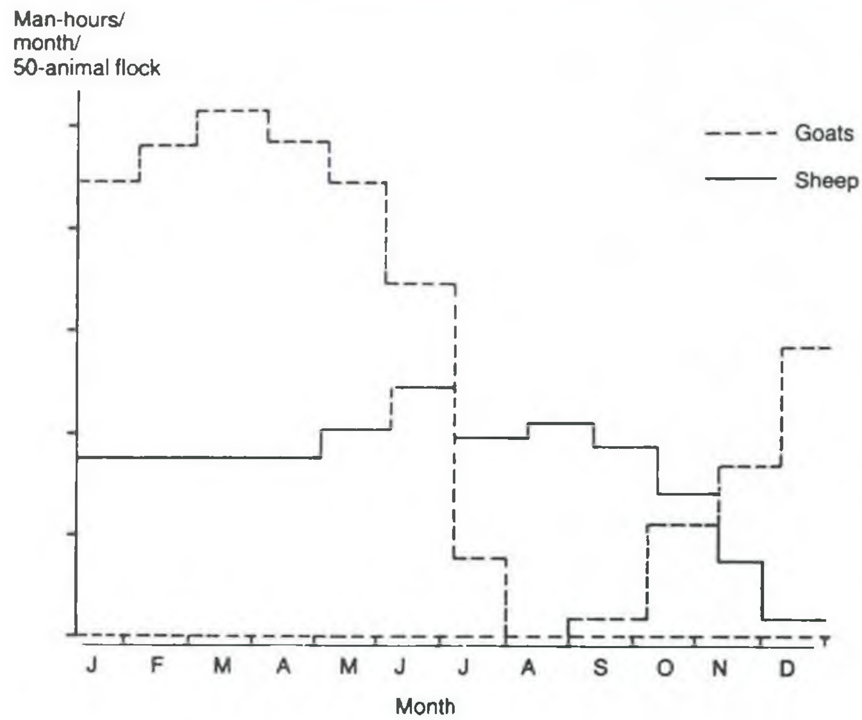
Labour-use pattern

When the crucial farm and non-farm tasks have been identified, and the labour allocated to these tasks by permanent and absentee household members has been determined (along with the extent of the use of shared or hired labour), then **labour use/availability profiles** can be constructed for different household activities and related to the labour requirements of proposed interventions.

4 If individuals are uncertain about how old they actually are, guesstimates can be made by relating date of birth to important events in the life of the individual (e.g. religious ceremonies, weddings, deaths, droughts and wars). Alternatively, local concepts of age division can be used. The guesstimates should then be converted to year equivalents, whenever possible.

An example of labour-use profiles for two 50-animal flocks (one of sheep and the other of goats) in West Africa is given in Figure 1. The profiles show the amount of labour needed for watering and milking, but do not give the time spent on these operations by age and sex category.

Figure 1. Labour spent by the Twareg of Adrar N Iforas to water and milk two 50-animal flocks, Mali



Source: J Swift, ILCA, Bamako, Mali, unpublished data.

Summary

To estimate the supply and use of household labour, information will be needed on:

- age, sex and education of individuals residing in the household, and the relationship of these individuals to the household head
- occupation of resident household members (e.g. farming, working off-farm, schooling)
- availability of household members for work on the farm
- age, sex, occupation and location of non-resident household members who contribute to production on an intermittent basis
- sources and uses of hired and shared labour
- man-day or man-hour conversion weights for different tasks and different age/sex groups, and
- allocation of labour by age and sex group to different tasks in different seasons of the year.

PART C: METHODS OF DATA COLLECTION

The method adopted to collect data on labour use will depend on the complexity of the information required which, in turn, will depend on the objectives of the study. As in all forms of data collection, different methods may be applicable to different stages of the collection process.

> For instance, the first stage in labour data collection may be to collect general information on the structure of the household, the availability of individual members for farm work, the hiring or sharing arrangements used, the major production tasks carried out during different seasons of the year etc. Such information is best collected by single-visit surveys.
>
> Subsequently, it may be decided that labour is a critical constraint and that more detailed information on labour use is needed. However, extensive recall methods are usually too costly, so a less costly method confined to measuring the amount of labour allocated to the most important production tasks might be used (see 'Critical task analysis' on next page).
>
> If detailed labour data for all production tasks are necessary, and keeping costs down is desirable, then the 'Time-allocation method' described below may be applicable.

Time-allocation method

This is a type of direct-observation method based on randomly timed short visits to measure/observe **all activities carried out by all members of the household at the particular time of the visit.** Records produced after a series of visits (each scheduled for different times of the day) can give "a thorough description of activities by such parameters as age, sex and season" (Grandin, 1983, p. 311).

Advantages. The advantages of the time-allocation method are that all potential workers can be surveyed, recall problems are minimal and there is little respondent fatigue, as visits of five to 10 minutes are usually sufficient for a household of up to 10 people. The method covers not only the complete range of activities, but also tasks performed simultaneously. If sufficiently large samples are chosen, households can be compared on the basis of available labour supply, wealth, neighbourhood or other variables which might affect the use of labour. Another advantage of the method is that it is relatively cheap considering the amount of information it can provide.

Disadvantages. If some household members are absent at the time of the interview (because they are out herding or performing some other tasks off the farm), the data obtained with this method may be inaccurate. Also, since the method does not distinguish between critical and non-critical tasks, there is the possibility that the labour requirements of a production system could be overestimated. Finally, if access to a computer or its capacity are limiting factors, it may be unwise to use the time-allocation method because of the high costs of data coding involved.

Summary

The steps involved in carrying out a labour time-allocation study are:

- decide whether the overall allocation of labour to farm and non-farm activities requires in-depth study
- determine the resources available for study (e.g. manpower and financial resources and computer facilities)
- ascertain whether the time allocation method is appropriate
- design questionnaire, train enumerators and pre-test questionnaire
- select sample groups and individual households within each sample group for study

continued...

Summary continued....

- determine the frequency of visits to the selected households
- select, at random, the days and times when individual households will be visited
- collect labour use data and check for inconsistencies and errors, and
- analyse data and draw conclusions related to the overall objectives of the systems research carried out.

Critical task analysis

The critical task analysis relies on the use of recall to collect information on critical tasks from carefully chosen informants, but it may also involve direct observation and measurement. The recall method usually relies on average household estimates, but analysis on the basis of wealth class may sometimes be more useful (Module 1, Section 1).

The chief objectives in a *critical task analysis based on RECALL* are to:

- Identify the tasks which appear to be critical in terms of the consequences for the household if enough labour is not allocated to them. These tasks may or may not be the tasks which require the most labour.
- Determine whether the household has sufficient labour to meet the demands (i.e. whether there is a 'labour-sufficiency' problem).
- Determine how households overcome deficiencies in the labour required to perform critical tasks (e.g. by labour-sharing or hiring).

Advantages. The method makes it possible to identify rapidly the critical tasks performed and the extent of labour shortages for such tasks (see example below). It is low-cost and interviews can be conducted within a relatively short period of time. Critical task analysis is often the first step in identifying labour constraints in livestock systems research, after which more in-depth analysis may be required.

Example: In a study of the Samburu by Sperling (1987), informants identified herding and watering as the critical tasks performed by the average household. They estimated that between five and nine workers were required for these tasks in the wet season, and between eight and 14 in the dry season.

An estimate of the average household size was then obtained from other sources and adjusted by deducting the number of children too young, and of adults too old, to work. This gave an average available work force of 5.2 persons. The conclusion was that the average household could not perform herding and watering adequately without access to alternative labour sources.

A study of the methods used to overcome labour shortages showed that the average household provided only 14% of the overall labour requirement for herding. Households used complex hiring and labour-sharing arrangements, yet many continued to experience problems with getting enough labour for herding.

Disadvantage. If the tasks which are critical for given households are incorrectly or inadequately specified, or if their selection or the interview approach adopted are biased by preconceived notions, then there is danger that the data collected will be irrelevant.

Summary

The steps involved in a critical task analysis are:

- identifying informants fully acquainted with the livestock operations carried out in the study area (Module 1, Section 1)
- asking the informants to estimate:
  - the average livestock holding in the area
  - livestock production tasks critical in terms of labour use, and
  - the number of workers needed to carry out critical tasks. (If there are large seasonal differences, then the number of workers required for the tasks in different seasons should also be estimated.)
- estimating the average household size in the area, using survey or census data if these are available
- relating average household size to the worker requirements estimated by the informants for each critical task
- determining whether there is a labour sufficiency problem or not, and
- investigating the methods used by an average household to deal with labour deficiencies for a critical task(s) and ascertain whether they are considered adequate to overcome the problem.

When *DIRECT OBSERVATION* is used (e.g. Torry, 1977), the tasks critical to household production are identified in a rapid survey of selected informants (as above). This is followed by direct measurement of the amount of time spent on these tasks. Measurements are conducted over a relatively short period of time, on the assumption that the labour patterns observed are not seasonal (Collinson, 1972, p. 226). If, however, seasonal differences are suspected, several measurements will be required.

The labour requirements measured for particular critical tasks are then related to data on household labour supply to determine whether there is a labour sufficiency problem for these tasks. If labour shortages are apparent, the extent and nature of labour sharing or hiring is assessed (e.g. Gryseels et al, 1988).

Advantage. The technique provides detailed information about time spent on critical tasks during short periods of the production year, thereby complementing rapid surveys on labour use and availability and enabling in-depth analyses of other crucial aspects of labour use.

Continuous recall survey

Continuous recall surveys can be single- or multiple-subject and involve frequent visits to selected households on a regular and pre-arranged basis (e.g. twice weekly). They are often used to estimate the amount of time spent on particular tasks performed between two consecutive visits.

Three factors should be taken into account when designing continuous recall surveys of labour inputs:

- labour time
- frequency of data collection, and
- respondent selection.

Estimation of labour time. When estimating the amount of time spent on a given job, the time spent working and that spent resting are normally lumped together, because it may be difficult to distinguish between them (Norman, 1973). Use local concepts of time to improve the accuracy of recall.

Frequency of data collection. This largely depends on the characteristics of the system studied and on the overall objectives of the survey. Sample size, the geographic dispersion of selected households and financial considerations will also influence the frequency of enumerator visits.

When a production system is complex or when the work to be done changes from day to day, interviews conducted more than two to three days apart lead to increasingly inaccurate recall (Collinson, 1972, p. 229). For less complex systems (e.g. pastoral) where labour inputs tend to be fairly regular, the periods between interviews can be longer without markedly affecting recall. In general, recall for regular tasks such as herding or watering will be longer than for operations such as milking. Twice-weekly interviews are, therefore, commonly used for pastoral as well as mixed farming systems (Grandin, 1983, p. 310).

Increasing sample size may mean that the visiting frequency will have to be reduced. However, as the recall period increases, the accuracy of the data obtained tends to decline because farmers are more likely to forget details about the work they have done. Conflicts between accuracy and the statistical usefulness of the data collected are common in continuous recall surveys (Norman, 1973; Coleman, 1982).

Because of these conflicts there may be a tendency to concentrate on fewer tasks, which, in turn, may mean that information on other important activities is missed. Estimating the returns to labour is then more difficult, the consequence being that the suitability of proposed interventions cannot be fully assessed. The same applies to other variables surveyed by continuous recall.

Another problem is that the longer the time spent in collecting detailed information on labour use, the more difficult it is to maintain a high standard of accuracy. This is because enumerators and respondents tend to become fatigued in long surveys, especially if the desired amount of cooperation from respondents is lacking. However, if there is cooperation, and if enumerator/respondent fatigue can be avoided, recall may improve with time due to better understanding by both the respondent and the enumerator of what is required (Grandin, 1983).

Long survey periods may also entail difficulties with enumerator supervision. Thorough supervision adds to costs, thereby often curtailing the budget available for actual data collection.

Respondent selection. Ideally, the person(s) involved in each particular operation should be interviewed. This may, however, be costly or impractical, and conflicts between the amount of detail, the level of data accuracy and the statistical usefulness of results may arise. General principles applicable to enumerator selection and questionnaire design for labour input surveys are outlined in Module 2 (Part C) of Section 1.

Summary

The steps involved in collecting labour data using a continuous recall method are:

- decide whether the method is appropriate i.e. whether data on labour flows over time are required
- if so, decide whether labour data should be collected separately or with data on other, related variables (e.g. income and expenditure)
- design the questionnaire, select sample households, train enumerators, pre-test questionnaire and correct if necessary (Part C of Module 2, Section 1)
- decide on the frequency of visits given the required data accuracy and cost/manpower constraints
- collect data and review them for errors/inconsistencies, and
- analyse results and draw conclusions related to the original objectives of livestock systems research.

Appendix

Task conversion factors used in a study of mixed farming systems in northern Ghana.

Labour category	Task					
	Clearing	Hoe-ridging	Leading bullocks	Planting	Weeding	Harvesting
	adult-male equivalent					
Males						
6–9 years	0.10	0.10	0.35	0.41	0.10	0.35
10–15 years	0.75	0.75	0.95	0.90	0.85	0.85
15–55 years	1.00	1.00	1.00	1.00	1.00	1.00
> 55 years	0.50	0.50	0.70	0.65	0.65	0.65
Females						
6–9 years	0.00	0.00	0.25	0.41	0.10	0.35
10–15 years	0.40	0.35	0.75	0.90	0.65	0.90
15–55 years	0.75	0.65	0.85	1.00	0.80	1.00
> 55 years	0.45	0.25	0.00	0.81	0.45	0.85

Source: Panin (1986).

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SECTION 1

MODULE 4

HOUSEHOLD BUDGETS AND ASSETS

MODULE 4

Household budgets and assets

PART A: PURPOSES

When collecting household budget data, attention will be given to assets, sources of income and patterns of expenditure. Data of this type are collected to determine the effect of income, expenditure and asset ownership on livestock investment decisions, livestock management practices and the allocation of resources to other farm and non-farm activities by households.

The effect of income, expenditure and asset ownership on livestock production and other farm and non-farm activities

In most communities, a household's relative wealth will be determined by its access to resources such as capital, land and labour. This, in turn, will determine how that household invests, obtains its income and spends cash on items such as food, clothing and farm inputs.

The same general principle holds in an African context where livestock holdings often represent the best approximation of the relative wealth of a household (Grandin, 1983, p. 231). The household's wealth influences livestock management practices and sales levels, as well as consumption behaviour and allocation of resources (Table 1). It thus influences the household's interactions with the cash economy.

> For instance, households with larger herds tend to market absolutely more stock (e.g. Doran, 1982; Zimbabwe Government, 1982a, b; 1983; Grandin, 1983, Table 2), own more oxen, plough more land, achieve higher crop yields and sell greater amounts of crop products (e.g. Norman, 1973, p. 135; Gryseels and Anderson, 1983). Their greater wealth and income-generating capacities have also been shown to influence their access to external sources of capital, i.e. credit (Grandin, 1983, p. 238), which, in turn, influences their willingness to adopt new technologies.

An understanding of these linkages is therefore an important aspect of the descriptive/diagnostic phase of livestock systems research. It may also be necessary to determine how expenditure patterns affect the need for cash since this will often determine **when** particular transactions take place. The sale of cattle will often be dictated by the need to pay school fees or to buy food, for example (Swaziland Government, 1980, Ch. 2).

The user of this manual is encouraged to explore cause-and-effect relationships between livestock holdings and such variables as:

- **Livestock offtake rates**. An example from eastern Botswana is given in Figure 1.
- **Crop income and livestock sales and purchases**. For instance, how does crop income affect the sale or purchase of livestock and the number of livestock held by a household?
- **Off-farm remittances and livestock sales and purchases**. For instance, how does the level of remittances affect the sale or purchase of livestock and the number of livestock held by a household?
- **Cultivated area**. In the Ethiopian highlands, for instance, larger holdings of oxen permit a greater area of land to be cultivated (Gryseels et al, 1988; Figure 2).
- **Expenditure on livestock and other farm inputs**, e.g. veterinary supplies and fertiliser.
- **Cash needs** (e.g. school fees, food expenses) and **sale of livestock.**

The different methods of analysis used to assess the significance of results are outlined in Module 11 of this manual.

Table 1. The effect of wealth on livestock offtake, management practices, household income, labour use and expenditure patterns in a Maasai group ranch, Kenya, 1983.

Item	Household	
	Poor	Rich
Livestock holdings		
- number of cattle	31	302
- number of smallstock	42	213
- smallstock: cattle ratio	1.35:1.00	0.7:1.00
Net livestock offtake (%)		
- cattle	20	7
- smallstock	23	6
Livestock herding		
- cattle herded alone (% of HH[1])	0	57
- smallstock herded alone (% of HH)	29	57
- mean cattle-holding group size	160	372
Labour inputs		
- total number of workers	6.3	9.8
- number of adult men	0.9	1.5
- number of women	1.7	3.4
- children at school (%)	38	15
- ratio of cattle/worker	5	31
- hours/day/worker given to livestock	3.9	5.2
Income and expenditure (KSh[2])		
- income from livestock	657	1420
- livestock income per worker	104	145
- mean value of cattle sold	577	971
- per caput expenditure on:		
food	195	460
other household necessities	165	238

[1] HH = household.

[2] KSh = Kenya shilling.

Source: B E Grandin, International Laboratory for Research on Animal Diseases, Nairobi, Kenya, personal communication.

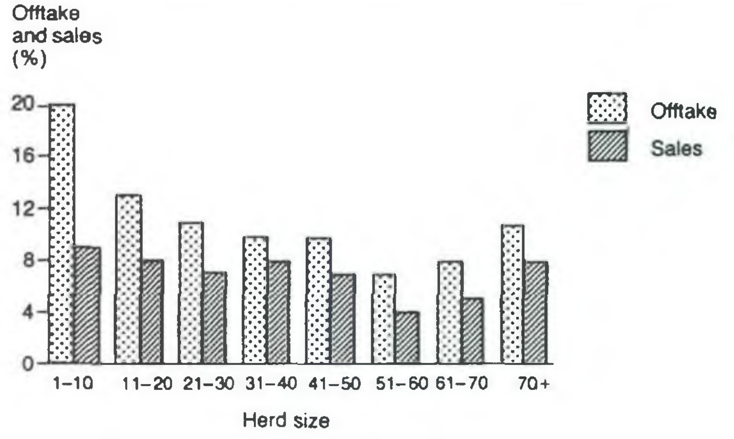
Determining the suitability of new technology

The potential for introducing new technology is determined during the descriptive/diagnostic phase of livestock systems research. This will depend on the economic and social circumstances of households, which constrain or motivate responses to new opportunities.

The potential of a new technology to increase productivity and income at the farmer's (or pastoralist's) level may not, **by itself**, be adequate to induce adoption. Two considerations will always need to be borne in mind:

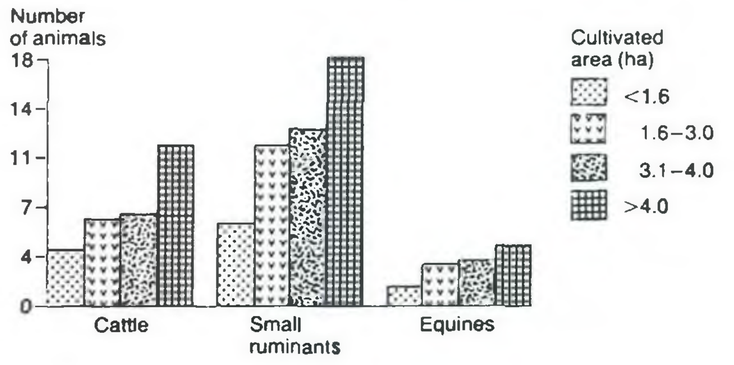
- Whether the farmer/pastoralist **can** in fact adopt the new technology, which is known as the **necessary condition of adoption**; and

Figure 1. Livestock holdings and sales and offtake rates, Botswana, 1981.



Source: Bailey (1982).

Figure 2. Livestock holdings by cultivated area, Ethiopian highlands.



Source: Gryseels and Getachew Assamenew (1985).

- Whether the farmer **will** adopt the new technology, which is known as the **sufficient condition of adoption** (Caldwell, 1984).

With respect to wealth, income and expenditure, the following issues will need to be considered already in the design of diagnostic surveys:

- Will the household have the financial and labour resources to make the change?

  For instance, if the technology involves additional capital expenditure, it may favour those who are relatively wealthy. Such equity considerations can be important in the design of new technologies.

- Will the technology affect sources of income and/or expenditure patterns by shifting resources to different activities? How will this affect household cash flows, control over household resources and labour, risk and uncertainty?

  For instance, the subdivision of communally owned grazing lands into fenced ranching enterprises is likely to release child-herding labour for other activities, such as school, cropping etc. If the labour released to cropping activities improves crop yield, for instance, such an effect should also be taken into account when evaluating a new livestock technology.

- Will the new technology involve investment in assets which are less easily converted to cash during times of need? Will this increase the risk for the household?

PART B: TYPES OF DATA

For all types of data, the objectives of the survey must be decided at the outset since these will influence the design of questionnaires and the amount of detail required. The approach to data collection must be both **systematic** (to ensure that what is wanted is in fact obtained) and **selective** (to make sure that only the necessary data are collected). The latter is true particularly for household expenditure data. Precise information may be difficult to obtain, and too much emphasis on detail is often counter-productive, not to mention costly in terms of manpower and financial resources.

Data collected will normally fall into three broad groups:

- **assets inventory data**
- **income data**, and
- **expenditure data**.

Assets Inventory

The assets which a household owns or holds will determine its income generating capacity. An inventory of household assets also gives a good indication of its investment and production patterns. Depending on the farming system, **physical** assets data will include information on any of the following:

Livestock	- cattle, sheep, goats, donkeys, camels etc.
Cropping equipment	- ploughs, harrows, planters, tractors
Transport equipment	- carts, vehicles
Other equipment	- wire fencing, water points, fixed housing structures.

The collection of livestock data is dealt with in Module 10 of of this manual. It requires special consideration because it is often difficult to obtain reliable information, particularly for cattle, and because distinction must be made between the number of animals **owned** and **held on loan** by a household. Other assets data are, however, relatively simple to collect in a once-off, single-subject or multi-subject survey.

In the valuation of assets, livestock will normally be valued at current market price and other assets at their depreciated value. A simple formula for estimating the depreciated value of an asset is:

Depreciated value of asset = original value of asset – (annual depreciation x current life of asset)

Example: The purchase price for a plough with an expected useful life of 10 years is US$ 200. The depreciated value of the plough at the end of the fifth year of use is:

Original value – (annual depreciation x 5) = 200 – [(200 – 1/10) x 5] = US$ 100.

Income data

Before designing income data questionnaires, it will often be useful to conduct an informal survey to determine the main sources of income in the area. When measuring income, distinction must be made between **cash** and **non-cash transactions**, since in pastoral communities, for instance, the exchange of livestock between households has important economic as well as social functions. Separating sources of income into these two categories helps to ensure that all major items of income are included by informants.

Depending on the system being studied and the purposes of the study, the following types of income data may need to be collected:

- **Cash transactions**
  - livestock and livestock products

    (animals, meat, milk, ghee, eggs, hides, skins and manure)
  - agroforestry products

    (crops, wood, charcoal, fruit and honey)
  - handicrafts and brewing products
  - off-farm employment

    (remittances, hire of labour and trading operations)
  - other sources of cash

    (borrowings, gifts in cash).
- **Non-cash transactions**
  - livestock products

    (exchanges or gifts, bride wealth, livestock products consumed directly, e.g. milk, meat and eggs)
  - agroforestry products

    (exchanges or gifts of crop products and wood, home consumption of food crops)
  - other non-cash transactions

    (e.g. labour exchanges).

The valuation of items sold involves recording the amounts sold and multiplying these by the relevant market price. For most non-cash transactions, the valuation procedure is the same: the amount exchanged is recorded and this is multiplied by the prevailing market price.

Products produced on the farm which are retained for household consumption must also be valued. The price used to value this output will depend on whether the household normally sells or buys the product, i.e. whether there is a deficit or surplus of that commodity in the household.

For households which are **deficit** producers, any output consumed at home is valued at the price paid to buy the equivalent amount of product. For **surplus** producers, output consumed at home means that sales opportunities have been foregone, and the value to use is the price which the producer could have obtained if the item had been sold at the market, minus marketing costs.

When valuing the output of **intermediate livestock products** which directly contribute to crop production,[1] such as manure, these should be given an imputed value. If the manure can be sold within the area, the appropriate value is the price which can be obtained on the seller's farm. If it cannot be sold, its value can be estimated by converting the dry-matter nutrient content of the manure to the equivalent fertiliser market price per unit of N, P and K,[2] provided that fertiliser is used in the area.

1 Techniques for estimating crop production and income are adequately described in the literature on crop farming systems research (e.g. Collinson, 1972).

2 One tonne of wet manure is equivalent to about 0.25 t of dry manure, but the plant nutrient value will vary. For example, in a study in the Ethiopian highlands, the N and P contents of dry manure were estimated at 1.46 and 1.3%, respectively (Newcombe, 1983). Jones and Wild (1975) quoted 1.4% for N and 0.26% for P.

When valuing total farm income, the value of the manure applied to a crop is reflected in the value of crop produced.

Similar principles apply in the valuation of animal traction. Animal power can be valued at the price paid in the area to hire draft. Alternatively, if hiring of draft animals is not common, it can be valued at the cost of hiring labour to do an equivalent job. When valuing total farm income, the value of draft provided is reflected in the value of the crop produced.

The accuracy of the data obtained on production and income will depend on:

- **The importance of the commodity** to the household.

  For instance, in pastoral and agropastoral households, information on cattle sales will tend to be fairly reliable because of the importance attached to cattle in these households.

- **The regularity of sales** or exchanges.

  For instance, for commodities which are produced and consumed regularly and in small amounts, recall after a relatively short period of time becomes unreliable. For commodities which are sold less regularly and in significant amounts, recall will usually be quite reliable even after a considerable time lapse.

The appropriate method of data collection will therefore depend on the type of income data being collected (see Part C).

Expenditure data

The collection of reliable data on household expenditure patterns can be difficult, so care should be taken that the data to be collected are essential to the overall objectives of the study.

Expenditure on food, clothing and transport tends to occur fairly regularly and in small amounts. Recall of the precise amounts purchased or of the timing of those purchases tends to be poor, and frequent visits are necessary to obtain reliable information. It is usually advisable to avoid **unnecessary detail**, but if there is strong evidence that particular items in the budget will influence production decisions, sales levels and/or the uptake of new technologies, then data on these items will need to be collected.

> For instance, when livestock are sold to buy food, as is common in pastoral and agropastoral systems, data on total food expenditure will be relevant but a detailed breakdown of food quantities purchased, and of costs by individual item, is not likely to be important.

The same general principle applies to the collection of most types of household expenditure data: rather than collecting data on individual expenditures, it is sufficient to concentrate on broad categories of household expenditure. However, data on the use of livestock production inputs are often essential since these reflect livestock management practices and may indicate possibilities for technological intervention.

The frequency of expenditure on livestock inputs will vary with the production system, and this will influence the method of data collection. Thus, for extensive production systems, expenditures will tend to be irregular, but for more intensive systems (e.g. dairying) there will be regular outlays on feed supplements, drugs and other items, so that more frequent visits will be required to obtain reliable data.

Livestock purchases tend to be irregular in most systems, and the collection of such data is discussed in Module 9. The collection of data on crop production inputs may be important, particularly when attempting to understand the linkages between crop and livestock activities in livestock systems research. Methods suitable to collect such data are described in Collinson (1972) and elsewhere.

Summary

When collecting expenditure data, it is useful to begin by categorising expenditures into broader groups:

- **Livestock purchases**
- **Livestock inputs** – veterinary inputs, water, dip fees, drugs, feed supplements (salt licks, concentrates)
- **Crop inputs** – seed, fertiliser, insecticides
- **Purchased food**
- **Clothing**
- **Transport**
- **Durable household goods**
- **Health and hygiene**
- **Other items** – loans, labour hire.

Then, you will decide which categories need to be broken down into specific items or which can be left as they are, and which could be deleted from the survey questionnaire.

PART C: METHODS OF DATA COLLECTION

An inventory of assets can be obtained from once-off, single- or multi-subject surveys, while income and expenditure data may have to be collected using intermittent or continuous recall visits. The important issues which determine the approach to data collection and must, therefore, be considered at the outset are:

- types of income and expenditure data needed
- common patterns of income and expenditure
- level of accuracy required
- frequency of visits needed to obtain the desired level of accuracy, and
- financial and manpower resources required to meet set objectives.

Once-off recall methods

When an accurate recall of income and expenditures is possible over a long period, reliable data can be collected from once-off surveys. To ensure that recall is related to a specific time period, the reference point must be clearly defined. Useful reference points are local events, such as important ceremonies, the dates of previous harvests or special market occasions, since these tend to be more easily remembered by respondents than, for example, calendar years.

Notes: In mixed crop–livestock production systems where herd sizes are relatively small, and the sale of an animal is, therefore, a significant event, the recall period may be as long as one year without substantial loss of accuracy. For such systems, the collection of data on livestock sales and purchase can be incorporated into once-off multi-subject surveys which include information on household size and structure, the occupation of household members, assets ownership and livestock holdings.

Similarly, where expenditures on livestock inputs are infrequent, once-off questionnaires will often give a reasonable approximation of the timing of expenditures and the amount of cash spent. Depending on the system and the objectives of the study, rough orders of magnitude in the estimation of income and expenditure levels may be sufficient.

Once-off surveys are relatively cheap, require minimal enumerator supervision, and the costs of data processing are low. They will often provide guidelines for subsequent in-depth studies on particular aspects of the system, bearing in mind that when income or expenditure patterns are regular and recall is short, the data obtained through them are likely to be inaccurate. If greater detail is needed and the type of data required is unsuitable for long recall periods, multiple visits would be more appropriate.

Intermittent recall methods

If more detailed information on income and expenditure is required than can be obtained from once-off recall surveys, but cost or manpower constraints make continuous visits impossible, then intermittent visits may be appropriate during which receipts and expenditures occurring in the period immediately before the visit are recorded.

The period of recall is relatively short (e.g. 1 week) and return visits are scheduled in such a way that recall relates to a different week of the month on each occasion. After a series of visits, 'typical' patterns of household income and expenditure can be obtained and the results extrapolated for the entire season or year.

Example: To obtain information on household budgets for a 'typical' month of the year, four visits with a recall period of 1 week would be required, but not necessarily within the same month . The procedure could then be repeated at a later date to check whether the patterns first observed are consistent throughout the year or whether marked differences occur with time.

An example of a data collection based on 1-week recall is given below. The data were collected in two series of visits (four visits in each) over a 6-month period.

	First series									Second series							
Month	1				2				....	8				9			
Week	1	2	3	4	1	2	3	4		1	2	3	4	1	2	3	4
Visit No.	1			2		3	4				5	6		7			8
Recall period	x		x		x	x				x	x		x			x	

Intermittent recall methods are relatively cheaper than continuous recall methods, supervision of enumerators is less, and the data obtained by intermittent visits can be as reliable as for continuous recall, particularly if patterns of income and expenditure remain relatively constant throughout the year. In addition, problems of respondent fatigue, which is common to methods relying on more numerous visits, are reduced.

The danger with intermittent visits is that important differences in seasonal income and expenditure might be missed if visits are spread too widely apart, and, as a result, extrapolations of monthly cash flows might be very inaccurate. Where differences between seasons are expected (e.g. because of observed sale patterns for livestock), it will be advisable to plan visits on a seasonal basis and extrapolate accordingly.

Continuous recall methods

Certain types of data require frequent visits and short recall periods, if a high level of accuracy is to be achieved.

Notes: Receipts from remittances and outlays on food and clothing tend to be fairly regular and often in varying amounts, so that recall over long periods tends to be poor. Similarly, production information for systems in which output is produced regularly or where inputs are used frequently, will be unreliable if the recall period is longer than 2–4 days (Solomon Bekure, 1983, p. 294).

In a study of the Maasai pastoralists in Kenya, the use of monthly recall for this type of data greatly affected the accuracy of results. A comparison of results from the monthly recall survey with those of a simultaneous, detailed survey of income and expenditure patterns in the area, showed that respondents of the monthly survey recalled only 70% of their actual cash receipts and 73% of their expenditure outlays (Solomon Bekure, 1983, p. 293).

Continuous recall surveys are costly and suffer from such problems as enumerator boredom and lack of farmer cooperation (Module 2, Section 1). Moreover, frequent data collection does not necessarily guarantee accuracy. Swift (1980), for instance, reports only partial success in obtaining household budget data through continuous recall. He says, "There was inevitably some resistance to such detailed questioning and at times, clearly false information was given or important transactions were concealed. Regular checking of data is, therefore, necessary to ensure that inconsistencies are detected early". This adds to the costs of data coding and enumerator supervision.

Nevertheless, continuous recall methods may be essential for some types of data. The approach to be adopted will depend on the objectives of the study, which should be carefully formulated at the outset, and on the resources available.

Careful examination of the types of data needed and of the patterns of income and expenditure in the survey area may mean that simpler and less costly methods of collecting budget data can be employed. It is therefore useful to gather as much information as possible on income and expenditure patterns through pre-survey inquiries or more formal questionnaires before commencing in-depth continuous recall surveys on household budget data.

Summary

The procedure for collecting household budget data is:

- Establish a register of the main farming operations and items of income and expenditure by interviewing local farmers, shops, extension staff and traders or by conducting preliminary formal surveys. Determine whether further budget information is needed.
- Determine the type of budget data required and the methods of recall needed to obtain them. Relate these methods to the requirements of accuracy and available financial/manpower resources.
- When the appropriate method(s) of recall is identified, decide on the frequency of visits required.
- Design questionnaire and train enumerators on methods of data collection and pre-test survey, if necessary.
- Collect data and review for consistency. For continuous recall methods, check data at regular intervals.
- Analyse results and draw conclusions related to original objectives of the systems research.

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SECTION 1

MODULE 5

ANIMAL PRODUCTION

MODULE 5

Animal production

PART A: PURPOSES

This module concentrates on the measurement of animal productivity in traditional African livestock systems. The discussion is applicable to the main species held in these systems – cattle, sheep, goats, camels and donkeys.

Constraint identification

Measuring animal performance will, by itself, be of little use to livestock systems research if the factors which affect that performance remain unknown or unstated. These factors can be identified by examining within-system linkages/relationships or by comparing the performance of similar production systems. When making between-systems comparisons, appropriate criteria should be used.

WITHIN-SYSTEM LINKAGES/RELATIONSHIPS. Adequate information on the general features of the system under study is desirable because animal productivity is influenced by a range of inter-related factors, one or a number of which may set limits on the level of output achieved. Some of these factors are:

- **availability of grazing/feed resources**
- **water availability**
- **labour availability**
- **land tenure systems (e.g. communal grazing)**
- **management practices, stock wealth and production goals**
- **animal diseases**
- **animal genetic potential, and**
- **economic conditions (e.g. market prices, availability of inputs and infrastructure facilities).**

After singling out the factors it is helpful to determine how they interact with each other.

> For instance, the land tenure system may have a direct effect on management practices, grazing resources or water availability. Management practices, on the other hand, may affect the prevalence of particular diseases, market prices or access to grazing resources.

Next the effect of the above factors on animal performance should be determined by examining the relationships, such as those between:

- *Stocking rate/grazing pressure and animal performance* (e.g. calving rate, weight gain, mortality rates, milk production).

Example:

Part A of Table 1 shows the sort of relationship one expects: cattle stocked at lower densities have better performance because of better access to feed.

Part B of Table 1 shows the opposite relationship, under uncontrolled conditions, and provides a useful warning example of the dangers of too simple an approach. What happened in this case was that areas with good grass cover (which brought about good condition in the animals) also attracted large numbers of them.

Table 1. Relationship between stocking rate and cattle performance.

A. Matopos Research Station, Zimbabwe, 1978–82.

Performance indicator	Stocking rate	
	3.6 ha/head	8.1 ha/head
Conception rate (%)	57	73
Total milk yield (kg)[1]	548	752
Calf body weight at 270 days	145	180
Mortality (%)		
Cow mortality	2.9	1.7
Pre-weaning calf mortality	8.6	4.5

[1] For 0–150 days postpartum.

Source: Zimbabwe Government (1984).

B. On communal grazing areas of Botswana.

Stocking rate (ha/head)	Percent of cattle in condition class[1]		
	Worst (C)	Medium (B)	Best (AB+)
< 4	5	56	39
> 4 < 7	13	59	28
> 7–10	36	52	12
> 10–20	37	58	5
> 20	30	56	14

[1] For information on condition scoring see page 119.

Source: Derived from Abel et al (1987).

- *Seasonal conditions and animal productivity*

For instance, season of birth can affect reproductive performance and may be manipulated by management. Seasonal control of mating is traditionally practised in the Maasai pastoral system and in some Sahelian and Arab countries.

- *Herd/flock size and animal performance*

Example:

Table 2. Effect of cattle herd size on animal performance, Botswana communal areas, 1979/80.

Performance indicator	Herd size							
	1–10	11–20	21–30	31–40	41–50	51–60	61–70	70 +
Conception rate (%)	88.4	71.3	68.6	62.5	74.6	75.6	57.1	70.8
Abortion rate (%)	32.4	23.1	16.9	12.3	11.1	19.3	8.2	10.0
Calving rate (%)	56.0	48.2	51.7	50.2	63.5	56.3	48.9	60.8
Calf mortality rate (%)	61.8	39.7	29.7	26.4	21.5	32.8	17.7	21.3
No. of calves/cow lifetime	4.6	5.5	7.0	9.8	10.2	6.7	6.8	8.9
Adult mortality rate (%)	9.3	8.3	8.8	10.5	8.0	7.8	8.5	7.1

Source: Bailey (1982).

- *Disease prevalence and animal performance* (see Module 8 of Section 1).
- *Herd/flock structure and animal performance*
- *Animal breed and animal performance* under similar environmental conditions (see Table 3 as an example).

Note: Overall indicators of performance (e.g. average mortality rates) are too general to be useful. To identify realistic options for improvement, information on the relationship between performance indicators for individual animals and such parameters as age, sex, type of birth and season of birth will be needed. A significant positive relationship between pre-weaning mortality and type of birth (singles, twins etc) in sheep may, for instance, indicate the need to select against multiple births in African pastoral systems (e.g. Wilson et al, 1985a, Chapter 6).

Example:

Table 3. On-station growth and productivity of pure and crossbred cattle in Botswana.

	Weight (kg) at:		Weight of weaner/cow/year (kg)
	Weaning	18 months	
Purebreds			
Africander	174	277	102
Tswana	181	296	131
Tuli	177	289	141
Brahman	181	305	n.a.[1]
Bosmara	204	324	n.a.
Crossbreds[2]			
Tswana x Tuli	182	293	135
Tswana x Brahman	191	323	149
Tswana x Bosmara	184	313	152
Tswana x Simmental	194	328	162

[1] n.a. = not available.

[2] In each case, the female was Tswana.

Source: Bailey (1982).

BETWEEN-SYSTEMS PERFORMANCE COMPARISONS. These are usually done between similar production systems to identify constraints more precisely.

> For instance, a low calving rate found for particular groups or areas could point to specific causal factors which may have been difficult to single out without performance comparisons between similar production systems.

Criteria for between-systems comparisons. To be useful, between-systems comparisons should be done using appropriate criteria.

> For instance, the performance of African livestock systems is commonly assessed on the basis of productivity per head rather than per herd or per hectare which may be more relevant, particularly for communal range management systems (Behnke, 1984; de Ridder and Wagenaar, 1986) (Module 6, Section 1).

Scope for improvement

Proposed improvements to livestock production should be technically feasible, economically attractive to the target group and culturally acceptable.

Technical feasibility. This means that proposed improvements are compatible with the managerial, institutional, infrastructural and environmental resources which exist in the target area.

Economic attractiveness. Often, potential increases in output may not be sufficient to induce the target group to adopt the improved technology. Therefore, cash costs and market prices facing producers, as well as the opportunity costs of making the change, must also be taken into account. Moreover, distinction must be made between outputs achieved on-station and on-farm and those achieved under traditional management, because they differ considerably.

Cultural acceptability. Unfortunately, this common- sense requirement is often ignored in the design and promotion of new technologies.

> For instance, a particular land tenure system might be considered a major causal factor limiting livestock production, yet changing it may not be politically or culturally acceptable. In such a case, considerable improvement could be achieved by introducing innovations into the existing system rather than exchanging it for a completely new one (e.g. disease control measures, alterations in the seasonal timing of particular operations and better distribution of water points).

PART B: TYPES OF DATA

When studying animal productivity, data may need to be collected on:

- **inter-species composition of the production system's (household's) livestock holding**
- **herd/flock structure**
- **reproductive performance**
- **mortality**
- **growth and weight gain, and**
- **outputs (meat, milk, hides and skins).**

Inter-species composition of the livestock holding

By 'inter-species (between-species) composition' we mean the balance between different kinds of animals (e.g. camels, cattle, sheep, goats and donkeys).

We normally compare the inter-species composition of different holdings in terms of the relative total liveweight ('biomass') of the different species, rather than in terms of their number. This is because relative biomass roughly parallels both relative output and relative pressure exerted on feed supplies.

The unit used to measure animal biomass may be kilogrammes of liveweight, but often we talk in terms of TLUs – tropical livestock units, which is the equivalent of 250 kg of biomass. The average weight of members of different species obviously differs between different areas according to the dominant breeds in each species and other conditions. In the absence of precise local information, the researcher can use the following figures which are conventionally applied for sub-Saharan Africa as a whole.

Table 4. Tropical livestock unit equivalents for sub-Saharan Africa.

	Species	Average biomass (kg)
Camels	250	1.0
Cattle	175	0.7
Sheep/goats	25	0.1
Horses/mules	200	0.8
Donkeys	125	0.5

Thus a herd of 10 cattle and 30 sheep, for instance, has a biomass composition which is 70% cattle and 30% sheep.

Knowing the inter-species composition can give us a clue to both resources and constraints. Table 5, for instance, shows how water shortage determines the inter-species composition of the livestock holdings of Somali-speaking people in southeast Ethiopia. But inter-species may also reflect (and, therefore, alert us to importance of) the availability of browse and grass or the scarcity of motor transport.

Example:

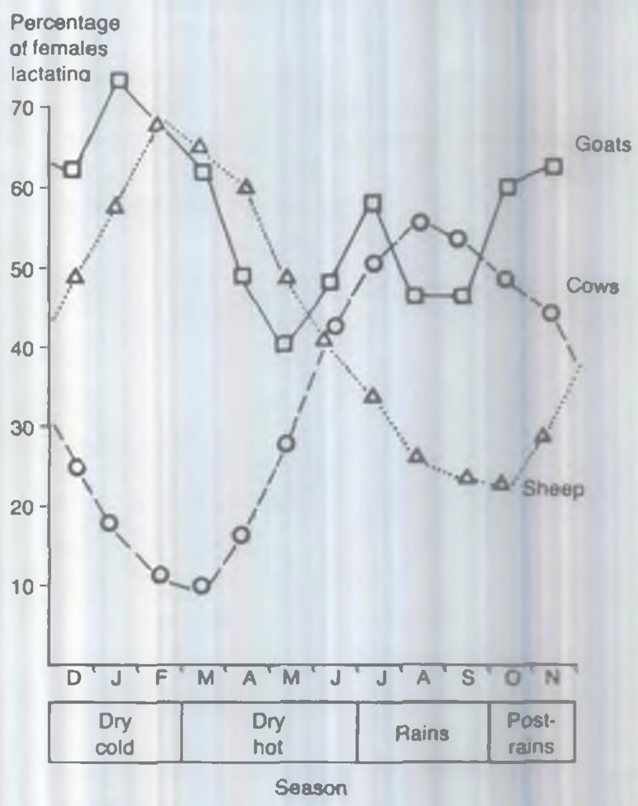
Table 5. The relative proportions of livestock species in two Somali clans in southeast Ethiopia.

Clan	Density of dry-season water points (number/km^{2})	Per cent of total biomass			
		Camels	Goats	Sheep	Cattle
Habar Awal	0.04	72	4	15	9
Abaskul	2.57	27	9	33	31

Sources: Cossins (1971); Watson et al (1973).

The inter-species structure of herds can also reflect management objectives. Keeping herds with mixed species composition decreases competition for feed resources, since different species tend to make rather different use of different components (e.g. grass and browse) in the total feed supply. Keeping a mix of species also reduces risk by lessening the dependency on one species for meat and milk (Wilson et al, 1985a, Chapter 6). Mixed species production also increases the likelihood of meeting basic consumption needs, particularly in terms of milk. Figure 1 provides an example of the effect of mixed herding on annual milk production in pastoral herds in western Sudan.

Figure 1. Annual cycle of lactating females in Southern Darfur, Sudan.[1]



[1] Assumes that lactation lasts for four months for sheep (rarely milked), five months for goats and seven months for cows.

Source: Wilson et al (1985a, Chapter 6).

Herd/flock structure

By the expression 'herd structure' we mean the proportion (in terms of number of head) of the herd of a single species which is formed by different age and sex classes of animals, e.g. breeding females, calves, mature bulls, mature oxen etc.

Table 6 gives an example of herd structure data from an agro- pastoral system in Zimbabwe. Figure 2 shows how structure data can be depicted graphically in the form of an 'age pyramid'.

Herd structure is usually the easiest data to collect and can indicate which further data may most need to be collected subsequently. Information about herd structure can tell us something about:

- **The owner's management objectives** (i.e. whether he is mainly interested in the production of milk, meat or draft power).

  For instance, pastoral herds tend to have as many cows as possible to produce milk for human consumption, which is an important production objective. On the other hand, males not needed for reproduction are sold to generate cash for food and other purchases.

  In mixed production systems where animals are used for draught and transport, the proportion of mature oxen or donkeys in herds tends to be relatively high. (Donkeys are extensively used for draught and transport in Botswana, Mali, Ethiopia, Niger and parts of Zimbabwe.)

Table 6. Average number of cattle owned/held per household in the Matabeleland communal area, Zimbabwe.

Livestock category	Average holding/household Number ± S.E.	Per cent of total herd
Calves	1.91 ± 0.17	19.2
Young stock[a]	1.20 ± 0.17	12.0
Cows	4.76 ± 0.43	47.8
Oxen	0.27 ± 0.05	2.7
Bulls	1.90 ± 0.15	19.1
Total	9.96 ± 0.80	100.0[b]

[a] Stock less than three years old.

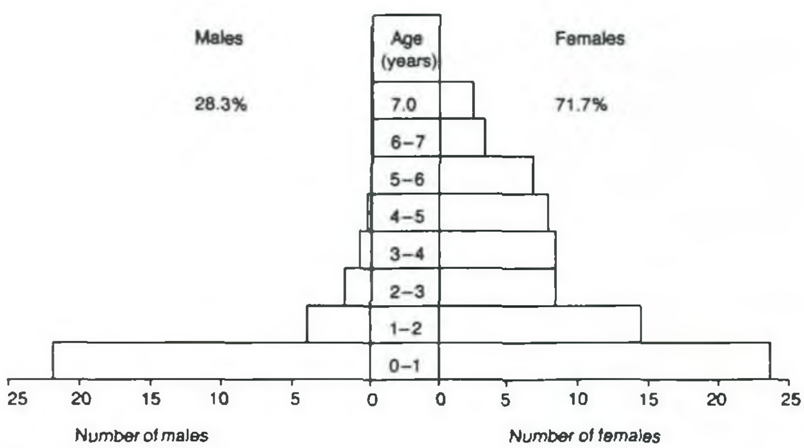
[b] Difference due to rounding error only.

Source: Zimbabwe Government (1982).

- **Problems or constraints in the system.** Data on herd/flock size and structure will give an idea about birth and death rates and offtake levels (Wilson and Semenye, 1983; Matthewman and Perry, 1985), which, in turn, may indicate where more in-depth studies are needed.

  For instance, a relatively low proportion of young stock in a herd (or the target area) would suggest that adult mortality is low or pre-weaning mortality is high, or that calving percentage is low. Alternatively, it may mean that calves were sold during the year. To determine which of these causes is most likely, it will be necessary to study the general conditions of calves and cows, the level of nutrition and disease prevalence, and interview the owners.

Figure 2. Age pyramid for transhumant goats in Chad, 1976.



Source: Wilson and Semenye (1983).

Information about herd structure can also provide the basis for calculating or forecasting herd productivity. After a drought, for instance, pastoralists' herds often have a structure which is 90%

breeding females. Knowing this enables one to forecast a large crop of calves and a rapid increase in milk supply or herd numbers in contrast to the more usual case where breeding females make up 40% of the herd.

Reproductive performance

The reproductive performance of the breeding female is probably the single most important factor influencing herd/flock productivity. This is so because:

- **all forms of output** (milk, meat, traction, wool and hides) **depend on it**, and
- **it is the determinant of output which varies most** (has highest coefficient of variation) **between flocks within a population**. This variability is not random but caused by identifiable influences which can usually be manipulated.

Reproductive performance, therefore, is often the determinant of output which is most susceptible to improvement, simply by using management practices already used by some in the farming community. The usefulness of data on reproductive performance lies in their ability to help us identify causes for poor reproductive performance, and hence opportunities for improvement.

The purposes of collecting data on reproductive performance are to:

- establish the relationships (correlations) between different parameters and variables which influence reproduction, and
- calculate reproduction ratios enabling comparisons of productive performance.

Many different factors influence reproductive performance, such as:

- **nutrition**
- **genes**
- **animal disease and health, and**
- **the huge variety of management practices**, either alone (e.g. control of the mating period) or in conjunction with the above (e.g. mating on a rising plane of nutrition).

Establishing relationships between these factors and reproductive performance is a must when identifying constraints in particular systems. Table 7 gives an example of the relationship between feed and the reproductive performance of small ruminants in the Maasai area of Kenya.

Example:

Table 7. Effect of feeding *Acacia tortilis* pods in 1983 on the reproductive performance of goats and sheep.

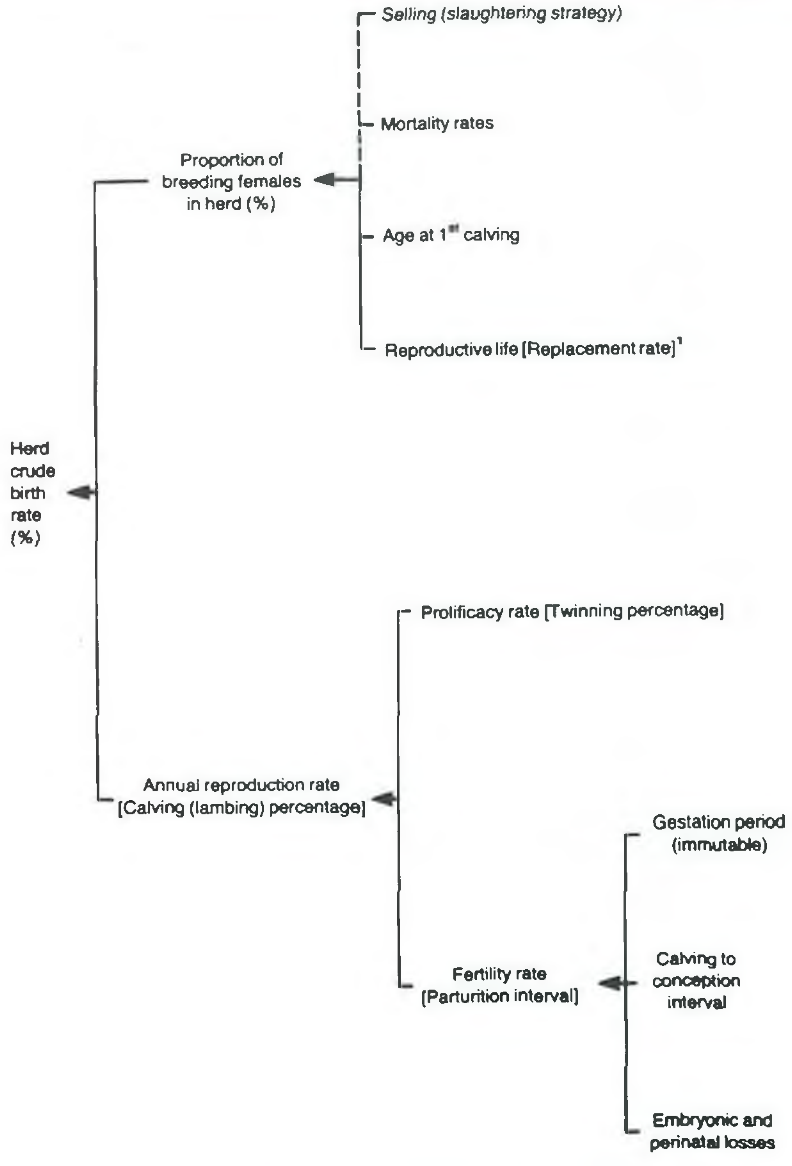
	Pod feeding		No pod feeding	
	Goats	Sheep	Goats	Sheep
	Per cent of all breeding females			
Mated	97	73	20	47
Conceived	70	54	20	47
Gave birth	79	54	13	44
Aborted	1	0	7	13

Source: Adapted from Peacock (1984).

The expression 'reproductive performance' does not usually refer to a single trait, but to a combination of many. We can deal with these at various levels of complexity. Figure 3 shows, with only a moderate degree of complexity, the relations between the various components reproductive performance. We shall briefly describe and define the various concepts and their relations with each other in a way which will enable the reader to use the concepts to measure reproductive performance.

Herd crude birth rate. We can express the total number of calves (lambs/kids) born as a proportion of the total number of animals in the herd, and call this expression the 'herd crude birth rate', by analogy with the crude birth rate in human demography. The concept is, however, rarely used for other animals than humans.

Figure 3. Components and determinants of herd/flock reproductive performance.



[1] Terms in square brackets, [ ], are synonymous or closely related.

The crude birth rate is a function of the annual reproduction rate (see below) of the breeding females, and of the proportion of breeding females in the total herd. This, in turn, is determined by certain management strategies (selling/slaughtering), by the relative mortality rates of different classes of animals, and by two reproductive traits, the 'average age at entry to the breeding herd' (i.e. when a heifer is thought to be ready for breeding), which is related to the average 'age at first calving', and the 'reproductive life' (i.e. the average number of years between first calving and last calving).

The *annual reproduction rate* (ARR) is the average number of births per breeding female per year. Particularly with cattle in Africa it is also referred to as the **calving rate**, but outside Africa, this latter term is increasingly being used to express, instead, the number of calves born per impregnation (either by natural service or by artificial insemination).

The *prolificacy rate* is the number of live offspring born, on average, every time a breeding female gives birth. This is usually unity (i.e. 1.0) with African cattle but is often much higher with small ruminants, for whom the expression **twinning rate (percentage)** may also be used.

The *fertility rate* is the number of times per year, on average, that a breeding female gives birth. It is also often expressed as the **parturition interval**, i.e. the average period of time (usually given in days) between successive births. However, expressing the fertility rate solely in terms of intervals between successive births ignores two further elements which should rightly be included. These are:

- the period of time after a heifer is considered ready for breeding before she produces her first calf, and
- the time after a cow produces her last calf before she is culled or otherwise removed from the category of breeding females.

The fertility rate, in turn, is determined by the (immutable) average **gestation period**, by the **calving to conception interval** and by **embryonic and perinatal losses** (also loosely referred to as 'abortions').

An approximate **annual reproduction rate for the herd/flock** as a whole can be calculated by dividing the average number of young born per breeding female by the average parturition interval for the animal species in question (see Table 8).

Alternatively, the annual reproduction rates for individual breeding females can be calculated and aggregated to determine the overall reproductive rate for a herd or flock. Calculating the rate on an individual animal basis gives also information about the distribution of litter sizes and parturition intervals. Individual calculations are, however, time consuming and costly.

Examples:

a) Annual reproduction rate for goats

Assuming that the estimated average number of kids born per parturition in a flock of goats is 1.2 and the average parturition interval is 240 days, then the ARR for the breeding flock is:

ARR (%) = $\{(1.2/240) \times 365\} \times 100 = 182.5$

The average number of young produced per year per breeding female thus is about 1.8.

b) Annual reproduction rate for cattle

Assuming that breeding cows produce, on average, one calf per parturition and that the average parturition interval is 550 days, then the annual reproduction rate for the herd is:

ARR (%) = $\{(1.0/550) \times 365\} \times 100 = 66.36$

The average number of calves produced per year per breeding female therefore is 0.66.

When measuring the parameters of reproductive performance in on-farm surveys, users of the manual should remember that:

- short-term studies may underestimate the true parturition interval, because they only take account of females which give birth twice or more during the survey period, and these will be the most fertile ones; and

- not all breeding females may actually be exposed to effective impregnation (e.g. because of shortage of bulls) and the wrong conclusions may be drawn about the poor performance of the female.

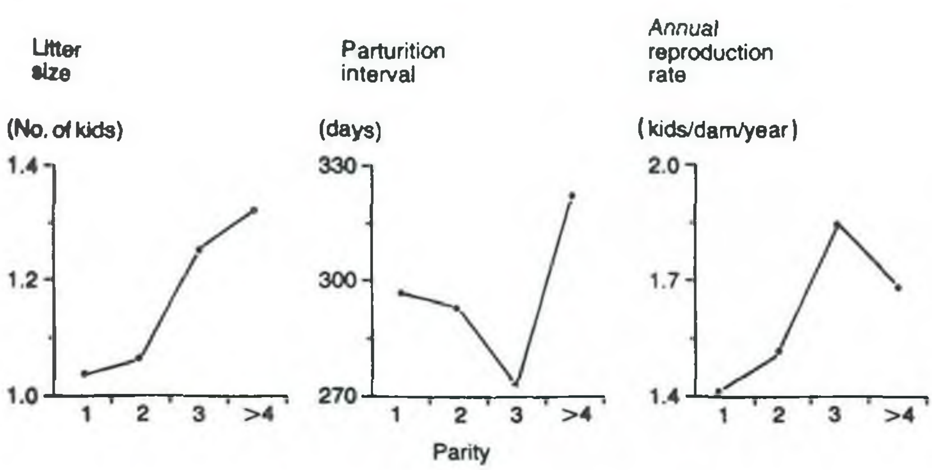
Table 8 gives some typical values of reproduction parameters in Africa and Figure 4 gives specific examples from Mali.

Table 8. Reproductive parameters for African domestic livestock.

Parameter	Camels	Cattle	Goats	Sheep	Donkeys
Gestation period (months)	12	9	5	5	11
Age at first parturition (months)	60	48	15	15	42
Parturition interval (months)	26	18	8	8	11
Life expectancy (years)	15–20	10–12	6	5	14–18
Mean number of births/ reproductive period	2.7	2.1	6	5	3
Maximum number of births/ reproductive period	9	8	12	8	8

Source: Wilson et al (1985a, Chapter 6, p. 118).

Figure 4. Annual reproduction rate and its components for traditionally managed goats in central Mali



Source: Wilson (1989).

Mortality

Pre-weaning mortality

High mortality in young stock is a major cause of low productivity in many African livestock production systems. Mortality rates of 20–25% are commonly recorded for calves (e.g. Zimbabwe Government, 1984; Butterworth, 1985), and rates of between 25 and 35% appear to be fairly typical for small ruminants (Wilson et al, 1985a, Chapter 6). For camels, the mortality rates for young stock range between 20 and 50% (Wilson, 1984a; 1986a). During drought, young-stock losses are likely to be much higher.

Causes of death. Young-stock losses before weaning are influenced by:

- **season of birth** which has an effect on the quality and quantity of feed (milk and forage) available, the incidence of disease and the level of parasite infestation
- **type of birth** i.e. single, twin or triplet
- **sex of the offspring**
- **age of the offspring** (the ability to survive up to weaning time increases with increasing age)
- **parity**, which affects the dam's mothering ability and milk production, and
- **management**, which affects disease prevalence and season of birth.

Analyses of the relations between these variables and pre-weaning mortality will often provide the basis for the design of improved management systems, e.g. through selection against twins in sheep where survival rates tend to be low (Wilson et al, 1985b).

Figure 5 is an example of 'improvement pathways' devised for small ruminants in Kenya. For additional practical examples, the reader can refer to Wilson et al (1985b, c).

Measurement of pre-weaning mortality. The pre-weaning mortality rate for a herd/flock is defined as:

$$\text{Pre-weaning mortality rate (\%)} = \frac{\text{Number of deaths before weaning}}{\text{Number of animals born}} \times 100$$

The estimates are usually based on animals born alive, probably because data on abortions and still births tend to be incomplete.

Post-weaning mortality

In traditional production systems, post-weaning mortality tends to be lower than mortality before weaning (Traore and Wilson, 1988).

Causes of post-weaning mortality. The factors which commonly cause death after weaning are disease and malnutrition. The age of the animal also affects post-weaning mortality rates, such that the risk of death initially declines and increases again towards the end of the animal's life (Figure 6). In some parts of Africa, predators can also cause significant losses.

Measurement of post-weaning mortality rate. When data on herd/flock structure are available, overall mortality rates for particular age/sex groups within the herd/flock can be calculated as follows:

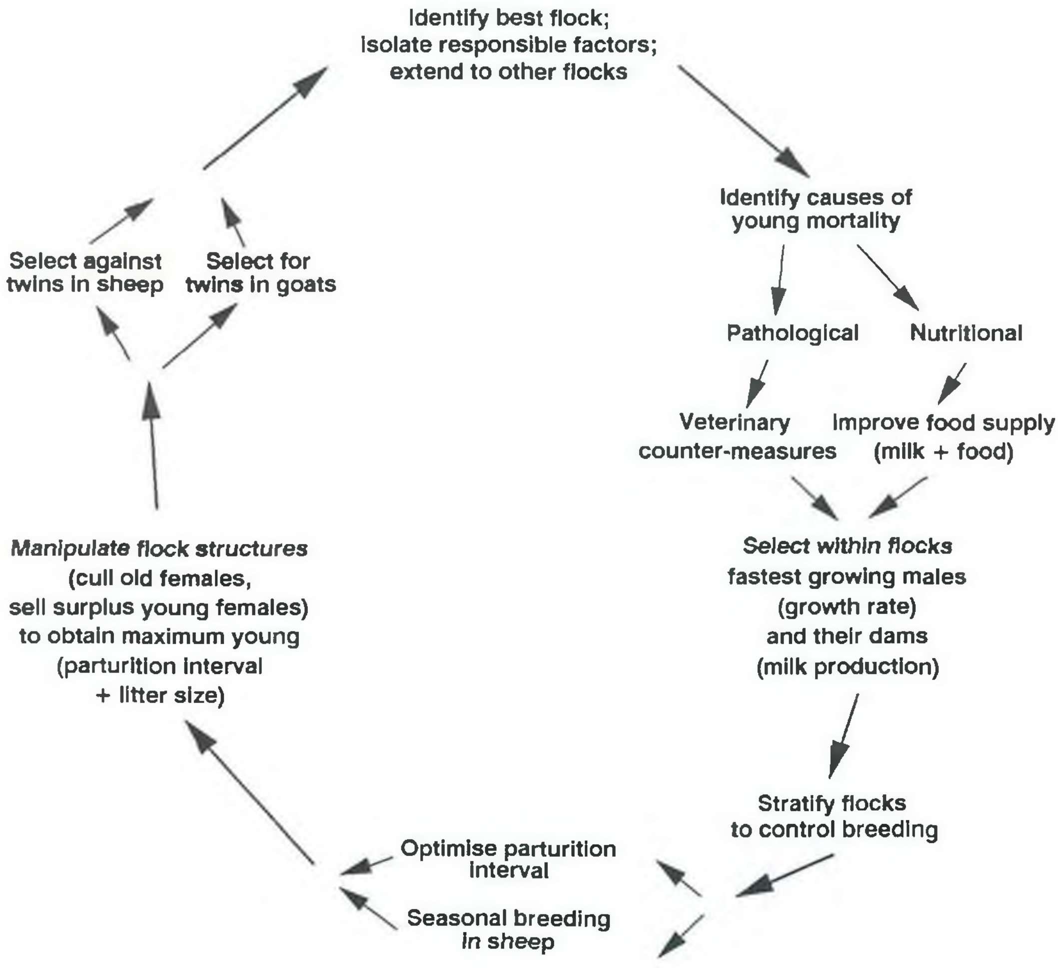
$$\text{Overall mortality rate (\%)} = \frac{\text{Number of deaths per age/sex group}}{\text{Number of stock within each group}} \times 100$$

For the herd or flock as a whole:

$$\text{Overall mortality rate (\%)} = \frac{\text{Total deaths}}{\text{Total number of animals in herd/flock}}$$

Example:

Figure 5. Potential improvement pathways for traditionally managed small ruminants on Maasai group ranches, Kenya.



Source: Wilson et al (1985 b).

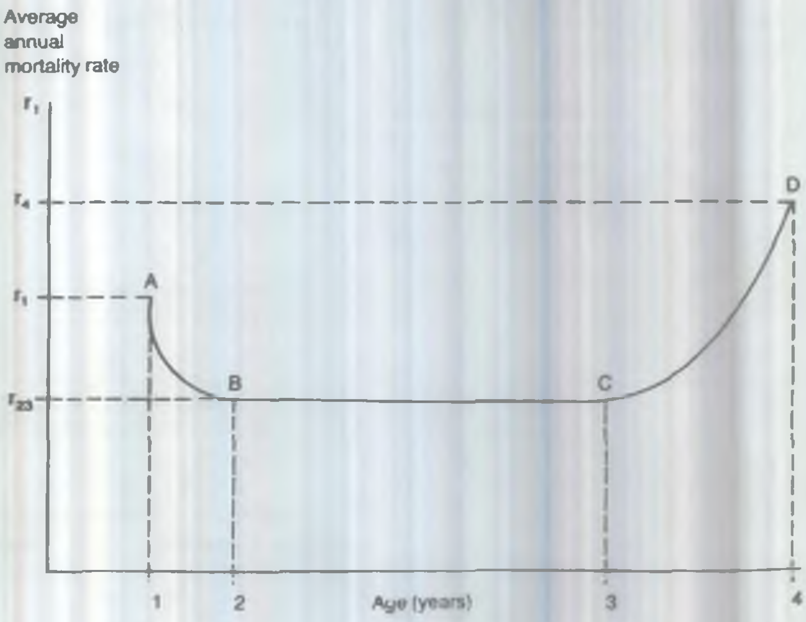
The **denominator** commonly used in such calculations is the number of animals at the beginning of the period over which overall mortality is measured, which means that animals sold or purchased during the period are excluded. This can bias the result obtained (e.g. if purchases occur just after the beginning of the year, the formula will give an overestimate of the actual rate).

Therefore, the average of the opening and closing numbers is usually used as a denominator, even though this can result in bias as well. (For instance, if a large number of stock is purchased at the end of the period, the formula will underestimate the true mortality rate.)

No general recommendation can be made: the approach adopted will often be a matter of choice based on knowledge of the 'typical' patterns of acquisition and disposal in the surveyed area, and on the degree of accuracy required. However, if accurate results are needed, it is preferable to base the

Example:

Figure 6. Average annual mortality rate ($\overline{r}_t$) as a function of age.



Source: Wilson (1987).

denominator on the length of time animals were actually present in the herd/flock. The procedure in this case is to:

- define the period over which mortality is to be measured
- define the age/sex group for which mortality rate is to be recorded (e.g. 1- to 2-year-old males; 3- to 4-year-old females etc)
- for each individual animal in the herd/flock, sum the number of days during the measurement period in which the animal was actually present. If sold or otherwise disposed of, or if the animal died during this period, sum the days present to that date
- aggregate the total number of days present for all individual animals in the selected age/sex group and divide this figure by the length of the period over which measurement took place (e.g. if the period of measurement is one year, divide the aggregate by 365), and
- relate this figure to the actual number of deaths recorded and express the result in percentage terms.

For a period of 1 year, the rate would be calculated as follows:

$$\text{Mortality rate (\%)} = \frac{\text{Total number of deaths}}{\text{Total days present for all stock/365}} \times 100$$

This formula requires precise records for each animal for the intended period of measurement. It will improve the accuracy of the result but will involve frequent visits to selected households. When this level of accuracy is not needed, the previous formula will normally be sufficient.

Growth and weight gain

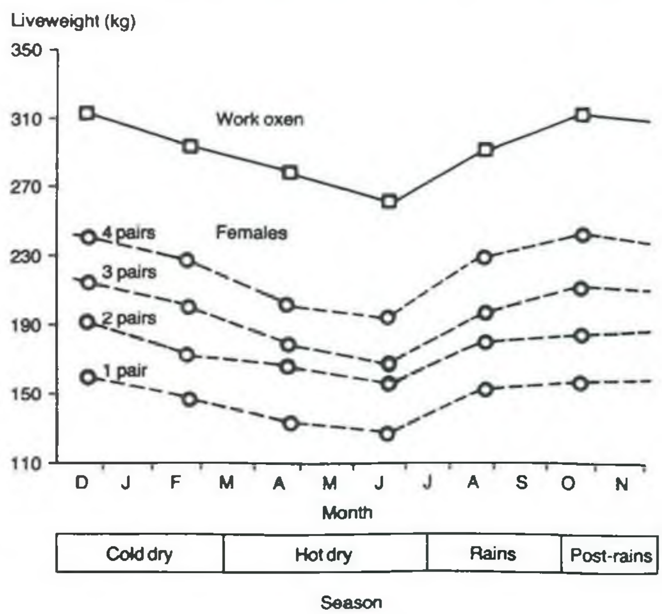
Slow growth rates in African livestock are a major cause for low productivity, affecting the age at which reproduction commences or oxen become available for ploughing, and the weight (and age) at which animals are slaughtered.

In the study of growth and weight gain,[1] one or more of the following parameters will often be measured:

- weight for age
- growth rates over time by age, sex or genetic group (e.g. Msanga et al, 1986)
- seasonal variations in body weight (Figure 7) and growth rates, and
- compensatory gain (Module 7, Part A) following periods of seasonal stress. This may, for instance, affect the capacity of oxen to plough and the timing of crop operations.

Example:

Figure 7. Effects of season on body weight of cattle, central Mali.



Source: Wilson (1987).

Weight and growth measurements should be directed towards research into the factors affecting animal performance. Weight for age records will normally be based on measurements taken at birth, weaning and after weaning.[2] Measurements of liveweight over time may make it possible to isolate environmental effects and to determine whether improvements in productivity are feasible, e.g. through selection for improved weight gain or through seasonal adjustments in grazing pressure.[3]

---

1 Measurement of carcass composition is not discussed in this manual because the parameter is relatively unimportant in the context of African livestock production systems.

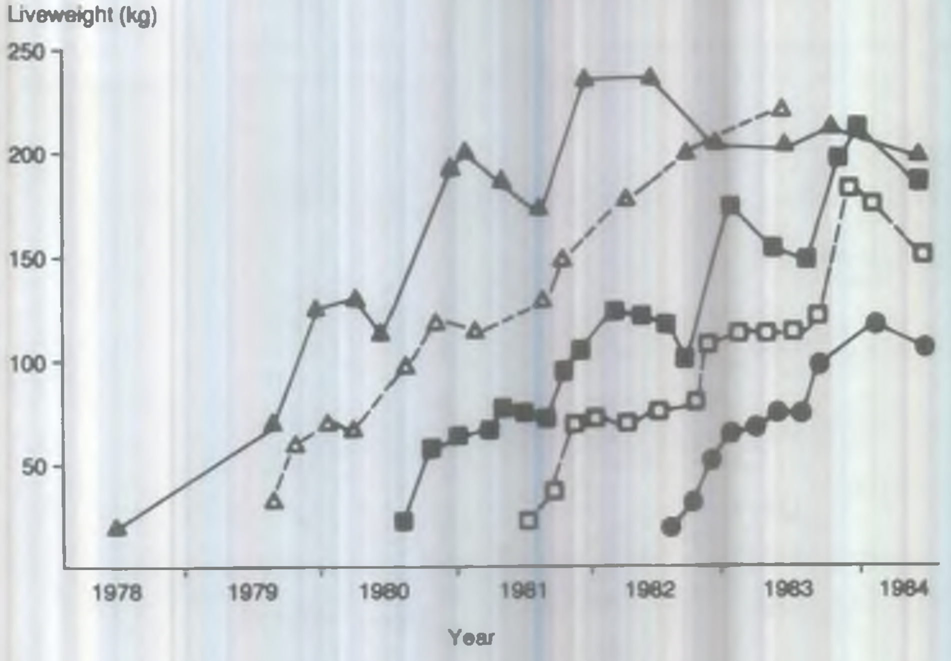
2 Measurements at birth enable a more accurate estimate of daily liveweight gain and weight for age from birth up to weaning. After adjustments to normal weaning age and correcting for environmental effects, weaning weight ratings can be used to assess mothering ability as a basis for dam selection. Post-weaning weight records obtained at various intervals can be used as a basis for individual animal selection, after making adjustments for environmental effects.

3 Selection for least-weight loss is also feasible, and this trait is highly heritable in some adapted populations.

Thus, when measuring growth and weight gain,[4] it is often useful to explore their relationships with breed, type of birth (singles, twins etc.), sex, parity, season of birth (which can have medium- to long-term effects on growth rate, see Figure 8), seasonal conditions, disease and management system (Wilson, 1987). Care must be taken (and this may require sophisticated statistical techniques, such as analysis of variance which is beyond the scope of this manual) not to attribute to one of these factors effects which are really caused by another factor.

Example:

Figure 8. The effect of season of birth on growth rate of calves born in Mali in May during the period 1978–84.



Source: Wilson (1987).

Comparisons of growth rate performance over time can be done on the basis of average daily weight gain which is calculated as:

$$\text{Average daily weight gain} = \frac{\text{Weight at period } (t+1) - \text{weight at period } (t)}{\text{Number of days between } t, t+1}$$

> **Example**: The average birth weight for a group of Mpwapwa calves in Tanzania was 27.8 kg under trial conditions. At weaning (75 days), the average weight had increased to 59.3 kg (Msanga et al, 1986). The average daily weight gain (ADWG) during the period thus was:
>
> ADWG = (59.3 – 27.8)/75 = 0.42 kg/day.

4 Weight gain is only one component of growth but it is the one most commonly measured in livestock systems research. Other measurable components of weight are height and girth circumference (Wilson and Maki, 1988).

Average daily weight gain makes, however, no allowance for differences in body frame (i.e. skeletal structure), nor does weight, of itself, accurately reflect an animal's condition. Although having the same body weight, an animal with a large frame will be in a poorer condition than an animal with a smaller frame. To correct for this bias, relative daily weight gain may be used:

$$\text{Relative daily weight gain} = \frac{\text{Average daily weight gain}}{\text{Average liveweight over period } t,\ t+1}$$

Outputs

In African traditional systems, animals perform a variety of functions. Depending on the species, they provide milk, draught power, transport, meat, manure, hides, skins and wool. They are also good investment and a handy source of savings which can be drawn on in times of emergency or to meet particular cash needs (e.g. school fees). Last but not least, owning livestock is prestigious in some societies and confers a higher social status.

The outputs usually measured in livestock systems research are meat, milk, manure and draught power.[5] This module also focuses on the measurement of milk and meat outputs and shows how composite productivity indices can be developed to provide an overall measure of animal performance. The measurement and valuation of manure as a farm input is discussed in Module 4.

Milk

Milk is widely consumed in both rural and urban areas of Africa. It constitutes a major part of the diet in pastoral communities and influences herd structure and the timing of lactations of different animal species within the herd or flock (Wilson et al, 1985a, Chapter 6).

Milk output is affected by such factors as animal species, breed/genetic potential, parity, lactation length, weaning period, disease, seasonal conditions and feed supply, and management system.

In some countries (e.g. Kenya), small-scale dairy operations produce the bulk of the marketed milk supply for urban and rural communities, while in others (e.g. Zimbabwe, Swaziland, Nigeria and Ethiopia), governments are actively involved in the promotion of such operations. Attempts are also being made to extract surpluses from the traditional sector through co-operative and other marketing agencies.

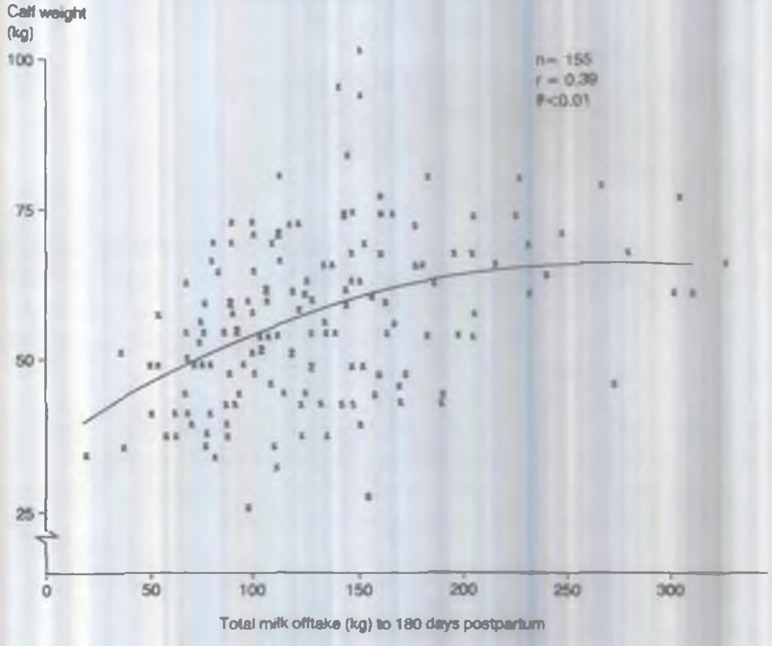
Although the type of milk data collected will largely depend on the system being studied and the objectives of the study, **milk output per lactation** and **lactation length** will almost always be measured. These parameters are particularly important in subsistence systems, where they not only are themselves affected by a number of factors but also, in turn, have an effect on human nutrition and the growth rate of young stock before weaning (Wagenaar et al, 1986; Wilson, 1987) (Figure 9).

Information on **milk sales** will also be needed. The amount of milk sold will depend, among other things, on such socio-economic factors as prices, market outlets, household size and household income. However, unless the system is geared towards commercial dairy production, sales will usually be opportunistic, and the amounts sold, difficult to measure. Quality assessments in terms of butterfat and protein content will usually be done for small-scale dairy operations supplying milk for processing in commercial plants.

Milk produced by a cow may either be used for feeding its own calf or be extracted for human consumption, and it is highly desirable, in order to avoid confusion, to use consistent terminology in describing these two fractions. Unfortunately, this is frequently not done, and it is difficult, when reading

5 Hides, skins and wool are generally of minor importance in African livestock systems. Animal transport, though much used in some areas, is difficult to measure accurately and is not dealt with in this manual.

Figure 9. Correlation between milk offtake for human consumption and calf weight at 180 days post-partum, Diafarabe, Mali, 1979–83.



Source: Wagenaar et al (1986).

other people's reports, to be sure which fraction they are referring to. The following terminology is recommended:

- *Extracted milk* is milk taken from the cow for human consumption, in whatever form (e.g. fresh milk, yoghurt, butter), and however disposed of (i.e. by sale or by subsistence consumption in the farmer's household). In theory, although this is not a practical issue at present in Africa, extracted milk includes milk used for non-food industrial use or for feeding animals other than calves in the same herd.
- *Milk consumed by calf* is milk consumed by the cow's own calf or by other calves within the same herd, whether this is by suckling or by bucket feeding.
- *Milked-out production* is extracted milk plus milk consumed by calf.

Expressions such as 'milk output', 'milk production', 'milk yield', and even 'milk offtake' are ambiguous as to whether or not they include both 'extracted milk' and 'milk consumed by calf' and should not be used unless a clear indication is given as to their definition. Because of this ambiguity, it is recommended that terminology suggested above is routinely used.

How milk production should be valued for surplus and deficit milk producing households is discussed in Part B of Module 4.

Liveweight output

The output of liveweight in African livestock production systems consists of four components:

- slaughter for home consumption
- sales for cash
- disposals for other reasons (e.g. gifts, ceremonies, exchanges), and

- liveweight gain of the herd.

Herd liveweight gain can result from a net increase in herd size and/or an overall increase in average body weight. If herd size and average body weight decline (e.g. during periods of drought), herd liveweight gain will be negative. The value of output, however, can increase or decrease during periods of constant body weight due to variations in price.

Each component of meat output should be measured and valued separately to obtain a true indication of liveweight production in a herd or flock. Output resulting from herd liveweight gain can be valued by its liveweight market price or converted to a dressed weight price equivalent.[6] The price used to value unsold liveweight output will depend on whether the household is a deficit or surplus producer (see Part B in Module 4).[7] Measurement of offtake and of changes in herd/flock numbers over time is discussed in Module 9.

Productivity indices

In order to make meaningful comparisons of performance within and between different production systems, composite productivity indices have been developed for goats, sheep and cattle, taking into account reproductive performance, viability[8] and liveweight (Wilson, 1983; Wilson et al, 1985c; Wagenaar et al, 1986). Each index is based on the assumption that breeding female productivity provides a good indication of overall herd/flock performance.

The productivity indices are defined as:

$$\text{Index 1: } \frac{\text{Weight of weaned progeny}}{\text{Parturition interval}} \times 365$$

$$\text{Index 2: } \frac{\text{Index 1}}{\text{Postpartum dam weight}}$$

$$\text{Index 3: } \frac{\text{Index 1}}{\text{Postpartum dam weight}^{0.75}}$$

Index 1. This index gives the liveweight of progeny produced per dam per annum. It reflects reproductive performance, liveweight output and the mortality rate of young stock. For small ruminants, the ratio makes allowance for the fact that females breed more than once a year and have litter sizes of more than one. However, because the index only accounts for the weight of weaned progeny, it is deficient in that it ignores:

- differences in dams' liveweight, and hence their need for feed
- advantages (social or financial) of having two smaller animals instead of one larger one, and
- milk output for human consumption or sale, even though the value of this output may be significant. There may also be significant opportunity costs associated with suckling the young for the whole of the normal weaning period. By valuing milk used for this purpose in terms of progeny liveweight, the index may understate the true value of output produced.

Indices 2 and 3 take into account the differences in dam weight by relating liveweight of progeny produced per dam per annum to the weight of the dam postpartum. Index 3 expresses dam size in terms of metabolic weight.[9]

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6 Dressing percentage fails to take account of the value of offal (i.e. the 'fifth quarter' – Staatz, 1979) which is often consumed. If used, a liveweight conversion factor of 0.45–0.55 is normally applied. For small ruminants, a factor of approximately 45% would appear to be applicable (Wilson, 1984b).

7 Wool, hides and skins output will be valued at market price. The liveweight price of an animal for slaughter will include the value of its hide or skin.

8 Viability is the rate of survival, e.g. if annual mortality is 5%, then viability is (100 – 5) = 95%.

9 For a discussion of metabolic weight (i.e. body weight$^{0.75}$) refer to Butterworth (1985, pp. 30–32).

Overall performance expressed by the indices can then be correlated with different parameters, such as parturition interval and dam weight, to determine how it is affected by them. (Examples of correlation analysis are given in Wilson, 1986b). However, since gathering case-by-case information on such parameters is costly and time consuming in traditional livestock production systems, correlation analysis should only be done when it is absolutely necessary.

Table 9 shows the steps to be taken in calculating Index 2. For index 3 an additional step has to be taken to convert liveweight to metabolic weight.

Example:

Table 9. Steps in the calculation of productivity indices for cattle.

Parameter	Code	Calculation
Cow mortality during year (%)	A	
Calving percentage	B	
Calf mortality to one year (%)	C	
Percentage of cows maintained with calves reaching one year	D	B(100 – C)/100
Calf weight at one year (kg)	E	
Extracted milk yield/completed lactation (kg)	F	
Percentage of cows maintained who produce the equivalent of a completed lactation annually	G	[B/100] [100 – (C/2)][a]
Total liveweight equivalent of extracted milk yield per cow maintained (kg)	H	F[G/100]/9[b]
Total liveweight of 1-year calf produced per cow maintained (kg)	I	E[D/100]
Liveweight of 1-year calf plus liveweight equivalent of milk extracted, per cow maintained (kg)	J	[I + H] / [{100 – (A/2)}/100][c]
Average cow body weight (kg)	K	
Liveweight of 1-year calf plus liveweight equivalent of milk extracted per 100 kg of cow maintained annually (kg) (Index)		J[100/k]

[a] A cow whose calf dies during the lactation period is considered to have actually produced milk during half the period.

[b] Conversion factors constructed from Drewry et al (1959).

[c] Cows dying during the year are considered to have been maintained for half a year.

Source: Derived from ILCA (1979).

PART C: METHODS OF DATA COLLECTION

Herd/flock structure

Herd/flock structure data may be collected independently in a single-visit interview or as part of a multiple-subject survey of household size, asset ownership etc. Repeat surveys may be needed if significant changes in numbers/structure are suspected (as a result of prolonged drought, for instance). Three methods of data collection are commonly used:

- **ageing by dentition**
- **owner/holder interviews, and**
- ***interpretation of aggregate livestock statistics.***

Ageing by dentition. Using this method, animals are individually handled by the survey team, and their age is determined on the basis of the number of erupted teeth they have (see Table 10). At the same time, their sex and functions are recorded on cards for future use. Large samples (of about 1000 animals of each species) will normally be required to obtain reliable estimates of the overall herd/flock structure in an area.[10]

The time of tooth eruption differs between species and may be influenced by management system, seasonal conditions, sex, nutrition and body size. For camels, the pattern of tooth eruption is different from that of cattle and small ruminants (Wilson, 1984a).

Owner/holder interviews. The owners' knowledge of their animals' age may not be precise but will be sufficient if only approximate data on herd/flock structure are required. When more accurate age estimates are needed, interviews should be combined with structuring by dentition. If herd splitting is practised (see Module 10), owners/holders should be interviewed when all the animals are at the home base, so that specific animals may be examined and their individual characteristics identified and recorded. Recent losses may also be noted (see 'Progeny history method' below).

Table 10. Ages for incisor eruption in cattle, sheep and goats.

	Pairs of incisors			
Species	1st	2nd	3rd	4th
	eruption at month			
Cattle	27–32	32–36	40–44	47–54
Sheep	14–20	21–25	26–32	32–38
Goats	14–17	19–22	24–28	31–37

Sources: Kikule (1953); Wilson and Durkin (1984).

Aggregate livestock statistics. Estimates of herd/flock size and structure obtained from national, regional or district statistics (e.g. from vaccination or dip-tank records) are rarely reliable and should always be interpreted with caution (see Module 9).

Reproductive performance

Rough indications of reproductive performance can be obtained from herd/flock structure surveys. More detailed information can be obtained by using:

- **progeny history method**, or
- **continuous recall.**

10 ILCA staff in West Africa have been able to handle up to 300 head of smallstock or 80–100 head of cattle in a 5-hour session (Wilson and Semenye, 1983). The numbers handled will depend on the average size and dispersion of herds/flocks within the target area, and experience.

The progeny history method. This involves recording the breeding history and reproductive performance of each mature female in the herd/flock.[11] Offspring are identified and details about sex, function etc are recorded; if some are no longer in the herd/flock, the reason for their not being there should also be determined (see example below).

The progeny history method has been used by ILCA to obtain data on herd structure, transactions and reproductive performance in Niger, Nigeria, Ethiopia and Kenya (Grandin, 1983). As with all other single-interview methods, the accuracy of the results will largely depend on the length of the recall period: the older the animal, the greater the likelihood of error for births early in the dam's life.

Management system and the animals' role in the overall production system also influence the reliability of recall. For instance, pastoralists, who attach great value to their animals, have been shown to have accurate knowledge of animal breeding histories, even when herds/flocks are large (Grandin, 1983, p. 284). However, in the agropastoral system where animals are bought or sold frequently, recall may be relatively poor, even when herds or flocks are small. Recall of abortions and deaths soon after birth is usually unreliable.

Example: The questions commonly used to solicit information on reproduction and other performance in a progeny history interview are:

- How old is this cow?[12]
- How did you acquire it (e.g. by inheritance, purchase, birth within herd etc)?
- How many calves have been born to this cow?

  Focus on the first calf:

  - Was it a male or a female?
  - Which season and year was it born?
  - Where is it?
    - Is it in the herd today? Show me.
    - Is it dead? Is so, at what age did it die and why?
    - Did you sell it? If so, at what age and to what sort of purchaser?
    - Did you slaughter it? If so, at what age?
    - Did you give or lend it to someone? If so, at what age?
    - Where else is it? (If not covered above)

  Now focus on the second calf ...... etc.

As the above shows, additional information related to management and marketing strategies, and reasons for sale or death, may be obtained during this questioning.

11 To ensure that all breeding animals are present, interviews should usually be conducted early in the morning before the herd/flock is released for grazing and watering.

12 Dentition checks could be made at the same time.

For a rapid appraisal of reproductive performance, the choice of animals can be opportunistic but for more in-depth studies, proper sampling techniques should be used. Where possible, local terms should be used to identify season of birth, age of dam, type of birth and parity (Wilson and Wagenaar, 1983). Person(s) most familiar with the animals being sampled should be interviewed. In pastoral communities, for instance, the most reliable information on progeny histories can be obtained from women and/or herd boys (Grandin, 1983).

A reasonable approximation of reproductive performance can also be obtained from a general survey of the ***overall breeding rate*** in a herd/flock, defined as the number of parturitions per number of breeding females in a defined period (Wilson and Semenye, 1983, pp. 169–170). However, data obtained by general surveys on age at first parturition, parturition intervals, abortions, still births or losses soon after birth are unreliable, particularly if the recall period is long (e.g. 1 year). Continuous survey techniques, with shorter recall periods, will then be preferred.

Continuous recall. To obtain reliable data on reproductive performance with this type of method, visits every 10 to 14 days during the breeding season and up to weaning will be required. The dam and progeny should be identified and all details recorded, including data on matings, type of birth, sex of progeny, weaning periods, mortalities and management practices. An example of a record sheet used by ILCA is given overleaf.

The animals included in the survey are commonly identified by an ear tag. In some societies (e.g. the Fulani of Mali and the Maasai of Kenya), individual animals are identified by name. Using them together with ear tags will improve identification of animals on subsequent visits.

Mortality

Mortality data can be obtained from single-interview or continuous recall surveys. They can also be obtained from progeny history interviews (see progeny history example above), but recall over long periods is likely to be less accurate than for data on reproductive performance.

Single-visit surveys. These can be used to obtain overall herd/flock mortality, but long periods of recall will decrease its accuracy, especially for young stock which had died early in life.

Continuous recall surveys. This type of survey is suitable for recording individual animal losses and identifying causes of death. Details on age, sex, type of birth, parity, disease, seasonal conditions and management systems should be recorded for each animal lost to examine the effects of these variables on mortality. Disease, in particular, will require careful monitoring to determine the exact causes of death.

Example:

CONTINUOUS RECALL SURVEY

Country		Date of first visit	
Region			
District		Sex: Female	☐
Household number		Male	☐
....		Castrated male	☐
Species: Sheep	☐		
Goat	☐	No. of animal	☐
Breed		Type of birth	☐

Continued...

Example continued

1. Reproduction

			Offspring			
Date	Parturition number	Litter size	Sex	Identification	Weight	Age (days)
	1					
	2					
	3					
	4					
	5					
	6					
	7					
	8					

Observations

2. Weight performance and teeth observations

Date	Age given by owner	Age by teeth	Weight	Remarks

3. Health interventions

Date	Intervention	Date	Intervention	Date	Intervention

4. Mortality and offtake

Lambs	Date	Born and died (reason)	Born and killed for meat	Born and killed due to lack of milk	Born and lost (accident, hyena etc)

Adults	Date	Died (reason)	Sold	Gift	Lost

Obtaining reliable information on stock mortality is very difficult, because respondents are often reluctant to declare losses caused by death. On the other hand, hopes for compensation may sometimes encourage the respondent to overstate the mortality figures. Identifying animals with ear tags should improve the chances of getting reliable information.

Growth and weight gain

Data on growth and weight gain should be collected separately, not as part of a multi-subject survey. This is because such data have to be obtained by measuring animals or by visual assessments which take time and require careful recording. The owner or holder of livestock will also need to cooperate more actively.

Weight gain and growth in livestock can be estimated using four methods. In all cases, individual animals are identified (e.g. by ear tagging) and data are entered on separate record sheets.

Measurement techniques

Weighing. The weighing scales should be regularly calibrated to ensure that accuracy is maintained. If individual animal performance is to be traced over time, weighings should always be at the same time of the day to ensure consistency.

The time at which weighings take place will depend on the management system. In many cases, weighing just after daylight is comparatively easy on the animal and minimises the variations which might result from grazing and/or watering during the day. Calves which remain with the dam overnight should be weighed in the evenings.

Small ruminants and calves can be weighed on sling scales, but after calves have reached four months of age they should be weighed in a weighbridge. An ideal weighbridge is one which has a yoke to restrain the animal so that other measurements (e.g. mouthing) can be performed without difficulty. Mobile weighing scales mounted on the back of a vehicle enable the operator to cover large areas quickly. A sling with a 200-kg dial can be used for donkeys and foals, while a squeeze will be needed for horses. For camels, mobile weigh scales are inappropriate, but weights can be estimated from girth measurements.

Wilson and Semenye (1983) evolved the following formulae:

$$P = 53\,TAH$$

where:

P = weight in kilogrammes

T = girth behind the breast pad (in metres)

A = abdominal girth over the hump (in metres)

H = shoulder height (in metres), and

$$Y = 5.071X - 457$$

where:

Y = weight in kilogrammes

X = girth in front of breast pad (in metres); best taken with camel in squatting position.

From a practical point of view, it must be noted that large variations in gross liveweight can occur as a result of changes in gut or bladder fill, pregnancy, parturition and tissue hydration. Also, if weight gain is used to give a measure of seasonal range productivity, mature steers or wethers should be used because the changes in their liveweight are not affected by physiological status or milk production.

Girth measurements. Estimating animal liveweight from girth measurements involves establishing a conversion factor or a regression equation which relates actual weight to girth measurement. Other relationships which include length as well as girth may only marginally improve the accuracy of results and are more time consuming and cumbersome.

Various linear, quadratic and logarithmic relationships have been used but Wilson and Henrici (1979) argue that complex formulae add little to accuracy and are of little practical use. However, because of the large variations in weight occurring even among cattle of the same girth, sex and age, weight/girth regressions have been developed for different sex and age groups. Equations for different cattle breeds have also been established in Africa (Thornton, 1960). A summary of results of a comparison between actual weights and weights estimated from girth measurements for a sample of cattle in Sudan is given below.

Example:

Table 11. Proportion of estimates within 10% of actual weight.

Class of animals	Number of animals	Proportion within 10% of actual weight
Males	60	61.7
Females	60	75.0

Source: Wilson and Henrici (1979).

One of the main practical problems in the use of girth to estimate weight is that animals must be properly restrained. Girth measurements vary according to posture, positioning, tension of the tape, gut fill and thickness of the coat, resulting in small errors in technique.

Estimation by visual appraisal

The weight and condition of an animal can be estimated by simple visual inspection or condition scoring. Reasonably accurate estimates can be made, particularly if the observer is experienced. Less experienced observers should periodically compare their visual estimates with actual weight measurements.

Condition scoring. This is a quick, low-cost and easy method of making comparisons between systems or animals. Animals are scored by external visual examination of those parts of the body which best indicates the animal's condition.

Condition scoring relies on subjective assessment of animal condition by means of scores, but with practice, consistency can be quickly developed. The scores can then be correlated to body weight or other parameters affecting animal productivity (Nicholson and Butterworth, 1986[13]).

13 Nicholson and Butterworth's (1986) manual can be obtained by African researchers free of charge from ILCA.

Different scoring scales have been developed for cattle in African and European management systems. ILCA has recently developed a nine-point system for African zebu cattle *(Bos indicus)* in which three main conditions are scored – 'fat' (F), 'medium' (M) and 'lean' (L). Within these categories, further scoring subdivisions are made:

Category	Subdivision	Score
Fat	F+	1
	F	2
	F–	3
Medium	M+	4
	M	5
	M–	6
Lean	L+	7
	L	8
	L–	9

Source: Nicholson and Butterworth (1986).

Changes in condition score have been shown to be positively correlated with conception rate (Ward, 1968; Steenkamp et al, 1975), grazing resources and management skills (Reed et al, 1974), and body weight and heart girth (Nicholson and Sayers, 1987). Condition scoring can also be used to monitor changes in animal body reserves and weight over time, which is relevant for African rangelands where wide variations in feed availability are common (Modules 6 and 7).

Single versus continuous surveys

The number of weight measurements or estimates made per animal will depend on the type of survey being undertaken. If the aim is to establish an overall growth curve, samples of animals in different age groups will be weighed at one point in time. If the season in which the measurements are made is unrepresentative, several measurements will need to be made at different times to establish the curve (see Figure 9 as an example).

If, however, the aim is to determine the effect of birth type, parity, management system, season of birth, seasonal conditions and disease on liveweight, continuous surveys over a period of time will be required. The data obtained from these surveys can then be used to estimate production indices (Part B above) and to establish individual growth rates (Wilson et al, 1985a, Chapter 6; Wilson, 1987).

The frequency of weighing or weight estimation will vary with age. For calves, four weighings at 1, 3, 7 and 18 months will be necessary. Birth weight should be taken within 24 hours of actual birth whenever possible. Two weighings before four months of age are recommended, because this is the critical period of growth during which calves are almost totally dependent on their mothers for milk. Seven months is taken as the weaning date but because this is only an estimate, weights should be recorded at actual weaning and then adjusted to 210 days for comparison.

For smallstock, weights of unweaned animals should be recorded about once a fortnight. After weaning, weighings once a month will generally be sufficient.

Outputs

Milk output

There is a general problem in measuring milk output in Africa, because the total milk output of a cow tends to be divided between extraction for human use and consumption by the calf, and because zebu cows often have to be stimulated by the presence or suckling of a calf before they will let down their milk. However, to face this problem, milk output from cows can be estimated by:

- weighing before and after suckling
- bucket-feeding
- oxytocin injection, and
- partial suckling and liveweight equivalents.

Weighing before and after suckling. This method is applicable to both cattle and small ruminants. Suckling animals are weighed in sling scales. These need to be sensitive because differences in weight (before and after) may range from as little as 50 g up to 3.5 kg (Wilson and Semenye, 1983). To make a proper measurement, young stock must be penned for the night before weighing.

The method is not particularly reliable because the animal may urinate or defecate between weighings. It also requires careful supervision and involves much labour.

Bucket feeding. If the calf can be trained to bucket-feed, total milk output can be measured by weighing the output hand-milked into a bucket. Complete milking out can, however, underestimate total yield by as much as 18% (Amble, 1965). To carry out the measurement, the calf must be kept away from the cow for about 12 hours.

Oxytocin injection. Injecting the cow with oxytocin will result in complete milk let-down. This method has been used for zebu cattle which are difficult to hand-milk because of their partial let-down. However, oxytocin is not commonly available, and because of this, the method is not generally applicable.

Partial suckling and liveweight equivalents. When part of the milk is used by the household and the remainder is reserved for the calf (as is common), it is possible to estimate milk yield by measuring the milk extracted for human consumption and making an additional allowance for calf consumption by use of a weight/consumption conversion factor.

The method is only applicable before the calf begins supplementing its feed requirements by grazing, which happens at about four months of age. The weight/consumption conversion factor will depend on conditions, breeds etc., and no general formula is very accurate, although a rough ratio of 1 kg of liveweight to 9 litres of milk has been suggested (ILCA, 1979). However, Montsma's (1960) co-efficients for zebu cattle in Ghana, i.e.

7.25 litres milk/kg growth from 0–8 weeks of age

7.87 litres milk/kg growth from 9–13 weeks of age, and

10.53 litres milk/kg growth for 14 weeks of age,
were found useful in a study of zebu cattle by Wagenaar et al (1986) in Mali.

In order to establish reasonably reliable estimates of output over the length of lactation, a minimum of four measurements per month should be taken for cattle. The measurements should be taken on days of average activities, not when cows are on heat or after dipping or vaccination. For smallstock, measurements should be taken about once per week.

Meat output

The methods used to estimate herd/flock growth and the offtake of meat from traditional African livestock production systems are described in Module 9.

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SECTION 1

MODULE 6

RANGE RESOURCE EVALUATION

MODULE 6

Range resource evaluation

PART A: DEFINITIONS AND CONCEPTS

This module is concerned with livestock–range interactions. It is particularly applicable to those systems of livestock production in which communal grazing is practised and is perhaps most relevant to the semi-arid and arid regions of sub-Saharan Africa, where pastoral and agropastoral systems predominate.

This module follows the same general outline adopted for the other modules in this Section, except that it begins with a definition of the concepts which form the basis for a proper evaluation of range conditions and for any study of livestock– range interactions.

Vegetation definitions and concepts

Vegetation structure. This term refers to the arrangement, spacing and size of plants within a given area. Particular structural features of plants which are often measured are height, volume, stem size, crown size and spacing.

Species (or floristic) composition. This term refers to the proportion of different plant species found in association within a given area (Tothill, 1978). The proportion can be estimated by using one or more of the following measures:

- **dry-matter weight** of individual species per unit area
- **number** of plants of each species per unit area (i.e. **density**)
- **occurrence**, i.e. the relative frequency of different species per unit area, and
- **cover**[1] per unit area occupied by individual species.

The particular measure chosen will depend on the objectives of the study and on the type of vegetation studied.

Note: The composition of a plant community can change because of many factors, including grazing practices, burning, drought and temperature effects, pests, diseases and erosion. Depending on the nature of this compositional change, the productivity of an area (in terms of its capacity to support livestock) may change. A change in plant composition results because of the relative adaptability of different species to these influences (Stoddart et al, 1975; Butterworth, 1985). The process of change from one equilibrium compositional state to another is known as plant succession.

Plant biomass. Plant biomass is the total dry-weight equivalent of plant matter per unit area. Vegetation utilised for grazing and/or browsing may be only part of total biomass. A distinction is often made between above-ground biomass and standing crop. The former includes plant litter in the estimation of dry-matter production in an area (Clarke, 1986).

Significant intra- and inter-seasonal variations in plant biomass and standing crop can be expected for most African range production systems, where rainfall is usually seasonally distributed and often highly variable (Sandford, 1982). Under similar rainfall conditions, soil type will have an effect on plant

1 Cover is defined as the proportion of the soil surface covered by vegetation. That might be near 0% in the desert or in an unplanted cultivated field and as high as 100% in dense grassland or forest. The kind of cover should always be defined, thus: basal cover (percentage of the soil surface occupied by the bases of plants), litter or mulch cover, rock cover, tree canopy cover or foliage cover (Heady and Heady, 1982).

biomass production (Abel et al, Vol. 1, 1987). Since plant biomass and standing crop are affected by species composition and density, composition should be related to productivity (in terms of quality and quantity) when assessing vegetation–livestock interactions. The palatability of grass and browse is also affected by species composition (Module 7).

Range condition. This is the state and health of the range, which can be assessed on the basis of an area's vegetation composition, plant vigour, ground cover and soil status (Pratt and Gwynne, 1977).

The concept of 'condition' implies that an optimal or desired vegetation cover (in terms of quantity and composition) exists for each particular land system. However, since it will often be uncertain what the desired or 'optimum' condition is (particularly in areas which have undergone misuse for a considerable period of time), and since optimum range condition will differ according to the manner in which the range is used (e.g. cattle, sheep, wildlife), the comparison used should be clearly stated as well as whether this is based on actual measurements or whether it is assumed.

Range trend. This indicates the direction of change in range condition over time. The detection of range trend in the early stages of change may be difficult because vegetation characteristics will often fluctuate widely as a result of seasonal variations in climate (Heady, 1981; Ng'Ethe, 1986).

Climatic variations affect the **stability** of the environment or range, while trends in range productivity reflect the **sustainability** (or resilience) of existing management practices and of the ecological system itself (see text below and Figure 1). The criteria most commonly used to assess range condition and trend are (Pratt and Gwynne, 1977):

- herbaceous cover - i.e. species composition, vigour, percentage of total cover and stand density
- shrub/tree cover - i.e. number of trees (shrubs)/unit area, species composition, height, vigour and age
- forage value - i.e. nutritive value of forage, seasonal variation, potential productivity and palatability, and
- soil stability and fertility - i.e. depth of soil, structure, rainfall infiltration and nutrient status.

Range stability. Stability is the degree to which range productivity remains constant despite normal fluctuations in environmental variables, such as climate (Conway, 1985). Figure 1 illustrates the concept by comparing a stable range production system with a relatively unstable one.

Range sustainability. The term 'sustainability' refers to the ability of the range to maintain its long-term productivity when subject to particular environmental and management stresses or disturbances[2] (Figure 1).

Management definitions and concepts

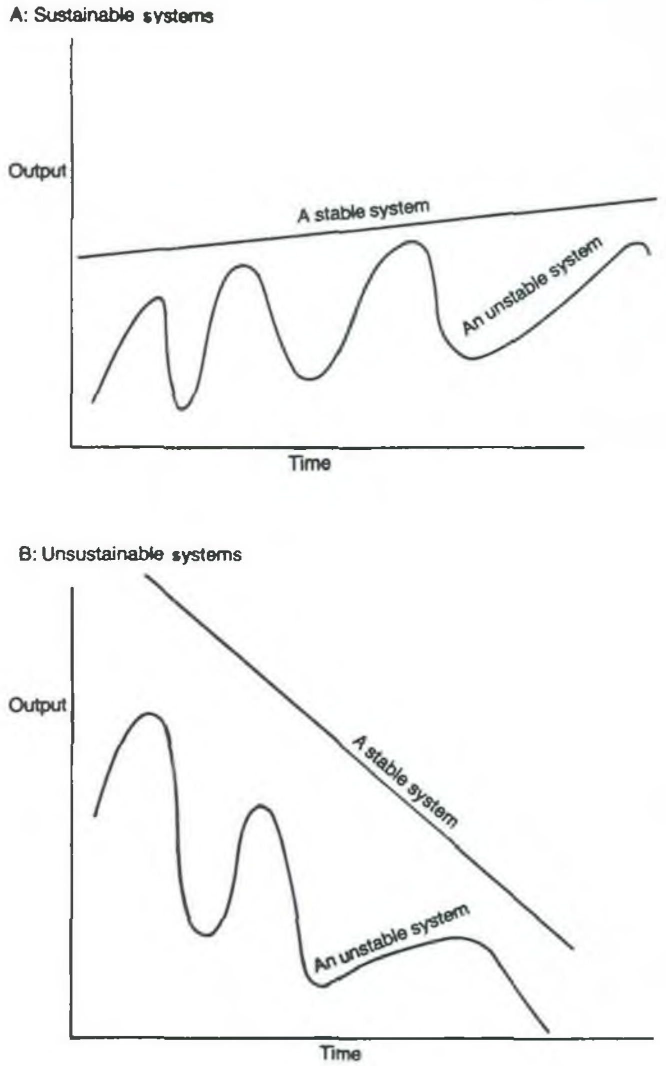
Stocking rate. This is defined as the actual number, at a specific time, of tropical livestock units (TLUs) per hectare, where a tropical livestock unit is the equivalent of one bovine animal of 250 kg liveweight.

Standard livestock-unit conversion factors are often used in the estimation of area stocking rates. The factors used by ILCA are shown on a table on the next page.

A distinction is often made between **gross** and **net** stocking rate per hectare. The first concept does not differentiate between land used for grazing or other purposes (such as cropping), while the second relates animal numbers to land specifically allocated for grazing.

2 Conway (1985) defines stress as a regular (sometimes relatively small and predictable) change in environmental conditions. A disturbance, on the other hand, is an irregular, infrequent, relatively large and unpredictable change, such as drought.

Figure 1. Stability and sustainability: Illustration of concepts.



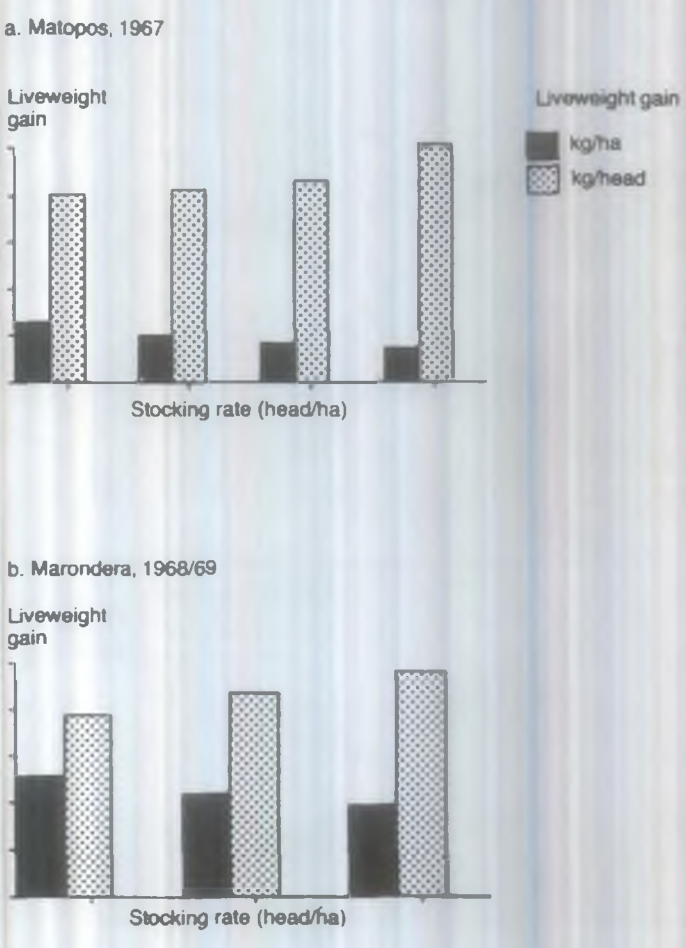
Species	Conversion factor (head to TLU)
Camels	1.0
Cattle	0.7
Sheep	0.1
Goats	0.1
Horses	0.8
Mules	0.7
Donkeys	0.5

Also, the concept of an 'optimum stocking rate' has been debated in the literature (Sandford, 1982; Butterworth, 1985). The definition of 'optimum' will depend on the criteria of evaluation used or the grazing strategy adopted (see below under carrying capacity). When maximum productivity per head is the objective, a lower stocking rate will be used, but when the aim is to maximise productivity per hectare, higher stocking rates will be applied.

Under the latter circumstances, animal productivity per head will fall, but overall productivity per unit area will (within limits) normally rise (Stoddart et al, 1975; Abel et al, 1987) (Figure 2). This conclusion is particularly relevant to African livestock systems since traditional producers normally attempt to maximise returns per hectare, not per animal (Behnke, 1984; de Ridder and Wagenaar, 1986). The long-term environmental implications of these different approaches to optimising productivity will need to be carefully considered.

Grazing pressure. This is the number of animals per unit of available forage. Different animal species will have different preferences for different kinds of forage (e.g. grass or browse), and this will influence grazing pressure within a given area (Cooperrider and Bailey, 1981). The grazing habits of different animal species may be complementary or competitive: preferences may vary between seasons, thereby altering the degree of complementarity/competitiveness over time.

Figure 2. The relationship between stocking rate and liveweight gain per head and per hectare, Zimbabwe.



Source: Butterworth (1985).

Grazing capacity. Grazing capacity is the maximum stocking rate which the rangeland can support without causing damage to vegetation or other range resources (such as soil and water). If the actual stocking rate exceeds this level for a sufficiently long period and leads to irreversible changes in range condition,[3] the area is said to be overgrazed. An area may, however, be overstocked in the short term, without being overgrazed (i.e. the number of animals carried on the area may exceed its carrying capacity at that point in time).

Understocking may also result in a deterioration of grazing resources. This occurs when, in the absence of grazing, the vegetation composition on the range tends to change in favour of less palatable or lower-producing plant species (or plants become less palatable because of senescence). In these circumstances, selective grazing by fewer animals (or animal species) means that large areas remain ungrazed and become increasingly infested with less palatable species. Also, because grazing is confined to patches of the range, localised overgrazing and deterioration of range condition will occur.

The use of vegetation as a primary indicator of environmental degradation caused by overgrazing is based on the premise that vegetation is a reliable mirror of its ecological environment (Mouat and Johnson, 1981). The vegetation indicators which are usually considered cause for concern (Stoddart et al, 1975) are:

- low plant cover
- preponderance of plants of low palatability, and
- change from a species composition in which perennials predominate to one dominated by annuals, particularly forbs (i.e. herbaceous weeds).

Other indicators of environmental status are soil erosion, decreased soil water availability, and livestock condition or productivity which may, however, lag behind a deterioration in vegetation or soil conditions.

Carrying capacity. This is the maximum number of animals which can be carried on a given area of land, during a period of the year when the quantity and/or quality of forage is at its lowest (Butterworth, 1985), or in dry years.

A distinction between opportunistic and conservative grazing strategies needs to be made in this context. An ***opportunistic*** strategy is one in which the holder/owner varies the number of stock according to current forage availability - i.e. grazing pressure is held at a constant level. This strategy is said to be efficient if livestock numbers are varied at the appropriate time (Sandford; 1982, 1983a). An efficient opportunistic grazing strategy will not, normally, lead to environmental degradation.

A *conservative* strategy is one which maintains the population of grazing animals at a low level, in both good and bad years - i.e. grazing pressure is variable. Under this strategy, no attempt is made to exploit periods of forage abundance by increasing livestock numbers. It is essentially a risk-averting management practice which is less likely to cause environmental degradation.[4]

Neither of these strategies will be wholly attainable in practice, and both approaches to herd/flock management are likely to be evident in African livestock production systems.

The tendency to retain or increase livestock numbers, even under adverse environmental conditions, is characteristic of many sub- Saharan African production systems. Coupled with the practice of communal grazing, this tendency is often said to be causing widespread environmental deterioration,

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3 Distinction should be made between irreversible and reversible changes in range condition. According to Abel et al (1987), loss of clay and silt particles from the rangeland is detrimental and irreversible. Loss of soil organic matter is, in theory at least, slowly reversible. Bush encroachment caused by overgrazing can be either.

4 This statement needs qualification. If, for instance, forage abundance were to occur over a 3-year period without a compensatory increase in livestock numbers, undesirable changes in vegetation composition could occur, resulting in lowered carrying capacities in the long term.

particularly in the semi-arid and arid areas of the region. However, the evidence for environmental decline on a wide scale is inconclusive (Horowitz, 1979; Breman et al, 1979/80; Sandford, 1983a). Relationships between livestock management practices and the environment have rarely been quantified and have often been misinterpreted or misunderstood. Technological interventions have thus often been inappropriate.

PART B: PURPOSES

The main objectives in range resource evaluation, therefore, are to:

- quantify important relationships and interactions between livestock management practices and range resources (vegetation, soil and water),[5] and
- assess the necessity and scope for improvement through technological intervention. Technologies may be aimed at improvements in range condition and/or livestock production.

Livestock – range interactions

For any livestock production system, management practices will directly affect the productivity of the range.

> For instance, exploitative management practices may alter species composition towards less palatable, lower-producing plant forms which are less able to support animal populations. Long-term overstocking will lead to overgrazing, soil loss and reduced water infiltration.[6] Such trend relationships need to be understood since they will affect the stability and sustainability of rangelands. If used on a wide scale and over a long period of time, inefficient opportunistic (and conservative) management practices will have similar effects.

Range conditions also vary in the short term (i.e. within and between seasons), and this can affect performance levels and the management practices adopted. Seasonal variations in the quantity and quality of feed can, for instance, affect the movement of stock (e.g. herd splitting - see Module 10) as well as the amount of time an animal spends grazing/browsing (Dicko-Touré, 1980).[7] These, in turn, can affect birth and growth rates, mortality rates, and milk and meat production.

Proper diagnosis of short- and long-term relationships between livestock and the range is thus an essential first stage in the design of appropriate technologies. Some of the important livestock–range interactions are between:

- **stocking rate per hectare and vegetation composition**
- **stocking rate per hectare and animal productivity per hectare and per head**
- **plant species composition and animal performance**
- **grazing pressure/stocking rate per hectare and the incidence of soil erosion** (and the effect on water availability)

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5 However, the different types of cyclical change present in all ecosystems must be separated from the effects of management, to avoid confounding of the two and ascribing changes in range condition to the wrong causes (Heady, 1981).

6 The effect of overgrazing on the environment will also depend on the existing level of soil fertility and, to some extent rainfall. Heavy stocking on high-fertility soils may, for instance, induce the growth of higher-producing plant species, while on low-fertility soils, unfavourable species may become predominant.

7 The traditional requirements of different animal species requirements, priority rights for animals in different age/sex categories and cultural or security considerations will also affect stock movement and grazing/browsing habits. Seasonal stock movement is, however, largely due to an attempt to match feed supplies with feed requirements i.e. to equilibrate grazing pressure. If the movement does not or cannot occur (e.g. because of encroachment of pastoral grazing areas by agropastoral communities), stocking rates may become too high and performance levels may decline as a result.

- **livestock movements and seasonal range productivity,** and
- **seasonal range production and seasonal animal production.**

The relationship between stocking rate per hectare and vegetation composition. Table 1 gives an example of this relationship under research-station conditions in Uganda.

The relationship between stocking rate per hectare and animal productivity per hectare and per head. In studies of this nature, variables such as birth rate, mortality rate, growth rate, meat and milk production (Module 5) could be related to grazing pressure or stocking rate in studies of this nature. Figure 2 provides examples of such a relationship for two locations in Zimbabwe.

The relationship between plant species composition and animal performance. When examining differences in composition, the attention should be on the nutritive value of the feed consumed. This is because changes in vegetation composition are unlikely to affect performance unless they are associated with changes in the nutritive value (e.g. as a result of a higher/lower proportion of legumes in the pasture or browse).

Example:

Table 1. Botanical composition at different stocking rates, Serere, Uganda, 1970.

	Botanical composition (%) at a stocking rate (animal/ha) of		
	2	3	5
Hyparrhenia rufa	71	68	26
Stylosanthes guianensis	19	22	20
Sporobolus pyramidalis	1	2	39
Other	9	8	15

Source: Butterworth (1985).

Scope for technological improvement

Knowledge about the factors which constrain livestock production provides a basis for technological design. Two approaches may be used to effect technological improvement, including the development of technologies which:

- *WORK WITHIN EXISTING CONSTRAINTS TO PRODUCTION*

  In this case, an attempt is made to exploit flexibilities for short-term improvement within the system itself.

  For instance, overgrazing and overstocking may be localised near water courses or water points. Range condition and animal productivity could be improved by a spatial re-distribution of grazing pressure to areas which are relatively less affected (e.g. through the provision of additional water points) (Sandford, 1983b). Similarly, grazing pressure could be re-distributed through time by adjusting stocking rates more rapidly to changes in seasonal forage availability (Abel et al, 1987) or by improving marketing facilities.

- *ATTEMPT TO BREAK EXISTING CONSTRAINTS TO PRODUCTION*

  In this case, an attempt is made to achieve improvements of a long-term nature.

This strategy will be applicable particularly when:

- livestock production per hectare and per head is limited by range condition, or
- management practices limit the scope for improvement in range condition.

For instance, the scope for significant improvements in range condition and livestock production per hectare will be very limited if, because of culturally entrenched management practices, the vegetation is seriously degraded. A change in community perspectives may first be necessary before improvements of a long-term nature can be affected.

An understanding of the regional distribution of livestock numbers between seasons and of the seasonal availability of forage is, therefore, an important aspect of range resource evaluation. The effect of individual animal species on the range environment should also be determined. An understanding of the economic goals of the target farmer/pastoral group is equally necessary, if the right approach to technological design is to be adopted.

For instance, the farmer/pastoralist may aim to maximise returns per hectare rather than per head, or he may prefer opportunistic stocking rate strategies to conservative ones. The approach adopted to technological improvement must reflect these goals to be meaningful.

A number of basic questions will, therefore, need to be asked when designing new technologies for improved rangeland and livestock productivity. They are:

- Will the new technology be compatible with the range environment? How will it affect range stability and sustainability?
- Will the new technology be compatible with existing management practices? If not, will a change in management be culturally acceptable or economically rational from the recipient's point of view? Which group(s) in society will benefit if the technology is adopted?
- Can animal productivity per head or per hectare be improved without making simultaneous improvements to range condition? If not, what changes will need to be made?
- Can range condition be improved without making simultaneous changes to livestock management practices? If not, which changes in management will need to be made, and what are the costs and benefits involved?

Such questions should always be asked to determine the right approach to data collection in range resource evaluation. The approach adopted will, in turn, depend on the time available, cost considerations and manpower resources, because tracking trends in range condition can be both time-consuming and costly.

PART C: TYPES OF DATA

During the initial stages of livestock systems research, baseline data on the environment as well as on the historical, economic, ethnographic, infrastructural and political characteristics of the target area should be collected. Data on the environment should provide details on climate, topography, vegetation, soil and water resources and human agricultural activities (Module 1, Section 1). This information can often be obtained from secondary data sources (e.g. meteorological reports).

Objectives of data collection

To define the objective of data collection in range resource evaluation, it is useful to answer the following three questions (Clarke, 1986):

- How big an area needs to be covered to meet the overall objectives of the study?
- How often and over what time period should data collection be made?

- How detailed should the information be?

There are essentially two types of study conducted in range resource evaluation (USDA Forest Service, 1981):

- **resource inventory studies**, and
- **resource monitoring studies.**

Resource inventory studies. The aim of these studies is to assess resource use and availability at **one point in time**. They may be part of an initial baseline data survey, or they may be discrete studies which are more detailed in nature.

Resource inventory studies provide information about livestock numbers and herd/flock structures within an area (Module 9), as well as about existing vegetation characteristics, soil loss, water resources and stocking rates. Because they rely on data from one point in time, inferences about the relationship between management practices and range condition need to be treated with caution. They may indicate potential problems in resource use and availability, but trends cannot be established. However, the determination of trend relationships is often the chief concern in range resource evaluation studies[8] (Pratt and Gwynne, 1977; Schmid-Haas, 1981).

Resource monitoring studies. The aim of these studies is to track range resource **trends** through time and to relate these to livestock management practices. They tend to be costly, particularly in the arid/semi-arid regions of Africa where vast areas may need to be covered for several years in succession (Clarke, 1986).

They give information on vegetation trends, by monitoring successive changes in plant composition which should be distinguished from changes caused by intra- and inter-seasonal climatic influences. Successive changes are directional and relatively predictable (Heady, 1981). Meteorological data, if available over a sufficiently long period, may provide some indication of longer-term cyclical influences which affect the environment. Informal interviews with producers who have lived in an area over a sufficiently long time period may also be useful (Module 1, Section 1).

The level of detail in data collection will depend on the type of study conducted and cost, manpower and logistics considerations. It will often be more efficient to confine attention to a few key indicators of range condition rather than to attempt a broad- based study on a whole series of variables (Husch, 1981; Mouat and Johnson, 1981). This, of course, implies that the useful indicators of range condition are known by the researcher.

Ground, aerial and remote sensing data

Data used for range resource evaluation can be collected using ground, aerial and/or remote sensing surveys.

Ground surveys. Ground-sampling techniques are commonly used to 'ground-truth' data obtained from aerial and satellite surveys, by providing finer detail on environmental characteristics and management practices (e.g. plant composition, grazing pressure, grazing capacity and carrying capacity). They are also used to monitor animal sex/age structure, smallstock numbers and ground-cover species composition, which cannot, at present, be accurately monitored by other means. Ground-survey techniques are relatively expensive and time-consuming.

Aerial surveys. There are two main kinds of aerial survey. Low-altitude, usually sample-based, aerial survey using both observer's direct eyesight and some photography, and higher-altitude, complete

8 Methods applicable to these kinds of studies are outlined in Part D of this module.

photographic coverage. In the following discussion we are referring to the low-altitude sample survey, unless the context suggests otherwise. Such surveys[9] are suited to:

- estimate the numbers and densities of larger herbivores and wild animals. Where tree density is not high, seasonal stock movements can also be traced by using aerial counts or photography
- map major vegetation types in terms of physiognomy (i.e. woodland, scrubland, grassland) and basal or foliage cover
- map topography and soil types
- map of human settlement patterns and agricultural activities
- locate major seasonal water resources, and
- provide evidences of soil erosion and its causes (e.g. the distribution of erosion gullies, soil scalds and their relationship to human/livestock densities).

Aerial surveys conducted over a number of years can provide useful information about changes in range conditions, the distribution of human activities over time and livestock densities. General indications of the causes for and direction of change will often provide a useful starting point for more detailed range - livestock interaction studies.

Remote sensing. Satellite information has been used to map ecological resources, monitor environmental conditions and estimate changes in green biomass (Lamprey and de Leeuw, 1986). The satellite series most often used for ecological monitoring and mapping purposes are the Landsat, NOAA and SPOT-1.[10]

The usefulness of satellite data for the estimation of rangeland grass cover is presently limited by a number of factors (Abel and Stocking, 1987):

- The techniques currently used depend on per cent cover of the green material present. This means that estimates must be confined to the growing season and that dry cover cannot be measured.
- It is uncertain whether the imagery can distinguish between the canopies of the woody vegetation layer and of the ground-layer vegetation.
- When ground cover is sparse, soil reflectance distorts the reflectance of vegetation (Robinove, 1981). Differences in soil type and topographic features create additional complications.
- Cloud cover distorts remotely sensed data, and atmospheric absorption of radiation can result in non-systematic biases in results.

Summary

Ground, aerial and remote sensing techniques complement each other (Figure 3). Each has its own particular limitations in terms of time, cost and the level of detail which can be provided, but, together,

Continued ....

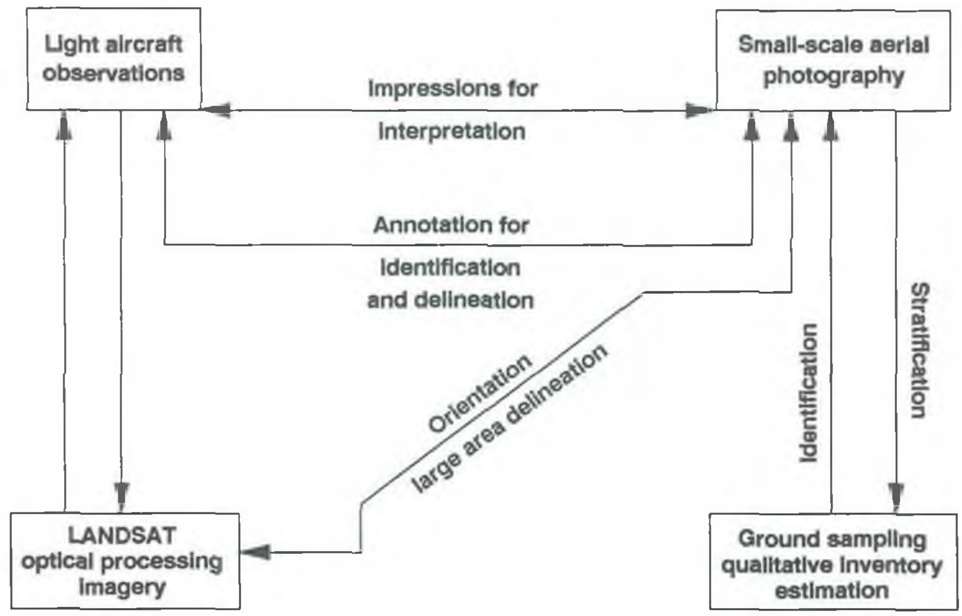
9 Although Clarke (1986) classified aerial surveys as the most cost-effective of the three methods, problems of aircraft availability and lack of skill in the use of the technique currently limit its application on a wide scale. In addition, much of the data obtained by aerial survey needs to be ground-truthed.

10 The satellites are equipped with sensors which record radiation reflected from the earth's surface, and the data are received in digital or image (photographic) form. Rangeland studies use satellite data based on the differential absorption of red and infra-red wavelengths by green vegetation (the so-called 'false colour' differences) to estimate changes in green cover. The data must be correlated with ground and/or aerial survey information for accurate interpretation.

Summary continued...

the three methods are a useful tool for a comprehensive assessment of range resources and regional land-use patterns (ILCA, 1983; de Leeuw and Milligan, 1984). They can also be used to identify specific areas requiring attention or as a basis for system description and diagnosis.

Figure 3. Complementary rangeland survey techniques.



Source: Thalen (1981).

PART D: METHODS OF DATA COLLECTION

This part of Module 6 outlines some of the common ground-survey methods used in the evaluation of livestock–range interactions. The general principles involved in sample selection are discussed in detail in Module 2 of Section 1.

It is not possible (or practical) to give a comprehensive coverage of remote sensing data collection methods in this manual. The literature on this topic is extensive and the user is referred to the reading list, and in particular to Clarke (1986), for some of the more important references currently available. Aerial survey methods used to assess vegetation and soil resources are discussed in manuals dealing specifically with these topics. Ground and aerial survey techniques used to obtain information about livestock numbers are described in Module 9.

Ground-survey methods for vegetation studies

Vegetation studies concerned with livestock–range interactions will normally concentrate on:

- **plant species composition** to assess the effect of livestock grazing practices on range condition and trend, and

- **plant biomass production**. Used together with data on livestock species and numbers estimates, data on plant biomass production provide a basis for the assessment of:
  - the quantity and quality of feed available, by season and by animal species, and
  - grazing pressure, grazing capacity and carrying capacity, by season and by animal species.
- **basal or foliage plant cover**. Data on basal cover will be needed when vegetation composition by percentage cover is studied, while data on foliage cover will be collected when soil structure, soil erosion or moisture conservation are suspected.

The selection of the method(s) to collect such data will depend on:

- the relationships which need to be studied
- the key composition or biomass variables which are to be measured
- the level of detail, and
- the sampling techniques most appropriate for vegetation studies.

Methods for the assessment of vegetation composition

Vegetation composition can be determined by using plot (or quadrat), intercept and plotless methods.

PLOT (QUADRAT) METHODS. These involve establishing sample plots (quadrats) of vegetation whose size and shape will depend on the type of vegetation being sampled, the density of the vegetation encountered and the type of survey being undertaken.

> For instance, range scientists often use a large sample of small quadrats (50 x 50 cm), because it is easier to absorb information quickly from small units. However, when the vegetation is sparse (as is the case in the arid/semi-arid rangelands), larger quadrats should be used to ensure adequate sample data (e.g. IPAL, 1983).

The general guidelines on the size and shape of quadrats applicable to three different types of vegetation are shown in Table 2 below.

Table 2. Size and shape of sample plots.

Type of vegetation	Quadrat shape	Quadrat dimensions	Ratio of quadrat sides (rectangular plots)
Herbaceous	Rectangular	$0.5 - 1.0\ m^2$	1:2
	Circular	$0.2 - 0.5\ m^2$	n.a.
Shrub	Rectangular	$50 - 100\ m^2$	1:5 – 1:10
Trees	Rectangular	$200 - 1000\ m^2$	1:5 – 1:10

n.a. = not applicable.

Source: Clarke (1986).

'Nested' quadrats are usually used for mixtures of trees, shrubs and herbaceous vegetation. A nested unit might include a 1000-m^2 quadrat for the estimation of tree composition, several 200-m^2 shrub quadrats and further, randomly sited, herbaceous units enclosed within the larger area.

Vegetation composition can be estimated on the basis of frequency of occurrence, density, dry weight (biomass) and basal cover.

The **frequency** sampling method records the species present/absent in each quadrat. Large areas can be surveyed very quickly, especially if attention is focused on a few key indicator species (Tothill, 1978).[11] The presence/absence method can be used to estimate the composition of tree, shrub and/or herbaceous species. Because it reflects the distribution of vegetation species within an area, it can also be very useful in the study of **vegetation patterns**. Pattern recognition is easier if the sample layout is regular rather than random.

The density method is suitable when individual species are clearly distinguishable, as in woodland, and it is, therefore, often used to estimate woody species composition.

Foliage cover is affected by seasonal effects; for this reason, the measure is not suitable for determining long-term trends in composition. This can be done using **basal cover**, especially that of perennials, which is not subject to seasonal influences.

Biomass or dry-matter weight measurements (for herbaceous material and foliage from low shrubs) will help establish vegetation relationships between:

- composition and plant biomass production, and
- biomass production and soil type or rainfall.

The conventional method involves cutting, sorting and weighing the different species in each quadrat by hand, which is time-consuming and requires considerable skill, particularly in multi-species grasslands.

Therefore, the *dry-weight-rank method* (t'Mannetje and Haydock, 1963; Jones and Hargreaves, 1979) is often used. This method involves the selection of the first, second and third heaviest species (on the basis of biomass) within each quadrat,[12] each of which is then assigned a weighting based on **standard multipliers** which have been shown to be applicable over a range of pasture types in Australia, the United States and Zimbabwe (Jones and Tothill, 1985). The multipliers are:

Rank 1 (heaviest): 0.70

Rank 2 (middle) : 0.24

Rank 3 (lightest): 0.06

The values for each quadrat are then summed for each species and expressed as percentages of the total score (see example below). This approximates the percentage contribution by weight of each species, from which the overall composition of the sample area is derived.

Example: Determine the average plant species composition over four sample quadrats with plant species A, B and C, using the dry-weight-rank method.

Table 3. Estimated biomass (g) and rank (in brackets).

A = 60 (1)	A = 65 (1)	A = 10 (2)	A = 5 (2)
B = 5 (3)	B = 10 (3)	B = 40 (1)	B = 20 (1)
C = 15 (2)	C = 15 (2)	C = 6 (3)	C = 3 (3)

By applying the rank weights given above, the following overall percentage biomass is contributed by each species:

Continued...

11 Using a small number of indicator species within an area will usually give the information required, e.g. the relative importance of palatable versus unpalatable species or of annuals versus perennials. The key species are not necessarily the dominant species of the area (Werger, 1981).

12 The three most important species usually account for about 90% of the overall biomass of a quadrat and also for about 90% of plant species, if composition is assessed on the basis of frequency or cover.

Example continued...

Table 4. Percentage of biomass contributed by each species.

Species	Sum of quadrat scores	Total rank score	Per cent composition
A:	0.7+0.7+0.24+0.24	= 1.88	47.0
B:	0.06+0.06+0.7+0.7	= 1.52	38.0
C:	0.24+0.24+0.06+0.06	= 0.60	15.0
		4.00	100.0

Based on the overall percentage biomass of each species given in Table 4, the overall composition of the sample area would be:

Table 5. Overall composition for the sample area.

Species	Sum of quadrat weights (g)	Total weight (g)	Per cent composition
A:	60 + 65 + 10 + 5	= 140	55.1
B:	5 + 10 + 40 + 20	= 75	29.5
C:	15 + 15 + 6 + 3	= 39	15.4
		254	100.0

If there are only two to four species making up the pasture, the method could also be used to estimate proportions or the weight of the component species. Field estimates are recorded directly onto data sheets for computer processing or into small portable computers. The data are then processed, e.g. by using a computer programme called BOTANAL (Jones and Tothill, 1985).

The dry-weight-rank method assumes that there is variability between quadrats and that there are at least three species present in the majority of sample units. If the number of species is less, the problem can be overcome by increasing the size of each quadrat. Alternatively, direct estimates of the proportions of different species can be used.

INTERCEPT METHODS. These involve the sampling of plant species which contact a line transect. Transects are usually placed within areas which have relatively homogeneous vegetation and soil characteristics. Such areas may be identified by ground or aerial reconnaissance surveys or from maps. Three intercept methods are commonly used:

- **the line-intercept method**
- **the step-count method, and**
- **the wheel-point** or **frame-point method.**

The line-intercept method measures **actual** vegetation intercepts with a tape measure. These data can then be used to determine foliage or basal cover and frequency of occurrence.

The method tends to be tedious and time-consuming and has limited applicability in situations in which vegetation is highly variable. Cruder systems, such as the presence/absence sampling, often provide information on vegetation composition of comparable or even better accuracy, and take less time to perform.

The step-count method counts the number of different plant species contacted by the point of the foot when walking along a transect. If bare soil is contacted, this is also recorded to give an indication of cover.

The step-count method is a simple and rapid means of making a preliminary assessment of composition (based on frequency) and of basal or foliage cover, and is best suited to areas with low-growing herbaceous vegetation. It can therefore be used for rapid rangeland monitoring where data precision is not essential.

The wheel-point (Tothill, 1978) or the ***frame-point*** method (Clarke, 1986) is a more sophisticated modification of the step-count method. In both cases, points mounted on a frame are used to measure vegetation characteristics related to composition or cover. Meeuwig (1981) describes the use of this method for estimating shrub cover and biomass.

To be able to measure **changes** in the composition or cover by the intercept methods, the same transect lines must be used each time measurements are made. Transects are therefore often permanently marked and may be set in a **grid pattern** or along a **basal marker**. Grid methods of laying out sample areas have two advantages:

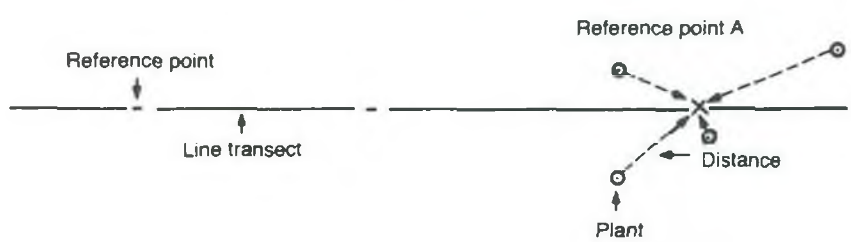
- the transects are easy to identify, and
- the grids help define vegetation patterns within the sample area.

PLOTLESS METHODS. The best known of these methods are the **nearest-neighbour** and the **point-quarter** methods (Clarke, 1986). Both involve the use of transects along which **reference points** are taken at random (e.g. by pacing according to a random number table) to measure composition in terms of density.

The nearest-neighbour method. With this method, the plant closest to the sample reference point and its neighbour are identified and the distance between each is measured. This procedure is repeated at each of the random reference points, and the overall data are then used to calculate composition on a density basis.

The point-quarter method uses a sampling frame (or compass). The frame, which has two arms outstretched at a right angle to one another (forming a cross), is placed at each selected reference point. The closest plant to the centre of each of the **four quarters** of the cross is identified and the distance is measured (Figure 4). The area occupied by each plant is calculated by squaring this distance. The overall average along the transect is then calculated to give mean vegetation density (see example below). Composition can be obtained by recording each species type along the transect line.

Figure 4. Schematic representation of the point-quarter method.



Example: Assume a transect of 100 m long on which 20 reference points have been identified. At each point, the distance to four plants is measured and the sum of all these distances is 1000 metres. For 80 plants (4 x 20), the average point to plant distance is 1000/80 or 12.5 m and the average area occupied by each is 12.5 x 12.5 m or 156.25 m^2. Since 1 ha is 10 000 m^2, the density of plants per hectare is 10 000/156.25 = 64. Of the 80 plants identified, 30 are of species A, 20 of species B, 20 of species C and 10 of species D. Thus, the composition of species along the transect is:

Species	Composition (%)
A	37.5
B	25.0
C	25.0
D	12.5

Plotless methods are relatively quick and low-cost methods suitable for determining the composition of tree and shrub communities. They can be combined with plot methods by placing quadrats at each reference point to make more detailed measurements of plant cover, frequency and/or biomass.

Estimation of plant biomass and standing crop

Vegetation biomass and standing crop are measured to determine the dry weight of plant material available for grazing and/or browse during different seasons of the year and over the long term.

Plant biomass and standing crop can be directly measured by cutting and weighing of all individual samples, but since both procedures are costly and impractical in most situations, **indirect** or **double-sampling** methods have been developed where the procedure is:

- Locate sample quadrats or plots (along transects or at randomly determined sites) within the area to be surveyed.
- Select a number of these quadrats and then measure in them dry- matter weight (usually by destructive sampling, i.e. cutting and weighing of sample material) for the whole sample area or for the individual species present. The latter is most meaningful when only a few species are present (species).
- Use the dry-weight data to calibrate visual estimates of dry matter in other sample quadrats. This is done by means of linear regression relationships (Module 11) established from initial dry-weight measurements (e.g. IPAL, 1983, pp. 264–318). Repeated estimates from the same site can then be made within or between years.

The procedure makes it possible to estimate biomass or standing crop over large areas, at relatively low cost. Because the initial measurement of dry weight takes some time, details about other relevant vegetation characteristics (e.g. density, cover, frequency and/or composition) may also be obtained. Such data can be of value when the sample needs to be stratified, e.g. on the basis of productivity differences resulting from factors such as irregular grazing, burning, soil characteristics etc.

The measurement of plant biomass and standing crop for herbaceous plants and shrub and tree species is outlined below.

ESTIMATING THE PLANT BIOMASS AND STANDING CROP OF HERBACEOUS PLANTS. This is done by the **scale** or **comparative-yield method** which was developed in Australia (Haydock and Shaw, 1975) and involves the following steps:

- Examine the survey area to determine the likely variation in biomass/standing crop.
- Select visually four plots, two each close to the 'average low' and the 'average high' levels of forage yield and give the pair in each group values of 1 to 4, respectively. One plot of each group is cut and the forage is weighed green, the others are left uncut.
- Select a fifth plot which falls within the middle of these two extremes. The plots estimated to be slightly above and below this middle plot are then cut and their forage is weighed to decide whether the identified plot does indeed fall within the middle of scales 1 and 5. If so, the plot is assigned a scale of 3.

- Repeat the same procedure to determine scales 2 and 4, which lie half-way between scales 1 and 3, and 3 and 5, respectively.
- Use the five ranking standards to rank visually other plots in the sample area. One or several individuals (recorders) may be involved in the ranking.

Note: Periodic checks to ensure consistency are required, particularly if the process is carried out over several days. Photographs can also be used for reference purposes: ideally, each recorder should have a set of photographs to carry out the ranking exercise.

- Assign, at random, about 15 plots to each recorder for ranking on the basis of a scaling factor. The plots are then cut and the dry matter is weighed.
- Determine linear regression equations for each recorder relating estimated weight (or scale) to actual weight, and correct any recorder bias identified.
- Determine overall herbaceous biomass for the sample area. Depending on the accuracy of the initial weight:scale calibration, results under this system have been shown to be remarkably accurate. The initial process is time consuming but once completed, large areas can be surveyed in a relatively short time period.

Estimates of species composition can be made if the comparative-yield method is carried out alongside the dry-weight ranking method (see page 139 of this module). The method can also be used to determine changes in production resulting from seasonal or long-term influences. Under range conditions, the same quadrat sites (or very similar and close to them) should be used during each sampling, but on each sampling occasion, new ranking standards may need to be established.

The scale or comparative-yield method was modified by ILCA field researchers in Kenya. ILCA's method relies on estimation of green biomass, green percentage, percentage cover and leaf canopy height in 0.5 m^2 quadrats selected at random in the survey area. After visual estimates have been made, one plot in 10 is cut and the forage weighed. The sample is then dried to obtain the dry-matter percentage (DM %), and regression relationships are established between the estimated and actual green-matter weight. Finally, visual estimates are corrected by the equation derived (Module 11), which makes it possible to make DM extrapolations over large areas.

ESTIMATING THE BIOMASS OF STANDING CROP OF SHRUB AND TREE SPECIES. This is done whenever browse forms a significant component of the animal diet in an area. Methods used to estimate browse productivity are, however, comparatively undeveloped and detailed work has been confined to relatively few sites (Bille, 1980).

One of the problems has been that different standards of measurement have been applied to different situations. In some cases, only the **edible** or **accessible** portions of the vegetation have been measured while in others, **total biomass** or standing crop production was determined. The plant parts which are accessible or usable by livestock vary between seasons, species and environments. In addition, there is considerable variation in production within species, which makes it difficult to obtain reliable data without increasing sampling time and cost.

Highly sophisticated methods have been devised to measure browse production (e.g. by the use of radio-isotopes), but these are not broadly applicable on African rangelands and, therefore, are not discussed in this module. The general procedure in the more commonly used methods is:

- Identify the major browse species within the survey area, using ground and/or aerial surveys (for woody cover) local vegetation maps. This provides the basis for stratifying the area into major vegetation types.
- Within each vegetation type, determine such characteristics as height and density, using the survey methods described above.

- Estimate biomass production by means of direct harvesting of selected trees or shrubs. The extent of destructive sampling will depend on the objectives of the study. For instance, if we are interested in the accessible parts of the plant (e.g. leaves, new twigs, flowers and fruits), samples will be taken from those parts only.[13]

The amount and type of vegetation actually consumed will normally depend on the browsing habits of different animal species. The IPAL (1983) study in northern Kenya determined biomass production on the basis of the following assumptions made with respect to how high the browsing animal can reach - i.e. up to 1 m for sheep; up to 2 m for goats; and up to 4 m for camels.

In addition, litter samples may be collected in trays placed under the canopies of similarly sized trees or shrubs which are protected from browsing. By taking into account plant litter (which is an important part of the diet of domestic stock, particularly during the drier months of the year), the yield potential of the sampled plant species will be estimated more accurately (IPAL, 1983, p. 287).

- Measure particular tree/shrub attributes (e.g. size or height, crown diameter, stem diameter) and relate the measurements of these indicator (or surrogate) variables to actual, recorded biomass using regression analysis (Module 11). The indicator variables may also be used to predict biomass over the entire survey area.[14]

- Predict the browse-species biomass in the surveyed area on the basis of the density and composition estimates obtained during initial surveys.

The use of indicators in predictive equations means that biomass production can be estimated over large areas at relatively low cost. The estimates of utilisable browse can then be related (together with data on herbage production) to the numbers of different animal species in an area to determine the overall grazing pressure. Trends in browse productivity can be monitored by repeating the process over time, taking care to exclude seasonal and cyclical influences.

Ground-survey methods for soil studies

Soil erosion is influenced by soil type, rainfall intensity, topography (slope and length of slope), vegetation cover and composition. Therefore, the methods used to determine vegetation cover and composition can also be used to **indicate**:

- the likelihood of soil erosion occurring in an area, and

- the scope for preventing soil erosion through changes in livestock management practices.

Assessments of this nature can result in false conclusions about the causes for and/or the extent of soil erosion in an area, but **actual measurement** of soil erosion in African rangelands is fraught with problems, as well. According to Abel and Stocking (1987), some of these problems are:

- Because of the vast areas involved, accurate assessment of soil loss is both difficult and costly to make, requiring between 10 and 20 years to obtain conclusive results.

- Lack of technically feasible and low-cost methods applicable to the rangelands.

- Erosion itself is difficult to measure because rates of soil loss are highly variable over space and time. Periodic observations (e.g. comparison of aerial photography over time) may, for instance, indicate **average** changes but will not register the events which determine the average.

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13 Bille (1980) briefly discussed the relative importance of individual plant components as browse biomass, for different tree species in West Africa.

14 For instance, crown diameter was found to be a good indicator of wood biomass for the woody species in northern Kenya. As a measure of forage biomass, however, it was generally unreliable (IPAL, 1983).

- Precise measurements of soil loss taken in one area cannot be readily extrapolated. Extrapolations of soil loss from trial plots will, for instance, tend to overestimate actual losses over large areas.
- When soil loss from one area results in soil deposition in another area, the net effects of soil relocation need to be considered. Losses (in terms of productivity) from the eroded area may, for instance, be countered or even outweighed by the gains which occur in the deposition area, but this may prove to be extremely difficult to estimate in practice.

Of the field methods developed for the measurement of soil loss, the **erosion pins method** is the most common and the most likely to be applicable to African rangelands. It involves placing pins (or pegs) at randomly located sites throughout the sample area, which then represent fixed reference points for the measurement of changes in soil movement over time. A net drop in soil level is taken as an indication of soil loss from which estimates of rates of erosion are made.

The advantage of the method is that it is low cost and that the pins can be sited over large areas in a relatively short period of time. One of its disadvantages in the field is that the pins can be easily lost or destroyed, or they may be difficult to locate because of vegetation growth between survey periods.

On large areas, the movement of soil is complex and apparent losses may be compensated for by deposits elsewhere. Unless such deposits are accounted for, by determining net changes, the method will not measure actual erosion rates. Furthermore, measurements must continue over a sufficient time period before the results can be considered conclusive. This is because short-term changes will often be reversed due to changes in climate, management practices etc.

Instead of using pins, some researchers have used **tree-root exposure** and **pedestal development** to measure erosion rates. In some instances, soil loss measured on experimental plots has been used to **predict erosion rates** over larger areas, but such extrapolations are dubious, particularly when applied to rangelands.

Soil-loss equation models have been developed in the United States, which are based on regression relationships established from trial plot data. Most of these models rely on technical expertise and data precision not found in developing countries. A model has, however, been developed for the southern African rangelands which uses aerial-survey data. It is relatively low cost and adaptable to conditions elsewhere in Africa, provided that an adequate data base exists (Abel and Stocking, 1987).

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SECTION 1

MODULE 7

ANIMAL NUTRITION

MODULE 7

Animal nutrition

This module provides a framework for the diagnosis of nutritional problems in traditional African livestock production systems. The discussion is confined to the main ruminant species (cattle, sheep and goats),[1] because of their relative importance in an African context[2] and because of the emphasis given to ruminants in ILCA's research work. The module follows the format used elsewhere in this section but it also includes definitions of some of the basic concepts used in the literature.

The reader is encouraged to use the support references given at the end of this module to ensure that an adequate background on the topic is obtained. Butterworth's (1985) book is a useful complement in that it provides a comprehensive review of research on animal nutrition in the tropics and includes an extensive reference list. Other references such as Van Soest (1982), Church and Pond (1982) and McDowell et al (1986) are useful basic texts on the theory of ruminant nutrition.

PART A: CONCEPTS

In any discussion of the principles of animal nutrition, the concepts most commonly used relate either to the animal (as the user of feed) or the feed (as the source of nutrients). The concepts defined below are grouped accordingly into animal- and feed-related concepts.

Concepts related to animal productivity

The term 'productivity' refers to the ability of an animal to grow, reproduce and produce outputs such as milk, wool, draught power and transport.[3]

In order to perform these functions on a **sustained** basis, essential nutrients in the form of energy, proteins, minerals, vitamins and water (above those necessary for the maintenance of normal body functions), must be provided. For a given animal species, the **level** of production achieved will, in turn, depend on the quantity and nutritive value of feed available, breed, genetic potential, sex, age and management.

Below are some of the basic concepts related to animal productivity and their definitions.

Maintenance. When an animal is not reproducing or producing any other output, and when body weight and condition are stable (i.e. the ratio between fat and muscle), it is said to be in maintenance condition (McDonald et al, 1973, p. 261),[4] with its energy requirements in 'balance' or 'equilibrium.'[5]

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1 The anatomy and physiology of the ruminant is not discussed in this module. It is assumed that the reader is familiar with the basic characteristics of ruminant digestion, which are discussed in several textbooks (e.g. Van Soest, 1982; Church and Pond, 1982).

2 Ruminants and camels (also known as pseudo-ruminants) comprise approximately 90% of domestic livestock units in sub-Saharan Africa (FAO, 1986).

3 Liveweight growth can be negative (through a loss of weight), while the production of other outputs such as milk and draught continues. Put in another way, the requirements for maintenance need not always be met in order for production to continue, e.g. feed intake needs to fall substantially below maintenance requirements before wool production actually ceases (Davies, 1982).

4 The use of body weight as the sole criterion for assessing maintenance condition is not reliable since an animal can maintain weight by an increase of water in body tissues, while losing condition (fat and/or muscle). For a discussion of condition and body weight refer to page 152 of this module.

5 The same applies to other essential nutrients. If, for instance, an animal is fed a diet lacking protein, it will continue to lose nitrogen in its faeces and urine and will be in a state of negative nitrogen balance. The concept of maintenance, therefore, implies that all nutrient requirements are in balance, with nutrient inputs being exactly offset by nutrient losses. It is more common, however, to refer to maintenance in terms of the energy requirements of the animal.

However, this definition is complicated by the fact that animals can adapt to sub-maintenance energy levels by lowering their requirements in order to stabilise their body weight and condition. This phenomenon has been observed in African cattle in Kenya (Ledger and Sayers, 1977).

The ability to adapt to lower energy levels has important implications for feeding requirements on tropical African grasslands, where animals spend long periods in a state of maintenance or near maintenance. The fact that *Bos indicus* cattle appear to be more efficient in this respect (Butterworth, 1985) is also of interest. Thus, the standards for cattle maintenance and growth[6] used in the northern hemisphere, may not be applicable in the context of African tropical grasslands.

Metabolism. Metabolism is the sum of all the physical and chemical processes taking place in living organisms. Some of these processes involve the degradation or decomposition of complex compounds to simpler materials (**catabolism**) and others involve the synthesis of simpler materials into complex compounds (**anabolism**). The excretion of waste products from the body is part of the metabolic process.

Fasting metabolism. The amount of energy used for the maintenance of an animal is known as fasting metabolism, and it is estimated as follows:

Fasting metabolism (kcal of NE/day) = $70\ W^{0.75}$

or

Fasting metabolism (kJ of NE/day) = $293\ W^{0.75}$

where:

NE = net energy (see page 154 of this module)

W = the animal's liveweight in kilograms, and

$W^{0.75}$ = the so-called 'metabolic weight' of the animal.

This relationship between the liveweight of a ruminant animal and the amount of energy it uses for fasting metabolism is applicable to all ruminant species, though variations occur between species as well as within species (e.g. on the basis of age and sex). The equation can be used to estimate whether the energy intake of an animal is sufficient to meet its energy requirements for maintenance and/or production (see Part D of this module).

Compensatory growth. This concept refers to the ability of an animal to recuperate or recover growth after periods of underfeeding. Recovery following underfeeding has often been associated with higher than normal rates of growth (see Figure 1) and has been observed in cattle and small ruminants.

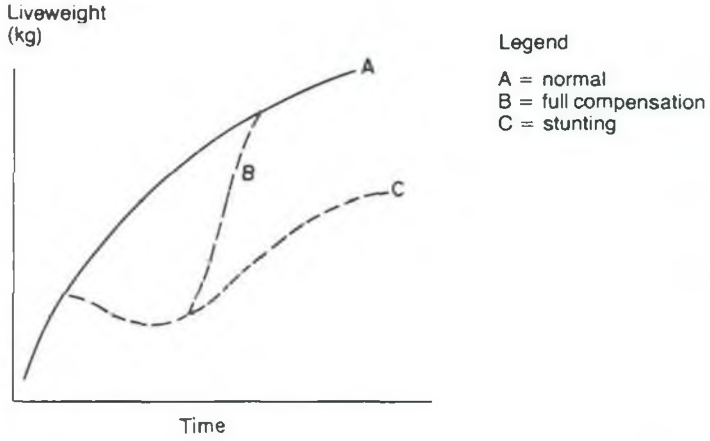
As a general rule, the earlier in life nutritional stress occurs and the longer the period of feed deprivation, the less the compensatory growth will be. In the African rangelands, periods of nutritional stress are common because of long dry seasons and frequent droughts.

Condition. The condition of an animal is reflected in the proportion of body fat and muscle on its carcass. It is generally a more reliable indicator of an animal's nutritional status than body weight since variations in the latter may merely result from changes in gut fill, body water, parturition etc.

Condition measurement has, therefore, been used to monitor changes in animal body reserves over time (Nicholson and Sayers, 1987), and rapid appraisal methods have been devised to 'condition score' African cattle for this purpose (Module 5) (Pullan, 1978; Nicholson and Butterworth, 1986).

6 Standards have been devised in the USA, by the National Research Council (NRC), and in Britain, by the Agricultural Research Council (ARC), which relate to the daily nutritional needs for growth and production (energy, protein and minerals) of different species of livestock. The standards used in the United States are summarised in a series of booklets published by the NRC (1976) under the general title *Nutrient requirements of domestic animals*. ARC (1965; 1980) gives similar tables. The standards adopted by ARC (1980) are likely to be closer to the animal requirements of tropical livestock.

Figure 1. Patterns of growth.



Source: Davies (1982, p. 14).

Intake. Intake is the amount of feed voluntarily consumed by an animal. It is determined by:

- the availability, palatability and digestibility of feed
- the nutrient content of the feed

  For instance, feed intake is depressed when a diet contains inadequate amounts of minerals, vitamins and various sources of nitrogen (Davies, 1982), or when it is poorly digestible.
- bite size and frequency which, in turn, is influenced by plant structure and feed availability

  For instance, Stobbs (1973) found that the amount consumed per bite tends to increase with the amount of green leafy material in the sward.
- the physiological status of an animal

  For instance, pregnant animals have different intake requirements according to litter size and stage of gestation.
- environmental conditions

  For instance, the availability of water will affect the amount of feed an animal consumes, as will temperature and humidity.
- infectious, parasitic and metabolic diseases, which may depress intake.

The measurement of intake is discussed in detail in Part D of this module.

Feed selection and palatability. Animals show distinct preferences for particular types of feed. The animals' feed preferences are influenced by feed availability, plant structure, nutrient deficiencies (e.g. salt), appetite and, of course, different species of animals prefer different types of feed (Chacon et al, 1978; Gammon and Roberts, 1980; Van Soest, 1982).

The term **palatability** is a subjective concept and refers to the assumed reason behind an animal's choice of one source of feed over another (e.g. the choice between different parts of a plant or the choice between different plants). **Selection**, on the other hand, is an objective term, referring to the actual choice that is made. The ability of an animal to select feed of an adequate quantity and nutritive value affects its productivity.

Grazing time. This is the amount of time a ruminant spends consuming feed. While generally applied to actual grazing on pasture, the definition can be widened to include time spent browsing, consuming stover etc. Grazing time is determined by the availability and nutritive value of feed and by the management system used (Gammon and Roberts, 1980; Lambourne et al, 1983). There is often an inverse relationship between grazing time per day and the quantity and quality of feed available (Butterworth, 1985).

Feed-related concepts

These concepts include:

Digestibility. The digestibility of a feed determines the amount that is actually absorbed by an animal and therefore the availability of nutrients for growth, reproduction etc.

Apparent digestibility is estimated by subtracting nutrients contained in the faeces from nutrients contained in the dietary intake. Therefore, it does not account for nutrients lost as methane gas or as metabolic waste products excreted in the faeces.

True digestibility is estimated by correcting for the endogenous and microbial amount of a nutrient actually lost in the faeces.

The measurement of apparent digestibility is less complex than measuring true digestibility and, therefore, more suited to the requirements of diagnostic livestock systems research.

The amount of energy in (or the energy content of) feed potentially utilisable by animals can be expressed in the form of **gross energy** (GE), **digestible energy** (DE), **metabolisable energy** (ME) or **net energy** (NE) for maintenance and production. The relationships between them are as follows:

DE = GE – energy lost in faeces

ME = DE – energy lost in urine and gases

NE = ME – heat loss (heat increment)

Gross energy is the total heat of combustion of a feed substance measured in calories or Joules per unit weight of dry matter (DM) or organic matter (OM).[7] Because it takes no account of energy losses, gross energy provides no real indication of the energy value of a feed.

Net energy is the energy actually available for maintenance and production (after all losses have been accounted for). It is the most precise estimate of a feed's energy value, but, because of the complexities involved, net energy is rarely measured.

Digestible energy is commonly taken as an indicator of a feed's energy value because faecal losses are relatively easy to measure. Metabolisable energy can be approximated by multiplying digestible energy by a factor of 0.82 (ARC, 1965; 1980).

Crude protein. Protein is the basic structural material from which all body tissues (e.g. muscles, nerves, blood cells) are formed. It is, therefore, essential for production and maintenance and cannot be replaced by other nutrients in the feed.

Ruminants are able to synthesise protein from non-protein nitrogen sources (e.g. urea) by microbial action in the rumen. The nitrogen content of a feed is, therefore, often used to estimate the amount of protein available to the ruminant, which is expressed as the **crude protein** (CP) content of a feed and calculated as:

% CP = % nitrogen content x 6.25

where the figure 6.25 is based on the assumption that feed protein contains, on average, 16% nitrogen.

7 Dry-matter weight is determined by drying the feed in the oven at 105°C for 12–15 hours and weighing. Dry organic matter (DOM) is determined by weighing the dry matter, then burning its organic matter in a furnace at 550°C for eight hours. The difference between the dry-matter weight and the weight of the ash remaining is the DOM weight of the feed. In dry tropical pastures, dry organic matter usually lies in the range of 90–92% (by weight) of its parent dry-matter material.

Fibre. This fraction refers to the cell-wall content of feeds and consists of carbohydrates (hemicellulose and cellulose) and lignin. Carbohydrates are partially available for digestion by rumen micro-organisms and represent a major source of energy for ruminants. The lignin component of the fibre fraction limits the digestibility of cell-wall carbohydrates.

Crude fibre (which is used in the Wende system of feed analysis) is a poor estimate of cell-wall content because it does not recover lignin and hemicellulose. Instead, the detergent system of analysis (described in Part D below) should be used where feasible, although there are other methods for estimating total fibre (Van Soest, 1982).

Minerals and vitamins. Minerals are required for tissue growth and the regulation of body functions. They are normally categorised as macro-minerals (when required in the order of g/day) or as micro-minerals (when required in mg/day or less). So far, 22 mineral elements have been shown to be essential to animal nutrition (Little, 1985) (Table 1).

Table 1. Essential mineral nutrients.

Macro-minerals:	Ca	P	Na	K	Mg	S	Cl	
Micro-minerals:	Cu	Zn	Mn	Mo	Se	I	Fe	Co
	F	V	Sn	Ni	Cr	Si	As	

In tropical feeds, deficiencies of phosphorus (P), sodium (Na) and copper (Cu) are those most likely to occur, while deficiencies of potassium (K) and chlorine (CL) and of the micro-minerals listed in the bottom row of the table are most unlikely in the field.

Vitamins are organic substances required by animals in very small amounts for the regulation of various body processes which ensure normal health and production. Under most conditions, the ruminant is able to synthesise most of its vitamin requirements.[8]

PART B: PURPOSES

Diagnostic research on animal nutrition problems

During the descriptive phase of livestock systems research, data obtained from informal surveys, secondary data sources and other diagnostic studies can be used to determine the need for further diagnostic research on animal nutrition issues. The following types of data will often be useful in this respect:

- **production data**

  Production performance (i.e. mortalities, birth rates, milk production, condition/liveweight gain) may point to nutritional problems in the target area.

- **environmental data**

  Soil surveys may indicate mineral deficiencies. Also, the vegetation characteristics of an area (e.g. plant composition, density, biomass) can be used to identify probable deficiencies in dietary energy and crude protein.[9]

8 Ruminants do not synthesise vitamin A which can be deficient in tropical pastures and crop residues. The synthesis of vitamin B_{12} requires Co which may also be deficient in these feeds. The specific functions of the different minerals and vitamins are discussed in any text on ruminant nutrition.

9 Plant composition may also indicate the likelihood of mineral deficiencies. For instance, a high proportion of forbs in the diet can usually be taken as an indication that minerals, in particular phosphorus, may not be deficient.

- **management data**

  Information about management systems can be useful with regard to the use and availability of crop residues, communal grazing practices, stocking rates etc. Evidence of overgrazing on a wide scale will indicate nutrition problems, particularly during the dry season when feed quantity and nutritive value are lowest.

- **producers' opinions**

  Local opinions about particular problem should be taken into account, after having weighed them against evidence available from other sources.

The nature of nutritional constraints

If solutions are to be identified, the nature of nutritional problems must be clearly defined. Studying the relationships between nutrition on the one hand and performance, management and grazing conditions on the other hand, as well as other nutritional relationships, might be useful in this context.

Relationships between nutrition and animal performance. By using techniques such as linear regression analysis, the relative importance of the different factors affecting production performance can be compared simultaneously. Table 2 shows how performance could be related to different variables of which nutrition is only one.

Example:

Table 2. Retionships determining the effects of animal nutrition on production performance.

Dependent variable (production performance)	Independent (influencing) variables
1. Liveweight/condition	DM intake, breed, type of birth, sex, parity, disease, management system
2. Fertility rate	Seasonal conditions, breed, parity, disease, type of birth, sex of progeny
3. Milk production	DM intake,[10] breed, parity, weaning period, disease, lactation length

Various indicators or measures (e.g. digestibility, DM intake, crude protein) can be used to determine the effects of nutrition on production performance. Surrogate or substitute variables for feed availability or intake can be used, as well.

> For instance, seasonal rainfall is often assumed to be an indicator of feed conditions while stocking rate has been used as a substitute for feed intake (Abel et al, 1987).

Relationships between nutrition and management. The link between management practices and animal nutrition is often pronounced and needs to be understood. Examples of the relationships which might be studied are:

10 When making comparisons between animals of different size to determine the importance of nutrition as a constraint, DM intake should be expressed in relation to the liveweight (and preferably the metabolic weight, i.e. $LW^{0.75}$) of the animal. When comparing animals of different species, the preferred exponent is $LW^{0.9}$ (Graham, 1972).

- **the relationship between stocking rate and intake**
- **the relationship between animal feeding practices and herd size** (as an indicator of wealth)

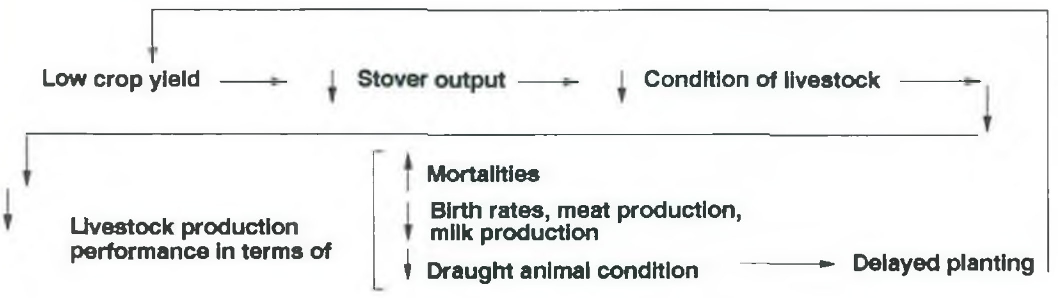
  For instance, the use of supplements (salt, bonemeal etc) may vary with herd size (Bailey, 1982).
- **the relationship between crop stover utilisation** (intake) **and oxen condition at ploughing time**
- **the relationship between stock movement to feed or mineral sources and animal productivity**

  In other words, is the performance of herds which are moved to these sources superior to that of herds which are not? (Dahl and Sandford, 1978; Sandford, 1983).

In mixed production systems, an understanding of crop/livestock linkages may point to potential areas for improvement. Crop residues can, for instance, have an important bearing on animal nutrition (Bayer and Otchere, 1985), by providing energy to carry stock through the dry season when feed quantity and nutritive value from grazing are low. The availability of energy from stover will, therefore, influence mortalities and birth rates (Powell and Waters-Bayer, 1985; Reed and Goe, 1989).

Figure 2 gives a schematic representation of some of the linkages which commonly affect both crop and livestock performance. Diagrams of this kind are useful in that they force the researcher to think through the system and identify some of the important linkages which exist. From this information, it is often possible to identify the data needs of research more precisely.

Figure 2. Example of negative linkages between crop and livestock production in a mixed farming system.



Relationships between nutrition and grazing conditions. These include the relationships between:

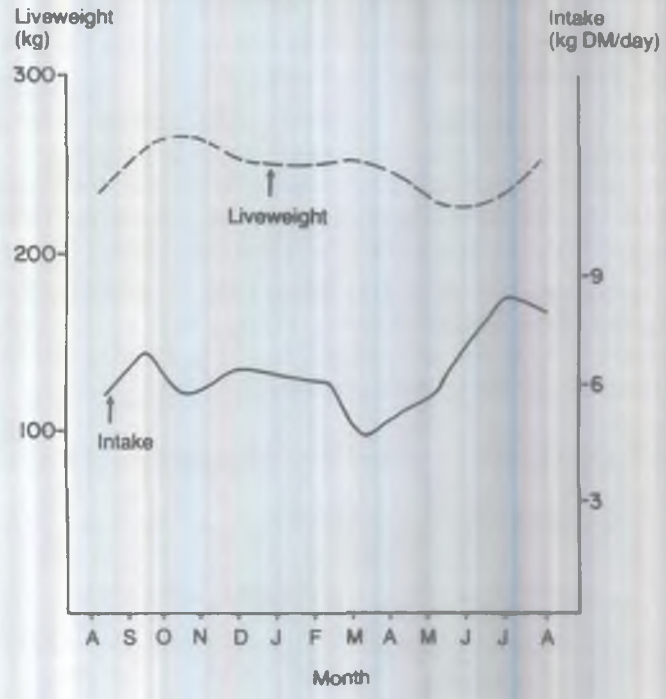
- the amount of intake and the nutritive value of feed (measured in terms of energy or crude protein content)
- selection and the nutritive value of feed, and
- grazing time and animal production performance

  For instance, Smith (1961) found that liveweight gains of cattle grazing seven hours per day were only half those of cattle grazed for 11 or 24 hours a day. Bayer and Otchere (1985) also suggest that grazing time affects calving and weaning percentages for cattle owned by pastoralists in the Nigerian subhumid zone.

Other nutritional relationships. This includes the relationships between digestibility and feed quality, and between seasonal conditions (rainfall) and the nutritive value of feed consumed (measured in terms of energy or crude protein content). Such relationships need to be adequately understood if problems are to be correctly identified.

For instance, a positive correlation between digestible energy or dry-matter intake and liveweight gain is commonly observed (Ademosun et al, 1985; Zemmelink et al, 1985) (Figure 3). While this correlation may correctly imply that energy is a limiting factor in the diet, the availability of energy may itself be limited by some other factor (e.g. intake and, therefore, the amount of energy available could be limited by mineral, vitamin or protein deficiencies). Effective diagnosis thus depends on the identification of the primary limiting nutrient (Little, 1985).

Figure 3. Relationship between intake and liveweight gain in cattle, Mali, 1980.



Source: Lambourne et al (1983).

Scope for improvement

The scope for alleviating nutritional problems will depend very much on the characteristics of the system being studied. In pastoral systems, where the range vegetation is the major source of feed, improvements in animal nutrition may be virtually impossible without first addressing issues related to land tenure (communal grazing)[11] and management (e.g. stocking rates). While in mixed cropping systems, technologies which increase the quantity and nutritive value of stover fed to animals at the end of the cropping season might be applicable (Powell, 1985).

It should be remembered that in livestock systems research, the solution to a particular problem may not always be technological. (For instance, it may be more important to correct particular aspects of policy before significant improvements in production can be achieved). Any technology studied

11 Work by ILCA in Nigeria on fodder-bank use by Fulani pastoralists suggests that there is scope for improvement in pastoral systems, despite overgrazing on communal lands.

should, in any event, be consistent with farmer/pastoralist objectives and circumstances (Module 1, Section 1; Module 2, Section 2).

Feasible technological solutions to improve animal nutrition may come through one or more of the following pathways:

- **crop improvement**
- ***changes in livestock management***
- **pasture improvement,** and
- **feed supplementation.**

Crop improvement strategies. In mixed systems of production, livestock nutrition may be enhanced by improving the quantity and nutritive value of crop residues used by stock through:

- the selection for crop varieties which yield residues of higher nutritive value or quantity

  For instance, strong positive correlations between crop yield and stover production and nutritive value have been observed in Nigeria (and elsewhere) for sorghum and millet (Grove, 1979; Powell, 1985).

- changing crop combinations so as to produce residues favoured by livestock

  For instance, Powell (1985) found in Nigeria that livestock preferred millet (which had a higher nutritive value) to sorghum residues. However, the change from sorghum to millet would need to be consistent with farmers' crop preferences and/or income-earning objectives to be adopted.

- changing the time of planting, which affects stover production

  For instance in northern Nigeria, sorghum stover yields were observed to decline by 1700 kg/ha for each week's delay in planting beyond the optimum date (Kassam and Andrews, 1975).

Livestock management strategies. This involves changing livestock management strategies to match feed availability with livestock feed requirements.

For instance, Wagenaar et al (1986) and Wilson and Sayers (1987) have shown that change in the timing of births (to match feed demands with feed supplies) can have significant effects on conception rates and parturition number in sheep and goats.

Pasture improvement strategies. These involve ranching schemes which aim to improve the management of the range and raise productivity, principally through increasing in the amount of available forage. The available evidence suggests, however, that such schemes have mostly been unsuccessful in Africa (Danckwerts, 1975; Behnke, 1984). The redistribution of water points to better utilise grazing resources is another example of a pasture improvement strategy.

Feed supplementation strategies. These involve the use of fodder banks, fodder trees, byproducts such as oilseed cakes and meals, and urea/molasses licks to supplement crude protein shortages.

Fodder banks are concentrated stands of forage, often legumes, sown either on natural grass or fallows to provide dry-season supplementary grazing (Bayer, 1986; Mohamed-Saleem, 1986; Taylor-Powell and Ingawa, 1986). Those tested by ILCA in Nigeria are mainly *Stylosanthes* spp and have been shown to be viable. However, widespread adoption of forage legumes is constrained by competition for land with food crops, labour shortages during crop operations and lack of adapted species (Reed and Goe, 1989).

Among fodder trees, leucaena and sesbania have been shown to be suitable for animal feed supplementation by the ILCA alley farming programme in Nigeria (Atta-Krah, 1986). Browse gardens and multipurpose trees have also been tried (Reed and Soller, 1987).

PART C: TYPES OF DATA

Animal data

The objectives of data collection in this case are to (Table 3):

- examine the effect of nutrition on production
- determine the amount of feed consumed, and
- determine the composition of the feed consumed.

With some of these data (e.g. intake, grazing behaviour, liveweight gains) it may also be necessary to differentiate on the basis of age, sex, breed, productive activity, species, season and/or management system.[12]

Table 3. Types of animal data used to diagnose animal nutrition problems.

Objective	Types of data
Production effects	Liveweight gain, condition scores, traction power, milk production, wool production
Amount of feed consumed	Feed intake
Composition of feed consumed	Oesophageal or rumen fistula samples, faecal samples, grazing behaviour studies (selection data)

Feed data

The principle objective, in this case, is to determine the nutritive value of the feed consumed and digested by the animal. This may also involve an assessment of sources of feed as yet unutilised but with the potential for introduction into the diet.

In particular, data will be collected on **digestibility, the energy value of feed** (dry matter, dry organic matter, digestible energy and metabolisable energy), and **crude protein content**. When assessing the nutritive value of feed, differentiation on the basis of season or system of production (which affect feed sources and feed availability) will often be useful. Under certain circumstances (see Part D below), data on the mineral content and fibre composition of a diet may be necessary. When determining mineral content, samples of the feed consumed and of blood or bone may be needed.

PART D: METHODS OF DATA COLLECTION

The discussion in Module 11 of different methods of data collection is generally applicable to all types of diagnostic research, and the user is encouraged to read it before embarking on studies of animal nutrition. The emphasis here is on those methods which have been tested by ILCA staff.

Following the format adopted in Part C of this module, these methods have been grouped into methods used to measure:

- **the effects of nutrition on animal production**
- **the amount of feed consumed (i.e. feed intake)**

12 Data on animals' nutrient requirements have not been included since the methods used to collect such data are not discussed in this module. It is recommended that, when such data are required, the ARC (1980) standards should be used.

- **the composition of feed consumed**
- **the digestibility of feed**, and
- **the nutritive value of feed.**

Effects of nutrition on animal production performance

The production performance of an animal often reflects its nutritional status. Liveweight and body condition, for instance, provide a measure of the nutritional response, integrated over weeks or months (Lambourne et al, 1983).

Studies which attempt to isolate the key factors influencing animal production performance may, therefore, be the first step in the diagnosis of animal nutrition problems (see Part B above). If nutrition is identified as the critical constraint to performance, further studies on specific aspects of nutrition (related to the animal or the feed) may be needed.

The various methods used to assess animal production performance are discussed in Module 5, and the reader should refer to it if detailed diagnosis of production performance is envisaged.[13]

Feed intake

Intake, or the amount of feed an animal consumes, can be estimated by using either digestibility data or 'markers'.

Digestibility data. When such data are available, intake can be estimated by multiplying the dry-matter weight of faeces by a digestibility factor. The factor is known as the **feed:faeces** ratio and is expressed as:

DM intake = 100/(100 – digestibility) x DM weight of faeces where digestibility is in per cent.

> **Example:** If the dry-matter weight of faeces of an animal is 870 g/d and the percentage digestibility of the feed consumed is 60%, then the amount of dry feed consumed would be:
>
> DM intake (g/day) = (100/40) x 870 = 2175

The methods used to determine intake and to measure faecal output are discussed below.

Markers. Digestibility and intake data can be derived from the indigestible components of a diet, known as 'markers'. Markers are classified as **internal**, if they are ordinarily present in the diet (e.g. lignin), or as **external**, if they are added to the diet (e.g. chromic oxide).[14] They are used when the measurement of feed intake and faecal output is difficult.

The formula to estimate faecal output is:

$$\textit{Faecal output (g)} = \frac{\textit{Grams of marker in feed/day}}{\textit{Concentration of marker in faeces}}$$

13 Prior evidence may be available which removes the need for such studies. For instance, there may be data available from range evaluation and animal production studies and farm management surveys, which specifically identify nutrition as the critical constraint to production.

14 Other markers used include iron oxide, barium sulphate, titanium oxide, and radioactive tracers (Dicko-Touré, 1980). Synthetic organic substances such as beads, rubber and ribbon have also been used, since they can be easily separated from the feed. Van Soest (1982) provides a detailed account of the various markers used to estimate intake and digestibility, and of their advantages and disadvantages. The term 'indicator' is sometimes used instead of 'marker' (Dicko-Touré, 1980; Church and Pond, 1982; Lambourne et al, 1983).

Example: An animal is dosed with 50 g of chromic oxide per day to determine its daily faecal output. The concentration (proportion) of marker in the dry-faeces sample is 5.75%, and the dry-matter weight of the faecal output is:

Faecal output = 50/0.0575 = 870 g/d

Let us now take the estimated dry-matter weight of the faecal output and the concentrations of the marker in the diet and in the dry faeces, and calculate intake by using the following formulae:

$$DM\ intake = DM\ weight\ of\ faeces \times \frac{Concentration\ of\ marker\ in\ faeces}{Concentration\ of\ marker\ in\ diet}$$

Example: The dry-matter weight of faeces excreted per day is 870 g and 5.75% of this is the marker. The proportion of the marker in the diet is 3.4%. Calculate the DM intake of the animal.

DM intake (g/day) = 870 x (5.75/3.4)

Different intake rates can be calculated for animals classified on the basis of age, sex, weight or productive activity. These can then be related to such variables as seasonal rainfall, stocking rate, management practices or plant composition to isolate its main determinants.

Summary

The normal procedures to estimate DM digestibility and intake are to:

- identify animals (3–5) for sampling
- sample the feed consumed by these animals (e.g. by the hand-plucking, oesophageal-fistula or rumen cannula methods described below)
- take faecal samples from the animals (as described below) and mix them to eliminate differences between animals
- determine the proportion of the marker in the (mixed) faecal sample
- determine the weight and proportion of the marker in the feed sample taken, using standard laboratory techniques[15]
- calculate digestibility of the feed as the ratio of feed:faecal marker concentrations (digestibility can also be estimated using *in vitro* procedures on feed samples – see next page) and
- calculate intake from the formula given above. This requires the further estimation of faecal output either by total faecal collection or dosing with known quantities of, for instance, chromic oxide.

15 These techniques are discussed in most texts on animal nutrition. When facilities for laboratory analysis are not available or are inadequate, intake should be calculated on the basis of digestibility. Simple methods to estimate digestibility are given in the text which follows.

Composition of consumed feed

There are various methods used to determine what the animal is eating. Those discussed here are:

- **the oesophageal fistula method**
- **the rumen cannula method**
- **direct observation of grazing habits**
- **pasture analysis before and after grazing,** and
- **faecal samples.**

Oesophageal fistula. The botanical composition of feed consumed by an animal can be determined by using a surgical fistula inserted into an animal's oesophagus. The food eaten passes into a collection bag attached to the neck, and samples are taken directly from the bag after allowing the animals to graze for not more than two hours before re-inserting the fistula plug.

The oesophageal fistula method provides an accurate indication of the botanical composition of the feed consumed. An illustration of this type of approach is given by McLean et al (1981). However, because of salivary contamination of the samples, accurate direct estimates of the chemical composition of feed eaten are restricted to nitrogen, neutral detergent solubles, calcium, magnesium, sulphur and copper (Little, 1972; 1975). Dietary phosphorus concentrations can be estimated accurately only from oesophageal extrusa labelled with radioactive P (Little et al, 1977). It also tends to be time-consuming and costly, and farmers are unlikely to cooperate when their own stock is involved. Nevertheless, ILCA research workers have used the method in the field.

In Kenya, for instance, oesophageal fistulae were fitted to cows which had been purchased from Maasai pastoralists and herded with farmers herds during three seasons in several locations (Semenye, 1988a, b). The data obtained on feed composition were then complemented by studies on grazing behaviour of the type discussed below. ILCA has also used the fistula method with a small sample of cattle in Mali (Dicko-Touré, 1980; Lambourne et al, 1983).

Material collected with the fistula method can be used in the determination of digestibility by in vitro estimation procedures (see page 167).

Rumen cannula. This method is applicable to both cattle and smallstock and allows direct sampling of the contents of the rumen by means of a cannula surgically inserted into the rumen. It involves physically emptying the contents of the rumen by hand before the animal goes to graze and then taking samples from the freshly ingested material two to three hours after the animal started grazing. The method has been used by ILCA field researchers in Ethiopia (Nicholson and Sayers, 1987) and Mali (Dicko-Touré, 1980) but the technique is elaborate, labour-intensive and costly. It is therefore more likely to be applicable to on-farm/on-range experiments described in Section 2.

Direct observation of grazing habits. The content of food consumed by grazing animals can be guesstimated by following selected animals in a herd or flock at distances which are close enough to observe what is being eaten. Each selected animal is observed at regular intervals. Two field examples demonstrate the principles.

Examples:

De Leeuw and Chara (1985) used the technique to compare goat and sheep browse preferences in mixed Maasai flocks in Kenya. Observations were carried out during the dry season with randomly

Continued...

Examples continued...

selected animals being followed for periods of one to two hours by one or two observers who were familiar with the local flora. Because the animals were familiar with humans, observations could be made at distances of 2–10 m.

The aim was to obtain an equal number of 'hits' for sheep and goat - a 'hit' occurring each time a particular plant species was eaten. Hits per plant species were then summed and compared with the total number to determine the proportion of each plant eaten. These figures were then used to derive an index of preference or selection. Between 200 and 400 hits were collected for both sheep and goats in each sample flock.

Nyerges (1979) observed the grazing habits of 120 sheep, by following each for a period of 20 minutes (measured by stop watch). Animals were followed at distances of 5–15 m and the shrub and ground species consumed (including ground litter) during the observation period were recorded.

Direct observation can also be applied to other studies of animal grazing behaviour, e.g. time spent eating, walking, resting and watering (Dicko-Touré, 1980). These variables can then be related to such parameters as intake, digestibility, stocking rate and distance to water, to isolate the more important determinants of grazing behaviour (Lambourne et al, 1983, pp. 195–198).

A modification of the direct-observation method was used by Dicko-Touré (1980) in Mali to determine the composition of feed consumed. Selected animals were followed for a period of one minute, and distance walked as well as the number of mouthfuls taken during this period were recorded.

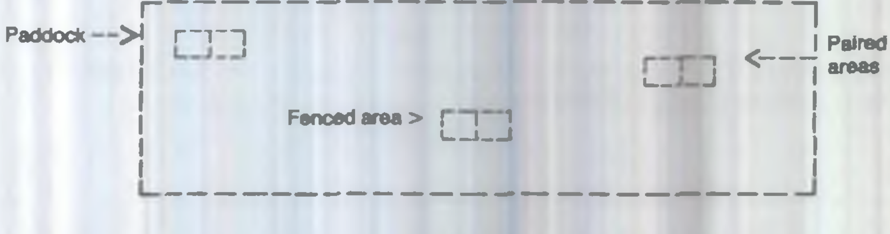
A sample of forage was then collected by hand from the area grazed during the one-minute observation period. The size of the sample taken was in proportion to the observed number of mouthfuls (one hand-grab for every five mouthfuls). Similar measurements were made for each selected animal every 45 minutes throughout the day in order to obtain comprehensive data on feeding habits and feed composition.

Lambourne et al (1983) argued that, for most purposes, such rapid-survey techniques provide sufficient detail on diet composition. They are low-cost, require minimal supervision and can be completed in a relatively short time. Observers should, preferably, have a good knowledge of local flora, but it is more important for them to be observant. If hand samples are collected to mimic grazing habits, these can be analysed at a later stage by someone who is thoroughly familiar with the flora.

Data on diet composition can be complemented by opinions obtained from herdsmen in the area. Their knowledge about species differences in terms of selectivity and palatability is often very precise.

Pasture analysis before and after grazing. The 'before' and 'after' method involves the demarcation of quadrats in a paddock before and after animals are released into an area for grazing (Figure 4). Adjacent to each fenced quadrat is an equally sized area, with similar vegetation characteristics. The biomass and vegetation composition of the two'paired' areas are measured using one of the techniques described in Module 6 and animals are then released into the area to graze (t'Mannetje, 1978).

Figure 4. Schematic representation of the pasture analysis method.



After a prescribed period (e.g. one week) biomass and plant composition in the paired areas adjacent to each fenced quadrat is remeasured and preferences for different species of vegetation are determined. The method will give reasonable estimates provided that the two areas are not highly variable in terms of species composition. When vegetation is highly variable, the number of paired samples required must be increased, making measurement more time-consuming.

Faecal samples. Faecal samples have been used for microscopic analysis of the plant part they contain, to provide an indication of the vegetation consumed by an animal (Stewart, 1967). However, as an indicator of dietary composition such samples tend to be unreliable since the indigestible portion of the diet may bear little relationship to the portion actually consumed. The faeces may, for instance, contain high proportions of woody ligneous material consumed during browsing. This does not necessarily mean that the diet also contains similar proportions of this component.

Feed digestibility

The methods used to assess digestibility are based on:

- **the use of markers**
- **the use of 'faecal indices'**
- ***in vitro* analysis of consumed feed, and**
- ***in vivo* analysis of consumed feed.**

Of these, only the first three are relevant to the diagnostic phase of livestock systems research. The *in vivo* method is more applicable to on-station research and involves intensive laboratory work and careful supervision.

The use of markers. When it is impossible or inconvenient to measure total feed intake or to collect total faeces, markers can be used to determine intake (see pages 161–162) as well as digestibility. The formula used to calculate apparent digestibility[16] is:

$$\textit{Apparent digestibility}\ (\%) = 100 - \left(100 \times \frac{\%\ \textit{indicator in feed}}{\%\ \textit{indicator in faeces}}\right)$$

Example: A sample of feed contains 13% lignin and a dry-faeces sample taken after the animal consumed the feed contains 22% lignin. Calculate the apparent digestibility of the feed.

Using the above formula,

Apparent digestibility (%) = 100 – 100(13/22) = 41

The formula for feed digestibility can be extended to estimate the apparent digestibility of a given nutrient or component of the diet as follows:

$$\textit{Apparent digestibility}\ (\%) = 100 - \left[100 \times \frac{\%\ \textit{indicator in feed}}{\%\ \textit{indicator in faeces}} \times \frac{\%\ \textit{nutrient in faeces}}{\%\ \textit{nutrient in feed}}\right]$$

To obtain data for the analysis based on markers, follow this procedure:

- collect 3–5 grab samples of faeces from the area in which the animals are grazing and mix them thoroughly

16 The reciprocal of apparent digestibility is per cent faeces.

- collect grab samples of the forage consumed after observing animal behaviour (see pages 163–164)
- determine the percentage of the indicator in the faeces and the feed, using standard laboratory techniques. If you are interested in the estimation of crude protein and energy intake or nutrient digestibility, assess the same samples for nutrient content, and
- determine digestibility (and intake) as shown above.

Note: There are two obvious sources of error in such a methodology. First, lignin may be partly digestible and is thus not always a reliable indicator (marker). Second, the feed samples taken will often be not truly representative of actual intake, particularly when pasture is highly variable, and where the choice of samples is entirely dependent on the enumerator judgement.

There are various methods available to sample faecal output in the field, including:

- taking 'grab samples' from several animals and mixing them thoroughly to ensure that differences between individual animals are eliminated. This method is practical in a range context.
- total collection by bags attached to the animal. The method is generally regarded as being inapplicable to most range/pasture studies because of the cost and supervision involved (e.g. Schneider and Flatt, 1975).

However, Dicko-Touré (1980, p. 248), who used a low-cost modification of the method on pastoral male cattle in Mali, reported that this need not necessarily be the case. She argued that the costs of using indicators to estimate faecal output would, in fact, have been more expensive since this method would have involved sending samples to another country at a cost that is at least 10 times higher than the cost actually incurred by using the bag-collection method.

Thus, the methods adopted in any diagnostic study to sample faecal output should be tailored to the particular circumstances of the study, bearing in mind the financial and manpower resources of the research team.

The use of faecal indices. The methods using faecal indices to estimate digestibility are based on established regression relationships between faecal indices and the digestibility of dry or organic matter (Van Soest, 1982). The general model for these relationships is:

Digestibility of forage grazed = f (faecal index)

The faecal indices in this model are calculated on the basis of the nitrogen, lignin or chromogen contents of the faeces, i.e. the components of faeces known to be closely related to digestibility.[17]

The estimation of digestibility via faecal indices involves the following steps:

- conduct conventional studies to determine, from faeces and feed samples, regression relationships between digestibility and the content of these substances in the faeces. (The principles of regression analysis are discussed in Module 11 of this section)
- analyse faecal samples collected in the field to determine the percentage(s) of selected substance(s) in the faeces. (The methods used to obtain faecal samples are described above)
- predict digestibility using the faecal indices calculated from these data.

The main advantages of this method are that it is relatively low-cost and results can be obtained fairly quickly. Its chief disadvantage is that it is site-specific, and the derived parameters and relations

17 The relationship is not causal. The two variables merely happen to go together i.e. they are concomitant (Dicko-Touré, 1980, p. 248).

are only relevant to the site at which data were originally collected or to sites with very similar vegetation and animal species (Dicko-Touré, 1980; Semenye, 1987).

***In vitro* analysis of consumed feed.** When digestibility is analysed by *in vitro* methods, samples of feed ingested are subjected to artificial tests which **simulate** digestibility under controlled conditions. The more commonly applied methods involve the use of rumen fluids, chemical fermenters and nylon bags (see Church and Pond, 1982).

Rumen fluids. Rumen fluids are extracted from rumen-fistulated animals and used in combination with buffers to simulate the action of saliva. The substances are added to feed taken from the fistula, and the mixture is heated at rumen temperature (39°C) for periods of 24–48 hours (Church and Pond, 1982). The Tilley-Terry (1963) method, which is widely used, involves an additional stage in which the feed is further digested with acid pepsin for another 48 hours. The residual represents the indigestible portion of the feed.

Chemical fermenters added to the feed have been used to predict digestibility. The method is also used to study rumen function and the metabolism of certain compounds, e.g. to determine types of non-protein nitrogen (NPN) that can be utilised by rumen micro-organisms.

The advantage of the two methods is that the analysis is not expensive (if laboratory facilities are available) and that it can be performed fairly quickly. The methods can also be used to assess the digestibility of grab samples of grass or of cut samples of stover and straws taken after crop harvesting.

Nylon bags. These are inserted into the rumen of test animals and removed after a prescribed period. The loss of material from the bag as a result of fermentation is then calculated. The method is more applicable to on-station research, but it can be used together with the rumen cannula method to determine intake (see page 163).

Nutritive value of feed

This part of the module focuses on the methods and techniques used in estimating the supply of different nutrients to animals in particular situations or systems, in relation to their need for these nutrients. It starts with a general section on estimating the main feed components. It then goes straight to fibre analysis because of the difficulties involved in estimating feed values in very fibrous diets. Finally, it looks at some of the techniques in use for the physical sampling, from stands of different kinds of feed, for laboratory analysis.

Methods to estimate feed components

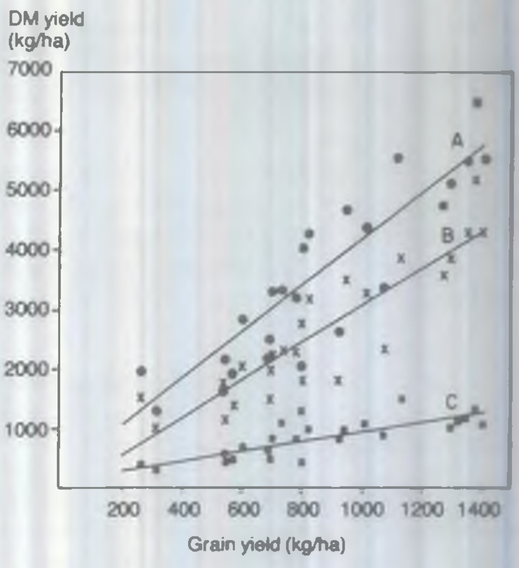
The feed value of a source of feed can be assessed on the basis of its energy value, crude protein content and mineral content, using methods specifically designed to estimate these components of feed.

Energy. The energy yield of a source of feed (such as natural pasture) can be estimated from its dry-matter weight per unit area. Module 6 discusses the various methods used to estimate biomass or dry-matter weight under rangeland conditions. Many of these methods rely on the use of predictive equations based on the relationship between biomass and the vegetation characteristics (e.g. height, density, crown diameter, stem diameter) of an area in order to extrapolate biomass estimates over larger areas.

Samples can be taken to establish similar predictive relationships for the estimation of dry-matter weight of crop residues. Powell (1985), for instance, used grain yield to predict total stover dry-matter weight and stalk and leaf dry-matter weights for millet and sorghum. The relationships, which were based on data obtained from randomly chosen sites in Kaduna State, Nigeria, were highly significant (Figure 5).

Van Raay and de Leeuw (1971) adopted a similar procedure to determine the DM weight of crop residues in Katsina, Nigeria. They established predictive relationships on the basis of stalk and stand density, plant height and plant edibility (subjectively estimated).

Figure 5. Relationships between sorghum and millet grain yields and stover dry-matter (DM) yields.



Note: The three relationships shown are between grain yield and, respectively, stover DM weight (A), stalk DM weight (B) and leaf DM weight (C).

Source: Powell (1985, p. 79).

Having obtained an estimate of dry-matter yield, an estimate of digestibility is then required before the desired approximation of the energy yield can be calculated. The fibrous portions of a feed must, therefore, be considered before more accurate estimates of nutritive value can be made.

Feeds with a high biomass per unit area are often low in energy since they also contain a high proportion of indigestible fibrous matter. Methods of fibre analysis have been devised to separate those portions of fibre which can be utilised by the ruminant from those which are essentially indigestible.[18] These methods are briefly discussed on page 171.

For the purposes of illustration, however, the following average relationships can be used:[19]

GE (gross energy) = 18.0 MJ/kg DM of feed intake

DE (digestible energy) = 0.50 (for example), and

ME (metabolisable energy) = 0.81 DE.

So in this illustration, ME = 7.3 MJ/kg DM of feed intake.

The metabolisable energy available in the feed intake can then be related to energy requirements for maintenance and/or production to provide an indication of the energy status of the animal.

18 The digestible portion of the fibrous fraction of crop residues and agro-industrial byproducts is a major source of energy for ruminant animals. Fibre analysis is thus particularly important in the assessment of the nutritive value of these feeds.

19 The average relationships used in the text which follows are feed energy supply and requirements derived principally from King (1983) to whom reference should be made for all supporting details.

Example: Let us calculate the feed energy requirements of a 300 kg (liveweight) ox for maintenance, foraging and production, and compare these with the availability of energy to that animal from its feed supply.

The maintenance (fasting metabolism) requirement is determined as follows:

Daily maintenance requirement (E_m) = 0.293 $W^{0.75}$ MJ of NE

where:

MJ = megajoules

NE = net energy, and

W = liveweight in kilogrammes.

In this case, W = 300 kg, so

E_m = 0.293 $(300)^{0.75}$ MJ of NE = 21.12

To convert this figure into metabolisable energy (ME), we need to divide it by the efficiency of conversion (K_m) of ME to NE for maintenance.

K_m tends to lie in the range 0.64 to 0.70, and here it is assumed to be 0.67. So,

E_m = 21.12/0.67 = 31.52 ME

To obtain its energy needs for maintenance (fasting metabolism), an animal needs to walk while grazing and trekking to water. We can call this 'foraging'. The energy requirement for foraging (E_f) are given by the formula:

E_f (in MJ of ME) = 1.8/1000 x W x distance walked in km

On the assumption that our ox walks 18 km daily at a speed of 3 kph:

E_f = 1.8/1000 x 300 x 18 = 9.72 MJ of ME daily

so its daily energy requirement for living (E_l), i.e. fasting metabolism and foraging, is:

E_l = E_m + E_f = 31.52 + 9.72 = 41.24 MJ of ME

If the daily energy intake of our ox is greater than 41.24 MJ of ME, it will be able to put on weight. To gain weight, an animal needs between 12 and 27 MJ of ME per kg liveweight, depending on the percentage that fat constitutes in the meat accumulated. Under African conditions, the average figure may be about 16 MJ of ME/kg LW gain (derived from Ledger and Sayers, 1977).

Assume now that we are conducting our study in a region where the remaining stock of standing hay in the early dry season (three months or 90 days before rain will bring fresh growth) is estimated at 200 kg DM/ha. Assume also that the stocking rate in the area is the equivalent of three ha/ox. We can now compare supply and requirements of feed energy per ox for the 90 days of the dry season as follows:

Supply

3 (ha) x 200 (kg DM/ha) x 7.3 (MJ ME/kg DM) = 4380 MJ ME/ox

Requirement for living

90 (days) x 41.24(E_l/days) = 3712 MJ ME/ox

Balance available for liveweight gain

Supply – requirements for living = 4380 – 3712 = 668 MJ ME/ox or the equivalent of about 42 kg of liveweight gain at the rate of:

42/90 = 0.47/head/day.

Crude protein. The standard laboratory method for the estimation of crude protein is the Kjeldahl method which is described in most texts on animal nutrition (e.g. McDonald et al, 1973; Church and Pond, 1982). The analysis is used to determine the crude protein content of a sample of grass or stover, and the results can then be used to establish predictive regression equations similar to those illustrated in Figure 5.

Powell (1985), for instance, found that the relationship between grain yield at the time of harvest and total crude protein (CP), and between grain yield and leaf CP/ha were highly significant. Such relationships can be used to indicate the availability of crude protein from different sources and/or at different stages of plant growth.

When estimating the crude protein content of browse plants and crop residues, it should be borne in mind that the presence of certain phenolics (tannins) in these feeds can affect the availability of nitrogen to the ruminant. This is particularly true of feeds high in insoluble polyphenolics, for which the calculated crude protein content may overestimate the amount of nitrogen which can actually be synthesised into protein (e.g. Woodward and Reed, 1989).

Minerals. Analysis should only be attempted if mineral deficiencies are clearly evident. Even then, if other nutrients such as energy or crude protein are more limiting (as is likely to be the case on African rangelands), the mineral constraint should be dealt with only after the primary deficiencies have been rectified (Little, 1985).

The methods used by ILCA researchers to diagnose the more common deficiencies involve blood, bone, liver, milk and faecal samples and are discussed in general terms below. All the methods outlined rely on adequate laboratory facilities. For a more detailed account of symptoms of mineral deficiency and the role of minerals in animal nutrition, the user is referred to basic nutrition texts, e.g. Cullison (1982) and Church and Pond (1982).

Blood samples. Whole blood, blood serum and blood plasma samples have been used to diagnose mineral deficiencies (particularly phosphorous and magnesium) in livestock. Values significantly below 'normal' concentrations (or ranges) indicate the nutritional status of an animal with respect to a particular mineral, but the evidence is not always conclusive (McDowell et al, 1986).

Precautions must, for instance, be taken when samples are taken in less than optimum conditions since exercise, stress, temperature and other factors can alter mineral concentrations. Such factors are often difficult to control in African conditions (Mtimuni, 1982) and have resulted in high concentrations of phosphorous in serum when the concentration in forages consumed was, in fact, extremely low.

Little et al (1971) described a method for obtaining accurate estimates of blood inorganic P concentrations, but the difficulties of interpretation of such data were noted by Gartner et al (1980). Basically, only low blood inorganic P values have any diagnostic value.

Bone samples. Because of the problems just described, tests using bone samples have been developed to test for phosphorus deficiency in livestock. Samples of rib bone can be obtained by simple surgery. For FSR diagnostic work, simple measurements that can be made on certain long bones at slaughter can provide results which are generally more reliable than those obtained from blood samples. These methods have been described by Little (1984).

Liver samples. Liver samples have been used to diagnose for copper, cobalt and vitamin A deficiencies in African livestock (Tartour, 1975; van Niekerk, 1978).

Milk samples. ILCA has used samples of milk to diagnose mineral deficiencies in cattle in Ethiopia. However, since milk composition is influenced by such factors as cow age, stage of lactation and genetic potential, milk sampling tends to be unreliable. The 'let-down' problem associated with zebu cattle (Module 5) also means that it is difficult to obtain representative samples in field studies. Large variations in butterfat content between successive milkings of the same cow reflect this problem (Lambourne et al, 1983). However, milk samples are very useful in the diagnosis of iodine deficiency (Committee on Mineral Nutrition, 1973).

Faecal samples. Apart from their use in digestibility and intake studies, faecal samples have been used to diagnose for phosphorus and sodium deficiencies (Little, 1987). Sodium problems are diagnosed more accurately, but with more difficulty, from saliva samples.

However, the analysis of mineral deficiencies is probably best done by feed analysis at the diagnostic phase of farming systems research. The methods described above are more applicable to specific problems requiring more sensitive analysis (Little, 1987). A knowledge of the symptoms involved will provide further confirmatory evidence (e.g. bone chewing is an indication of phosphorus deficiency). The opinions of traditional herders will also be useful in identifying mineral deficiencies (particularly the need for salt), as will be the movement of stock over large distances to natural sources of minerals.

Fibre analysis

The crude-fibre (Weende) method is described in most texts on animal nutrition. The method has been widely used to determine the fibre content of feed, but it has two serious shortcomings, particularly with respect to highly fibrous feeds such as crop residues, straws etc. These are:

- The method treats all fibre components (cellulose, hemicellulose and lignin) as uniformly digestible. Ruminants can, however, utilise some cellulose and hemicellulose though lignin is essentially indigestible. The digestibility of a feed therefore tends to be underestimated.
- Not all of the lignin and hemicellulose is extracted by the crude-fibre method. As a result, a portion of these components is included in the nitrogen-free extract (sugars and starches) and is, therefore, assumed to be highly digestible. The digestibility of a feed therefore tends to be overestimated.

Because of these shortcomings, Van Soest (1988) devised a method which separates feed dry matter into two fractions - one of high or **uniform** digestibility and the other of low or **non-uniform** digestibility. Feed samples are boiled in a neutral-detergent solution and components are separated as follows:

- **neutral-detergent solubles** (NDS), consisting mainly of lipids, sugars, starches and protein with a digestibility of about 98%, and
- **neutral-detergent fibre** (NDF), consisting of plant cell wall components (lignin, silica, hemicellulose and some protein). This fraction more closely corresponds to the true fibre fraction than the estimate of the Weende crude-fibre analysis.

However, NDF is not a uniform chemical entity; its overall nutritive value is considerably influenced by the amount of lignin present. To determine this amount, the feed is treated by acid detergent, and the procedure is known as the acid-detergent fibre (ADF) analysis. By heating the NDF in acid detergent, the presence of tannins can also be detected.

The detergent analysis and its different procedures are discussed in greater detail by Van Soest (1988) and Reed and Van Soest (1985). Because of the high costs of reagents and apparatus used in detergent analysis, developing countries have been slow to adopt the method. ILCA's Animal Nutrition Section has recently developed a low-cost micro-fibre apparatus which uses one tenth of the amount of reagent used in conventional detergent analysis experiments. This method is described by Reed (1984), and the specifications of the apparatus can be obtained from ILCA, Addis Ababa, Ethiopia.

Feed sampling for laboratory analysis

The types of feed usually sampled for laboratory analysis are crop residues and hays, grains and fresh forage or silage.

Crop residues and hays. Most African farmers store crop residues and hays in stacks, and the nutritive value of the feed tends to be highly variable both within and between stacks. This increases sampling requirements and complicates the procedures involved.

Because of the variability in the nutritive value of crop residues and hay commonly encountered, it is useful to make a visual estimate of the variation in a selected stack before sampling begins, and to interview the farmer about the time of harvesting, the methods of stacking used and the composition of the stack (i.e. whether it contains material from more than one source or crop).

Sampling may be done with a coring device or by hand. Samples should always be taken from a cross-section of each chosen stack. When large stacks are encountered, dismantling may be necessary to ensure that samples from the less accessible parts are obtained.

When the *coring device* is used, at least 10 samples should be taken per stack. The material gathered should be properly mixed, weighed and stored in a dry place before dispatching it to the laboratory. The combined dry weight of corings taken per stack should not be less than 2 kg. The samples should be clean and stored in a porous paper or a piece of cloth to avoid moisture contamination. Relevant information (date, feed type, sample weight, identification) should be recorded in duplicate.

When *samples* are taken *by hand*, several visits are normally required to ensure that the nutritive value of the stack is properly assessed. At each visit, 12–15 grab samples should be taken from the face of the stack and mixed. They should be taken at every 50-75 cm, as the farmer makes use of the stack. If the farmer finishes one stack and starts another, or alternates between different stacks, new samples should be taken following the same procedure.

Although hand-sampling is tedious, changes in feed quality over time (e.g. resulting from storage or environmental effects) can be monitored at the same time. With coring, several return trips would be required if specific information on quality change over time was needed.

Grains. Grain samples are usually taken with a grain probe. Between 5–7 cores should be taken at random from the storage bin. The samples should then be mixed and separated into subsamples of about 450 g. Each sub-sample should be placed in a porous paper or cloth sack and properly labelled before dispatch or storage.

Wet feeds. These are usually fresh forage or silage.

Fresh forage should be weighed immediately after sampling and put in a porous paper or cloth sack for dispatch to the laboratory, where it should be dried at 65°C to a constant weight and weighed again (Van Soest and Robertson, 1985).

If it is not possible to weigh the sample when it is taken, one half should be placed in a sealed plastic bag to retain moisture and then weighed after returning from the field. This fresh weight is needed to calculate dry-matter content after drying. The other half of the sample should be kept in a porous paper or cloth sack for other analyses than dry-matter content.

In the event that samples cannot be transported to the laboratory the same day, they should be dried either by hanging under cover or by spreading them out on paper in a dry and protected place. Alternatively, samples can be hung in sacks above the coil of a kerosene refrigerator. If drying is delayed, samples should be kept in plastic bags out of direct sunlight to avoid spoilage, or they should be stored frozen.

Silage. Cored samples should be taken from the pit using the procedure outlined above for stacked hay and crop residues. If sampling is done by hand, about 20 grab samples should be taken from the freshly cut face and mixed thoroughly. A subsample of 2 kg is required for analysis. The procedure should be repeated every third or fourth face cut to account for within-pit variability.

After weighing, samples should be placed in sealed plastic bags, frozen or dried at 65°C and sent immediately to the laboratory. If oven-drying is not possible, one of the drying methods given for fresh forage will suffice.

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SECTION 1

MODULE 8

ANIMAL HEALTH

MODULE 8

Animal health

This module should be seen as a complement to the manual produced by ILCA on veterinary epidemiology (Putt et al, 1987),[1] which deals with the basic techniques involved in the planning, monitoring and evaluation of livestock disease programmes and explains all the important definitions and concepts involved.

The principles of veterinary diagnosis and the specific characteristics of the important economic diseases common in Africa (e.g. foot-and-mouth disease and rinderpest) are not discussed in this module. Such topics are covered in texts which deal specifically with African disease diagnosis and treatment (e.g. Schneider et al, 1972).

PART A: PURPOSES

The mere presence of disease[2] in an area does not mean that an in-depth study of animal health issues is needed. The decisive factor is whether production itself is constrained by disease, and we can establish this by screening all the available evidence beforehand from exploratory surveys and secondary data sources (Module 1). Mortality data, in particular, will often provide an indication of the seriousness of disease problems, especially if they are supported by information from other sources (e.g. veterinary records, farmers' opinions). Data on herd/flock structures and reproductive performance may also provide supportive evidence.

Example: A high mortality rate can be explained by the presence of certain diseases in an area. Does this imply that disease is a constraint to production, warranting further detailed study? To answer this question, we would have to decide whether:

- mortality due to disease is relatively high
- other causes of death are more important (e.g. nutrition,[3] management practices), and
- diseases (apparently prevalent[4]) are likely to have serious long-term consequences if left uncontrolled, in other words, whether the relative importance of disease as a *constraint* is likely to increase with time.

Similar questions could also be asked about other performance parameters affected by disease, such as output levels, reproduction rates and condition. For instance:

- Is reproductive performance relatively low?
- Is disease considered to be a major contributor to low performance?
- Are other factors (e.g. genetics, nutrition) considered more important? Why are they considered more important?

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1 Veterinary epidemiology is the study of disease in animal populations. A population may include all animals of a particular species in the area studied, or subcategories within that species (e.g. all male stock within a certain age group).

2 A distinction should be made between 'disease' and 'infection'. Infection can result in: (a) no reaction (but, maybe, with detectable levels of antibodies; (b) subclinical infection (which may affect production but is not clinically detectable); and (c) clinical disease (where infection is clinically detectable and considerably affects production).

3 Emphasis in this module is given to diseases caused by 'living agents' (such as viruses, bacteria, rickettsia, helminths and arthropods) and those caused by non-infectious agents (such as toxins, metabolic diseases and injury), not to diseases caused by poor nutrition. Module 6 deals specifically with animal nutrition issues.

4 Prevalence is the total number of cases of a disease occurring at a particular point in time divided by the total number of individuals present in that population at that moment in time.

If preliminary enquiries indicate the need to conduct more detailed research on animal health issues, the broad objectives will then be to determine whether:

- disease is, in fact, a constraint to animal production, and
- improvement in animal health is possible through vaccination, wider veterinary coverage or altered management practices at the producer level.

In order to address these objectives, we would need to:

- **identify the prevalent disease**(s) in the target area and rank them on the basis of predetermined criteria
- **quantify the effect**(s) of these diseases on animal production performance, and
- **identify the determinants** of those diseases which have a significant effect on animal production performance.

Identifying and ranking the prevalent diseases in the target area

At this point, the first task will be to identify the main diseases prevalent in the target area. Prevalence is usually measured at one point in time.[5] Depending on the purpose of the study, it can be determined on the basis of species alone, or within a given species, taking into account age, sex or production function.

The diseases identified as being present in the area can then be **ranked** using one or more of the following criteria:

- **proportional morbidity rate**
- **proportional mortality rate, and**
- **assumed productivity effects.**

Proportional morbidity rate is the number of observed cases of a specific disease in a specified population during a specified time period (t), divided by the total number of observed cases of all diseases in that population during the time period (t).

This rate provides a numerical measure of the relative importance of disease in a target area, but it does not indicate whether the disease itself is significant in terms of its effects on livestock production.

> **Example:** Suppose that an outbreak of contagious bovine pleuropneumonia (CBPP) occurs in a herd of cattle (Putt et al, 1987, p. 22). During a 6-month period there are 45 cases of different diseases, including 18 cases of CBPP. The proportional morbidity rate for contagious pleuropneumonia in that herd for the six months would then be 18/45 = 0.4 or 40%.

Proportional mortality rate is the total number of deaths resulting from disease A in a specified population during a specified time period (t), divided by the total number of deaths in that population during that time period.

5 Point prevalence studies will only provide an indication of (or indicators of) diseases present at a particular time. Such studies may therefore miss important diseases which occur sporadically over time (e.g. peste des petits ruminants (PPR) in small ruminants in West Africa). It should be distinguished from the incidence rate which refers to the proportion of new disease cases in the population during a given time period (Thrusfield, 1986; Putt at al, 1987, pp. 20–23). In diagnostic systems research, prevalence rates can be estimated by once-off surveys and incidence rates by continuous surveys.

The proportional mortality rate is used for ranking purposes when mortality rates for specific diseases are known. If these mortalities are significant, the ratio can provide a useful basis especially for initial rankings.

The implicit assumption, of course, is that mortality is the criterion by which the effects of a disease on animal productivity should be judged. Other parameters (e.g. reproductive rate, weight gain) are not considered although they may also be directly affected by disease.

For instance, a disease with a low mortality rate (i.e. one of those caused by intestinal parasites) may have a considerable effect on weight gain. It may also contribute **indirectly** to mortality by predisposing the animal to other sources of infection. Thus, ranks assigned on the basis of the proportional mortality rate may fail to reflect the true importance of a disease in the target area.

Furthermore, it can be very difficult to obtain reliable information on mortality and to assign deaths to specific causes, even when visits to sample households are conducted on a regular basis (e.g. by continuous surveys). This is because producers are often unwilling to divulge such information. Assigning deaths to specific diseases after the event is also likely to be fraught with problems unless the stockholder can identify diseases accurately. Methods used to collect mortality data are discussed in Module 5, together with the problems likely to be encountered.

Assumed productivity effects. When specific information on mortality is not available, the effects of disease on animal productivity can be approximated by veterinarians. Diseases can then be subjectively ranked according to predetermined criteria, such as reproductive performance, mortality rates, output levels etc. Alternatively, producers in the area be asked to identify and rank diseases according to the criteria they consider to be important (Perry et al, 1984).

Such preliminary rankings can then be used to determine future courses of action in diagnostic systems research. Diseases ranked high on the list may, for instance, be given priority in studies directed towards identifying the critical constraints to production. Others may not warrant further consideration.

Quantifying the effects of disease on animal production performance

It should be remembered that a mere description of the diseases present in an area is never the aim in diagnostic systems research. On the other hand, the presence of a disease does not always imply that eradication is necessary. The costs and benefits of doing so must always be taken into account, in other words, we must **quantify** (as nearly as possible) the effects of the disease on production and the costs associated with its effective treatment (Putt et al, 1987).

In some cases, the effects of disease will be fairly obvious and pathways for improvement will (in theory) be 'available', though not necessarily easy to choose between. To make the optimum choice we will need to consider such things as efficiency in terms of disease eradication, logistical considerations and manpower resources and the costs of implementation and administration.

> For instance, East Coast fever (ECF) has obvious effects and its cause - inadequate tick control in endemic areas - is well known. Dipping and/or vaccination may appear to be the best strategies but the costs, benefits and practical implications of the various options available will need to be carefully considered before embarking on any programme for 'improvement'.

In many other cases, where effects are not clearly understood, further studies will often be needed before an appropriate strategy can be identified.

> For instance, the effects of intestinal parasite infestation on productivity or on the animal's predisposition to other diseases are not always clearly understood. Detailed studies may, therefore, be necessary to quantify these effects before the need for intervention (and its mode) can be positively stated.

To quantify the effect(s) of a disease more precisely, it will often be helpful to study the relationships between:

- the prevalence rate of the disease and measures used to determine overall production performance[6] (e.g. annual reproduction rate, fertility rate)
- the incidence rate of the disease and changes in production performance measured on such variables as mortality rate and reproduction rate, and
- the proportional morbidity rate and production performance.

We must **not** assume that disease will automatically have a significant effect on production performance,[7] simply because the prevalence rate is high or because the incidence rate has increased. Such assumptions often form the basis of expensive eradication programmes which may not be justified upon further examination of the evidence.

The effects of disease on production performance are illustrated in the examples below. Note that relationships such as those shown in Table 1 and Figure 1 are not always easy to establish in animal health studies. Other factors (e.g. management) may confound the results or lead to spurious conclusions (see pages 184 and 185).

When quantifying the effects of disease on production performance, the population at risk should always be correctly identified. Measures of prevalence based on the whole population are likely to give low correlation coefficients, if the disease only affects a subgroup of that population.

Examples:

Table 1 shows that while calving rate was affected by exposure to trypanosomiasis, the effect was not statistically significant because of the large standard errors calculated. We can, therefore, conclude that trypanosomiasis does not significantly affect N'Dama production performance in Gabon.

Table 1. The effect of induced trypanosome infection on the calving rate of N'Dama cows kept on a research station, Gabon, 1983–85.

Number of infection	Number of cow-years	Calving percentage $\bar{X}$	±	SE
0	106	55.7		5.18
1	61	55.3		6.99
2 or more	75	38.3		8.56

Source: Ordner et al (1988).

Analyses such as this can, however, be used to indicate the importance of a disease in terms of its quantitative effects and whether there is need for intervention.

Figure 1 gives the results of an experiment conducted with 60 male weaner calves at a research ranch in Kenya. Calves were divided into four groups of 15 animals and subjected to four different tick-control treatments in order to test the effect of tick infestation on growth rates over a period of 16 months.

The treatment groups were: weekly spraying with acaricide (group 1); spraying every three weeks (group 2); spraying whenever the mean tick count reached 200 per animal (group 3); and no treatment (group 4). Tick counts were estimated on the basis of monthly means of weekly totals.

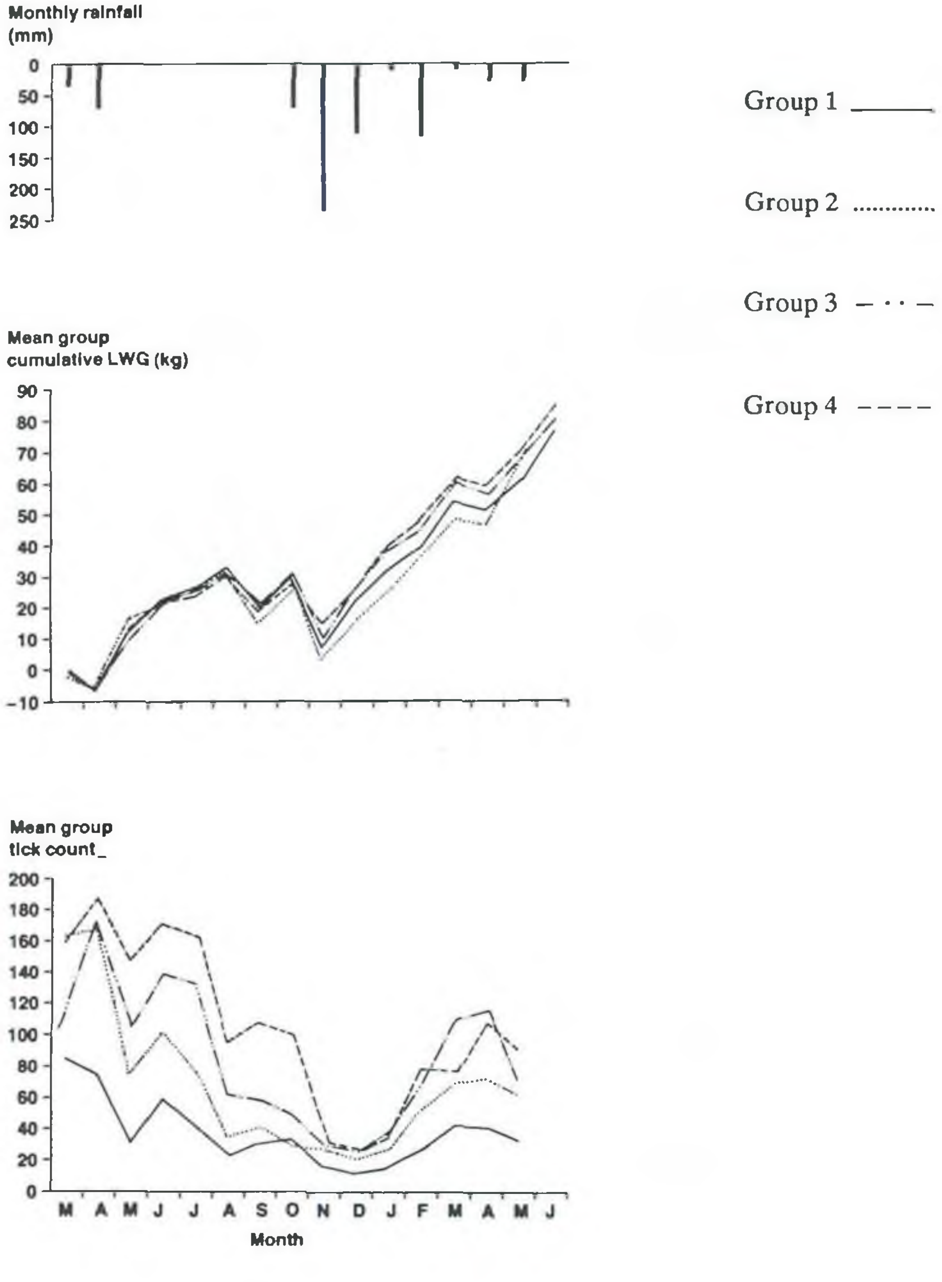
Continued...

6 The methods used to measure animal production performance are discussed in Module 5. Module 12 shows how such relationships can be tested statistically.

7 Production performance is not the only criterion upon which disease control or eradication programmes should necessarily be based. Sometimes other criteria (e.g. access to export markets) will be the overriding consideration in control programmes (e.g. the control of FMD disease and rinderpest in Botswana in order to maintain access to the European Common Market).

Examples continued...

Figure 1. Comparison of mean liveweight gains (LWG) and mean tick counts in relation to rainfall, Kenya, March 1984 – June 1985.



Source: Tatchell et al (1986).

The results of this study showed no significant difference in weight gain between the different treatment groups, and the conclusion was that the benefits resulting from control would not be sufficient to cover the costs. Other studies have, however, shown that a threshold tick burden may be reached after which significant effects on productivity can be expected (Sutherst, 1987).

Breaking down the population into subgroups affected by a disease (i.e. on the basis of populations at risk), and relating productivity to the prevalence rate for that group alone (e.g. calves), will often help to improve the correlations obtained. Refining data like this can, however, be time-consuming and costly if representative samples from each subgroup are to be studied.

Furthermore, studies which determine disease prevalence on the basis of antibodies present in the sample group (see page 188) may only provide an indication of exposure to a disease agent in the past. This may bear no relationship to present production performance.

Generally, circulating antibodies bear a relationship to production performance and disease agents can be detected 1–3 weeks after exposure to the agent. However, there is considerable variation in both the time it takes to detect antibodies and in the levels of antibody which are detectable.

Identifying the determinants of disease

It is not enough to merely state the effects of a disease. This helps us to understand the magnitude of the problem, but not what are the **determinants** of that disease, which must be identified if realistic solutions are to be proposed.

A determinant is "any factor or variable that can affect the frequency with which a disease occurs in a population" (Putt et al, 1987, p. 6). Determinants can be broadly classified as being 'intrinsic' or 'extrinsic' in character. Intrinsic determinants are physical or physiological characteristics of the host or disease agent which are usually determined genetically. Extrinsic determinants are normally associated with some form of environmental influence. Technological interventions aimed at the control or prevention of disease are examples of extrinsic determinants.

In some cases, the mode of disease transmission is obvious, while in others a careful analysis of system linkages and relationships will be needed, since there is always a danger that inadequate knowledge of the system will lead to:

- spurious conclusions about the determinants of a disease. Such conclusions are likely to result in misplaced 'solutions' to the problem, or
- a failure to account sufficiently for the impact of changes resulting from the corrective action taken.

Example: Take a disease for which the effects on production performance (e.g. on mortality rates) are known to be significant. Its presence is attributed to the fact that veterinary services in the area are inadequate, and the solution therefore involves a need to improve those services. However, the main determinant of the mortality observed is a low plane of nutrition due to overgrazing, which predisposes animals to infection.

Rectifying the problem by concentrating on the disease itself may, in such circumstances, only have a temporary effect. Reduced mortality will increase stocking pressure and, eventually, worsen the nutritional situation. This, in turn, is likely to result in an increase in mortality rates from other causes (poor nutrition or increased susceptibility to other diseases - assuming that the first disease was effectively eradicated). A two-pronged attack involving nutritional as well as veterinary measures may, therefore, have been more appropriate in the first place.

Of course, knowing what the determinants of a particular disease are does not always imply that a solution is possible. If the problem cannot be rectified completely, tackling the clinical signs of disease (in order to reduce the fatality rate among cases) may, sometimes, be the only appropriate course of action.

In some cases, the determinants of a health problem can be extremely difficult to identify, but attempts should nevertheless be made to do so. Thrusfield (1986) argues that investigations of this nature ideally require knowledge of disease **incidence** rather than disease **prevalence.** This is because it is easier to isolate the cause of a problem when it actually occurs rather than after it has occurred.

Prevalence measures are, however, useful during the preliminary stages of enquiry. When incidence figures are unavailable, prevalence studies which measure **changes in prevalence** over time can be used to indicate changes in the incidence of a disease, provided that the disease is not chronic. Prevalence surveys conducted at appropriate intervals may thus be used to substitute for the more costly and time-consuming continuous surveys.

Example:

An example of the types of determinant–disease relationships which could be studied during the diagnostic state are the relationships between:

- **disease incidence and distance from watering points** (i.e. does the incidence of disease increase closer to watering points?)

  Rationale. Watering points are frequent sources of disease carriers, particularly liver flukes and helminths. The contamination of water supplies by infected animals can often result in other animals being infected with rinderpest, foot-and-mouth disease, salmonellosis and brucellosis (Nicholson, 1987; Perry and Hansen, 1989).

- **disease incidence and nutrition** (which is affected by the stocking rate)

  Rationale. Disease and nutrition are often very closely linked: low levels of nutrition may predispose animals to disease and disease can affect feed intake (Module 6). Due to this interaction, it may be difficult to identify the factor causing low production performance.

- **disease prevalence/incidence rates and management practices** (i.e. do pastoralists who split or move their herds regularly have less problems with disease than those who do not?)

  Rationale. The regular movement of stock by herders is often motivated by a desire to minimise the effects of disease (Dahl and Sandford, 1978; Dahl, 1979; Swift et al, n.d.). In this context one could ask: Is management related to herd/flock size? Do those with larger herds/flocks manage their animals better? What characterises their management practices and how does this affect disease incidence/prevalence? (Module 9)

- **disease prevalence/incidence and the availability of veterinary services** (i.e. do animals, exposed to regular dipping, perform better than animals in another area where such services are not available? Do the latter develop immunity to tick-borne diseases? What implications would this have for the proposals to widen dipping coverage? - Tatchell et al, 1986).

At this stage it is useful to point out that a statistically significant relationship between two variables does not imply a causal relationship. Therefore, one should guard against making conclusions about causal relationships which are spurious.

Example: Suppose that the frequency of occurrence of variable A is determined by the frequency of occurrence of variable B, which also determines the frequency of occurrence of disease D (Putt et al, 1987, p. 44). What is the relationship between variable A and disease D?

Note that although this arrangement would produce a statistically significant relationship between variable A and the disease D, the relationship is not a causal one, since altering the frequency of occurrence of variable A would have no effect on the frequency of occurrence of the disease which is determined by the variable B. Variables which behave in the way that variables A and D do are known as **confounding variables** and can cause serious problems in the analysis of epidemiological data.

Thus, to avoid making spurious conclusions about causal relationships, a logical biological explanation should be found for those relationships which are found to be statistically significant. This general principle holds for the study of relationships of any kind (see also Module 10).

PART B: TYPES OF DATA

Data collected in epidemiological studies is typically classified as **passive data** (i.e. information obtained from existing or secondary data sources such as government veterinary records) and **active data** (i.e. data obtained from surveys and studies of various kinds).

Passive data

Passive (secondary) data can be commonly obtained from veterinary records, the records of diagnostic or research laboratories, slaughter houses, and quarantine stations and checkpoints (Putt et al, 1987, pp. 46–47). These sources of secondary data are briefly described below.

Veterinary records. Provincial or district veterinary offices will often provide information on disease outbreaks and treatments or vaccines administered. If the records have been properly kept, and if the methods of investigation have been clearly specified, veterinary records can provide useful information on the important diseases and their frequency of occurrence in an area.

However, the quality of such data is often poor. Record-keeping is typically anecdotal, erratic and unreliable, or confined to historical prevalence data which are difficult to relate to a particular animal population or production system. In addition, the methods of data collection and the sampling procedures used are usually not reported.

Experience also shows that stock owners will not report disease problems if they think that restrictions on movement or selling of stock are likely to be imposed. If the prevalence of a disease in the herd/flock is low, the producer is unlikely to report its presence unless he is in frequent contact with the veterinarian.

Records of diagnostic or research laboratories. Data from such sources can provide background information on the diseases which exist in an area. Statements about disease prevalence will, however, have little relevance unless complemented by information on populations at risk, frequency of occurrence etc.

Information about when and where a particular disease has occurred can provide a useful starting point for the design of in-depth diagnostic surveys. Data from these sources tend to be limited by the research facilities available and are thus highly selective. Diagnoses can only be carried out on the material submitted, and the records obtained will often be biased by the interests of the veterinarians/researchers working in the laboratory or by the willingness of farmers to report the disease problems of their livestock.

Samples mostly come from small private or commercial producers who can afford to spend money on diagnosis. State support for sample processing tends to be confined to specific disease campaigns or surveys, which means that the data obtained rarely provide the detail needed for an assessment of the overall disease problems in an area (Perry and McCauley, 1984).

Slaughter houses. It is rare for slaughter houses to keep disease records. Even if they do, the data collected generally relate to relatively healthy animals that have survived to slaughter and may fail to give a reliable picture of the diseases prevalent in an area. Inspectors' reports also tend to be highly variable, often failing to distinguish clearly major diseases. Properly kept records from slaughter houses can, however, be used as the starting point for the design of in-depth studies on animal health in the target area.

Quarantine stations and checkpoints. Records from these sources can provide data about the time and the location of outbreaks of such diseases as foot-and-mouth disease and contagious bovine pleuropneumonia.

Active data

Active data include data supplied by farmers, pastoralists and other informants (e.g. district veterinarians and extension officers); data obtained from laboratory analysis; and productivity data (e.g. mortality and reproductive rates).

DATA OBTAINED FROM PRODUCERS. Farmers and pastoralists (whose knowledge of diseases, their associated clinical signs and methods of treatment often closely correspond to the orthodox) can provide useful information on disease prevalence and incidence in an area. Many cattle-owning societies (e.g. the Dinka of Sudan, the Fulani of Nigeria, the Maasai of Kenya and the Oromo of Ethiopia) have particular names for the most common diseases and use their own diagnosis to identify and treat the diseases (Dahl, 1979; Halpin, 1981; Ibrahim et al, 1983; Perry and McCauley, 1984). In general, the accuracy of diagnosis tends to be greater in pastoral than in sedentary societies (Perry and McCauley, 1984).

Information provided by producers on the main diseases in an area can be used to complement surveys which rely on laboratory analysis and direct observation (see page 189). Its value will, of course, depend on the knowledge of the interviewed farmers or pastoralists about diseases, which is likely to be variable within and between systems. The data should, therefore, be cross-checked and compared with the observations of local veterinarians and with data obtained from secondary sources (see these two pages 186–187) or surveys (e.g. sentinel-herd studies – see pages 190 and 194).

DATA OBTAINED FROM LABORATORY ANALYSIS. Where access to reliable laboratory facilities is assured, three types of surveys and studies may be conducted to obtain information about disease prevalence or incidence in an area (Table 2). They are:

- **serological surveys**

  These surveys are conducted to determine previous exposure to a disease. Previous exposure is determined by the presence or absence of antibodies in the serum of selected sample animals. Serological surveys do not provide an indication of when an animal has been exposed to a disease and are, therefore, of doubtful value in the identification of determinants.

- **identification of disease agents**

  In these studies, samples are taken to isolate the disease agent(s) responsible. Disease agents can be classified as 'living' or 'non-living'. Living agents include viruses, bacteria, rickettsia and helminths, and their identification is discussed below. Non-living agents include heat, cold, nutrients, toxic substances etc.

- **indicative sampling**

These studies are conducted to indicate the probable cause(s) of a disease in an area, without isolating its specific agent. An indication of the presence or absence of a particular disease in the animal population concerned is obtained from so-called 'indicator samples'.

Table 2. Types of tests necessary for laboratory analysis and examples of diseases or disease agents which can be indicated by such analysis.

Survey category	Test or sample	Disease or disease agent
Serological surveys	Complement fixation test	Brucellosis
	Indirect fluorescent antibody test	Babesiosis
	ELISA test	Rinderpest
Agent	Blood in anticoagulant	Viruses (e.g. in Rift-valley fever)
	Blood smears	Trypanosomiasis, babesiosis
	Faecal samples	Gastro-intestinal nematodes, salmonella
	Ulterine discharges	Brucellosis
	Skin scrapings	Dermatophilosis
	Biopsies	*Theileria parva* (from lymph-node biopsies)
	Milk samples	Mastitis
	Urine discharges	*Leptospira*
	Ectoparasites	Ticks
	Red and white bloodcell counts	Haemoparasites
	Discharges (presence of inflammatory cells)	Bacterial infections
	Skin scrapings	Tuberculosis
	Milk samples (white-cell counts)	Mastitis
	Urine (presence of haemoglobin)	Babesiosis, anaplasmosis

The methods used to carry out the types of tests shown in Table 2 are covered in standard veterinary texts which deal specifically with disease diagnosis and treatment (i.e. Thrusfield, 1986; Martin, 1988; Hancock et al, 1988).

Serological surveys can be used to provide an indication of the proportion of animals at risk in the population, but they may tell us nothing about the actual time of exposure to a particular disease or its incidence. The presence of antibodies in serum samples can, however, be used to give an indication of the seriousness of a disease problem and the need for intervention. By stratifying the population on the basis of age and/or sex, precise information can be obtained on population groups which are at greatest risk to a given disease.

Example: A low prevalence of antibodies for tick-borne diseases (e.g. 20%) is likely to cause considerable concern if the cattle in a tick-infested area are predominantly of exotic origin.

When serum samples are taken it is normal to do antibody tests for more than one disease. Serum sampling is, however, suitable only for certain diseases (e.g. rinderpest, babesiosis, anaplasmosis and theileriosis).[8] Even then, false negative and positive results can occur (e.g. when animals show a natural or induced tolerance to antigens and, therefore, do not produce antibodies when challenged with the disease agent). The terms used to describe the reliability of diagnostic tests of this nature are discussed in detail by Putt et al (1987, pp. 40–42) and Martin (1988).

Identification of disease agents. In tropical environments, blood smears and faecal samples are most commonly used to detect disease agents.

Blood smears are used to detect blood parasites actually present in the host. Such samples are commonly used for the detection of trypanosome, babesia, theileria and anaplasma parasites. One of the chief problems with this type of diagnosis is that while parasites are often easily detectable during the early stages of infection, they may be less so later on (e.g. during the transmission stage). The time at which samples are taken is, therefore, of great importance. Furthermore, even if a parasite has been identified as being present, this is not necessarily indicative of the presence of clinical disease caused by it, as 'carrier' animals are not uncommon.

Faecal samples are collected to obtain information on gastro-intestinal helminths (worms). From the samples taken, eggs are counted and identified. Egg counts should be interpreted with caution because:

- helminth eggs are almost always present in faeces. The number of eggs found should, therefore, be related to what is considered 'normal' for the animal and to the pathogenicity of the worm species identified.
- some worm species are prolific egg producers but are relatively harmless, while others can be extremely pathogenic before egg counts reach high levels. Deaths from *Haemonchus,* for instance, may occur well before faecal egg counts reach noticeable levels.

PRODUCTIVITY DATA. The collection of disease data will often involve the need to collect information about production performance in order to establish the types of relationships discussed in Part A. The type of data collected will depend on the purpose of the study and the nature of the disease(s) found in the target area. The collection of animal production data is discussed in Module 5.

PART C: METHODS OF DATA COLLECTION

This part of the module focuses on the collection of 'active' data for the diagnosis of animal health problems in livestock systems research. It does not discuss the principles involved in the collection and interpretation of secondary or passive data since these are dealt with in Part C of Module 1 (Section 1). The principles of sample collection and questionnaire design for the types of survey discussed below are discussed in Part C of Module 2 (Section 1).

There are essentially two methods involved in the collection of active data for the diagnosis of disease problems. They are:

- *Recall methods*, which use once-off survey questionnaires to elicit information from stockholders, veterinarians or extension agents about disease prevalence in an area. Recall surveys are often carried out to indicate directions for more detailed research involving direct observation methods.
- *Direct observation methods*, which involve field observations and taking laboratory samples to confirm the prevalence or incidence of disease in an area and to identify its determinants. Direct observation is often used to validate the findings of questionnaire surveys (Perry et al, 1984).

8 Serological tests are generally unsuitable for diseases which cause localised infection, e.g. blackleg, trichomoniasis. Tests for heartwater are in the process of being developed.

Epidemiological studies of this nature are typically classified as cross-sectional, retrospective and prospective studies.

Cross-sectional studies are surveys in which sample herds or flocks are chosen to determine the presence or absence of a given disease at a particular point in time, or to identify its effects and determinants. They may be run in conjunction with recall surveys to confirm the statements made by farmers or pastoralists during interviews. Where necessary, access to adequate laboratory facilities should be ensured beforehand.

Retrospective studies aim to compare the frequency of occurrence of a determinant in two groups of animals ('case' and 'control' i.e. those which have been diseased and those which have not) by using data obtained from historical records/observations (Putt et al, 1987, p. 28). They are also known as case-control studies.

Prospective studies are aimed at establishing relationships between diseases and their determinants by monitoring changes as they occur. Animals are normally separated into groups (or 'cohorts') in which the determinant of the disease is either present or absent or where its frequency of occurrence varies. The incidence rate of the disease in the cohorts is then compared. 'Sentinel' herds may also be used for continuous studies of this nature (see page 187).

For each type of study, complementary data on animal production performance (Module 5) will have to be collected in parallel or separate surveys if the effects of a disease are to be properly understood. To identify the determinants of a disease, other types of data (e.g. on stocking rates, seasonal rainfall etc) will also need to be collected.

Recall methods

Where farmers/pastoralists have precise knowledge of the diseases present in the area, surveys based on recall can be a useful starting point in the study of animal health problems. The aim would be to obtain a rapid impression of disease prevalence (rather than incidence) and to rank diseases or disease syndromes according to the criteria which producers consider important (e.g. on the basis of losses which have occurred).

The information about diseases or syndromes which commonly occur is likely to be reasonably reliable if well informed producers/informants are interviewed (Perry and McCauley, 1984). Data on diseases and syndromes which occur infrequently are likely to be inaccurate, especially if the recall period is long.

To improve recall, questions asked about disease prevalence should relate to a specific time period. Questions such as "Have you ever seen such and such a disease?" or "How many calves died of this disease?" are not going to produce reliable results (Module 2, Section 1). Perry and McCauley (1984) note, however, that surveys with a specific recall period can produce misleading results if diseases which rarely occur happen to have been important in the year of the survey. Any disease control programme designed on the basis of such results will, naturally, fail to address the real situation.

The reliability of recall data can be greatly improved by selecting informants with direct responsibility for the animals surveyed. For cattle, this is generally a man and the head of the household. For smallstock, women will often provide the most reliable information (Mares, 1954).

Note: To determine whether the information obtained is reliable, consistency checks with secondary data sources or informant interviews are advisable. If sentinel surveys are run in conjunction with recall surveys (see below), the data collected from both sources can be compared for validation purposes (Perry et al, 1984). To date, however, few attempts have been made to validate the findings of recall surveys (Perry and McCauley, 1984).

Recall surveys can be designed to examine only disease problems (see examples of questionnaires in Appendix). Alternatively, disease may be studied in conjunction with a whole range of livestock- and management-related issues (e.g. nutrition, animal production, herd structure and household characteristics) in order to determine its relative importance for future diagnostic research. Case studies which have used recall surveys for disease surveillance are documented by Schwabe and Koujok (1981), Sollod and Knight (1983), McCauley et al (1983) and Perry et al (1984).

Direct observation methods

Direct observation is applied in cross-sectional, retrospective and prospective studies.

Cross-sectional studies. As was stated above, these studies are useful in establishing the presence or absence of a particular disease. Because they are normally once-off surveys, cross-sectional studies cannot provide data on changes over time (i.e. incidence rates). They will measure incidence only when the disease is of short duration and current presence or absence is measured rather than previous illness (Perry, 1988).

For some diseases, laboratory samples will need to be taken to confirm observed prevalence. For others, where the clinical symptoms are obvious (e.g. heartwater), collection of laboratory samples is not necessary and records can be made in the field. At the time of data collection, it is also useful to record productivity data for each sample animal. These data can then be used to determine the effects of disease on animal condition, progeny history etc (Module 5).

When selecting sample herds or flocks, care should be taken to choose units which are **representative** of the system under study or recommendation domain (Modules 1 and 2, Section 1). Too often, cross-sectional surveys fail to distinguish producers on the basis of system of production, defining the sample frame only in terms of political or administrative boundaries (e.g. veterinary districts). This can result in spurious conclusions about the determinants of disease, since these normally relate to management practices or production systems, not to the boundaries within which animal disease control is administered.

Another general principle is that if disease prevalence **within a system** appears to be related to factors such as herd size, the population should be stratified accordingly (Perry and McCauley, 1984). Stratified sampling techniques are discussed in Part C of Module 2 (Section 1).

Once the boundaries of the system (or strata within a system) have been identified, the size of the animal sample needed should be estimated, taking into account the objectives of the study as well as cost, manpower resources and logistics. Cross-sectional studies of prevalence will normally aim to:

- detect whether or not a disease is in fact present in a group of animals (or if it is known to be present), and
- determine the actual prevalence rate (i.e. the proportion of animals actually affected by or exposed to the disease).

The number of animals that will need to be sampled will differ in each case. Table 3 gives the sample size required for the detection of a disease when we wish to be 95% confident that that disease is in fact present in the chosen animal population, i.e. that there will be at least one positive case detected in the sample.

To calculate the sample size required, we need to know the actual population size and the expected proportion of animals affected (or should be able to estimate the proportion with reasonable accuracy[9]). The sample sizes shown in Table 3 are based on population sizes and expected prevalence rates obtained from preliminary enquiries.

Note that the size of sample required declines with increasing proportions of expected positive cases in the population. When, on the other hand, the expected prevalence rate is low, large samples are required to merely confirm the presence of a disease.

9 In Africa, statistics on animal populations are, however, notoriously unreliable. Moreover, it is very difficult to estimate population size in systems where households are either widely dispersed or highly mobile. If guesstimates are used instead, they should be conservative to ensure that a sufficiently large sample is chosen.

Table 3. Sample size required to detect (with 95% confidence) disease in different populations at different levels of expected prevalence.

Population size	Sample size required at expected prevalence rate of:											
	50%	40%	30%	25%	20%	15%	10%	5%	2%	1%	0.5%	0.1%
10	4	5	6	7	8	10	10	10	10	10	10	10
20	4	6	7	9	10	12	16	19	20	20	20	20
30	4	6	8	9	11	14	19	26	30	30	30	30
40	5	6	8	10	12	15	21	31	40	40	40	40
50	5	6	8	10	12	16	22	35	48	50	50	50
60	5	6	8	10	12	16	23	38	55	60	60	60
70	5	6	8	10	13	17	24	40	62	70	70	70
80	5	6	8	10	13	17	24	42	68	79	80	80
90	5	6	8	10	13	17	25	43	73	87	90	90
100	5	6	9	10	13	17	25	45	78	96	100	100
120	5	6	9	10	13	18	26	47	86	111	120	120
140	5	6	9	11	13	18	26	48	92	124	139	140
160	5	6	9	11	13	18	27	49	97	136	157	160
180	5	6	9	11	13	18	27	50	101	146	174	180
200	5	6	9	11	13	18	27	51	105	155	190	200
250	5	6	9	11	14	18	27	53	112	175	228	250
300	5	6	9	11	14	18	28	54	117	189	260	300
350	5	6	9	11	14	18	28	54	121	201	287	350
400	5	6	9	11	14	19	28	55	124	211	311	400
450	5	6	9	11	14	19	28	55	127	218	331	450
500	5	6	9	11	14	19	28	56	129	225	349	500
600	5	6	9	11	14	19	28	56	132	235	379	597
700	5	6	9	11	14	19	28	57	134	243	402	691
800	5	6	9	11	14	19	28	57	136	249	421	782
900	5	6	9	11	14	19	28	57	137	254	437	868
1000	5	6	9	11	14	19	29	57	138	258	450	950
1200	5	6	9	11	14	19	29	57	140	264	471	1102
1400	5	6	9	11	14	19	29	58	141	269	487	1236
1600	5	6	9	11	14	19	29	58	142	272	499	1354
1800	5	6	9	11	14	19	29	58	143	275	509	1459
2000	5	6	9	11	14	19	29	58	143	277	517	1553
3000	5	6	9	11	14	19	29	58	145	284	542	1895
4000	5	6	9	11	14	19	29	58	146	268	556	2108
5000	5	6	9	11	14	19	29	59	147	290	564	2253
6000	5	6	9	11	14	19	29	59	147	291	569	2358
7000	5	6	9	11	14	19	29	59	147	292	573	2437
8000	5	6	9	11	14	19	29	59	147	293	576	2498
9000	5	6	9	11	14	19	29	59	148	294	579	2548
10000	5	6	9	11	14	19	29	59	148	294	581	2588
ϕ	5	6	9	11	14	19	29	59	149	299	598	2995

Source: Adopted from Cannon and Roe (1982).

Table 4 shows the sample sizes required to estimate prevalence rates. To calculate the sample size, one would need to know the expected proportion of animals affected by the disease, the 'tolerable error' in the estimate obtained (i.e. the degree of absolute precision desired), and the level of statistical confidence required.

Example: If the population of animals under study is 400 and 2% of these are thought to be affected by a particular disease, the sample required to confirm the presence or absence of that disease would be 124 animals. However, if the expected proportion of positive cases were to increase to 10%, 28 animals would need to be sampled.

The example below demonstrates how sample sizes shown in Table 4 have been calculated.

Example: If we expect that 10% of animals in the population are affected by a disease and we wish to be 95% confident that the estimated prevalence rate is accurate with a ± 10% absolute precision, we would need to sample 35 animals.

Table 4. The approximate sample size required to estimate disease prevalence in large populations.

Expected prevalence	Confidence level: 90%			95%			99%		
	Tolerable error			Tolerable error			Tolerable error		
	10%	5%	1%	10%	5%	1%	10%	5%	1%
10%	24	97	2435	35	138	3457	60	239	5971
20%	43	173	4329	61	246	6147	106	425	10616
30%	57	227	5682	81	323	8067	139	557	13933
40%	65	260	6494	92	369	9220	159	637	15923
50%	68	271	6764	96	384	9604	166	663	16587
60%	65	260	6494	92	369	9220	159	637	15923
70%	57	227	5682	81	323	8067	139	557	13933
80%	43	173	4329	61	246	6147	106	425	10616
90%	24	97	2435	35	138	3457	60	239	5971

Note that for a given expected prevalence rate and confidence level, the sample size required increases markedly as the tolerable error diminishes.

Source: Adapted from Cannon and Roe (1982).

When the sample size required to detect differences in prevalence has been estimated, we can then attempt to test statistically various determinant - disease relationships. The types of statistical tests used are given in Putt et al (1987, pp. 59–64) and in Module 11 of this Section.

Example: Suppose that we wish to study the effects of management system on disease prevalence. To do that we will select samples of animals from different systems on the basis of assumed prevalence rates, using a prescribed statistical confidence interval and a tolerable error in the actual estimate. The chi-square test can then be used to test whether sample prevalences are statistically different between the different management systems/herds identified (Module 11).

If they are, the implication is that the determinant of the disease is related to the management system adopted. The systems research team would then need to search for those differences in management which explain differences in disease prevalence in order to identify possible avenues for improvement.

Retrospective studies. Retrospective studies use existing data and are, therefore, relatively cheap and quick (Putt et al, 1987, pp. 28–29). The method is particularly useful for studying diseases of low incidence. Data can be accumulated over time and analysed at a later date when sufficient cases and controls have been identified and properly matched. However, for the analysis to be meaningful, the recording and diagnostic systems used must be standardised (Perry, 1988), which may not be always the case in Africa.

In practice, retrospective studies are rarely conducted in Africa because of the difficulties involved in obtaining reliable and consistent historical data. Even if data had been collected properly, it is difficult to check their reliability because information about the data collection methods used and the populations sampled is rarely documented.

Moreover, available records are typically confined to the frequency of occurrence of the determinant in diseased (case) animals only. Separate studies often need to be conducted to determine the frequency of occurrence of the same determinant in healthy animals, and it is highly unlikely that the two data sets will be comparable. This makes it difficult to ascertain whether confounding variables are distorting the analysis. Retrospective studies which aim to isolate the determinants of a disease must therefore be treated with extreme caution.

Prospective studies. Continuous prospective studies permit the observer to obtain detailed information about diseases as they occur (i.e. about disease incidence). This improves the chances of identifying determinants correctly (Thrusfield, 1986) and of recording effects accurately (Module 5). Sentinel herd studies fall into this category. They involve following sample herds/flocks for observation purposes and have been shown to be useful when the findings of recall surveys need to be confirmed. They can also be used to obtain continuous data on management practices and performance levels.

Prospective studies should be carefully planned at the outset to ensure that only the data needed are collected. The cohorts used for comparison should be of the same age, sex and productive function, if the comparison of the disease/determinant and disease/effect relationships selected for study is to be meaningful.

Because one has to follow groups of animals over time, prospective surveys tend to be costly and time-consuming, particularly for rare diseases which require large samples to be detected. The high cost of continuous monitoring usually means that small non-representative samples are chosen for study.

To mitigate the problem, point prevalence surveys may be undertaken to track changes in prevalence over time and thereby provide an indication of changes in the incidence of a disease. Such studies would, in effect, be like taking a series of disease prevalence 'snapshots' throughout the year, using each time methods applicable to cross-sectional surveys.

Another problem often associated with prospective studies is the difficulty of ensuring the cooperation of producers over prolonged periods, particularly when there is no incentive for producers to do so. This tends to affect the reliability of the results (see 'Continuous recall survey' sections in Modules 3 and 5. Producer cooperation may also not be forthcoming when sample animals are exposed to different treatments (e.g. vaccinated/not vaccinated). This occurred, for instance, in ILCA's study of the effects of vaccination against peste des petits ruminants on the productivity of small ruminants in southeast Nigeria.

In pastoral systems, where herds are highly mobile, logistical considerations often make prospective surveys and sentinel herd studies impractical. There are, however, examples of successful sentinel studies used for livestock systems research in Africa (Fadlalla and Cook, 1985).

The advantages and disadvantages of the different types of observational studies used in veterinary epidemiology are summarised in Table 5.

Table 5. Comparison of the relative merits of observational studies.

Advantage	Disadvantage
Cross-sectional studies	
° Relatively quick to set up	° Large samples needed for rare diseases
° Relatively inexpensive	° Cannot compare incidence in exposed and unexposed animals
° Require comparatively few animals	° Disease/determinant relationships may be difficult to establish
° May be able to use current records	
° When random samples are used, they can estimate the proportion of the exposed (or unexposed) population	

Advantage	Disadvantage
Retrospective studies	
° Good for rare disease conditions	° Cannot estimate the proportion of the population currently exposed (unexposed) to determinants
° Relatively quick and cheap	° Rely on historical records
° Require comparatively few animals	° May be difficult to select controls
	° Cannot compare incidence in exposed populations
	° Difficulties associated with the study of determinants when case and control animals are from different populations
Prospective studies	
° Can estimate incidence in exposed/unexposed animals	° Cannot estimate the proportion of the population exposed/unexposed to determinants when non-random samples are used
° Can choose variables to be systematically recorded, including data on animal productivity etc	° Require larger samples to study rare diseases
	° Relatively expensive and time-consuming
	° Problems with producer cooperation

Sources: Adapted from Thrusfield (1986) and Perry (1988).

Appendix

A once-off recall survey of disease problems

In a study in Zambia on the health and productivity of traditionally managed cattle (Perry, 1982), once-off recall surveys were used to elicit information from farmers and pastoralists on disease problems in their herds. A list of 19 syndromes/diseases suspected to be present in cattle in the area was compiled. Using this list, respondents were asked[10] to:

- grade the listed syndromes/diseases into four categories - non-existent, present but no problem, moderate problem or severe problem;
- Indicate the total number of deaths in their herds for a specific period of time, and how many animals died of any of the syndromes/diseases listed;
- indicate which other syndromes/diseases have caused death in their herds during the specified period; and
- indicate the four most common causes of death by disease for cattle.[11]

The format of the questionnaire which was designed to record the answers to these questions is shown overleaf.

Note: For questionnaires of this type, local terms should be used for the diseases/syndromes listed. A preliminary survey with a small sample of farmers, pastoralists or other informants may be needed to obtain the most commonly used local terms. The survey should be specific about the recall period to ensure that the health problems studied are put in their proper perspective, e.g. regarding rainfall (and, therefore, nutrition), vector prevalence etc.

10 A similar approach to eliciting information on animal disease was used by a research team working with Maasai pastoralists in Kenya (Waghela et al, 1983).

11 One should not assume that disease is the only major cause of death; therefore, death resulting from causes other than disease should also be ascertained at this stage.

QUESTIONNAIRE

Q1: *How serious have each of the following diseases/syndromes been in your herd since this time last year? Tick the appropriate column for each disease/syndrome listed.*

	Non-existent	Present but no problem	Moderate problem	Serious problem
Ill thrift				
Depression				
Loss of appetite				
Sudden death				
Diarrhoea				
Subcutaneous oedema				
Coughing				
Nasal discharge				
Excess lachrymation				
Nervous symptoms				
Abortion				
Calving difficulties				
Mastitis				
Lameness				
Senkobo				
Blackleg				
Pink eye Red water				
Presence of ticks				

Q2: *Of the total number of deaths in your herd since this time last year, how many animals died of any of the diseases/syndromes listed above?*

Disease	Number of deaths
:	:
:	:

Q3: *What other diseases/syndromes caused deaths in your herd since this time last year ?*

______

______

______

Q4: *List, in order of importance, the four most important causes of death in your herd since this time last year. Select the four diseases from the diseases/syndromes listed under question 1 and from the other causes of death you mentioned.*

1. ______
2. ______
3. ______
4. ______

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SECTION 1

MODULE 9

LIVESTOCK MARKETING

MODULE 9

Livestock marketing

This module concentrates on the analysis of constraints in livestock marketing.[1] It shows how they can be examined at both the supplier (producer) and buyer levels in order to identify possible avenues for improvement. Emphasis is given to the **marketing of live animals**, though much of what is said is also applicable to milk, hides, skins and wool.

PART A: CONCEPTS AND DEFINITIONS

Below is a brief description of some of the terms and concepts used in the discussion which follows.

Exchange and price

Livestock marketing involves the sale, purchase or exchange of products such as live animals, milk, wool and hides for cash or goods in kind. When sales (or purchases) are made in cash, the price paid to (or by) the producer is known as the **market price**. This price may be set by a government-appointed marketing agency (e.g. a marketing board), or negotiated by the free interaction of buyers and sellers at **formally** recognised market centres (e.g. auction yards), or it may be agreed upon **informally** (e.g. between neighbouring producers or between producers and rural butcheries). Informal marketing also occurs when livestock or livestock outputs are exchanged for goods in kind.

Physical and facilitating functions

Marketing also involves the movement of goods from the point of exchange to their final destination. This movement involves such operations as transportation, storage and processing (physical functions), grading, the provision of finance, risk-bearing and the dissemination of market information (facilitating functions).

Market efficiency

In livestock systems research it may be necessary to examine the efficiency of the marketing system in order to identify avenues for improvement. From the producer's perspective, an efficient marketing system is one which:

- relays consumer preferences accurately and quickly to the producer,[2] and
- performs its physical and facilitating functions at the minimum cost compatible with the services required.

The cost of marketing will be reflected in the size of the **marketing margin** which is measured by calculating the difference between producer and retail prices per unit of good in question.

Gross offtake

At the herd or flock level, the total voluntary **disposal** of animals by sale, slaughter, exchange and/or giving is known as gross offtake. It is an absolute measure which, for a given time period (t), is defined as:

Gross offtake in period (t) = sum of sales + slaughters + exchanges + gifts during period (t)

1 Market theory is not dealt with in this module. A background on the theory of marketing can be obtained from any basic text on the topic (e.g. Beckman and Davidson, 1967; Kohls and Uhl, 1985). The macro-aspects of livestock marketing in Africa are discussed in ILCA's manual on *Livestock policy analysis* (1989).

2 Emphasis in this module is given to the identification of marketing constraints which directly affect the producer. Nevertheless, the importance of the consumer should not be forgotten since the ultimate goal in the marketing of any product must be the satisfactory fulfilment of the needs and wants of consumers. The methods used to study consumer demand is, however, beyond the scope of this manual.

The measure thus includes disposals for commercial and non-commercial purposes. It can be calculated at the individual herd/flock level or aggregated (summed) for an area as a whole (e.g. region, district, nation). When aggregated, gifts and exchanges between producers **within the same area** are treated as transfers which cancel out. They are therefore excluded from the equation. Strictly speaking, all exchanges and gifts to producers **outside the area** should be included. However, they are usually extremely difficult to measure and are, therefore, commonly ignored.

Gross offtake rate

For the purposes of comparison, gross offtake should be expressed in relative, not absolute, terms. To do this, the gross offtake rate is used, which, for a herd or flock, is defined as:

$$\text{Gross offtake rate in period (t) (\%)} = \left[\frac{\text{Gross offtake in period (t)}}{\text{Total herd/flock size at start of period (t)}}\right] \times 100$$

Gross offtake rate in period (t) is often termed as the **offtake rate**[3]. It only measures outflows and takes no account of acquisitions or inflows into the herd, flock or area.

Sales rate

When outflows are measured in terms of sales, the sales rate (or commercial offtake rate) is used for purposes of comparison. It is defined as:

$$\text{Sales rate in period (t) (\%)} = \left[\frac{\text{Livestock sales in period (t)}}{\text{Total herd/flock size at start of period (t)}}\right] \times 100$$

When gifts, slaughter for home consumption or ceremonies, and exchanges between producers are relatively unimportant, the sales rate can be used to approximate the gross offtake rate. In societies where such transactions are important (e.g. in pastoral communities such as the Maasai of Kenya), the use of sales rates alone for offtake comparisons may lead to erroneous conclusions. Data given by producers on the gifts they have made and on exchanges in such societies are often exaggerated because of a cultural tendency to over-report acts of generosity.

Net offtake rate

When acquisitions (i.e. purchases, exchanges or gifts) are significant, the 'net offtake rate' or 'net disposal rate' should be used, which is defined as:

$$\text{Net offtake rate in period (t) (\%)} = \left[\frac{\text{Gross offtake} - \text{Acquisitions in period (t)}}{\text{Total herd/flock size at start of period (t)}}\right] \times 100$$

Acquisitions may come from commercial or non-commercial sources. In pastoral societies, token data reported by producers on gifts they have received tend to be under-reported (Grandin and Solomon Bekure, 1982), and net offtake rates are often overestimated.

Example: A household holds 50 head of cattle at the beginning of the year. During the next 12 months, five head are sold, one is given away, one male castrate is exchanged for a heifer and one is slaughtered. In addition, two breeding cows are purchased from a neighbouring producer. The gross offtake rate (GOR), the sales rate (SR) and the net offtake rate (NOR) for the 12-month period are:

GOR = [(5 + 1 + 1 + 1)/50] x 100 = 16%

SR = (5/50) x 100 = 10%

NOR = [(5 + 1 + 1 + 1 - 1 - 2)/50] x 100 = 10%

3 The size of the herd or flock at the beginning of the year is commonly termed the 'opening number' and the size at the end of the year is known as the 'closing number'.

Inventory

An inventory is the number of livestock owned or held by a producer at a given point in time. It is normally expressed in terms of the different species present, with stock in each species being grouped into different age and sex classes (i.e. male and female calves, males older than three years, females older than three years, cows, bulls and oxen).[4]

A **negative** change in inventory occurs when losses through death, theft or offtake exceed gains resulting from natural increase and acquisitions between two points in time. A **positive** change results when gains exceed losses for the time interval in question. Annual inventory changes are normally calculated as:

Stock on hand at end of year – stock on hand at beginning of year.

PART B: PURPOSES

The main objective of studies of marketing issues is to determine whether marketing is a constraint to livestock production. To do this, there will be a need to study one or both of the following:

- **Price —exchange relationships** in order to decide whether the output of livestock products is limited by the price paid to the producer.
- **Physical and facilitating functions** in order to decide whether the operational aspects of marketing are efficiently performed and meet the requirements of both sellers and buyers.

Price – exchange relationships

When attempting to determine price–exchange relationships, one should consider which problems of measurement are likely to arise, which response relationships will need to be studied, and the determinants of the price paid by the buyers.

Problems of measurement. The study of price response relationships in livestock systems research can be both difficult and complex. The problems most commonly confronted relate to:

- **the lack of reliable data**

  Secondary data sources on offtake, sales and prices tend to be unreliable or incomplete (Part D of this module)

- **the use of appropriate prices**

  For instance, are current decisions to market livestock influenced by past or present prices (or both)? What weighting should be given to each in an analysis of market supply response and how should the effects of inflation be accounted for?

- **the measurement of supply response**

  Short- and long-term price/supply responses may be quite different and may point to very different policy options. For instance, conclusions based on short-term price responses alone may result in recommendations which are inappropriate in the long term (Doran et al, 1979; Jarvis, 1984; Rodriguez, 1985). Similarly, results and conclusions may be very different when partial versus overall market-supply responses are measured (Low et al, 1980).

4 See Module 5 which discusses the estimation and use of data on herd/flock structure in animal production studies.

- **the importance of informal market outlets**

  In some systems, producers prefer to use informal rather than formal market outlets. To obtain reliable information about prices and volumes sold or exchanged informally can be very difficult.

- **differences within and between species**

  Price responses for stock of the same species but within different age/sex classes can be very different. In mixed systems, for instance, the disposal of productive draught oxen tends to be relatively unresponsive to price (Low, 1980). The same applies to cows in pastoral production systems (Low, 1980). Differences between species in the same system are also likely to occur because farmers' reasons for owning particular species are often very different.

- **differences between types of producers**

  Producers of different cultures or of different sizes may respond differently to price changes, and their responses may need separate analysis (Rodriguez, 1985).

Response relationships. Bearing these difficulties in mind, a study of the following types of relationships will, nevertheless, be useful when the relative importance of price as a constraint to production is being examined. We may want to study the relationship between:

- **offtake and sales rates** (or levels) **and livestock price**

  Absolute measures of offtake (e.g. actual sales levels) take no account of herd or flock size, while relative measures (e.g. sales rates) do. Relationships between price and absolute or relative offtake measures may, therefore, be quite different. When using time-series data, these differences may be very important since offtake levels may (to some extent) be determined by changes in inventory levels (Low, 1980). Time-series studies aimed at determining the effect of price on marketed supply should, therefore, take into account inventory changes.

- **market price and inventory changes** (Tryfos, 1974; 1975; Jarvis, 1980).

- **herd/flock structure and offtake or sales rate**

  In other words, are offtake and sales rates determined by herd/ flock structure rather than by price? (Meadows and White, 1979) In livestock systems research it is important to understand how the producer manipulates his animals to fulfil both short- and long-term needs and aspirations (Grandin and Solomon Bekure, 1982).

- **market price and livestock purchases**

- **disposals/acquisitions and other factors** which may influence livestock disposals - e.g. season, household size or structure, food prices, off-farm remittances and wealth rank.

Table 1 below shows how net offtake rates were related to wealth category in a study of Maasai pastoralists in Kenya (see Appendix in Module 1, Section 1 for discussion on wealth ranking). Figure 1 on the next page shows how, in another study of the Maasai, rainfall and cattle sales were related to one another for the period 1956 –1977.

Table 1. The relationship between wealth rank and net offtake rate, Olkarkar ranch, Kenya, 1982.

	Net offtake rate (%)		
	Wealth rank: Poor	Medium	Wealthy
Cattle	21	12	8
Goats	9	14	10
Sheep	11	17	3

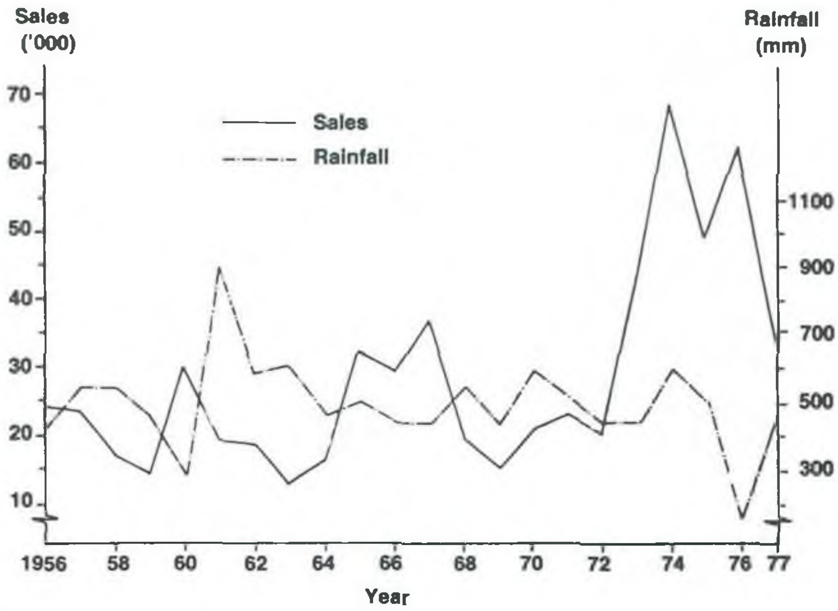
Source: Grandin and Solomon Bekure (1982).

Module 11 describes the various methods commonly used to test the statistical significance of relationships such as those illustrated in Table 1 and Figure 1. If price is found to be the factor which significantly influences sales, interventions which aim to improve the market price or the value of livestock can then be compared. These can be divided into:

- **direct measures** (such as price-support schemes), and
- **indirect measures**

  Such measures include upgrading the quality of stock sold by breed improvement schemes, fattening schemes, reducing the costs of marketing by improving infrastructure and offering transport subsidies.

Figure 1. Cattle sales and annual rainfall, Kajiado District, Kenya, 1956–77.



Source: Meadows and White (1979).

The determinants of the price paid by buyers. Information about the factors which determine buyers' preferences may indicate potential areas for improvement.

For instance, body weight, the condition of the animal and market location will affect the prices paid by buyers at formal and informal market outlets.

Physical and facilitating functions and their efficiency

Attempts to improve the operational efficiency of livestock markets have been the focus of attention of many African livestock development projects and programmes. This is because there has been a tendency to assume that lack of infrastructural or institutional support has been the major constraint on livestock production in the continent, but often the provision of additional facilities failed to improve efficiency or induce increased production and marketed offtake (Sandford, 1983; ILCA, 1989).

If a study of the operational aspects of marketing is considered necessary, the following questions will need to be asked:

- What infrastructural and institutional support currently exists?

  Both formal and informal market structures and outlets should be considered. The network of informal market outlets may be well developed and preferred by producers (see Part C below).

- How and by whom are the operational functions performed?
- How essential are these functions? Are they efficiently performed?
- Are additional functions necessary? Why are they necessary?

Secondary data sources and simple interview techniques will often provide adequate answers to most of these questions. If avenues for improvement are to be properly identified, it would be useful to examine the relationship between:

- **market throughput and the costs of marketing**

  Low levels of throughput can, for instance, affect the operational efficiency of processing plants and this can be reflected in lower prices paid to the producer.

- **the number of official sale outlets (e.g. auction yards) and the number of livestock or quantity of livestock products sold**

  The questions to be asked here are: Does the provision of official sale outlets improve the marketed offtake of livestock and livestock products? How does the location of market facilities affect offtake and throughput? Is distance from official sale points a factor affecting sales levels?

- **number of intermediaries involved in marketing and the costs of marketing**

  For instance, does the number of intermediaries involved increase or reduce the costs of marketing? (Cohen, 1969; Staatz, 1980; ILCA, 1989).

PART C: TYPES OF DATA

Data collected in market studies can be categorised as:

- **Producer data**

  Such data will include information about herd/flock numbers and inventories, offtake and acquisition of animals.

- **Market data**

  Such data will include information about prices, operational functions of marketing and formal and informal mechanisms for the disposal and acquisition of livestock and livestock products.

- **Other data** necessary for the study of relationships such as those discussed on pages 205–207. Such other information may, for instance, be wealth ranking which may be necessary to determine the effect of wealth on offtake rates etc.

Producer data

Producer data can be grouped into three broad categories: inventory data, offtake data and acquisition data.

Inventory data. In order to estimate offtake rates, data on herd/flock numbers and sale rates must be collected. These data can also be used to value herd/flock productivity (Module 5), determine stocking rates (Module 6) and examine the equity of livestock ownership within the target group (Module 11). Inventory data can be collected at two levels:

- **Target-area or regional level**

  When available in statistical reports, such data should be checked for consistency and reliability (Module 1). Changes in the methods used to collect data or in the manner in which livestock categories are defined can mean that the data series on livestock numbers are not comparable over time. Target-area or regional data on livestock numbers can also be collected by aerial survey (see pages 205–213).

- **Household level**

  This type of data can be obtained in surveys or by census. Depending on the system and the objectives of the study, we will aim to obtain information, for each species, on the numbers of livestock owned (or held/borrowed/loaned) by age and sex category.

In most circumstances, data on livestock holdings per household will be sufficient. It is, however, useful to distinguish between stock loaned to or borrowed by different members of the household and stock owned by the household as a whole. This is because in some societies (e.g. in the mixed farming systems of Botswana, Swaziland and Zimbabwe and in the pastoral communities of East and West Africa), lending of stock is commonly used for the purposes of resource re-distribution among relatives or neighbours.

> For instance, wealthy households with larger herds may lend livestock to poorer households in order to obtain herding labour or to split their herds. Poorer households, in turn, may obtain rights to use draught oxen or milk cows for subsistence.

Offtake data. When collecting data on livestock offtake, distinction should be made between data collected at the household and target-area (or regional) levels. The data should be related to a given time period and be species-specific.

At the **household level**, consideration should be given to:

- **Purpose of disposal**

  For instance, how many animals were sold, slaughtered for home consumption, slaughtered for ceremonies, given away or disposed of for other reasons (i.e. bride price).

- **Disposal outlets**

  For instance, how many animals were sold in formal outlets (i.e. government auction yards) and how many in informal outlets (i.e. butcheries and neighbouring farms).

- **Age and sex category of disposal animals**

  For instance, what number within each age/sex category was sold, slaughtered for direct consumption or ceremonies, and given away as gifts?

- **Price of animals sold**

  Producers may be unwilling to divulge this type of information if they fear that they may be taxed. Any information given should be cross-checked against the sale prices received at official outlets or obtained by other producers in official and unofficial outlets.

- **Reasons for livestock sales**

  For instance, to obtain cash for the purchase of food, because the animals were sick, because they were in the right condition for sale etc.

- **Time of disposal**

For instance, how many animals were sold during particular periods of the year?

At the **regional level**, information about offtake tends to be confined to export statistics and information about sales at official outlets, slaughters (where veterinary records of slaughters are required) and stock movements out of the area (obtainable from quarantine records, if they are kept).

Such information should always be checked for reliability, completeness and consistency. Changing market circumstances may channel sales away from official outlets, which may indicate a decline in offtake when, in fact, it may have increased. In the 1970s in Kenya, for instance, sales to the Kenya Meat Commission were diverted to 'illegal' urban butcheries because the prices they paid for inferior grades of beef were higher than those offered by the Commission (Aldington, 1978). It is, however, normally very difficult to obtain reliable data on sales to unofficial outlets.

The relative importance of these different outlets can often be determined from producer questionnaires. If they are relatively insignificant, official sales statistics may provide a reasonable indication of the overall offtake rate.

Table 2 gives data from a marketing survey conducted in Swaziland in 1978/79. It shows that 68% of cattle sales for the whole country were channelled through informal outlets, even though formal outlets were available and accessible to most producers. In cases like this, formal sales statistics will not provide a reliable indication of sales or offtake rates for an area as a whole. The table also shows that, even within the same country, there may be marked differences between different areas in the use of formal and informal market outlets for cattle sales. The reasons for these differences should always be examined in studies of this nature.

Table 2. The use of formal and informal market outlets for the sale of cattle, Swaziland, 1978/79.

Outlet	Sellers selling			Cattle sold		
	All regions	HV + MV	LV	All regions	HV + MV	LV
	per cent					
Informal	**83**	**91**	**68**	**68**	**81**	**55**
Diptanks	54	65	31	39	62	18
Locally	29	26	37	29	19	37
Formal	**27**	**11**	**57**	**32**	**19**	**45**
Auction yards	17	4	40	15	2	26
Gov. abattoir	9	6	17	12	5	19
Fattening ranches	1	2	0	5	12	0

Notes: The percentage of sellers selling at different outlets can be greater than 100% because most sellers sold at more than one outlet. The symbols HV, MV and LV refer to the three ecological zones of Swaziland - highveld, middleveld and lowveld.

Source: Swaziland Government (1980).

Acquisition data. Questions asked about purchases and acquisitions will be similar to those asked about offtake. The data collected should be specific to a given time period and livestock species and should relate to:

- **Method of acquisition**

  How were the animals obtained? How many animals were acquired by using cash obtained from the sale of other stock, crops, remittances or handicrafts and home-made beer? How many animals were acquired by inheritance or as gifts from other producers?

- **Place of acquisition**

  Fqr instance, how many animals were bought from neighbours or other farmers? How many were bought at official market points?

- **Age and sex of acquired stock**

- **Prices paid for purchased animals**

  Prices quoted should be compared with those given by other producers or with price data from official market sources.

- ***Reasons for acquisitions***

  For instance, how many animals were acquired for specific purposes such as draught, breeding etc? This type of data can generally be inferred from data on the age and sex of the livestock acquired.

- **Time of acquisition**

  How many animals were acquired at different times of the year?

Market data

Market data include data on prices, market throughput and physical and facilitating functions of marketing.

Price data. Official price statistics for the different livestock species marketed are rarely available (Solomon Bekure and Negusie Tilahun, 1983). If they are, they tend to be either too general or inaccurate to be useful, so that market surveys specific to the area and class of livestock will often be needed. Again, a distinction must be made in such studies between informal and formal outlets since the prices paid (and the factors which determine price) are often quite different at these two types of market outlet.

Data collected on price will fall into one of the following two categories:

- **cross-sectional data** for prices paid for particular grades and classes of stock at one (or several) market(s) at one point in time, and

- **time-series data** for prices paid for particular grades and classes of stock at the same or different outlets over time. Such data have been used to examine the effect of price on offtake over time (Meadows and White, 1979; Doran et al, 1979).

Where inflation exists, real, not current, prices should be used in time series analyses. Current prices should be deflated by an appropriate index of producer costs (e.g. by a relevant food price index if cattle sales are influenced by the need to purchase food, as is the case in many pastoral and agropastoral societies. (See Box overleaf).

In collecting price data it is highly desirable to collect data also on the weight of the animals, so that prices can be quoted on a per-kg (liveweight) basis and not per head. Price per head and price per kg often do not move parallel to each other, and misleading conclusions can be drawn as a result of believing that they do.

Market throughput data. Apart from collecting price data, data on the numbers and species of livestock sold or bought, and on the numbers of buyers/sellers involved in different formal and informal outlets, will often also be required. This type of data is called 'market throughput data'. They can be collected at one point in time (cross-sectional studies) or over time (time-series studies).

Physical and facilitating functions. In order to understand the operational aspects of marketing, both formal and informal mechanisms for the sale and purchase of livestock products need to be considered.

Example: Table 3 gives data on the current official beef producer price per tonne (in dollar equivalents) and the consumer price index (CPI) in an African country during the period 1980–86. Using the consumer price index as the relevant deflator for the producer price, calculate the real price for beef for each year of the period.

The real price is calculated by dividing the current price by the CPI multiplied by 1/100. In 1982, for instance, the real price was $185 (230/1.24 = 185). The real beef prices for the other years are shown in Table 3.

Table 3. Current beef price per tonne, consumer price index (CPI) and real beef price per tonne.

	1980	1981	1982	1983	1984	1985	1986
Current							
beef price/t ($)	230	230	230	260	270	285	290
CPI	100	115	124	142	148	158	165
Real							
beef price/t ($)	230	200	185	183	182	180	175

Note: The current prices rose from 1983 onwards while real prices per tonne declined from 1981.

At the formal level, the following general types of information will be useful:

- **Physical functions**

  This involves market outlets, their accessibility and frequency of operation (e.g. number of sale days per month), storage and processing facilities, modes of transport (which will indicate the relative importance of livestock for trucking, trekking and railing), and the role of government in the operations of the market.

- **Facilitating functions**

  This involves stock grades and the manner in which they are determined, credit facilities, market information services, and the manner in which information is disseminated.

At the informal level, similar information will need to be collected, but is generally more difficult to come by because of the unstructured manner in which market operations are often carried out. (For instance, it may be difficult to identify precisely a place where buyers and sellers meet to negotiate a price).

In the study of operational functions, attention will normally focus on the estimation of marketing margins (i.e. on market performance and efficiency). This may involve the calculation of the overall margin between the 'farm-gate' (i.e. point of first sale) and the retail level, the calculation of submargins (e.g. between primary and secondary market outlets) or the estimation of the individual costs of the different physical and facilitating functions.

Other data

A study of marketing constraints will usually involve the need to examine the types of relationships discussed in Part B. Complementary data on rainfall patterns, cropping activities, food prices, remittances, wealth rank, household size and structure will have to be collected for this purpose. The methods used to collect such data are discussed elsewhere in Section 1.

PART D: METHODS OF DATA COLLECTION

Producer data

The methods used to collect producer data will differ according to whether we wish to collect information on herd/flock numbers and offtake and acquisitions.

Inventory data

Data on herd/flock numbers can be collected at the area (regional) level or at the household level. This type of data can be obtained from:

Available secondary data sources, including government statistical reports, veterinary records (e.g. diptank or quarantine statistics).

If available, such reports tend to aggregate livestock on the basis of species without differentiating according to age and sex. Estimates for cattle are likely to be more reliable than those given for other types of livestock because of logistical and other problems commonly confronted when counts are attempted for smallstock, donkeys and camels.

The figures given are commonly derived by aggregating statistics obtained from veterinary or extension officers' monthly or quarterly reports. Such statistics are often based on guesswork rather than on detailed enumeration by survey or census (Module 8). Module 1 (Section 1) discusses the principles applicable to the use of secondary data of this nature.

Aerial surveys. Low-level aerial surveys are a useful method of collecting data on numbers of cattle, small ruminants and other species (donkeys, camels) in an area. Wide areas can be covered in a relatively short period of time and periodic counts can be made to determine changes which occur between seasons or years.

Stock cannot be differentiated on the basis of sex, although, sometimes, they can be differentiated by age, using as the yardstick the relative length of back measured on aerial photographs. The herds observed from the air do not necessarily coincide with ownership or management units.

Data obtained from aerial surveys may be complemented by household surveys to determine flock/herd size and structure, if data of this nature are required. Aerial surveys are particularly applicable to areas where livestock are dispersed over wide areas (e.g. in pastoral systems) and logistic problems make random-sample household surveys impractical.

Low-level aerial surveys can, in theory, be carried out by anyone with access to suitable aircraft and with a copy of a suitable manual on the subject (e.g. Norton-Griffiths, 1978). In practice, learning how to do them well is time-consuming and costly, and it will usually make sense to contract one of the experienced international organisations (e.g. ILCA) or consulting firms to do it.

The aerial survey method most commonly used in Africa is the Systematic Reconnaissance Flight (SRF) method.[5] The area selected for SRF survey is divided into systematic flight lines, usually based on a UTM grid pattern.[6] Each particular flight line is divided into fixed distance intervals or'grid cells' to ensure that every part of the area is covered systematically. The division of the area in this way makes it easier to transfer accurately information onto maps which can be easily interpreted (Milligan and de Leeuw, 1983; Clarke, 1986).

The area actually sampled during the flight is restricted to a band of fixed width on either side of the aircraft (Figure 2). The width of this band or 'sample strip' is directly proportional to the altitude (Figure 3) and the choice of height depends on the objectives of the study and coverage desired. Overall

5 The systematic reconnaissance flight method has been used by ILCA in East and West Africa to count livestock and monitor rangeland resources (de Leeuw and Milligan, 1984).

6 Sometimes a flight pattern which exactly corresponds to existing maps for the area will be more useful. This may, for instance, be the case when ground truthing is planned (Module 6) for the study area. The abbreviation 'UTM' stands for the Universal Transverse Mercurator which features on many national maps.

sample cover is usually between 5 and 20% and the altitude is between 300 and 800 feet above ground level (91 – 244 m). At higher altitudes than these, the width of the sample strip increases but the ability to count livestock accurately diminishes. For cattle counts, heights of 800 feet (244 m) above-ground level are sometimes used.

Figure 2. Flight pattern, grid system and sampling.

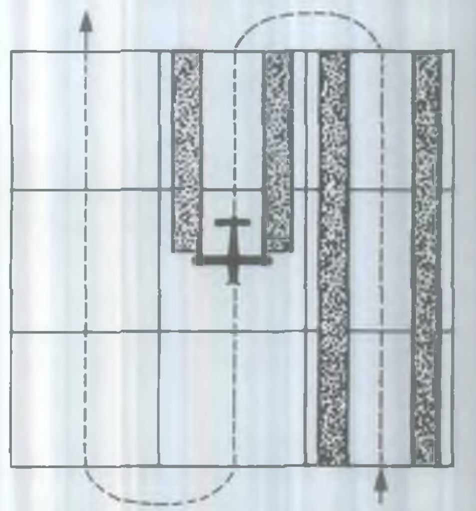


Figure 3. Schematic representation of aircraft during observation flight.

The strip sampled (w) on either side of the aircraft is determined by the projection, from the observer's eye to the ground, of the two rods (a and b) fixed on the wing struts. Strip width can be varied by altering these rods and is directly proportional to the aircraft height above the ground (h).

Source: Milligan and de Leeuw (1983).

Parallel adjustable rods are attached to each wing strut of the aircraft. An observer looks between these to ground level and this determines the width of the sample strip. Alternative sighting devices giving the same effect are available. Observers are located in the rear seats of the aircraft and are responsible for counting and photographing livestock and other easily quantifiable data such as human habitations or water supplies. The front-seat observer acts as a navigator and records relevant ecological information (e.g. vegetation, soil and farming activities).

Aerial surveys can be conducted once for rapid reconnaissance purposes or they may be repeated several times to determine seasonal changes (e.g. in stocking densities in a defined area). The data collected can be processed manually or by computer. Computer programmes are available to file and plot aerial survey data and estimates of animal populations (Clarke, 1986).

Household surveys. Willingness to declare information about livestock numbers varies within and between systems. In some societies, the counting of livestock is a cultural taboo (Grandin, 1983) while in others, the answers given are suspect because owners/holders fear the imposition of a per head livestock tax. The information given tends to understate the true position, particularly when cattle are concerned.

Additional complications occur in pastoral systems where herds or flocks are dispersed over wide areas or split on the basis of productive function. Under these circumstances it can be extremely difficult to estimate accurately the number of animals owned or held, largely because of logistical problems.

When collecting data on livestock numbers, attempts are often made to distinguish **ownership** and **holdings** of livestock at the household level. However, it can be extremely difficult to identify the actual owners of livestock within a household, particularly in societies with complex patterns of inheritance and control (e.g. the Borana pastoralists of northern Kenya) (Dahl, 1979). The team should, therefore, be absolutely certain of the need to obtain specific ownership data before attempts are made to collect them.

Household livestock numbers data can be obtained by once-off questionnaires,[7] using the following procedure:

- **Establish trust with the interviewee**

  Assure the interviewed person that the information you wish to collect is confidential. Do not rush the interview. Custom often requires that considerable time be spent on introductions during which it is important for the interviewer to explain the reason for the questionnaire and gain the confidence of the producer.

- **Interview, where possible, the person responsible for the management of the stock concerned**

  For cattle, in most parts of Africa, this person will normally be a man and the head of the household. For smallstock, it will often be a woman (Mares, 1954; Perry and McCauley, 1984).

- **Avoid sensitive questions**

  Rather than using a direct approach by asking questions such as, "How many cattle does your household hold?", adopt a more circumspect approach and ask such questions as, "Does your household hold cattle now? - How many were sold, slaughtered or given away since this time last year? - How many were purchased or received as gifts since this time last year? - How many died or disappeared since this time last year? - How many of these were cows, oxen, calves? - How many of these died as a result of disease, how many were stolen? - How many cows, oxen and calves do you hold now? - May I visit your kraal in the morning to see these animals?"

  Perry and McCauley (1984) suggest a similar approach, in which sensitive questions about livestock numbers are left to the end of the questionnaire, after confidence and interest in the aims of the survey have been established.

7 The principles involved in the selection of samples and of the design of questionnaires are discussed in detail in Module 2 (Part C) of Section 1.

- **Avoid complex questions about the ownership of specific animals**
- **Where possible, conduct interviews when the animals are physically present**

  For instance, early in the morning before they are moved away from the kraal for grazing.

- **Use the progeny history method**, if visits to the site where livestock are penned or kraaled are possible

  For detailed information on the progeny history method of data collection see Module 5, Part C. With this method, the owner or holder is asked to bring each breeding female to the interviewer. He is then asked to identify each of the progeny present. Animals purchased or received as gifts are also identified so that the total herd/flock size can be determined. Involving the producer in this way can help to overcome any reservations which may have existed beforehand.

- **Cross-check the information by**
  - *asking neighbours* (McCauley et al, 1983)

    The reliability of this information will depend on the willingness of the informant to divulge confidences about neighbours. The wealth ranking method described in the Appendix to Module 1 (Section 1) relies on this kind of informant knowledge.

  - *making a number of casual visits* to the household at the appropriate time of the day in order to check whether the original numbers given were correct, and
  - *incorporating cross-checks in the questionnaire*

    For instance, if the interviewee says he owns no cattle but, in another part of the questionnaire, he states that his own oxen are used for ploughing, there is good reason to believe that the information being given is unreliable!

Offtake and acquisitions

Problems involved in the interpretation and use of published secondary data on offtake and acquisitions at the regional or area level have been discussed on pages 208–210. Household surveys will normally be required if the data are to be at all useful. The discussion which follows therefore concentrates on the principles involved in the collection of offtake/acquisition data at the household level.

The collection of this type of data is based on the use of recall methods (Module 2, Section 1) which can be collected at one point in time (single-interview surveys) or over time (continuous or intermittent surveys). It can also be gathered separately or incorporated into a questionnaire which deals with other aspects of the production system (e.g. household size and structure data, remittance data, crop data). As with numbers data, it is advisable to interview the person(s) responsible for the day-to-day management of the species being considered.

Single-interview household surveys. When single-interview surveys are used to collect offtake and acquisition data, it is important to establish the reference period at the outset. Normally, this will be a one-year period, and questions about sales, slaughters and purchases should begin with such phrases as:

> **Since this time last year or since the festival of .....** (referring to a local reference system if possible), how many oxen have you:
>
> – sold?
>
> **Continued...**

- *slaughtered for household consumption?*
- slaughtered for ceremonies?
- given away to relatives or friends?
- disposed of for other reasons ? (give reasons)

The ability of the interviewee to recall this kind of information will depend on his/her involvement with the stock concerned, the frequency with which disposals or acquisitions occur and the number of stock owned or held. Where the household owns/holds relatively few livestock and disposals or acquisitions occur infrequently, recall is likely to be fairly reliable, particularly for cattle. In pastoral systems, where knowledge about each animal in the cattle herd is intimate, recall is likely to be very accurate, even for periods in excess of one year.

For smallstock, where sales and slaughters tend to occur frequently, the data obtained by single interview will tend to be less reliable. The reliability of data on prices received or paid will depend, to a large extent, on the number of animals sold or purchased at one time and the frequency of sale or purchase. Where large numbers are sold at one time, recall over long periods about specific prices (e.g. for animals within a particular age or sex group) will tend to be less reliable. Similarly, if sales or purchases occur often throughout the year, details about price at particular points in time will tend to be confused.

Intermittent and continuous surveys. To overcome these problems and to improve the accuracy of the data obtained, intermittent or continuous surveys can be used. Intermittent surveys would involve several visits at intervals of one or two months apart. Continuous (or repeat) surveys would be more frequent (e.g. once per week or fortnight over a 12-month period).[8] For these types of survey, over-reporting at the first interview can be expected. Grandin and Solomon Bekure (1982) therefore suggest that data collected during the initial stages (e.g. during the first month) should be excluded from the analysis.

Market data

General principles

Irrespective of the type of marketing study contemplated, a procedure should be followed which takes into account all the important aspects of the study. The discussion below outlines a procedure which is generally applicable to studies concerned with buyer/seller interactions, the collection of market throughput data, and the efficiency of market operations.

The general procedure for conducting marketing studies of the type mentioned above is:

- **overview market linkages and characteristics**
- **decide on the type of study to be undertaken**
- **select markets to be studied**
- **decide on the frequency of data collection, and**
- **decide on the method of data collection to be used.**

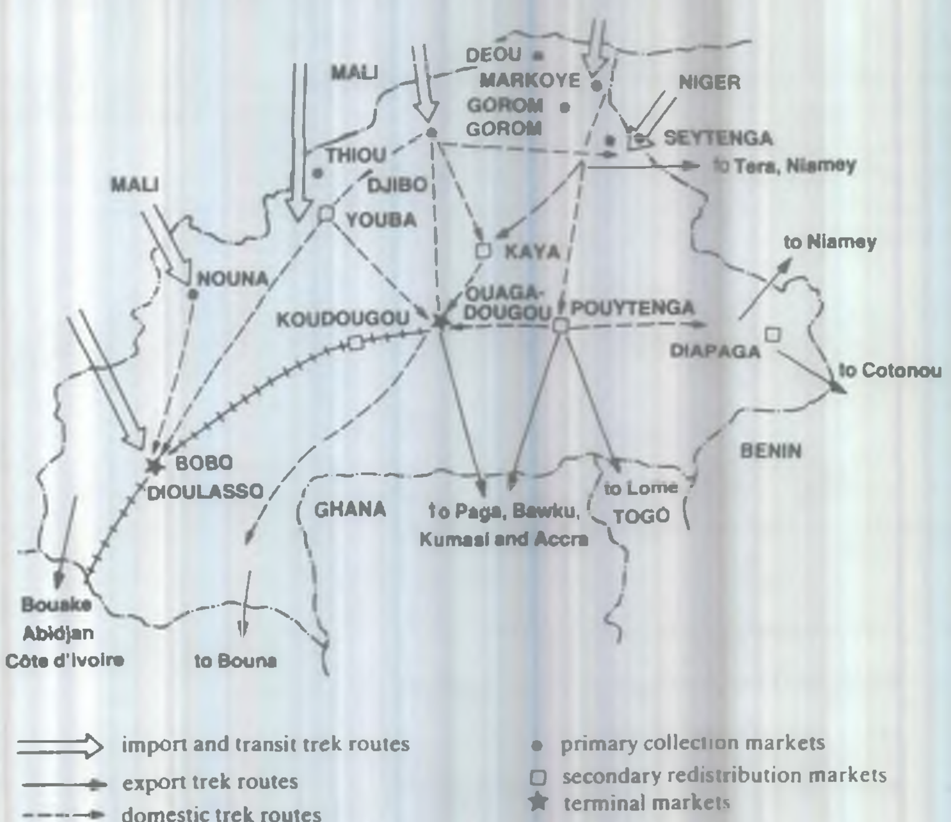
8 The readers should refer to Part C of Module 2 (Section 1) for a discussion of the principles of designing and planning repeat visit surveys.

Market linkages and characteristics. The first step in the analysis of market characteristics is to identify the outlets used, establish the manner in which they are linked to each other and to identify the operations performed. Livestock market linkages (formal and informal) within the region can initially be identified by drawing up a simple map which roughly establishes the movement of stock between areas and seasons. Market outlets can be classified as follows:

- **Primary markets** in which the main sellers are producers and the main buyers are other producers, local butchers or traders. In these markets, livestock is bought or sold for the purposes of stock replacement, slaughter or collection for resale at larger regional markets.
- **Secondary or redistribution markets** in which the main sellers are traders and the main buyers are butchers or traders. Livestock is bought or sold at these points for slaughter or resale at terminal or national markets.
- **Terminal markets** in which the main sellers are traders and the main buyers are traders or local slaughter houses. In these markets, animals are bought for the purposes of slaughter or export.

Figure 4 gives an example of the type of map described above. It shows the movement of stock to different destinations in Burkina Faso and identifies the important primary collection points, secondary

Figure 4. Cattle movements and major cattle markets in Burkina Faso.

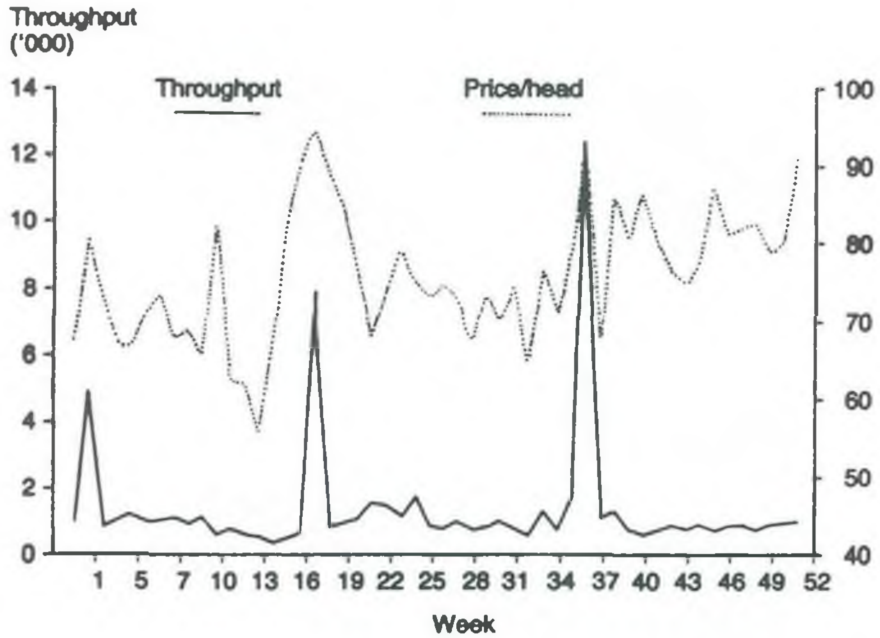


Source: Ariza-Nino et al (1980).

redistribution centres and terminal markets. Such information can often be obtained by questioning producers, extension officers or marketing agencies/traders known to operate in the area or region. The types of informal surveys suitable for this purpose are described in Part C of Module 1 (Section 1).

When stock movements and market outlets have been identified, it is also useful to plot on a graph official price and throughput statistics (if reliable). A simple exercise of this nature may highlight seasonal and trend influences in the marketing of livestock. Figures 5 and 6 give examples of such graphs.

Figure 5. Weekly throughput and price/head in a terminal sheep market of Addis Ababa, Ethiopia.



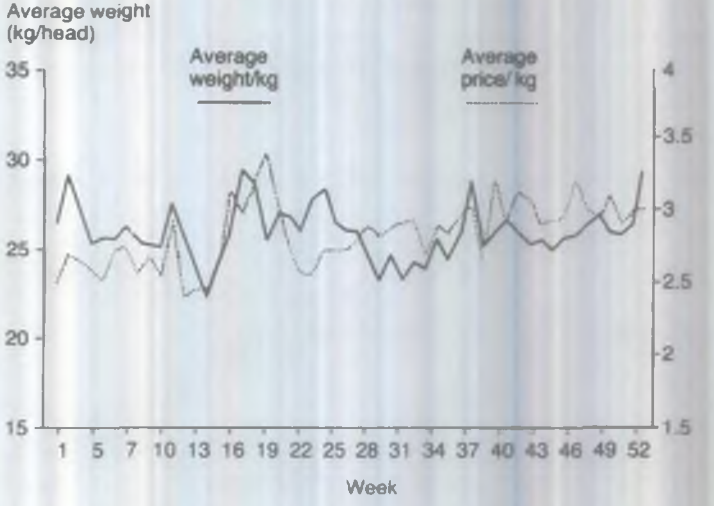
Additional information on the physical and facilitating functions performed should also be obtained using secondary data or informal interviews (Module 1, Section 1).

Type of study. The questions which should be answered at this point are: Is the study to be a cross-sectional or time series study? What types of data need to be collected - price or throughput data, information about the physical and facilitating functions performed? Can this type of study be carried out with the manpower and financial resources available?

Selection of markets. The selection of markets to be included in the study is essentially a sampling problem. It involves the need to establish, at the outset, the coverage desired and the resources available for study. If, for instance, there are several primary markets feeding one redistribution point, it is not necessary to collect data from all primary sources. A few can be selected on the basis of location, distance from secondary points and the volume of supply going through them (Solomon Bekure and Negussie Tilahun, 1983).[9]

9 The discussion here concentrates on clearly identifiable market outlets. It should be remembered, however, that informal sales between producers away from these centres can also be important. Data on informal sales of this nature can only be obtained by household surveys (see pages 215–216).

Figure 6. Weekly average weight and prices per kg in a terminal sheep market of Addis Ababa, Ethiopia.



Frequency of data collection. This will depend on the type of study envisaged, i.e. whether cross-sectional or time series studies are being planned.

Cross-sectional surveys. For such studies, data will only be collected once so that attention will be focused on the selection of the market(s) to be studied. There is always a danger that the time selected for survey will be atypical (e.g. if it corresponds to religious festivals which may affect demand and prices). If marked seasonal differences occur, these should be taken into consideration when results are being interpreted. In general, if seasonal variations are significant, time-series surveys should be used.

Time-series surveys. In such surveys, secondary data can be used to study the types of relationships outlined in Part B above. When not available, the frequency of data collection will be determined by the type of market being studied and the frequency of market days. In primary markets, livestock tend to be traded once or twice per week while in secondary and terminal markets, more frequently (e.g. several times per week). With time-series studies, the collection of data on all days will probably be impractical.

The representativeness of different market days within a week or month can be established by making initial enquiries to determine whether differences occur on particular days during the week. This can be done by checking available reports and interviewing producers, buyers and sellers.

If there are no obvious differences in market days, the number of days required for data gathering can be determined by using random sampling techniques. A convenient day each week or month can then be chosen for data collection. If there are differences, two possibilities exist:

- **group market days into broad categories** on the basis of differences in throughput and the numbers of buyers/sellers present, and decide on the frequency of data collection for each category, or
- **collect data only on the most important market day.** Use an adjustment factor which reflects the difference between this day and the less important days and guesstimate data for the latter on the basis of this factor. Initial informant surveys could be used to determine the size of this adjustment factor (Solomon Bekure and Negussie Tilahun, 1983).

Example: Initial surveys for a given outlet show that cattle are marketed on Wednesdays and Fridays. On average, throughputs on Fridays are double those obtained on Wednesdays, so that studies are confined to the collection of data on Fridays only. Guesstimates for throughput on Wednesdays can, however, be obtained by adjusting the sampled Friday data by a factor of 0.5.

Time-series data should be collected often enough and over a sufficiently long time period to capture seasonal variations in sales, purchases, prices, and in the number of intermediaries involved. Quantifying these variations over time will provide insights about the factors influencing the buyers' or sellers' behaviour, the market throughput and the market efficiency. Time-series and cross-sectional data can be collected by complete enumeration or by sample survey.

Exchange data

Exchange data include data on sales, purchases, prices, buyers, sellers and market throughput. Such data can be collected by complete enumeration, sample surveys or by observation or measurement of animals.

Complete enumeration. The types of data which can normally be collected by enumerators stationed at market points without much difficulty are:

- **total daily sales and purchases by livestock species**

  Such data can be obtained by interviewing all buyers and sellers involved or by making actual counts of individual animal lots marketed.[10] It may be necessary to distinguish animals 'on offer' from those actually sold; the numbers of animals offered for sale on a particular day may greatly exceed the number actually sold.
- **number of sellers, active buyers and intermediaries**

  In most situations, it is fairly easy to identify sellers even when animals are grouped into large lots. However, it is not always easy to identify the active buyers or intermediaries present. They may be other farmers or pastoralists, regular or itinerant traders, butchers or government agents.

  Regular attendance at a given market outlet by enumerators will improve the identification of these groups of people involved in livestock marketing. Interviewing those sellers or buyers who are well known will also help. Simple forms can be designed to record this kind of market information (see example below).

Example:

Daily record sheet of animals bought and sold at market X.

Species:______________ Date: ______________

		Number of animals			
Lot number	Lot size	Sold	Bought	Number of sellers	Number of buyers
1					
2					
:					
:					
n					

10 A lot could be as small as one animal involving the interaction of one buyer and one seller. It may, however, include animals marketed by several sellers with the price paid being determined by the interaction of several buyers.

Sample surveys. More detailed information about sales, purchases, prices, buyers, sellers, intermediaries and grades will normally be obtained by using sample survey methods.[11] Depending on the objectives of the study, it is common to obtain data by interviewing a sample of buyers or sellers or by observing or measuring animals.

Buyer/seller interviews. These are interviews of a sample of buyers or sellers present on a given market day. Where possible, the sample should be chosen at random to avoid bias and ensure that the information collected is representative.

> For instance, interviewing only those selling large lots will tend to bias results towards the larger, wealthier herd owners/holders whose absolute sales levels tend to be higher.

The probability sampling method which is applicable in this context is **systematic sampling** (see 'Sampling methods and errors' in Module 2, Section 1). Using this method, one would select for the interview every k^{th} buyer or seller arriving at the market. Where only a few buyers or sellers are involved, complete enumeration may be possible.

Questionnaires should be short since most buyers and sellers are inclined to move off soon after their activities are over. The questions asked should, therefore, be to the point, eliciting only the necessary information.

Careful planning of questionnaires beforehand is a prerequisite to the success of surveys of this nature. Preferably, enumerators should pre-test the questionnaire several times. This helps to ensure that the methods used to select sellers or buyers are properly understood. It also helps to highlight weaknesses in the questionnaire (e.g. sensitive questions).

The interviews with sellers will focus on prices received by class of stock, numbers sold, prices received by grade and class of stock, commissions and levies charged (e.g. trader commissions), reasons for sale, other outlets used, frequency of sale, distances travelled to market[12] and intermediaries involved. Such surveys can be designed to complement or confirm information obtained during household surveys or they may be discrete in themselves, e.g. if the intention is to monitor producer prices over time (time-series studies) or to determine whether prices paid at one point in time differ between different markets (cross-sectional studies).

When interviews with buyers are conducted, details given about prices paid for different classes of stock and commissions or levies charged should be cross-checked with data obtained in interviews with sellers. Questionnaires can also be designed to obtain additional information on the number and type of animals purchased, factors involved in the determination of price, proposed destinations for purchased livestock, mode(s) of transport used, buyer affiliations, other markets used, sources of finance and facilities available (Njiru, 1986; Solomon Bekure and Chabari, 1986). The data can be collected by single interviews or by continuous surveys. Single-interview surveys can give a rapid impression of the market system and of the need for more in-depth study.

Animal measurement/observation. This can be done on a sample of animals present on a given market day. The animals selected within each species may be differentiated on the basis of age, sex or grade (Chabari et al, 1987).

Data about the determinants of price[13] can be obtained by interviewing the buyers concerned or by direct measurement. For the latter, a sample of animals would be selected on each market day (e.g. by systematic sampling of pen lots) and records of specific features assumed to affect price (e.g. species, breed, age, sex, grade, weight and condition) would be made (Chabari et al, 1987). An example of the type of record sheet that could be used for this purpose is given on the next page.

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11 The methods will be essentially the same for cross-sectional and time-series studies.

12 Producers will rarely have an accurate idea of distances in kilometres. When questions of this nature are asked, it is useful to ask the seller to nominate the place where he/she originated from. The distance can be estimated later if necessary.

13 Cross-sectional or time series studies can be used to identify the determinants of price.

Weighing livestock is laborious and time-consuming and this tends to restrict the size of the sample used. Condition scoring can be used in conjunction with weighing or as a substitute indicator of weight. Age is best determined by dentition but this is also time-consuming. (Methods used to weigh, condition score and age animals by dentition are described in Module 5). Regression analysis can then be used to determine the effect of these and other relevant variables (e.g. breed and market location) on the price paid to producers (Module 11).

Example:

Record sheet for animal bought at market (X)

Species: ___________ Breed:__________ Date:_________

Animal number	Sex	Age	Grade	Weight/condition score	Price paid
1					
2					
3					
:					
:					
n					

Physical/facilitating functions

Measuring these functions involves the estimation of marketing margins for which there are essentially three approaches:

- estimation of overall marketing margins
- estimation of submargins, and
- complete disaggregation of physical and facilitating functions.

Overall marketing margin. The overall margin can be estimated by deducting the farm-gate price of the commodity from the price paid at retail. Comparisons between absolute margins in similar marketing systems can then be made to provide an indication of the relative magnitude of the overall marketing costs involved. (For examples of such comparisons see Sandford, 1983, p. 204).

However, where marketing systems are different (e.g. in terms of the number and quality of the services they provide) such comparisons tend to be difficult. Furthermore, even when the systems are similar there may be wide differences in the costs and efficiency of individual services offered and information about these may be needed if avenues for improvement are to be identified.

Submargins. An example of submargins is when the absolute difference between primary and secondary or between secondary and terminal market prices is derived. While providing a greater degree of disaggregation than the first approach, comparisons between similar systems can still mask differences which occur in terms of the quality and number of services offered.

Complete disaggregation of the physical and facilitating functions. This involves a more detailed breakdown of costs by operation. Individual services can then be compared in terms of cost and quality.

With the first approach, detailed understanding of the structure of the market is less important than with the second and third approaches. One only needs information about **equivalent** prices paid at the primary and retail levels to derive the absolute margin. A similar procedure can be adopted to calculate submargins, as is shown in the example below.

Example: The average price per kg liveweight (LW) of a 350-kg animal was $0.60 in a remote rural primary market. In the secondary market in the region's main town, the same animal was resold at $0.78/kg, and later in the wholesale terminal (live) market in the distant national capital for $1.14 per kg liveweight.

For simplicity's sake we assume this animal neither dies nor changes weight between these transactions. Later, after slaughter and butchering, the bone-outmeat of this animal is retailed at $3.94 per kg of meat, equivalent to $1.38 per kg of original liveweight. To this must be added the value of the 'fifth quarter' (hide, bones, offal) sold by the butcher at a further $0.25 per kg of original liveweight. The evolution of the price per kg of original liveweight is as follows:

	Price ($/kg LW)
Producer price	0.60
Primary to secondary market margin	0.18
Secondary to terminal markets margin	0.36
Terminal market to retail margin (incl. fifth quarter)	0.49
Total value at retail (incl. fifth quarter)	1.63

Data of this type can be obtained from secondary data sources or by conducting sample surveys to make estimates of prices paid/received at the different outlets. When livestock are sold informally and not through established government outlets, it may be more difficult to obtain reliable information at the primary level. Sales in such cases tend to be irregular and the precise place where negotiations take place may be difficult to identify. Household surveys, in such cases, will probably provide the best information about prices received at the outlets used.

When complete disaggregation of the physical and facilitating functions is being attempted, the following general procedure should be adopted:

- overview the market structure and linkages
- identify the main physical and facilitating operations performed between the different outlets specified (by interview, observation or the use of secondary data)
- disaggregate these operations into their sub-components

  For instance, there may be several assembling points between the primary and secondary markets and, therefore, several different transport operations. Different intermediaries or agents may be involved in each case.

- identify, where possible, the type of operator responsible for each particular subcomponent (e.g. agents, traders, government officials, slaughter house and managers)
- estimate the cost of operations performed within each subcomponent identified

  Hidden costs such as the opportunity costs of the traders' time, bribery charges (e.g. at border points), mortalities occurring in transit should also be accounted for. To obtain information on these costs, it may be necessary to use a combination of data collection methods - e.g. direct observation and measurement, interviews, examination of accounts (e.g. at government slaughter houses).

Costing specific physical and facilitating functions. When meat marketing margins are estimated by using complete disaggregation of the physical/facilitating functions, specific cost estimates will normally need to be made for the operations discussed below. Both the direct and indirect (hidden) costs incurred should be considered for each operation. All costs need to be expressed in equivalent terms (e.g. animal liveweight or cold-dressed weight or livestock units) if the margin is to be properly calculated.

Physical functions

The main physical functions of livestock marketing are transport, assembling and storage.

Transport. The direct costs of trucking, trekking or rail transport need to be estimated for each stage in the marketing process. It is relatively easy to calculate (or obtain information about) the costs of rail and road transport.

Rail charges will normally be based on official rates, prescribed in government gazettes. For trucking, the charges levied can often be obtained by cross-checking information given by the transport operators and producers or traders involved in the marketing process. This information should then be compared with calculated estimates of the cost per kilometre, taking into account fuel, repairs, maintenance, depreciation charges plus levies and taxes (e.g. road tax).

Trekking costs will normally involve a fee paid to hired trekkers. If farmers or pastoralists trek their own cattle, the opportunity cost of the trekker's time should be used (if this can be estimated).

Hidden or indirect costs can be important in the estimation of transport costs. In particular, the following should be fully accounted for:

- livestock deaths and forced sales which occur while animals are being transported (road and rail transport and trekking)
- weight loss during transport resulting in reduced grade at the final destination (road and rail transport and trekking)
- encroachment on cropping or grazing land resulting in conflict and the need for compensation (trekking)
- bribes paid at transport check-points (road transport and trekking)
- costs associated with government maintenance of roads and trek routes, water points and holding grounds, and
- interest on capital tied up from the point of sale to final destination.

Note: Do not 'double count' any of these costs. For instance, if a trader has made an allowance for loss through death or downgrading in the charge quoted for transport there is no need to take into account any mortality that may have occurred. Similarly, if levies charged by local authorities have been included in a quoted transport cost, they do not need to be accounted for.

Assembling. Assembling in an African livestock marketing context is a physical as well as an exchange function. The assembling of livestock may occur at various stages during the marketing process where exchange takes place (e.g. at primary, secondary and terminal markets), but other physical services (e.g. holding stock before transfer) also occur. Thus, apart from data on buyers, sellers and throughput, data on any of the following costs may be needed:

- *Feeding.* Animals held at transit points need to be fed and handled, and charges for these services will normally be levied. Grazing fees may be charged for the use of land at each assembly point. Alternatively, it may be necessary to impute a value for the land utilised (e.g. based on its opportunity cost).

- *Handling.* Handling charges may include health care, watering as well as wage payments for those involved. The provision of holding yards at assembly points also represents a cost directly attributable to the marketing of livestock. Annual costs such as repairs, maintenance and depreciation should, therefore, be apportioned equally to the livestock passing through each assembly point.

- *Levies and taxes* which are charged by local or government authorities for the use of land at each assembly point.

- *Hidden costs*. Costs such as death and loss of weight and grade which may occur at assembly points should also be accounted for if these have not been previously considered in the estimation of transport costs (see note above).

  Similarly, if animals are held at assembly points for prolonged periods, interest foregone on capital tied up during the waiting period should be included if this has not been accounted in previous estimates (see note above).

Storage. The storage of slaughtered animals at abattoirs and butcheries involves direct costs such as wages and salaries, insurance, repairs, maintenance and depreciation on equipment (in refrigeration plants, for instance). Hidden costs such as the interest foregone on capital tied up in animals stored should also be included.

All other factors being constant, higher throughput levels reduce the per unit costs of storage. Low throughput levels and unpredictable supplies have been associated with high per unit storage and handling costs for many regional abattoirs in Africa (ILCA, 1989).

Facilitating functions

The main facilitating functions of livestock marketing are grading and standardisation, finance, risk bearing and information.

Grading and standardisation. These operations may take place at several points in the marketing process (e.g. at the primary level between buyers and producers, at slaughter before distribution to consumers). The salaries and wages of those involved are the main direct costs of formal grading operations (e.g. at recognised government sale yards). If grading is done informally, the opportunity costs of the grader's time is a hidden cost which should be estimated.

Finance, risk bearing and information. Each of these functions involves direct costs (e.g. interest on borrowed funds, commission charges for risk bearing and information supplied by intermediaries or traders involved in the marketing process).

Such costs are difficult to estimate when informal barter-type arrangements are made between producers and sellers or buyers and other intermediaries. In these circumstances, careful questioning of those involved would be required to establish the kinds of informal arrangement made. It can, of course, be very difficult to actually identify the different intermediaries involved in the provision of such services. Hidden costs such as bribes for the provision of market information should also be accounted for when they can be identified.

Information about the physical and facilitating costs of marketing can best be obtained by using formally structured sample surveys (see pages 222–223). Such surveys can be designed to obtain specific information about the costs of one or more of the services provided or they may be incorporated into surveys which deal with other subjects as well (e.g. the exchange functions of marketing). They can be conducted at one point in time or over time.

When conducting surveys to obtain information about the physical and facilitating costs of marketing, it should be remembered that:

- costs should be expressed in real terms (i.e. net of inflationary effects) if comparisons between different periods are to be meaningful, and

- rising real costs of one or more operations (e.g. transport, grading) may not imply reduced efficiency in marketing.

  When rising real costs are observed in some operations one should determine whether the services embodied in those operations have changed at the same time (e.g. rising real costs associated with grading may result from the use of more sophisticated grades which have been considered necessary for the improvement of the marketing system).

After the costs involved in livestock marketing have been fully accounted for, possibilities for improving marketing operations can be examined. There may be several possibilities:[14]

- Some operations may be superfluous (e.g. the intermediaries involved in the process), though this should never be assumed (Cohen, 1969; Staatz, 1980).
- Some operations may be inefficiently performed (e.g. in trucking, if no return loads are secured or if excessive bruising occurs) (Staatz, 1980). Poor roads can also raise the maintenance costs of trucking.
- Grading may be more sophisticated than necessary, resulting in excessive processing costs (Aldington, 1978).
- Sale points, processing and storage facilities may be inappropriately located, resulting in uneconomic operation (e.g. in remote areas where throughput is limited or where informal outlets are preferred.
- Highly mechanised processing plants may be inappropriate (as was shown in parts of West Africa).

Operational aspects of marketing can be studied at one point in time or overtime. They can be studied separately or incorporated into studies which examine throughput or prices.

14 A more detailed discussion on African livestock markets and distribution systems can be found in ILCA (1989).

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SECTION 1

MODULE 10

MANAGEMENT PRACTICES

MODULE 10

Management practices

This module concentrates on specific aspects of livestock management which, though mentioned previously, have not been dealt with in any detail. They warrant special attention because of their importance in many African livestock production systems but should not be seen as unrelated to the topics discussed in the previous modules. Their study will, in most cases, involve the need to use the other modules in this section, and cross references are given for this purpose.

The main topics discussed in this module[1] include management, herding and breeding.

MANAGEMENT. Though management is commonly cited as the key factor affecting animal production performance, it is a concept which is often loosely used. If the main components of management can be quantified, directions for improvement can often be identified. The material discussed in Module 5 will, therefore, often prove to be of immense help in its study.

HERDING. Almost all livestock production systems in Africa involve the use of labour for herding (Module 3).[2] In most pastoral systems, herding is a major labour-using activity (Solomon Bekure et al, 1987), which, depending on the herding practice adopted, can have important effects on animal production performance (Module 5), animal nutrition (Module 7) and range condition (Module 6). Watering strategies and their effects are also discussed under this heading.

BREEDING. In this area, diagnostic research will concentrate on measuring the effects of breed on production performance (Module 5). The difficulties associated with separating out environmental and breed effects in an African livestock systems context are outlined.

While **housing** of livestock is practised in some systems (e.g. with small ruminants in parts of the subhumid zone of West Africa), it is relatively unimportant as a management practice and is not discussed for this reason.[3] Weaning practices are not discussed in the module either.

PART A: MANAGEMENT

Definition

Livestock producers have a particular set of objectives with respect to the stock they own or hold. These objectives include production (e.g. of meat and milk), income generation (e.g. by sale of produce) and security, and will influence the manner in which resources (land, labour and capital) are used and **managed**. They will also differ between producers and system. The ability to make correct decisions about resource use in order to meet individual objectives thus indicates a producer'managerial ability'.

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1 Since the type of data needed to determine management practices, as well as the methods involved in their collection, are described in detail in the modules which are referenced in the text, the format followed in this module differs from that adopted elsewhere in Section 1 in that it focuses on the various components of livestock management.

2 An exception are the intensive small-scale dairying enterprises in the high-potential areas of Kenya, for instance, where 'zero grazing' is practised.

3 If stabling is practised, the costs associated with constructing stables (Module 4) and the effect of the practice on production performance (Module 5) should be determined.

Indicators

Management performance is, therefore, essentially an individual capability, dependent on the personal objectives of each manager which are often very difficult to define or rank. For this reason, it can often be measured only by proxies (e.g. the management practices adopted, various performance criteria such as birth and mortality rates, and the personal characteristics of managers thought to influence management ability or performance, such as age, wealth or education).

Spurious indicators and relationships

While often providing an indication of managerial ability, the use of proxies such as those given above can lead to spurious conclusions.

> For instance, a producer who uses 'modern' or recommended management practices, may not be a good manager of livestock. Compared with others who use more traditional methods of production, his herd/flock may perform poorly simply because the techniques he uses are inappropriate or improperly applied. Thus, an assessment based merely on the management practices adopted may lead to wrong conclusions.

Similarly, the use of performance criteria to assess management ability can be misleading. Low mortality rates or relatively high output levels may simply be a reflection of better resource endowment (e.g. better grazing resources) seasonal effects and genetic potential.

Relatively low levels of performance may, on the other hand, result from the adoption of risk-averting strategies which are rational within a particular environment.

> For instance, the strategy of diversifying the species owned or held is often aimed at reducing risk (Dahl, 1979). Diversification – as opposed to specialisation (i.e. a concentration on one species) – may result in lower levels of performance per animal because resources (e.g. labour) are spread over a wider range of activities.

Relating educational level to managerial ability can also lead to spurious conclusions. A positive correlation between education and efficient management practices may, for instance, imply that education influences management. This may be true, or it may be that both education and management are determined by some other factor such as wealth.

Principal considerations in measuring management

When attempting to assess the effects of management on animal productivity, the following should be taken into account:

- **for comparisons to be meaningful, they should be made between producers with similar resources**

  To ensure that producers with similar resources are studied, farmers/pastoralists are separated into recommendation domains or target groups and households are subdivided on the basis of wealth-ranking criteria (Modules 1 and 2, Section 1).

- **different target groups within a system or between different systems will differ in their resources and objectives**

  Comparisons between different target groups may be useful to isolate constraints which, in turn, determine whether particular practices are adopted.

- **differences in output or performance measured in other ways will often result from factors other than managerial ability**

For instance, higher offtake rates may stem from the need to obtain cash to meet specific expenses such as school fees, *rather than from a more 'commercial' emphasis in management.*

Only when such factors have been identified, can the differences which are still evident be sometimes attributed to particular management practices or to the managerial ability of the producer.[4]

- **differences in management practices within a group or between different groups may not always be easy to isolate**

  When questioned about between-herd differences in performance, producers within a group can often separate the better managers from those whose performance is average or below average. However, it is often extremely difficult to get them to identify the specific reasons for varying performance. Soumare (1987) found, for instance, that better performance in an agro-pastoralist group in central Mali was commonly associated with having a'better shepherd', but this is not likely to be very helpful unless the characteristics of such a shepherd are specified or can be identified.

Methods used to measure management

Management performance can be measured by using informant ranking, management indices and zero/one variables.

Informant ranking. When informants are used to identify within-group differences in management performance, the following procedure is suggested:

- Ask informants to rank producers according to management performance and to specify, if possible, the characteristics and practices distinguishing the different groups. Procedures similar to those outlined for wealth ranking in Module 1 (Section 1) could be developed for this purpose.

- Stratify producers in the groups according to the criteria suggested and examine their characteristics and practices.

For practices which are continuous or regular in nature (e.g. herd splitting, dipping), continuous monitoring surveys may be needed (Module 2, Section 1). If once-off surveys are used, **indications** of the frequency and level of use can often be obtained by asking producers the following types of questions:

Example: How often do you dip your cattle? Enter the appropriate code number.

1. Once every month

2. Once every two months

3. Once every three months

4. About twice a year

5. About once a year

- Compare differences between producers within each stratum and across strata to determine whether the characteristics/practices identified have a significant effect on production performance (Module 11).

4 Regression analysis is frequently used to isolate the effects of particular variables on animal production performance (Module 11). The use or non-use of particular practices is represented by means of the so-called 'zero/one' variables which are then used to determine whether such practices have significant effects. In these equations, surrogate or substitute variables (e.g. education, age and wealth) may also be used for managerial ability, but there is always the danger that such variables will lead to spurious conclusions.

- If significant differences occur between different strata, directions for improvement may then be identified.[5]

> **Example** (hypothetical): Informants grouped pastoralists from a target group into three categories on the basis of management activities said to influence production performance. Better management was believed to be related to the frequency of stock movement, prompted to avoid disease risks.
>
> A sample of producers was then selected from each group to observe herding practices and animal grazing behaviour, and to measure production performance (Modules 3, 5 and 7). Production performance was found to be significantly different between groups with respect to body condition and growth rate (Module 5). These differences were, in turn, found to be related to the level of worm infestation (Module 8). Subsequently, this information was used to design strategies for improvement, such as regular drenching.

Management indices. Attempts have been made to measure the effects of management by the construction of 'management indices'. With this method, producers' management practices are assigned

> For instance, Bailey (1983) used an index of management for cattle owners/holders in Botswana. He assigned (on the basis of input use) the scores 0–10 to individual producers in different herd-size groups. Five input indicators (weighted equally) were used for this purpose:
>
> - vaccines and medicines
> - tick treatments
> - feed supplements (salt and bonemeal)
> - artificial insemination, and
> - improved bulls.
>
> Bailey then related the average index score per group to herd-size category to determine whether herd size (an indicator of wealth) had any effect on the use of inputs (an indicator of 'management') (Table 1).

Table 1. Management performance by herd-size class, Botswana.

	Herd size class							
	1–10	11–20	21–30	31–40	41–50	51–60	61–70	70 +
Average index score	41.3	40.1	45.0	49.1	53.9	56.0	60.5	56.8

> The author concluded that there was a significant relationship between herd size (wealth) and the management practices adopted.

5 A similar ranking procedure could be developed for different groups within the same system and incorporated into an initial wealth ranking of producers (Module 1, Section 1). If, for instance, individuals are ranked according to wealth and if management differences are believed to exist within each wealth rank, then these differences could also be specified by informants during the interview and used for further inter-group comparisons.

scores and weighted according to predetermined criteria to enable the ranking of producers on the basis of 'management performance' (Bailey, 1983; Mohamed, 1985).

The points to be taken into account when this kind of analysis is being planned are:

- the selection of management practices for the index will be based on subjective criteria and will thus be open to personal bias
- the weights assigned to different practices and the scores given to individuals are also based on subjective criteria
- the final score is thus based on a subjective assessment of what constitutes 'good management'. Good management and the use of 'modern' practices are not necessarily the same, and
- relationships such as those used by Bailey (1983) may, therefore, be spurious. Another researcher, because of his/her own preferences, may come up with completely different results.

Zero/one variables. Because of the potential for bias in the use of management indices, producers are often ranked simply on the basis of **use** or **non-use** of a particular practice.

This approach also has its inherent dangers. It makes the implicit assumption, for instance, that the users of a practice are better managers than non-users. By categorising producers into one of the two possible categories, the method makes no distinction between users as to the **frequency** or **level** of use. For some practices where continuity and level of application are meaningful (e.g. herd splitting, dipping, drenching), zero/one information is therefore inappropriate. For 'once-off' practices (e.g. administration of certain vaccines), zero/one variables may be used to determine whether the adoption of these practices has any effect on performance (Flint, 1986) (Footnote 4).

Management relationships

If differences in management practices or producers' characteristics can be isolated, and if the methods used to measure these variables are appropriate, constraints may be identified and possible pathways for improvement may be indicated by examining the relationships between the management practices adopted and:

- **production performance**

  For instance, do the stock of pastoralists who drive them to salt licks perform better than those who do not? If so, correction of mineral deficiencies by the provision of salt licks may be appropriate.

- **household size**

  For instance, do larger households adopt different practices? If so, is labour a constraint to the adoption of new techniques within a particular group? Do recommendation domains need to be redefined?

- **herd size (wealth)**

  For instance, do the owners/holders of larger herds adopt different management practices? (Botswana, 1982; Bailey, 1983).

- **other producers' characteristics**

  For instance, do producers with greater access to services (e.g. to extension agents) use different practices when compared with those who don't? If so, what distinguishes such producers - location, education etc? Having compared herds of high and low productivity, Mohamed (1985) concluded that the age of the manager (as an indicator of experience) was positively related to livestock productivity in the agropastoral systems of subhumid Nigeria. Such correlations must, however, be treated with caution.

- **cost of inputs used**

  For instance, Sandford (1983a) has shown that the use of vaccines in Tanzania declined after the imposition of fees by government. In Kenya, subsidising vaccinations increased their use. Improvements in production may, therefore, come via changes in policy rather than through changes in technology.

PART B: HERDING

Herding is one important element in management. It can be defined as the deliberate control and movement of livestock for the purposes of feeding, watering, avoidance of disease risks, crop damage etc. Dahl (1979) distinguishes between **herding tasks and herding tactics**, which are defined as follows.[6]

Herding tasks consist of the daily movement of livestock to sources of feed and water. In Africa, such tasks are often carried out by young children. Other tasks such as the care of young stock by women and children at the household site are also included. Decisions about these activities are made on a daily basis (i.e. they are short-term management decisions).

Herding tactics involve the actual planning of stock movements or herding tasks and the collection and evaluation of various kinds of information relating to feed, nutrition, disease and water availability. These are essentially management decisions made usually by the household head or recognised elders of a herding group (Solomon Bekure et al, 1987). Herding tactics will be much influenced by herd/flock composition and the requirements of different animal species in terms of water, feed and disease management. Decisions made about herding tactics can thus be of a short- and long-term nature.

Herding tasks

In the study of herding tasks, emphasis will be given to the measurement of labour spent on different activities[7] in order to determine the sufficiency of labour for basic herding tasks. The amount of labour required for herding tasks will depend on the system of production, proximity to feed and water resources, seasonal conditions and herd or flock size.

> For instance, time spent watering stock in pastoral systems is very much dependent on the distribution and adequacy of seasonal water supplies (Sandford, 1983a). For the Borana pastoralists in Kenya and Ethiopia, a critical constraint to production is the amount of labour available for watering from deep wells during the dry season. Insufficient labour to perform this task will affect the size of the herd a family can own or hold and may have significant effects on the productivity of animals (Dahl, 1979; Sandford, 1983b).

Larger households tend to have larger herds/flocks in most systems (Zimbabwe Government, 1982; Solomon Bekure et al, 1987). They thus often benefit from economies of scale, with less time being spent per animal on herding tasks.

To determine whether labour is sufficient to carry out herding tasks, data on household structure, the age/sex allocation of labour to different activities and the seasonal patterns of labour use will need to be collected (Module 3, Section 1). Where labour hiring and cooperative arrangements are used to compensate for shortages of herding labour, information on this type of arrangements will also need to be collected. While used to overcome labour deficits and increase mobility, such measures can have negative effects, e.g. through a loss in herding autonomy and the capacity to decide on herding tactics (Dahl, 1979; Solomon Bekure et al, 1987).

6 While Dahl's (1979) classification relates to pastoral communities in general, it is also applicable to most African livestock production systems.

7 Module 3 (Section 1) discusses the various methods which can be used to measure labour inputs.

The emphasis in labour studies should always be to isolate constraints, examine relationships and determine directions for improvement.

Example: To determine the sufficiency of labour, one may, for instance, examine the relationship between:

- the household labour available for herding and the size of the herd/flock owned or held, and
- the household labour available for herding and animal productivity.

Herding tactics

As already mentioned, choosing herding tactics involves the planning of stock movements or herding tasks, and the collection or evaluation of data. Herding tactics are, therefore, a particular set of management decisions.

In this section we shall look briefly at the different kinds of people by whom these management decisions are taken and at the factors which determine which options are chosen, and then, in some detail, at the content and consequences of some of these management decisions.

There is substantial anthropological literature (of which Dahl (1979) is an example) of how rights in livestock (e.g. ownership rights) determine who makes management decisions of various kinds, and how these rights alter over time demographic, economic and social change.

For instance, in many parts of southern Africa where male household heads migrate out of their home areas in search of work, there has been a perceptible change in the power of women to make management decisions over livestock.

Different types of decision-maker (e.g. pure pastoralists, trader-pastoralists, absentee bureaucrats and female household heads) have access, in different degrees, to the different kinds of information needed to choose optimal herding tactics.

For instance, the bureaucrat will get early news of impending government actions, the trader of changes in market conditions, and the pure pastoralists of site-specific rainfall, pasture and stock-water conditions.

One set of constraints to good management is lack of information; and one way to diagnose the relative importance of different kinds of information is to relate the productive performance of the livestock of different types of decision-makers to the kind of information to which they have privileged access, bearing in mind, however, that they may differ in several other ways (e.g. wealth) as well as in access to information.

One of the most important factors determining which herding tactics are adopted is labour availability. In pastoral communities, the availability of labour will affect a household's capacity to adopt such strategies as herd splitting, as well as the selection of water points and watering frequency. This, in turn, may influence the choice of milking strategies which may have an effect on productivity (e.g. in terms of milk offtake).

In mixed farming systems, crop and livestock activities will often compete for available labour resources. This may result in a reduction of the time spent on herding and livestock care (Sandford, 1983b; Mohamed, 1985), or may lead to farmers fencing areas for grazing in order to reduce herding labour requirements (Danckwerts, 1975).

In the examination of herding tactics, much of what has been said about management in Part A is relevant. In addition, specific attention may need to be given to herd splitting and watering practices.

Herd splitting

Herds and flocks are often separated into distinct herding units in order to exploit feed and water resources better and adjust mobility. The manner in which they are split varies with herd/flock size, season and productive function.

Herd splitting is common in pastoral communities (Dahl, 1979; Maaliki, 1982; Solomon Bekure et al, 1987) but less so in mixed systems, largely because of competition for labour from cropping. In pastoral systems, herd splitting is a management practice which can have significant benefits in terms of animal nutrition and productivity, and its relationship to performance should, therefore, be examined.

In the study of herd splitting as a management practice, the important considerations are:

- **the frequency and timing of herd splitting**

  Here we should find out whether herd splitting is a regular practice across seasons or only within particular seasons. If continuous surveys are not justified, approximations of frequency can be obtained by asking questions similar to those given earlier on page 235.

- **the effect of herd splitting on herd mobility and on the exploitation of grazing and water resources**

  Studies which attempt to answer such questions are likely to be time-consuming, though quick impressions can be obtained by using low-cost techniques. They may involve studies on grazing behaviour (Module 7), animal nutrition (Module 7), labour use (Module 3, Section 1), animal production (Module 5) and range resources (Module 6).

If low-cost survey techniques are used, the main objective will be to estimate the distances over which different herd units are moved and the sources of feed and water they exploit. This could be done by following split and unsplit herds at different times during the year.

During the wet season, when surface water is abundant, pastoral herds are often moved to exploit distant feed resources, and difficulties may be encountered in tracking stock if visits are infrequent. One way of overcoming this problem is to attach enumerators to different herd units. They should be trained to record basic data on the utilisation of feed and water sources and on time spent grazing (or browsing) and walking.[8] Average distances moved per day can then be estimated.

The same applies to monitoring herd-splitting activities during the dry season. The main objective of dry-season monitoring will be to establish the differences in the exploitation of feed and water resources by split and unsplit herds. Productivity differences between the different herd units could also be compared using simple rapid-survey techniques (e.g. condition-scoring). (See Module 5 for a description of the various rapid-survey techniques used to assess productivity.)

Watering practices

Studies of the watering practices adopted by livestock herders can be an important component of diagnostic research, particularly in the pastoral and agropastoral areas of the arid and semi-arid zones.[9] The distance travelled to water, the amount of feed consumed and the frequency of consumption can influence animal production performance (Module 5), feed intake (Module 7) and range condition (Module 6). In some systems, water intake may be limited by the availability of labour (Module 3, Section 1).

8 Grazing behaviour studies described in Module 7 can be modified to obtain more general data about the resource use by herds or flocks.

9 The discussion is confined to those livestock systems in which water is a major constraint on production throughout the year or during particular seasons. Typically, these will include nomadic pastoral systems in arid and semi-arid areas and semi-nomadic pastoral systems and mixed farming systems in semi-arid areas (Sandford, 1983b). Ranching and small-scale dairy operations and systems in high-altitude or high-rainfall areas are excluded because water is not normally limiting in such areas.

The following management-related issues may need to be examined in studies on watering practices:

- **water-management strategies**, and
- **relationships between water use** on one hand **and labour, livestock productivity, range condition, and equity**, on the other.

Water-management strategies. It is useful to distinguish between the various water-management strategies adopted by livestock herders to cope with water scarcity, because an understanding of their characteristics will often point to particular constraints or to avenues for improvement. The categorisation of strategies used by Sandford (1983b) for arid and semi-arid livestock production systems provides a useful guide.

Five water-management strategies can be identified:

- **Investment strategies**, which refer to the construction of water sources to alleviate water shortages (e.g. hafirs and dams in the Ogaden region of Ethiopia, boreholes on the communal grazing areas of Botswana, and deep wells in Niger and in southern Ethiopia).
- **Herd-composition strategies**, in which owners/holders adjust the age, sex or species mix of their livestock in a way which matches their ability to cope with water shortage to the actual distribution of water resources. These adjustments are also used to ensure more even supplies of milk (Module 5) and better utilisation of grazing resources (Modules 6 and 7).
- **Positioning and conservation strategies**, in which there is careful adjustment in space and time of the location of livestock relative to water supplies. In general, positioning strategies will involve herd splitting to ensure that individual species' requirements are met (Cossins, 1971). They will also involve careful conservation of permanent water sources as fallback points during dry seasons and the exploitation of more distant ephemeral water supplies during wet seasons. This strategy is common in African pastoral systems (e.g. the Borana of Kenya and Ethiopia, the Bororo of Niger, the Maasai of Kenya).
- **Husbandry strategies** which have two essential components:
  - the selection of livestock better suited to cope with water shortages (e.g. on the basis of species or skin colour)[10] (King, 1983, pp. 34–37; Nicholson, 1985), and
  - the manipulation of watering frequency (Nicholson, 1986).

Figure 1 gives an example from Kenya of the effect of rainfall on the relative composition of pastoral livestock holdings.

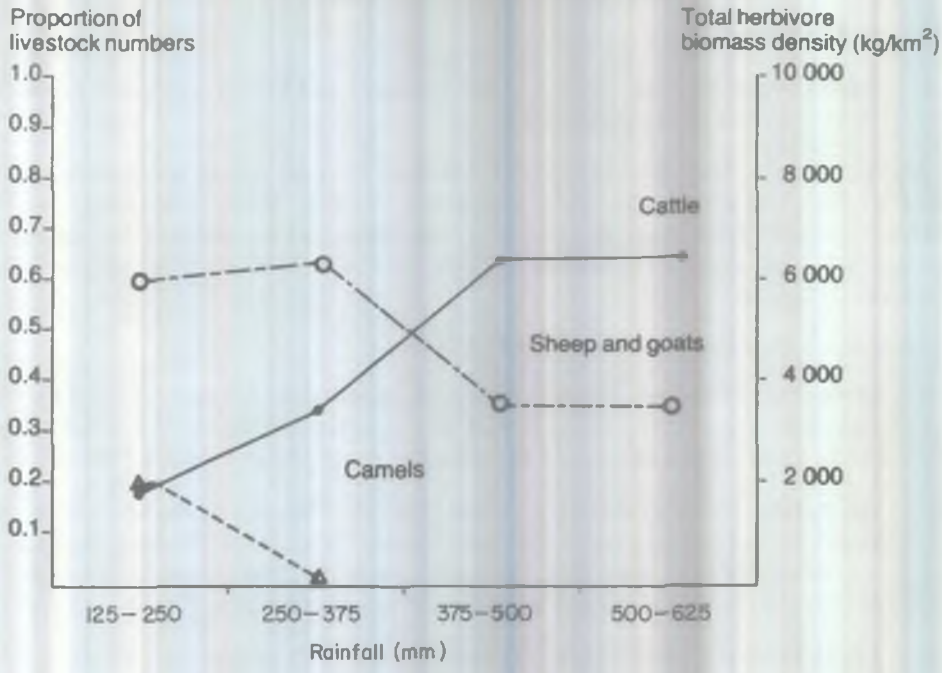
- **Control strategies** in which communities or individuals attempt to regulate access to water sources. The degree of control is related to the scarcity of water, the difficulty of extracting it and the amount of grazing adjacent to the water point. Attempts to obtain control are less common in situations where grazing and water are relatively abundant (e.g. during wet seasons).

Relationship between water use and labour. Labour required to extract water from ground and river wells can be a limiting factor in some systems (e.g. the Borana of Ethiopia, the Berti of Sudan). Households which are short of labour must enter into cooperative arrangements, or reduce herd size or the frequency of watering.

When operations such as watering are identified as critical during particular months of the year, rapid-survey techniques such as the'critical task analysis' can be used to determine labour requirements

10 For instance, white coats in zebu cattle reflect 40% more heat than black coats (Nicholson, 1985).

Figure 1. Effect of rainfall regime on pastoral livestock holdings in Kenya.



Source: King (1983, p. 79).

(Grandin, 1983) (Module 3, Section 1). This data can then be used to examine the effects of labour supply and herd size on watering frequency.

Relationship between water use and livestock productivity. Water functions in the body as a solvent for nutrients and as a medium for the excretion of metabolic waste. It affects feed intake and is important for the regulation of body heat. Water can, therefore, have important effects on animal nutrition and productivity.

In order to maintain the amount of water in body tissue within acceptable limits, water used (e.g. in evaporation, excretion or milk production) must be replaced by drinking or by moisture in the feed consumed. The proportion of water used per unit of time is known as the ' turnover rate' and this varies between species and according to breed, size, physiological status and environmental conditions.[11]

For this reason, relationships between water use, water management and productivity need to be examined in diagnostic research. In arid/semi-arid rangelands, one will need to examine particularly how production performance is affected by:

- distance walked to water
- frequency of watering, and
- water quality.

11 King (1983) deals in detail with water use and species requirements and provides an extensive bibliography on the subject. Nicholson (1985) provides a more general discussion on water requirements of livestock in Africa. Basic texts on animal nutrition (see Module 7) deal with the nutritional aspects of water use in livestock.

The effect of distance walked to water. In arid and semi-arid areas, water development schemes have often been based on the premise that distance walked to water affects feed intake and thus animal productivity. The energy expended in walking long distances to water limits performance and forces pastoralists to keep livestock species and breeds which are able to withstand water shortage, not because of their relatively productive potential. Also, the distribution of water points modifies the spatial patterns of grazing pressure, thereby affecting range utilisation and productivity, and through these, livestock performance (Squires, 1978; Nicholson, 1985).

Sandford (1983b), for instance, argues that an increase in water points from 1 to 100 per 1500 km^2 could more than treble milk production in pastoral areas. Nicholson (1985), however, argues that the evidence for energy loss through walking is inconclusive and that losses, if any, are likely to result from the added heat load caused by walking during the hotter time of the day, not from walking long distances

If the distance walked reduces the intake of food (Squires, 1978) and a net loss of energy occurs (from whatever the cause), animal productivity can be expected to decline. However, African livestock have been shown to adapt to submaintenance energy levels by lowering maintenance requirements (Ledger and Sayers, 1977; Butterworth, 1985) (Module 6). If this is the case then lower levels of feed intake caused by walking greater distances may have little effect on productivity.

The distribution of water points can affect the utilisation of rangelands and hence the number of animals which can be carried. In a study of the central Australian rangelands, Perry (1962) concluded that carrying capacities could be increased by 150–250% through better distribution of water points.

The relationship between water distribution and animal productivity could thus have important implications for water development policy in drier regions. Simple indicators of production performance (e.g. condition scoring for cattle, weight measurements for smallstock) for herds or flocks travelling different distances to water in the dry season could be used to estimate the significance of this relationship.[12]

To be meaningful, comparisons would need to be made between similar systems and environments with animals of the same breed, age and productive function. Several condition or body weight measurements would need to be taken during the dry season (e.g. per month or per a fortnight). Distances travelled to water could be measured by the technique described on page 240. Condition scoring is described in Module 5.

The effect of watering frequency. The frequency of watering can affect feed and water intake and the area over which an animal can graze. Its effect on productivity has not been widely tested, though the on-ranch trials conducted by ILCA in southern Ethiopia are worth citing as an example (Nicholson, 1985; 1986).

Example: Trial cattle were placed in four groups to test the effect of watering frequency on cattle production performance. The control group had *ad libitum* access to water, while the other three groups were given access at 1-, 2- and 3-day intervals, respectively.

The results showed that there were no significant effects on calving rate but the weight and condition of lactating cows was affected during the dry season (Table 2).

Continued...

12 Condition scoring has been shown to be closely correlated to productivity in terms of conception rates (Ward, 1968; Steenkamp et al, 1975) and body weight (Nicholson and Sayers, 1987).

Example: continued...

Table 2. The effect of watering frequency on the weight change and condition of lactating cows, southern Ethiopia, October 1983 – May 1984.

Watering frequency	Weight loss (%)	Per cent of starting weight	Condition loss (average points/month)
Daily	83.4	22.2	0.452
Every 2 days	68.4	18.6	0.268
Every 3 days	111.4	27.0	0.280

Growth of calves to weaning was affected as well. Compared with calves watered daily, calves under the 2-day watering regime were 9 kg lighter and those under the 3-day regime were 14 kg lighter. However, at 27 months there was no significant difference in the weight of steers, suggesting compensatory gain during the intervening period. In overgrazed and overstocked rangelands, the potential for compensatory gain may be limited, which, in turn, may mean that the growth of mature stock may be affected by the watering regime adopted.

The method used to monitor watering frequency would depend largely on the system being studied. Monitoring would be done during the dry season when water becomes limiting. Condition scoring could be used as an indicator of weight gain and productivity. In systems where watering is done at fixed water points and where labour for watering is limiting, the same herdsmen are likely to come to the water point each time a particular group of stock is watered. In this case we can select a sample of these herdsmen and monitor their return to the water point over a period of 1-2 months. Since watering frequency is likely to increase as the dry season proceeds, the monitoring should be done when the dry season is well advanced, rather than at its beginning.

In systems where watering is done by different herdsmen, ear tags may need to be used instead. These can be complemented by simple questionnaires to establish herd ownership and location and to record watering frequency.

The effect of water quality. The quality of water drunk can have noticeable effects on livestock productivity. Water quality is affected by the presence of dissolved salts, toxic and contaminating substances and disease-producing organisms (Nicholson, 1985). Livestock species vary in their tolerance to dissolved salts; the amounts recommended for different species are given in Table 3.

Table 3. Tolerance to salty drinking water.

Species	Total dissolved salts tolerated %
Camels	5.5
Goats	1.5
Sheep	1.3–2.0
Cattle	1.0–1.5
Donkeys	1.0

Source: King (1983).

Toxic substances may be natural or a result of pollution - e.g. arsenic and organophosphates near dips. Minerals dissolved in water can also reach toxic levels; data on these levels are available from Schoeller (1977) and Edwards et al (1983).

Disease is common at water points which are heavily utilised. Such sites are common sources of worm infestation (e.g. flukes) and other disease-bearing organisms (e.g. anthrax, rinderpest and foot-and-mouth).

It may thus be useful to examine the relationships between:

- stocking density adjacent to water points and the incidence of disease (Module 8), and
- water quality and animal production performance

The existence of toxic substances and dissolved salts in water can be tested by standard laboratory techniques.

Relationships between range condition, water use and stocking density. Overgrazing at, and adjacent to, water sources is widespread in Africa and is particularly serious in arid and semi-arid areas (Jarridge, 1980). Where water points are sparsely distributed, overgrazing normally occurs in concentric circles with vegetation conditions improving as distance from the water point increases.[13] Table 4 demonstrates this for a wet-season water point in Mali.

Table 4. The effect of gross overgrazing around a wet-season water point, Mare d'Arodouk, Mali.

	Distance from water point (km)				
	1	2	3	4	5
Bare soil as % of surface area	36	22	14	20	9

Source: Boudet (1976, p. 191).

Blench et al (1986) found in the subhumid zone of Nigeria that the number of water points per square kilometre explained 65% of the variation in cattle densities during the dry season. Fortmann and Roe (1981) also found a positive relationship between cattle density and proximity to water points in eastern Botswana. As the distance from water points increased, cattle and range conditions also improved.[14]

The relationships between water-point use and livestock concentration can, however, be confounded by seasonal environmental conditions or soil type. Abel et al (1987) found in southern Botswana that, because the presence of ground water and of soil moisture content near the surface were positively correlated in space, grass biomass actually declined as the distance from water points increased. The stocking rate in an area will also affect the relationship between distance from water and range condition - e.g. at low stocking rates, it is unlikely that the relationship will be significant.

In some societies (e.g. the Borana of Ethiopia), less frequent watering of stock has resulted in better exploitation of the range and less pressure near water points. Management strategies of this kind may, in some circumstances, be preferable to the construction of more water points (Nicholson, 1986).

13 The relationship between distance and grazing pressure is often sigmoid, not linear (Graetz and Ludwig, 1978). Pressure tends to be fairly constant in the first band. It then tends to increase sharply and in the extremities it flattens out again.

14 Fortmann and Roe (1981) used condition scoring and a simple range-scoring technique to demonstrate this.

The methods used to evaluate range condition are described in Module 6.

For instance, one could use line transects radiating from selected water points to assess biomass, density, cover or composition of the vegetation (Fortmann and Roe, 1981). The following simple procedure could be adopted in this case:

- Make a preliminary assessment of changes in range condition by walking or driving along two or three transects radiating from the water point
- on the basis of this information, decide how long the transects should be (e.g. to the point where vegetation condition appears unchanged) and how the vegetation should be sampled (e.g. more samples may need to be taken initially if vegetation changes in the sigmoid pattern described in footnote 13), and
- relate changes in vegetation to distance, stocking rate or animal condition, as required.

Aerial surveys can also be used to assess relationships between the distribution of water points and vegetation or livestock density, respectively. The principles involved in the use of aerial surveys for the assessment of range condition are outlined in Module 6. Module 9 shows how they can be used to make stock counts (Milligan, 1983).

Relationship between water use and equity. In some production systems, individuals or groups of owners are able to control access to water points because of position or wealth. As a result, they effectively gain the control over adjacent grazing, particularly during the dry season (Peters, n.d.). The poorer members of the community may then be forced to pay to obtain the right of use or they may be excluded. If the latter happens, their stock will need to be watered at publicly used water points where overgrazing, range degradation and disease tend to be more pronounced (Fortmann and Roe, 1981; Nicholson, 1986). Losses through death may, therefore, be greater for those without access to controlled water points during the dry season.

Comparisons between those who control access to water points and those who do not on the basis of herd size and production performance points to the need for policy changes which redistribute control over water points more equitably. However, it may be extremely difficult to enforce such policies.

PART C: BREEDING

Livestock development and research programmes in Africa have often emphasised the need for breed improvement schemes to raise animal production performance. This part of the module, therefore, deals with the diagnosis of breed/genetic effects on the performance of livestock in traditional production systems. The principles of genetics, breeding and selection are not described since such information can be found in numerous texts on the subject (e.g. Lush, 1945; Butterworth and Presswood, 1978; Pirchner, 1983). Information on breeds in Africa by livestock species can be found in Mason and Maule (1960), Mason (1969) and OAU (1985) .

When attempting to diagnose breed/genetic effects in livestock systems research, different animals are compared on the basis of productivity criteria (e.g. milk production, meat output, weight gain and mortality rates). The methods used to measure production performance are discussed in detail in Module 5.

In this module, the discussion will focus on:

- the difficulties involved in isolating breed/genetic effects when assessing production performance, and
- some of the breeding practices used in African livestock production systems, and how their effects on performance could be assessed.

Isolating breed and genetic effects

Production performance in any system is determined by the interaction of genetic characteristics and environmental conditions. Two types of genetic characteristics are commonly identified in animal breeding. They are:

- **characteristics which distinguish different breeds on the basis of visual appearance**

  For instance, colour, horns, dewlap, hump etc. Such characteristics are relatively unimportant in livestock breeding though they can play a role in crossbreeding for hybrid vigour. Breeding for skin or coat colour may also be required (see page 241).

- **performance characteristics**

  For instance, growth rates, carcass quality, milk production, wool production etc. These characters respond to selection. The chief problem here is to separate environmental effects[15] from gene/breed effects. If this can be done, selection of animals which are superior in **genotype** for one or more characters can be made.

Under experimental conditions where environmental effects can be controlled or held constant, the effects of breed can normally be isolated without difficulty. However, when these factors cannot be controlled (as is the case in most African livestock production systems), it is extremely difficult to diagnose for breed or genetic effects.

Even if the effects of climate, feed, water and disease can be assumed to be fairly constant within a given system, management is often highly variable and its effects are difficult to isolate. If differences in management skills are randomly and fairly evenly distributed between the herders looking after different breeds, the result will be great within-breed variability and, therefore, probably no statistical significance between the performance of different breeds. If, as is not unlikely, the herders with one breed are better managers than the herders with another breed, then management and breed effects will be confounded.

Thus, there are substantial problems in determining whether differences between flocks or herds are due to management or genetic factors or a combination of the two. Moreover, management influences feed and water availability as well as the incidence of disease, so that the environment, though apparently constant within a system, may in fact be very different for different flocks/herds within that system.

In summary, isolating breed and genetic effects in on-farm diagnostic research presents substantial difficulties. It has seldom been successfully done in African smallholder conditions. For further discussion see Peters and Thorpe (1988) and Peters (1989). Further issues to be considered in the diagnosis of breed/genetic effects in traditional African livestock production systems are:

- **comparisons between animals of the same breed**

  Diagnosing for genetic differences within the same breed and in the same production system has a very low chance of success unless management effects can be isolated. Moreover, time spent on this is likely to be unwarranted in traditional systems, since significant improvements can often be achieved by concentrating on the more obvious parameters such as disease or time of mating (if reproductive performance is low) (Module 5).

- **comparisons between different breeds**

  Inter-breed comparisons within the same system tend to be difficult because, within a given system, animals of the same species are usually of the same breed. The comparisons thus need

15 The term 'environmental effects' refers to effects caused by such factors as climate, feed, water, disease and management.

to be done between different systems where environmental factors are likely to differ as well. Since it is often impossible to isolate the effect of these factors, attributing differences to breed alone will tend to be spurious.

Even if different breeds do occur within a system, it is often extremely difficult to identify purebred animals. This is because in most African traditional livestock production systems, breeding tends to be uncontrolled and crossing between breeds is common. If crossing results in heterosis (hybrid vigour), the inclusion of such animals in the sample is likely to result in spurious conclusions.

Also, even if different breeds are clearly distinguishable within a system, the number of purebreds will often be too small to make meaningful statistical comparisons. Alternatively, the cost associated with diagnosing breed differences over a sufficiently large sample may be prohibitive.

Breeding practices

Three other aspects of breeding management warrants consideration in livestock systems research. They are:

- seasonal breeding control practices
- sire/dam ratios, and
- selection practices.

Seasonal breeding control practices. In some societies (e.g. the Maasai of Kenya and the various Islamic communities in the Sahel), aprons are used to control breeding in smallstock and, thereby, ensure that the young are born in the most favourable season. Such practices may point to potential areas for improvement (see Part A above) if significant differences in productivity occur between the users and non-users.

Sire/dam ratios. Sire/dam ratios in the traditional livestock production systems of Africa tend to be high: for cattle, ratios of 1:25 are common (Butterworth, 1985) and for small ruminants, ratios of between 1:4 and 1:6 have been widely observed (Wilson, 1988). In some instances differences in ratios between producers may point to potential improvements in management (Botswana, 1982), but in situations where communal grazing results in uncontrolled breeding there may be little scope for improvement by increasing the number of sires. Where excess breeding bulls are kept, the reasons for doing so should be ascertained if possible.

Selection practices. Producers select males for breeding but the criteria for this selection are not well known.

> For instance, do farmers in mixed production systems select males for castration because of superior weight and size? If so, are breeding males inferior in these respects? Does this affect the performance of the herd/flock owned or held?

If such questions can be answered, potential ways of improvement might be identified. Generally, however, it is usually extremely difficult to elicit uniform information about the selection criteria used.

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SECTION 1

MODULE 11

ORGANISATION, PRESENTATION AND ANALYSIS OF RESULTS

MODULE 11

Organisation, presentation and analysis of results

Previous modules in this Section have shown how different types of data can be collected during the diagnostic phase of livestock systems research. They have also stressed that data collection must never be an end in itself - it should always be directed towards making useful research and/or policy recommendations. This module has been written for that purpose.

The examples used in the text relate specifically to livestock systems research in Africa. The reader is encouraged to work carefully through them and to refer for details on the methods of statistical analysis described in this module to such widely available statistics textbooks as Dagnelie (1973; 1975), Cochran (1977), Draper and Smith (1981), Gomez and Gomez (1984), Casley and Lury (1987) and others given in the reference list at the end of this module.

PART A: ORGANISING AND PRESENTING DATA

To facilitate the interpretation and analysis of survey results, data should be organised and presented properly. Tables, graphs and charts are normally used for this purpose.

Statistical tables

GENERAL. Table 1 is an example of a data set which contains a lot of information which is very difficult to interpret. It shows that the mere representation of results in tabular form may mean very little. If, however, the same information were organised in another way, it might be very useful. For instance, the pattern of cattle holdings in the area can be more clearly presented in a simple one-way table grouping sample households into categories or class intervals by herd size (Table 2).

The information in Table 2 could, of course, be presented in other ways: for instance, more (or fewer) categories could be used or the information could be abbreviated to mean and range values (Table 3). In other tables where the categories have no natural order, the categories should be arranged in descending order by frequency.

Table 1. Cattle held by households in area A.[1]

1	10	0	3	7	7	22	1	0	4	1	2	9	12
5	12	1	2	5	2	0	4	1	0	19	5	3	0
3	5	20	8	4	15	20	5	4	0	3	0	16	1
1	4	9	16	0	8	1	4	6	7	4	0	1	3
21	5	11	0	0	0	2	6	5	23	13	0	1	4

[1]Sample size = 70 households.

Table 2. Cattle holdings in area A, grouped by herd-size category.[1]

Herd size category	Number of households
0	13
1 – 5	34
6 – 10	10
11 – 15	5
16 – 20	5
21 – 25	3
Total	70

[1]Sample size = 70 households.

Table 3. Mean and range of herd size in area A.

	Herd size	
	Mean	Range
Sample size (70)	5.67	0 – 23

Table 2 is a frequency distribution table, because it shows the 'frequency' of values occurring in each category or class. The mean in Table 3 is known as a 'measure of location' and the range as a 'measure of dispersion'. More will be said about measures of location and dispersion later.

FREQUENCY DISTRIBUTION TABLES. When frequency distribution tables are being constructed, the following points about class intervals should be noted:

- A frequency table with many class intervals gives more information about the data than one with fewer intervals, but it is more difficult to understand quickly.
- Too few class intervals can over-simplify the data and reduce its interpretive value.
- Class intervals need not be equal in size. Their size will largely be determined by the spread of the values obtained. If these are skewed or concentrated at one end of the distribution, more intervals may be needed at that end than at the other.

  For instance, the first category (zero cattle) in Table 2 is smaller than the other categories, each of which have class intervals of five head of cattle. Also, since the number of households falling within the intervals 16–20 and 21–25 is small, those intervals could be combined.
- Setting class intervals for discrete data poses few problems, because there are definite breaks in the possible values a variable can take.

  For instance, it is not possible to have a herd size of 1.7. Other examples of discrete variables are litter size, household size etc.
- When the data are continuous, it is necessary to create an artificial break for each class interval *because there are no definite breaks in the possible values a variable can theoretically take.*

  Continuous data may be presented in such intervals as:

  1 – 4.99

  5 – 9.99 etc

Examples of continuous data intervals are liveweight, feed intake and height. In practice, continuous variables are measured in discrete units such as grams, centimetres etc.

Note: For practical purposes, most survey data are treated as discrete.

- The number of intervals used will depend on the range and the amount of the data (number of observations), but it is common to use between 7 and 15 intervals.

RELATIVE AND CUMULATIVE FREQUENCY DISTRIBUTION TABLES. The frequency distribution table is commonly expanded to include additional information about the percentage and the cumulative percentage of sample units in each class interval. The percentage in each class interval is known as the 'relative frequency' and the cumulative percentage as the 'relative cumulative frequency'. Table 4 shows how these measures could be added to Table 2 to improve the interpretive value of the data.

Table 4. Frequency of cattle holdings in area A.

(A) Category	(B) Frequency (No.)	(C) Relative frequency (%)	(D) Cumulative frequency (No.)	(E) Relative cumulative frequency (%)
0	13	18.6	13	18.6
1–5	34	48.6	47	67.1
6–10	10	14.3	57	81.4
11–15	5	7.1	62	88.6
16–20	5	7.1	67	95.7
21–25	3	4.3	70	100.0
Total	70	100.0		(n = 70)

Whether all the columns shown in Table 4 are actually presented will depend on the purpose of the frequency table, as any of the columns B to E can be calculated from any of the others. Cumulative frequencies are simply the total of the frequencies up to that point, and are only relevant when the data categories have a sensible order. Relative frequencies are just the frequency in a category expressed as a percentage of the total number in the sample.

For instance, for the category 6–10 the cumulative frequency is 57 (= 13 + 34 + 10), i.e. there are 57 households with 10 or fewer cattle. Expressing this as a percentage of the sample size (n = 70) gives 81.4%.

Relative figures can be used to make comparisons between samples of different ..izes. They also tell us quite a lot about the sample itself.

Example: Table 4 tells us that in area A:

- about 20% of households in the sample hold no cattle at all
- about 80% hold 10 or fewer head of cattle, and
- about 11% hold more than 15 head of cattle.

In livestock systems research it may also be important to examine equity relationships. For this purpose, data on livestock holdings (such as those given in Tables 1–4) can be used, since in many African rural areas, wealth tends to be closely correlated to the number of stock owned or held. Table 5 shows that:

- about 19% of households (column D) in area A hold no cattle at all
- 67% of households (column D) hold 5 or fewer head of cattle. As a whole, this group holds only one quarter of the cattle in the area (column G), and
- 14 % of households hold about half of the cattle in the area (columns D and G).

From this information, we might conclude that cattle holdings are not equitably distributed within the area, i.e. relatively few of the households own a large proportion of the cattle while a substantial proportion hold none. Inequitable distribution of livestock holdings is fairly common in Africa, and similar distributions are found for income received and/or assets held (Module 2, Section 1). Households with larger livestock holdings also tend to have greater access to resources such as water points (Module 10), but policies which aim to correct inequities of this nature are generally fraught with problems (Module 10, Part B).

Table 5. The inter-household equity of livestock holdings in area A.

(A) Number of cattle	(B) Frequency (No. hhlds)	(C) Relative frequency (% hhlds)	(D) Cumulative relative frequency (% hhlds)	(E) Number of cattle held/category (A x B)	(F) Percent of cattle held/category (%)	(G) Cumulative percentage of cattle held/category (%)
0	13	18.6	18.6	0	0	0
1	10	14.3	32.9	10	2.5	2.5
2	4	5.7	38.6	8	2.0	4.5
3	5	7.1	45.7	15	3.8	8.3
4	8	11.4	57.1	32	8.1	16.4
5	7	10.0	67.1	35	8.8	25.2
6	2	2.9	70.0	12	3.0	28.2
7	3	4.3	74.3	21	5.3	33.5
8	2	2.9	77.1	16	4.0	37.5
9	2	2.9	80.0	18	4.5	42.0
10	1	1.4	81.4	10	2.5	44.5
11	1	1.4	82.9	11	2.8	47.3
12	2	2.9	85.7	24	6.0	53.3
13	1	1.4	87.1	13	3.3	56.3
15	1	1.4	88.6	15	3.8	60.4
16	2	2.9	91.4	32	8.1	68.5
19	1	1.4	92.9	19	4.8	73.3
20	2	2.9	95.7	40	10.1	83.4
21	1	1.4	97.1	21	5.3	88.4
22	1	1.4	98.6	22	5.5	94.2
23	1	1.4	100.0	23	5.8	100.0
Total	70	100.0		397	100.0	

Notes: Columns A–D are essentially the same as columns A–D in Table 4, except that the number of categories has been increased. Column E provides information about the total number of cattle per category. The total of column E shows that there are 397 cattle covered by the study. Columns F and G give the relevant percentages of cattle, based on a total of 397 head.

hhld = household.

The large quantity of data contained in Table 5 makes it difficult to relate the information between columns. Alternative methods of data presentation which give the same information more concisely and in a simpler form may therefore be preferred, such as the Lorenz curve and other graphs.

TABLES WITH MORE THAN ONE CLASSIFICATION. All the tables given so far have been concerned with only one classification (herd size) and are largely descriptive in the function they perform. However, in livestock systems research it is often useful to consider two or three classifications simultaneously in order to examine the relationships which might exist between them. To facilitate this, data can be presented in simple two- or three-way cross-classification tables.

For instance, herd size and household size may both be recorded for a sample of households and presented in a two-way table. Such a table would have one 'cell' for each combination of herd size and household size (e.g. one cell might be households of five adults with 6–10 head of cattle). Each cell could contain either the number of households or the mean of some other variable, such as number of cattle sold.

Example:

Table 6. Average numbers of goats by category of cattle holder and communal area, North Gwanda District, Zimbabwe, 1982.

	Communal area	
Category	A	B
Cattle holders	4.7	6.7
Non-holders of cattle	2.2	3.6

Source: Zimbabwe Government (1982).

There are two classifications in this table — cattle holding and communal area — and each has two categories, giving a table with four cells. The information given suggests that, on average, cattle-holding households hold more goats than non-holders. Also, farmers in area B have more goats than those in area A.

The statistical methods which can be used to test the significance of differences such as those shown in Table 6 are discussed briefly in Part C below and in many statistics textbooks.

Summary

Some hints to make tables easier to interpret:

- Keep tables as simple as possible. Do not include irrelevant rows and columns.
- Clearly label the rows and columns.
- Do not use too many digits for presenting numbers. If necessary, change the units of measurements and round the number of decimal places.[1]

  For instance, 12,647 g should be converted to 12.647 kg and then rounded to 12.6 or even 13.0 kg, depending on the context.
- If there is no natural order for the rows, sort the rows in the order of the most important column in the table, so that the first row of that column has the highest value and the last row the lowest.

Continued...

1 This advice applies to data presented in a tabular or graphic form, not to data stored for further analysis.

Summary continued...

- Organise table to facilitate visual comparisons between rows, which are easier to make than comparisons between columns.

  For instance, in Table 6 it is (slightly) easier to compare cattle holders with non-cattle holders than it is to compare areas A and B.

For more details on organisation of tables see the first few chapters of Ehrenberg (1975).

Graphs and charts

The types of graphs and charts most commonly used to present statistical data in livestock systems research are:

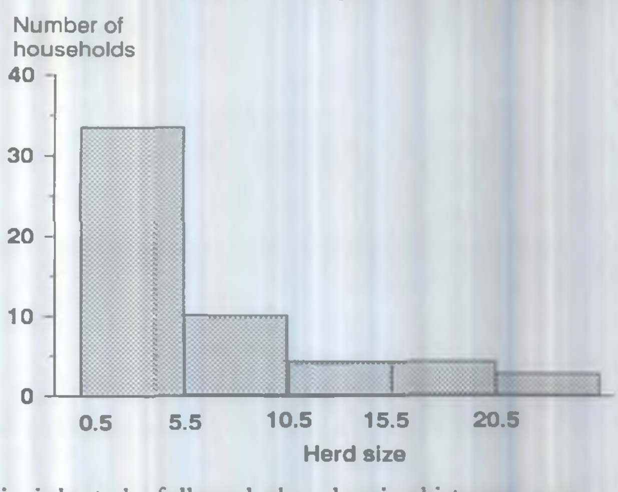
- histogram
- cumulative frequency curve
- Lorenz curve
- bar chart, and
- two-dimensional graph or scatterplot.

Each of these graphs and charts is briefly described below. Their derivations and use are described in detail in most of the elementary statistical textbooks cited in the reference list.

Histogram

A histogram is the graphical equivalent of the frequency distribution table. Figure 1 is the histogram for the data given in Table 2 earlier, omitting the first category (zero cattle).

Figure 1. Herd size in area A for a sample of 57 cattle-owning households.



The principles to be followed when drawing histograms are:

- Dividing points for each interval are marked on the horizontal axis. Frequencies or relative frequencies are marked on the vertical axis.

- For discrete data, the midpoint between the upper and lower values of two adjacent intervals is used as the dividing point.

  For instance, in Table 2, the dividing point between intervals 5–10 and 11–15 is (10 + 11)/2 = 10.5. The determination of intervals for continuous data is discussed on page 256 of this module.

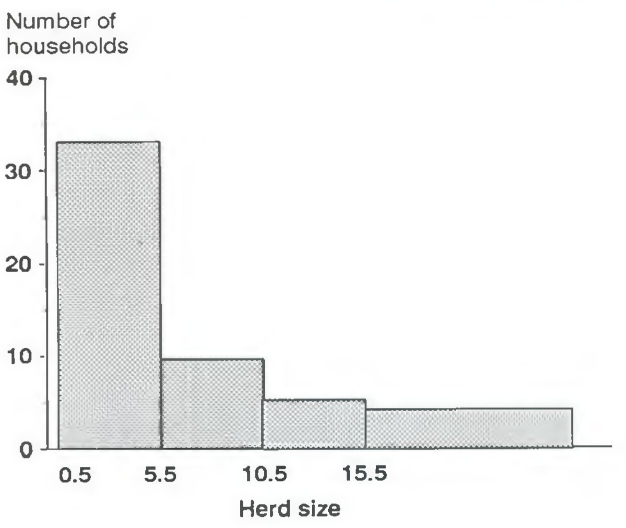
- The frequency per standard interval determines the height of each bar. This is to avoid distortion and is best explained by an example.

Example: In Table 2, all intervals except the first (zero cattle) are equal, having 5 units (cattle) in width. We can combine the last two categories (i.e. 16–20 and 21–25) to give an interval of 16–25 which is 10 units wide and contains 8 households (i.e. has a frequency of 8). This is equivalent to a frequency per standard interval of 4, which should be the height of its bar in the histogram, as shown in Figure 2.

The height of the bar for the combined 16–25 interval is the **average** height of the two bars in the previous histogram, rather than the total of their heights. Note that if we had used a bar height of 8 for the combined interval, the histogram would give a distorted picture.

To obtain the frequency for the combined interval from the graph, multiply the height of the bar (4) by the number of standard intervals contained in this larger interval (2). The answer is 8 which corresponds with the number of households in interval 16–25.

Figure 2. Redrawn version of Figure 1, combining categories 16–20 and 21–25 into a single category.



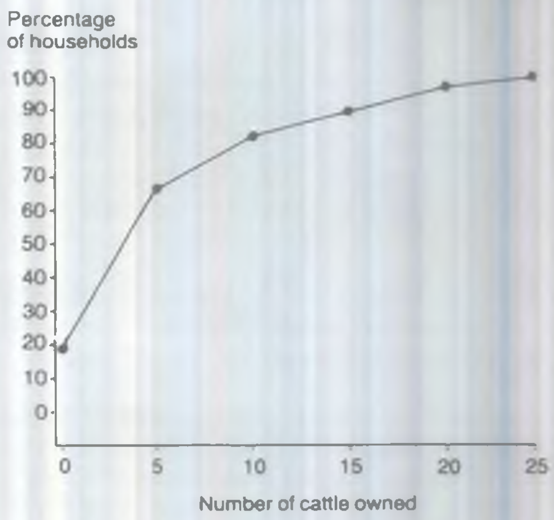
Cumulative frequency curve

The cumulative frequency data derived for herd size in Table 4 can be represented graphically, as shown in Figure 3 which relates the cumulative proportion of households holding cattle to the number of cattle held (herd size).

The figure can be interpreted by reading from the horizontal to the vertical axis. For instance, for a herd size 10, the corresponding cumulative frequency figure is approximately 80%, which means that about 80% of households hold 10 or fewer head of cattle. Table 4 gives the exact answer of 81.4%.

Note: Graphs give a very good visual impression, but are difficult to read accurately. Tables, on the other hand, give much better accuracy.

Figure 3. Cumulative relative frequency curve of herd sizes for 70 sample households in area A.

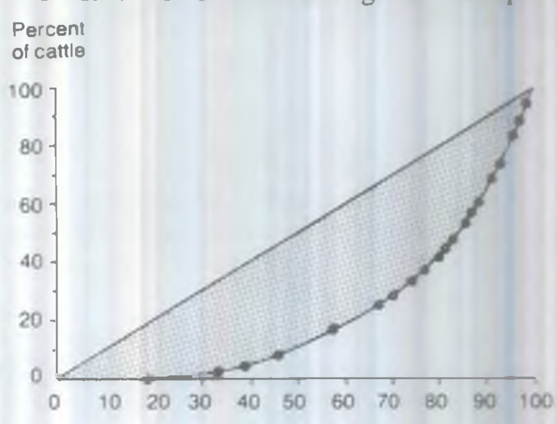


Lorenz curve

Information on equity relationships, such as that given in Table 5, is more easily interpreted when presented graphically. This is done in Figure 4 where a Lorenz curve is used to relate the proportion of households (column D, Table 5) to the proportion of cattle held (column G, Table 5).

The plotted Lorenz curve in Figure 4 is compared with a 45° line drawn from the origin. If the plotted curve were to follow this line exactly, a situation of perfect equity with respect to cattle holdings would exist in the area, i.e. 10% of the cattle would be held by 10% of the households, 20% of the cattle would be held by 20% of the households etc. The more bowed the curve from the 45° line, the more inequitable the situation. The magnitude of the bow is normally indicated by dotting in the area between the 45° line and the Lorenz curve, as shown. The graph is interpreted by reading from the horizontal to the vertical axis or vice versa.

Figure 4. The distribution of cattle holdings for 70 sample households in area A.



For instance, in Figure 4, 60% of the households with the smallest herds hold approximately 20% of the cattle, while 80% hold roughly 40% of the cattle etc. Note that Figure 4 relates cattle ownership to all households in the sample. If we were interested in the equity of holdings for only those households which own cattle, a different curve would have to be drawn, omitting the 13 households without cattle.

Bar charts

Frequency data are not always graphed by using a histogram. This is particularly so when the data have only a limited range of values and, therefore, grouping data into fewer classes is likely to be both undesirable and unnecessary. Table 7 gives an example of this kind of data.

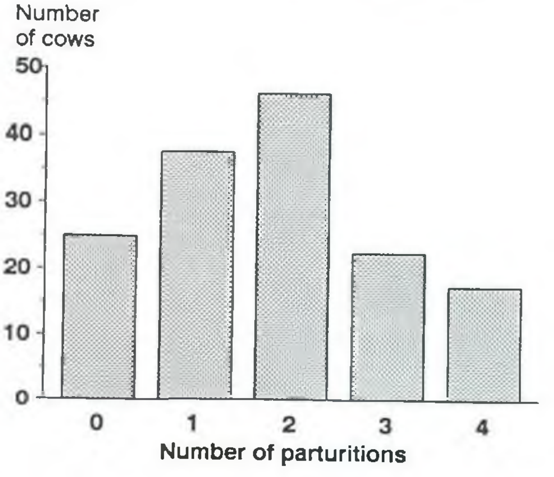
The data in Table 7 fall naturally into a few clearly defined or discrete classes and further refinement is unnecessary. Such data can be presented by using a bar chart or left in tabular form.

Table 7. Frequency of parturitions in a herd of 153 cows.

Number of parturitions	Number of cows	Relative frequency (%)	Cumulative relative frequency (%)
0	26	17	17
1	38	25	42
2	47	31	73
3	24	15	88
4	18	12	100
Total	153	100	

When a bar chart is used (Figure 5), data shown on the horizontal axis can only take discrete values. All bars are of exactly the same width and are separated from one another to emphasise the fact that the data can only take on the values actually marked on the horizontal axis. The height of each bar corresponds to the (relative) frequency of the value it represents. Alternatively, it could correspond to the mean (or total) of another variable of interest.

Figure 5. Bar chart of parturition data from Table 7.



When the categories in question have a natural sequence (as in Figure 5, from 0 to 4), they should be arranged in that order on the horizontal axis. If they do not have a natural order, it is often useful to arrange them in such a manner that the bars are in descending order of height, i.e. the first category is the one with the highest bar and the last with the shortest bar. Alternatively, if the frequency of occurrence of different diseases is being plotted, for instance, the most common disease could be shown as the first bar and the rarest disease as the last bar.

Line graphs and scatterplots

Graphs derived by plotting one variable against another are commonly used in economic and scientific literature to examine relationships between two variables. Figure 6 gives an example of a time series line graph derived from data in Table 8 and showing the volume of cattle sales over time. Since the amount of data is quite small, and we would expect a continuous trend, the plotted points are joined by a line.

Table 8. Cattle sales and annual rainfall in the Kajiado District, Kenya, 1966–76.

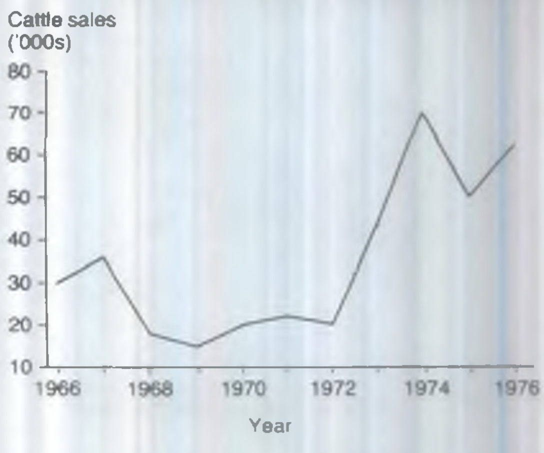
	Year										
	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
Sales ('000)	30	36	18	15	20	22	20	43	70	50	62
Rainfall (mm)	450	450	550	450	600	500	450	450	600	500	150

Source: Meadows and White (1979).

Figure 6 shows that the volume of sales increased dramatically from 1972 to 1974. Figure 7 is a modified version of Figure 6, with the rainfall data from Table 8 plotted against cattle sales on the same frame. This allows a comparison of the trend in sales with the trend in annual rainfall.

By comparing several variables at once in graphs of this kind, cause and effect relationships can sometimes be tentatively hypothesised and then subjected to further testing by the statistical methods outlined in Part B of this module.

Figure 6. Annual cattle sales in the Kajiado District, Kenya, 1966–76.



With time series data, relationships plotted over a relatively short time period may lead to spurious conclusions. There is a large subjective element in the interpretation of such limited data; apparently strong relationships in the short term may prove to be insignificant in the long term.

The time period used in Figure 7 is probably too short to draw useful conclusions about the relationship between annual rainfall and annual cattle sales in the Kajiado District of Kenya. Another, possibly more useful, way of examining such relationships is to draw a scatterplot of sales versus rainfall, as was done in Figure 8.

Figure 7. Annual cattle sales and rainfall, Kajiado District, Kenya, 1966–76.

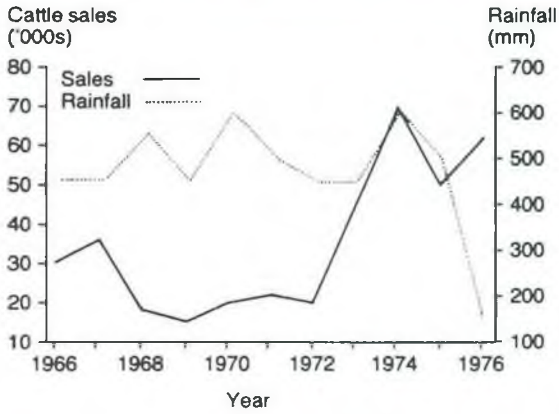
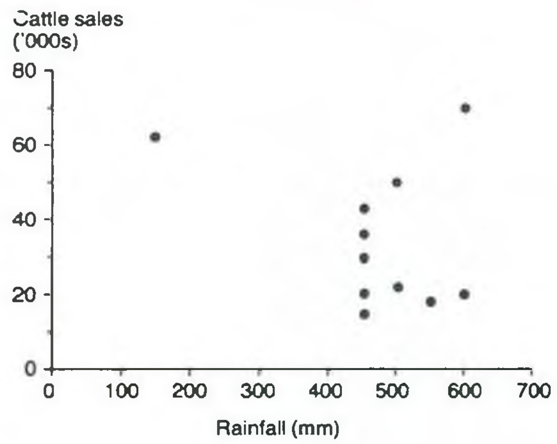


Figure 8. Plot of cattle sales against rainfall.[1]



[1] Rainfall data taken from Table 8.

In a scatterplot, the points are not joined by lines, and it can be seen from the figure that a line graph would be totally unsuitable. Drawing graphs like this can be a useful starting point in the analysis of relationships in livestock systems research.

Summary statistics

In Tables 2 and 4, frequency distribution was used to describe the distribution of cattle holdings in area A. The following discussion concentrates on statistical measures commonly used to concisely characterise a frequency distribution or even substitute for it. Such summary statistics may be classified into two groups:

- measures of location (or averages), and
- measures of dispersion (or variability).

Measures of location

If a frequency distribution can be represented by some central value, different distributions can be compared by comparing these values instead of the distributions themselves. Three measures of central location are commonly used to describe frequency distributions. They are:

- **the arithmetic mean**
- **the median**, and
- **the mode**.

Each is defined briefly below. Examples are given based on the data listed in Table 1, and the relative merits of each measure are also discussed. All elementary statistical texts discuss these measures in greater detail.

THE ARITHMETIC MEAN. For a variable X with values $x_1, x_2, x_3 \ldots x_n$, the arithmetic mean is defined as:

$$\textit{Arithmetic mean } (\bar{x}) = \frac{(x_1 + x_2 + x_3 \ldots\ldots + x_n)}{n}$$

which is normauy abbreviated as:

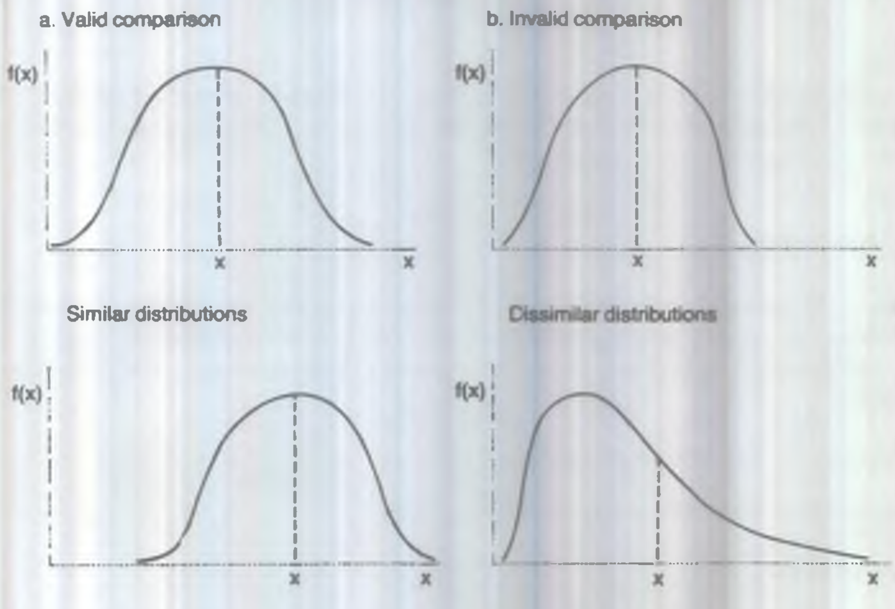
$$\bar{x} = \sum \frac{X_i}{n}$$

where the $\sum$ means the 'sum of '.

The arithmetic mean is normally called the 'average' or the 'mean'. The mean for the data in Table 1 is 5.67.

Let us now assume that a survey was conducted in an adjacent area (Y) and that the distribution of cattle holdings was found to be similar to that in area A. In such a case, a comparison of the two distributions on the basis of the mean alone is valid and meaningful (Figure 9a), but not comprehensive in the information it provides. If the distributions of cattle holdings in areas A and Y were not similar, comparisons on the basis of the mean alone would be less reliable (Figure 9b), because the mean (or any single summary statistic) would omit useful information.

Figure 9. Comparisons of distributions on the basis of the arithmetic mean.



The mean is affected by all observed values in the data set. When the distribution is 'skewed', extreme values will have a large influence on the calculation.

Example: Take the data set in Table 1 and assume that the two households with a recorded cattle holding of 20 animals, in fact, have 50 animals each instead. The mean for the sample is now 6.53 animals, not 5.67, which means that, by including the extreme values, it has increased by almost one animal per household.

THE MEDIAN. When the distribution has extreme values and is skewed, the median is generally a more appropriate measure of central location than the mean.

The median is the value that divides the frequency distribution exactly in half, i.e. 50% of the observations are above the median and 50% are below. In terms of Table 1 this means that half the households will hold less than the median number of cattle and half will have more. Starting from the lowest value and working upwards it will be the value which lies between the 35th and 36th households in the sequence, i.e. 4. Such a value is relatively simple to determine when a complete listing of data is available.

Note that the median value is lower than the mean by approximately 1.7 animals per household. This is because the distribution is skewed to the right, and the mean is influenced by the large herd sizes more than the median. When the distribution is perfectly symmetrical, the two values are exactly the same.

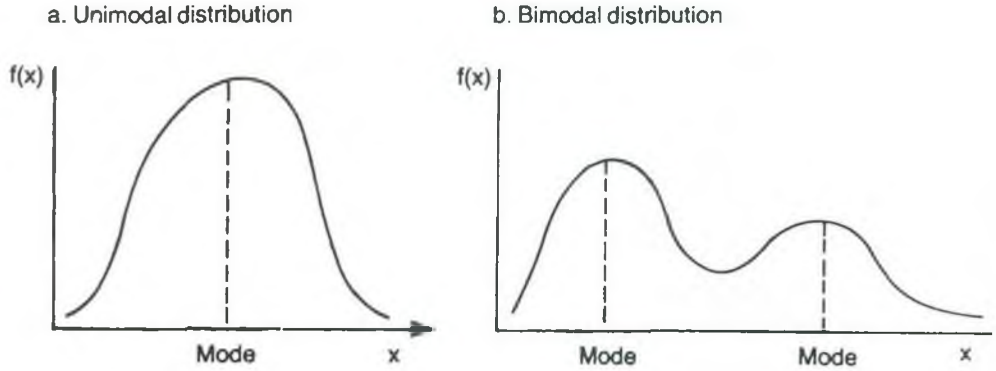
THE MODE. The mode of a frequency distribution is the value of the variable which occurs most frequently. If there is only one peak in the distribution, there is only one mode (which occurs at the peak) and the distribution is unimodal (Figure 10a).

For instance, in Table 5, which lists the frequencies corresponding to all cattle holdings, the mode occurs at 0 where the frequency is highest.

If there are two peaks, there are two modes and the distribution is said to be bimodal (Figure 10b).

For a unimodal distribution which is skewed to the right, the mode is always less than the mean and the median.

Figure 10. Unimodal and bimodal distributions.



Measures of dispersion

The mean, median and mode locate a distribution but provide no indication of the variation or the dispersion of the variable X (e.g. herd size). Two distributions may have the same mean (or median or mode), yet their values may be dispersed very differently. A measure of dispersion will therefore improve our understanding of the characteristics of the distribution. The measures of dispersion most commonly used are:

- **the range**
- **the variance**
- **the standard deviation, and**
- **the coefficient of variation.**

THE RANGE. The range is the span between the extreme values of the distribution. For Table 1, for instance, the range is from 0 – 23. The problem with the range is that we know nothing about the scatter of other values within the extreme limits, and that it is very sensitive to a single extreme value. Moreover, the range has few useful mathematical properties.

THE VARIANCE. Each value in a distribution deviates from the mean by an amount measured as:

$$Deviation = x_i - \bar{x}$$

where x_i represents the i^{th} value of the variable X (say herd size) and $\bar{x}$ is the mean value.

The magnitude of the deviation will depend on the characteristics of the distribution – the greater the variation, the greater the size of the deviation. The variance is calculated to provide a measure of the average deviation from the mean. Since some deviations are positive and some negative, the simple arithmetic mean of the deviations will always be zero. The way around this problem is to square all the deviations first, and then average them as follows:

$$Variance\ s^2 = \frac{\sum (x_i - \bar{x})2}{n - 1}$$

For simpler calculation, note that the term $\sum (x_i - \bar{x})^2$ - often referred to as the sum of squares, and abbreviated as ss - can be more easily obtained from the formula:

$$ss = \sum (x_i - \bar{x})^2 = \sum x_i^2 - \frac{(\sum x_i)^2}{n}$$

then, the variance $s^2 = ss/(n-1)$.

The variance is a very common measure and has useful mathematical properties, but, because it is measured in squared units, it is not very useful for presenting results.

THE STANDARD DEVIATION. To avoid the problem of unhelpful units of measurement for the variance, the standard deviation (abbreviated as SD or s) is often used. The standard deviation is the square root of the variance, and is measured in the same units as the original variable.

$$Standard\ deviation\ (s) = \sqrt{(variance)}$$

Many simple pocket calculators now have the facility to calculate the standard deviation for a set of data, and can save a lot of time.

> **WARNING: A number of calculators use a slightly different formula from the one given here. This difference may be important for small samples.**

THE COEFFICIENT OF VARIATION. The coefficient of variation (CV) expresses the standard deviation as a percentage of the mean, and is calculated as:

$$CV = 100 \times \frac{SD}{mean} = 100 \times \frac{s}{\bar{x}}$$

Care is needed when interpreting coefficients of variation, since a large coefficient of variation can be the result of either a large standard deviation or a small mean. Two distributions with the same standard deviation will have different coefficients of variation if their means are different.

Example: Table 9 gives offtake rates for a small sample of 10 cattle-holding households in a survey area. It also shows the variance and the standard deviation for the sample, which are calculated as follows:

$$\sum^{n=10} x_i = 44$$

$$x = \sum x_i / n = 44/10 = 4.4$$

The mean (4.4) is subtracted from the original data (column 2, Table 9) to give the deviations in the third column. The deviations are then squared to give the fourth column. The total of this column is:

$$ss = \sum (x_i - \bar{x})^2 = 74.4$$

Alternatively, ss can be calculated using $\sum x_i^2 = 268$ from the fifth column in Table 9 as:

$$ss = \sum x_i^2 - \frac{(\sum x_i)^2}{n} = 268 - \frac{44^2}{10} = 74.4$$

The variance s^2 is then $s^2 = ss/(n-1) = 74.4/9 = 8.27$.

The standard deviation $s = \sqrt{s^2} = \sqrt{8.27} = 2.88$

The coefficient of variation $CV = 100 \,.\, s / \bar{x} = 100 \times 2.88/4.4 = 65.5\%$

Table 9. Examples of calculations of variance and standard deviation.

Household (i)	Percentage offtake rate (x_i)	Deviation ($x_i - \bar{x}$)	Squared deviations ($x_i - \bar{x})^2$	$(x_i)^2$
1	1	-3.4	11.56	1
2	2	-2.4	5.76	4
3	3	-1.4	1.96	9
4	4	-0.4	0.16	16
5	6	+1.6	2.56	36
6	10	+5.6	31.36	100
7	3	-1.4	1.96	9
8	2	-2.4	5.76	4
9	5	+0.6	0.36	25
10	8	+3.6	12.96	64
Total $\sum$	44	0.0	74.40	268

Failure to account for the effects of auto-correlation can result in confidence intervals which are much narrower than they should be, and the results give an overly optimistic impression of the worth of a model because of the incorrect significance tests. More complicated statistical techniques than linear regression are needed to handle data with this problem.

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International Livestock Centre for Africa
PO Box 5689, Addis Ababa, Ethiopia

Tel: (251-1) 61-32-15 • Telex: 21207 ILCA ET • Telefax: (251-1) 61-18-92 • Cable: ILCAF/ADDIS ABABA

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