INTERNATIONAL
LIVESTOCK RESEARCH
INSTITUTE

Improving cattle for milk, meat and traction

ILRI Training Manual 4

International Livestock Research Institute

ILRI Training Manual 4

Improving cattle for milk, meat and traction

H. Ibrahim and E. Olaloku

ILRI
INTERNATIONAL LIVESTOCK RESEARCH INSTITUTE

International Livestock Research Institute
P.O. Box 30709, Nairobi, Kenya

ISBN 92–9146–081–8

Correct citation: Ibrahim H. and Olaloku E. 2000. *Improving cattle for milk, meat and traction*. ILRI Manual 4. ILRI (International Livestock Research Institute), Nairobi, Kenya. 135 pp.

Table of Contents

List of Tables

List of Figures

Foreword

The International Livestock Research Institute (ILRI) trains research scientists from national research systems (NARS) in sub-Saharan Africa. As part of this training, ILRI has conducted several training courses on improving cattle for meat, milk and traction. This manual is for young scientists who are actively involved in livestock research. The manual is designed for multiple users such as participants in ILRI and national research systems courses, and for individuals who desire to learn on their own.

Many individuals have contributed to the preparation of this manual. As a training materials specialist, Dr Habib Ibrahim wrote the first draft of the modules from the latest material available with ILRI's information unit. ILRI scientists then reviewed the modules. The manual in its entirety was internally reviewed by Dr Eb Olaloku and externally by Professor Margaret Wanyoike, Department of Animal Production, University of Nairobi.

This manual emphasises the integrated approach to research on cattle. The manual starts with describing cattle in various agro-ecological zones in sub-Saharan Africa with emphasis on the prevailing production systems. The user is then introduced to farming systems approaches to understand the needs of the smallholder farmer. The core of the manual is knowledge and skills in reproduction, biometry, economics and communication. The manual ends by stressing the importance of transfer of research results to farmers and the role of researchers in this vital process.

Even though this manual was written to stand on its own, it is part of ILRI's series of training materials. The material includes audio-tutorial modules, slide series and posters. We view them as complementary to each other.

ILRI is grateful to the European Union for funding the production of this manual through its financial support to the Cattle Research Network (CARNET).

Dr M.E. Smalley
Programme Co-ordinator
Strengthening Partnerships for Livestock Research
ILRI

About the manual

This manual is part of ILRI's effort to provide training materials for use in courses or self-teaching. The manual aims at providing an overview of improving cattle for meat, milk and traction. The manual is intended for young scientists in sub-Saharan Africa.

The modules were designed to provide the user with performance objectives to facilitate learning. The body includes text, illustrations and reference and reading materials. Exercises are placed at the end of each module to stimulate the user for further learning. Topics that further illustrate the main concepts in the body of the module are placed in boxes.

Many individuals have contributed to the preparation of this manual. Dr Habib Ibrahim prepared the modules from published knowledge on cattle with emphasis on publications from sub-Saharan Africa. ILRI scientists reviewed the manuscripts; the entire document was reviewed internally by Dr Eb Olaloku and externally by Professor Margaret M. Wanyoike. ILRI staff contributed to the modules as follows:

- Dr E. Olaloku reviewed modules 1 and 2
- Dr R. Eley reviewed module 3
- Dr N. Umunna reviewed module 4
- Dr B. Shapiro reviewed module 5
- Dr J. Rowlands wrote and reviewed module 6
- Mr P. Neate and Ms A. Nyamu reviewed module 7
- Dr S. Lebbie reviewed module 8
- Drs M. Mohamed-Saleem and M. Jabbar reviewed module 9.

Scientists in NARS are encouraged to use the manual in their training courses. It is hoped that users find the manual useful.

Habib Ibrahim
Training Materials Specialist
ILRI

Module 1: An overview of cattle production systems in sub-Saharan Africa

1.1 Performance objectives

Module 1 is intended to enable you to:

1. Describe the effect of agro-ecological zones in sub-Saharan Africa on cattle production.
2. Describe the major cattle production systems in sub-Saharan Africa.
3. Describe the distribution of cattle in sub-Saharan Africa by zone and region.
4. List constraints to productivity of cattle in sub-Saharan Africa.

1.2 Agro-ecological zones in sub-Saharan Africa

Sub-Saharan Africa (SSA) can be divided into five agro-ecological zones: arid, semi-arid, subhumid, humid and highlands. These zones vary in climate, natural resources and human and livestock population density. This classification is based on amount and distribution of rainfall, effect of altitude on temperature and length of annual plant growing period. The parameters defining the zones (rainfall and plant growth days) and percentage area across the different regions of SSA are shown in Table 1.1.

Table 1.1. *Agro-ecological zones of sub-Saharan Africa.*

Zone	Definition[1]	Rainfall range (mm)	Area (%) West Africa	Central Africa	East Africa	Southern Africa	Area of zone (%)	Total area ($\times 10^6$ km^2)
Arid	<90 pgd	0–500	54	1	52	20	36	7.7
Semi-arid	90–180 pgd	500–1000	20	7	18	34	18	4.0
Subhumid	180–270 pgd	1000–1500	16	29	16	38	22	4.8
Humid	>270 pgd	1500+	10	59	2	7	19	4.1
Highlands[2]	<20°C	n.a.	0	4	12	1	5	1.0
Total			100	100	100	100	100	21.6
Total area ($\times 10^6$ km^2)			7.3	5.3	5.8	3.2		

n.a. = not available.
1. pgd = plant growth days.
2. Defined as areas within the semi-arid, subhumid and humid zones where the mean daily temperature during the growing period is less than 20°C.

Source: ILCA (1987, after Jahnke 1982).

1.2.1 Arid zone

The arid zone receives 0 to 500 mm of rainfall annually capable of sustaining plant life for less than 90 plant growth days (Table 1.1). The low amount of rainfall and its erratic distribution prevents sustainable cropping in most years; some cropping takes place in oases or irrigated areas. Plant cover consists of short annual grasses, legumes, scattered shrubs and trees. Farmers use most of the trees and shrubs for fuel. The arid zone occupies 36% of the land area of SSA, most of which is in West and East Africa. Opportunities for livestock development are limited but existing techniques could be improved upon if not to increase productivity, to at least sustain it.

1.2.2 Semi-arid zone

The semi-arid zone receives 500 to 1000 mm of rainfall annually which sustains 90 to 180 plant growing days. The lower rainfall areas of this zone are used for grazing. Cropping and crop-livestock systems dominate the areas with higher rainfall. Farmers grow millet, sorghum, groundnut, maize and cowpeas. This zone occupies 18% of the land area of SSA and is found in all regions except central Africa.

1.2.3 Subhumid zone

The subhumid zone receives 1000 to 1500 mm of rain annually which sustains plants for 180 to 270 plant growing days. Food and cash crops are grown including cassava, yams, maize, fruits, vegetables, rice, millet, groundnut, cowpeas and cotton. From these crops, products such as cottonseed cakes and the residues of the crops are available as feed for livestock. In some areas of this zone farmers grow soybean and leguminous forage crops. This zone occupies 22% of SSA, mainly in southern and central Africa.

1.2.4 Humid zone

The humid zone receives more than 1500 mm of rainfall annually which sustains plants for 270 to 365 plant growing days. This zone consists of rain forest and derived savannahs. The soils have high levels of iron and aluminium and low levels of phosphorous. The organic matter content is therefore low, and the soils are fragile and easily degraded when the vegetative cover is lost. The zone occupies 19% of SSA mostly in central and West Africa. This zone has limited potential for livestock development, particularly because of the threat of the trypanosomosis-transmitting tsetse fly.

1.2.5 Highlands zone

The highlands zone occupies areas above 1500 m altitude that have a mean daily temperature of less than 20°C. This zone represents 5% of the land area of SSA, most of which is in eastern Africa; half of this zone is in Ethiopia. The soils are deep fertile Vertisols and Nitosols. The zone receives bimodal rainfall (>1000 mm annually) and there are two growing seasons. Farmers grow forages and animal traction assumes more importance as the population pressure encourages crop-livestock integration. The cool highlands are a high potential area for crop-livestock integration.

1.3 Growth rate of population

1.3.1 Population growth and the food problem in Africa

The human population in SSA currently is increasing by 3.1% a year (Table 1.2). The projections (Table 1.2) indicate a decrease in population growth rate after the year 2010 but the growth rate will still be relatively high by the year 2025.

Table 1.2. *Population projections for sub-Saharan Africa, 1990–2025.*

Year	Population ($\times10^6$)	Annual growth rate[1] (%)
1990	498	-
1995	580	3.1
2000	676	3.1
2005	784	3.0
2010	902	2.8
2015	1028	2.6
2020	1159	2.4
2025	1294	2.2

1. Five-year periods (1990–1995, 1995–2000, 2000–2005, 2005–2010, 2010–2015, 2015–2020, 2020–2025).

The increase in urban population is correlated with the general increase in the population of SSA. The movement of people from rural areas to urban centres will increase the demand for food of animal origin. In the year 2025 it is projected that the demand for meat and milk will exceed 19 and 43 million tonnes, respectively. This level of production will require a 4% annual rate of increase of livestock productivity compared with the estimated current rate of 2.5%. These projections show that cattle are expected to provide 60% of meat requirements and almost 100% of milk requirements. In spite of the many constraints facing livestock production, the 4% rate of productivity can be achieved through investment in research and development. Governments generally favour research on food and cash crops. They consider there is enough meat and livestock products to meet the current demand. Population pressures on agricultural land in SSA will also drive agriculture toward intensification and hence the evolution of mixed crop–livestock systems.

Livestock resources

Livestock populations and species mix vary across the agro-ecological zones of SSA (Table 1.3). According to FAO (1998) statistics SSA has 217 million cattle, 233 million sheep, 204 million goats, 14 million camels, 22 million pigs, 14.9 million donkeys, 4.9 million horses, 1.3 million mules and 1.1 billion chickens.

Table 1.3. *Distribution (%) of domestic ruminant livestock by agroecological zone and geographical regions in sub-Saharan Africa.*

Location	Cattle	Sheep	Goats	Camels	All domestic ruminants
Arid	20.7	33.7	38.2	100.0	29.8
Semi-arid	30.6	22.9	26.3	0.0	7.1
Subhumid	22.7	14.4	16.5	0.0	19.6
Humid	6.1	8.3	9.4	0.0	6.1
Highland	19.9	20.8	9.6	0.0	17.4
Total	100.0	100.0	100.0	100.0	100.0
West Africa	24.8	34.2	42.3	15.2	26.3
Central Africa	6.6	4.1	6.4	0.0	5.8
East Africa	54.1	59.5	46.2	84.8	56.3
Southern Africa	14.5	7.2	5.2	0.0	11.6
Total	100.0	100.0	100.0	100.0	100.0

In the drier areas, which are not suited for crop production, the rangeland is used for livestock. Livestock populations are therefore higher in the arid and semi-arid zones than in the others (Table 1.4). The humid zone and the wetter parts of the subhumid zone do not sustain large populations of livestock due to the presence of the tsetse fly. Animals in the cool highlands are less threatened by diseases and thus have a high potential production. In this zone and in the marginal area between the wet and dry zones mixed crop–livestock systems have evolved in response to high population pressure.

Table 1.4. *Ruminant density and carrying capacity in agro-ecological zones in sub-Saharan Africa.*

Zone	Ruminant density (TLU/person)[1]	Carrying capacity (ha/TLU)
Arid	1.00	10–30*
Semi-arid	0.35	4–8
Subhumid	0.25	3–6
Humid	0.10	-
Highlands	0.40	2.5–3.5

1. TLU = equivalent of an animal of 250 kg live weight.
* The carrying capacity is 30 for areas with <250 mm annual rainfall.

1.4 Cattle production systems in SSA

Livestock production systems can be divided into two broad types in SSA: (i) traditional production systems and (ii) improved production systems. They can be distinguished mainly by the three production factors, land, labour and capital.

1.4.1 Traditional production systems

The traditional type has two main production systems, namely pastoral and agropastoral.

Pastoralist system

In the pastoralist system, relatively large herds of cattle are grazed on communal and public land. Due to seasonal scarcity of feed and water cattle trek over long distances. In this system, cattle owners acquire minimal land holdings at the home base. In West Africa the home base is where the family stays. In this system a wet herd for milk is kept at the home base and it is the responsibility of women to market the milk and use the money to purchase family needs. The women also grow cereal crops for domestic consumption and use the crop residues to feed the wet herd. The dry herd travels long distances sometimes up to 400 km. Pastoralists are unable to settle and take advantage of available improved production technology. It is estimated that up to 70–80% of Africa's cattle population is within this system.

Agropastoralist production system

Agropastoralists own sizable pieces of land and practise integrated crop–livestock production. In this system, crop residues are utilised when feed is scarce but nutritional inadequacies remain. Transfer of technology is not easy and, in spite of this, in a few countries farmers in this system adopted improved technologies. For example addition of urea to crop residues was adopted in West Africa. Productivity nevertheless is below potential because animals are fed at below the optimum level. Agropastoralist and pastoralist production systems produce about 70% of the milk and meat in SSA. The agropastoral system is a considerable improvement over the pastoralist production systems. Increasing pressure on land results in more agropastoralists.

1.4.2 Improved production systems

Production systems in this category are characterised by high inputs. The production systems are market oriented and farmers adopt improved technology to optimise productivity. These systems are increasingly popular in eastern and southern Africa. A good example is milk production in Kenya.

The production systems are subdivided into: intensive crop–livestock smallholder systems, peri-urban production systems and semi-intensive medium- and large-scale systems.

Intensive crop–livestock smallholder systems

Producers usually own less than 10 cows and about 2–4 ha of land with intensive crop–livestock production. In these systems, farmers adapt and/or adopt available production technology. The systems have been successfully practised in Kenya in recent years, where approximately 80% of milk production (over 2.8 billion litres) comes from these systems. Zero grazing in Kenya is a system where the producers own 1 to 5 cows and an average 2 ha of land. Farmers in the zero-grazing system produce forage such as Napier grass in a cut-and-carry system. Generally, crossbred or high grade exotic cattle are used. In these systems farmers maintain high levels of management including animal health care and good observation of the oestrous cycle leading to high reproductive efficiency.

Peri-urban production systems

In peri-urban production systems herds are located within a 40–60 km radius of major cities. The system is located near highly populated urban centres where the producers have easy access to consumers. This production system is market oriented where the producers have adequate resources and have access to credit to acquire inputs such as feed supplements, veterinary inputs and improved genotypes. In many cases marketing is organised around co-operative societies.

The system is sedentary on minimum land where producers cut-and-carry feed for the animals. Peri-urban production systems are popular in the eastern African highlands and in West Africa. Usually cattle are crossbred but producers in West Africa may also use indigenous breeds of zebu cattle selected by owners for high productivity [see Box 1.1].

Box 1.1. Peri-urban production system in sub-Saharan Africa

Dairy in sub-Saharan Africa

The urban population in sub-Saharan Africa (SSA) is growing rapidly. This growth is favourable for dairy production. Systems with dairy components offer income generating opportunities because:

- there is unmet and growing demand for dairy products due to rapid population growth and increased urbanisation
- elasticity for livestock products is higher than for cereals
- global dairy prices are expected to increase.

Why is peri-urban dairy an attractive enterprise?

- smallholder units are labour and management intensive
- dairying is highly profitable and this makes it easy for smallholders to adopt new technologies
- it is located close to the areas where demand is high.

Peri-urban dairy systems

Peri-urban systems, as described in this module, occur around urban areas where the demand for dairy products is high. The main features of peri-urban dairy systems:

- composed of smallholder dairy producers
- main sources of feed are crop residues, cultivated fodder and agro-industrial by-products
- milk is often sold directly to the consumers and is the main source of cash for smallholder farmers
- many smallholder producers use relatively intensive stall-feeding technology in zero- or semi-zero-grazing systems
- high grade dairy cattle can be used, e.g. in the highlands in Kenya
- farm-grown fodder and supplementation can be used by many farmers, e.g. in the highlands in Kenya
- these systems exist in highlands and subhumid agro-ecological zones and in the semi-arid zones where fodder can be grown under irrigation; they exist also in the humid zone but require strict control of tsetse.

Features of an average peri-urban unit in SSA:

- Priority of the farmer: sale of milk
- Farmer's attitude: interested in cash income
- Type of enterprise: market oriented
- Yield of milk per cow per day: 5–15 kg milk/day
- Average daily surplus of milk per farm: 5–30 kg
- Inputs: concentrates, roughage, credit, extension, veterinary services, training, breeding services.

cont...

Box 1.1 cont...

Constraints facing peri-urban dairy systems in SSA

Development of peri-urban systems in SSA faces the following constraints:

1. Feed constraints
   - Feed quality is low especially during the dry season. Native pastures and crop residues are still the main feeds. Agro-industrial by-products are often scarce and whatever is available is poorly utilised.
   - Quantity of the feed is inadequate.
2. Health constraints
   - Soil-borne bacterial diseases, e.g. anthrax
   - Infectious reproductive tract diseases, e.g. brucellosis
   - Diarrhoea and pneumonia of the newborn
   - Mastitis
3. Genotype constraints
   - Indigenous cattle genotypes in SSA have been selected for adaptation to the enviornment rather than milk productivity.
4. Management constraints
   - Traditional management methods of stock often lead to low productivity. Technical support is also often lacking or inadequate.
5. Policy constraints
   - Exchange rate distortions
   - Trade restrictions
   - Marketing

Examples of successful peri-urban dairy systems in SSA

Successful peri-urban systems have evolved in many parts of SSA, including the larger Sahelian towns (e.g. Bamako), Ethiopian highlands, Kenyan highlands and humid West Africa (e.g. Accra). The Kenyan story will be used as an example to illustrate the features of peri-urban dairy systems (Brokken and Senait Seyoum 1992).

Kenya

The story of peri-urban dairy development in Kenya is a good example of what is needed to promote the system and sustain its productivity. The system which evolved due to high population pressure and urbanisation, has the following features:

- Smallholder dairy systems in Kenya offered higher financial returns than other activities in peri-urban areas. Milk and milk products rank sixth among agricultural products that earn profit.
- Smallholder dairy farmers produce 80% of the national milk output.
- The systems use crossbred or pure bred cattle. It is estimated that one out of every six smallholders owns crossbred cattle.

The peri-urban smallholder dairy farmers mostly use intensive stall-feeding technology in zero- or semi-zero-grazing operations. Farm-produced fodder is often used in these systems. The average herd size is 2 lactating cows on about 1.5 ha of land. The farming system usually includes small areas for cash crops (coffee or tea), small areas for food crops (sweet potatoes, maize and beans) and areas for Napier (elephant) grass for cut-and-carry stall feeding.

Interventions by public institutions have played a crucial role in the development of peri-urban dairy systems in Kenya.

The role for research

Issues that need to be addressed by research to solve the constraints faced by peri-urban dairy systems are:

- to maximise the yields and energy contents of feeds
- to develop/formulate nutritionally balanced diets
- to assess conventional and unconventional feed resources
- to determine feed enhancement and conservation techniques
- to study patterns (epidemiology) of diseases of economic importance related to intensification
- to study dairy policy issues such as intra-household resource allocation, income distribution and impact of policy reform on the supply and demand for livestock health services.

Semi-intensive medium- and large-scale systems

The semi-intensive medium- and large-scale production systems started with attempts of many governments to benefit from economy of scale. These systems usually had high input operations and were run with public funds. The schemes imported exotic breeds of cattle. In most cases they failed because of poor management. Similar operations in the private sector succeeded. These production systems are characterised by application of high levels of inputs, access to credit, detailed record keeping, monitoring animal productivity and profitability. When run efficiently, they benefited from economy of scale. Examples can be seen in private farms in Kenya, Zimbabwe and South Africa.

1.4.3 Improved systems versus traditional systems

Productivity is higher in the improved systems due to:

- improved crossbred, grade or exotic genotypes
- investing in forage and feed production thus ensuring adequate nutrition
- adopting many improved technologies (including better animal health care and management to improve reproductive efficiency) which can increase productivity three- to fourfold compared with traditional systems
- giving attention to hygienic milk production and reduced wastage through proper handling.

1.5 Constraints to cattle production

1.5.1 Technical and biological factors

Feeds and nutrition

Availability, quantity and quality of feed vary among the different production systems.

1. Feed situation under traditional systems

   Cattle depend largely on rangeland grazing or crop residues that are of poor nutritive value.

   - In the traditional systems feed is not uniformly supplied and quality is poor.
   - Multi-purpose cattle that produce meat and milk and are also used for traction are not given adequate feed supplies.
   - Cattle are allowed to graze crop residues that are high in fibre and low in nutrients. Adding urea or sodium hydroxide to the residues or supplementing with concentrates can increase digestibility but these additives are expensive. Technologies like chopping straw can also improve utilisation.

2. Feed situation under improved systems

   - Farmers in improved systems cultivate forages, feed their animals concentrates as supplements and provide agro-industrial by-products along with crop residues. Even then the problem of efficient feed resources utilisation remains.
   - Improved systems use conservation of forage techniques, e.g. silage and hay.

Genotype

- The cattle population is generally of low genetic merit. Little or no selection has been done for milk or meat in SSA compared with cattle in temperate climates.
- The productivity of current genotypes remains low due to late maturity and age at first calving (3 to 5 years).
- Cattle improvement schemes are poorly defined and infrastructure for improvement is inadequate, e.g. poor artificial insemination (AI) services.
- There is no clear definition of or policy for animal genetic resources in SSA.

Disease susceptibility, reproductive wastage and inadequate health care

- There is inadequate disease control for internal and external parasites.
- The major cattle diseases that result in poor health and limit productivity include East Coast fever, helminthosis and trypanosomosis.

- Governments have inadequate resources to maintain vaccination programmes for major diseases. Farmers may not afford such vaccinations unless subsidised.
- There is inadequate health care, e.g. brucellosis is passed during reproduction.
- Reproductive wastage results from inadequate nutrition such as mineral deficiency, vitamin deficiency etc. This results in delayed age at first calving and problems with the oestrous cycle after calving. At present the calving interval is more than two years in the traditional system compared with one year in the improved system.

Management

- Lack of good record keeping.
- Lack of information and knowledge about available recommendations on improved technologies.
- Shortage of skilled manpower.
- Poor management adversely affects cattle productivity. Poor management includes missing heat episodes, overuse of bulls and inbreeding.

Other constraints

- Cattle require a lot of water all year round for milk production. Farmers face shortages of water during the dry season. Governments in some cases build reservoirs and dig wells.
- Erratic weather patterns which result in droughts that affect water supplies for drinking and for crop production and forage growth, particularly on range.

1.5.2 Socio-economic and institutional factors

Government agricultural policies

Governments make unfavourable agricultural policies that affect production, marketing and consumption. Most policies do not assure producers of accessible markets and allow for unrestricted imports of dairy products. In some cases favourable policies (such as liberalisation of markets in Kenya) have encouraged farmers to produce more.

Access to credit facilities

Credit facilities are not widely available in SSA. Whenever they are available to farmers, the farmers are encouraged to adopt new technologies. Many governments are developing guidelines for lending.

Land tenure system

Land tenure varies among countries. Studies have shown that security of land tenure can lead to more investment in livestock.

Marketing and infrastructure

In most countries marketing is a constraint since markets are inaccessible to farmers because of poor roads. Many farmers have resorted to small-scale processing to convert milk into products that can be stored and hence reach distant markets.

Trained manpower

There is a shortage of range and pasture management specialists, veterinarians, animal scientists, AI technicians and extension agents in many of the countries in SSA.

Inadequate research support

Most governments do not favour research on livestock. They prefer research on crops that yields results quickly.

1.5.3 The role of research

Production increases are possible even among indigenous cattle if constraints are removed. This can happen if:

- Farmers, development agents and researchers work together to identify the priority problems at the system level. All parties then design solutions to these constraints. Following this approach, it is highly likely that most farmers will adopt the technologies developed, leading to new approaches in management.

- Researchers should collaborate with all parties including researchers in other institutions or regions. This increases the flow of information and reduces duplication of effort when resources are limited, e.g. research on cattle traction in the Ethiopian highlands need not be repeated in similar environments facing the same constraints.
- Certain problems are identified in many countries in similar regions. In such cases research should be conducted on a regional basis. This reduces duplication, and resources, funds and manpower can be used more cost effectively. The following are features common to countries in SSA that make regionalisation of research a necessity:
  - The economy in all the countries is based on agriculture (60% of the population is engaged in agriculture).
  - The increases in human population and urbanisation lead to a high demand for food.
  - Most countries would like to achieve food security.
  - Most countries have low rates of technology generation, transfer and adoption.
  - There is need for highly relevant technologies.
  - Most countries have an inadequate human resource base for research on the constraints facing farmers.
  - There are serious weaknesses in agricultural policies.
  - Governments invest very little in agricultural research.
  - Donor support to the national agricultural research systems is not well co-ordinated.

Due to the above features, in 1985 a group of donors and the World Bank established the Special Programme for African Agricultural Research (SPAAR) to address problems at the regional level. Sub-Saharan Africa was divided into five regions: Southern Africa, East Africa, West Africa (humid), Central Africa (subhumid) and Sahelian Africa. Countries in these regions were requested to develop and prioritise their research programmes, to discuss the programmes at the regional level to identify common areas and to formulate regional priorities. The resultant regional programmes were submitted to various donors for financial support. Donors were receptive but demanded accountability for the funds, reporting and improvement of the mechanisms for transfer of research results to the farming community. All parties agreed to improve linkages among farmers, researchers and extension agents. Following this development the following associations were established:

1. Association for Strengthening Agricultural Research in East and Central Africa (ASARECA) for east and central Africa.
2. Conference of Africa Leaders of Agricultural Research (CORAF) for West Africa.
3. Southern African Centre for Co-operation in Agricultural Research (SACCAR) for southern Africa.
4. Institut Du Sahel (INSAH) for Sahelian Africa.

In addition, networks for improving livestock productivity were established to operate in the various SSA regions, e.g. Cattle Research Network (CARNET).

1.6 Exercises

1. Between 1990 and 2025 there will be enormous demographic and social changes such as population increase, urbanisation and income change across SSA. Describe the effect these changes will have on cattle production using examples from your region or country.
2. List three major constraints to increased productivity of milk and meat from cattle in Africa.
3. List reasons for the rapid expansion in peri-urban dairy production in SSA.

1.7 References and reading materials

Brokken R.F. and Senait Seyoum (eds). 1992. *Dairy marketing in sub-Saharan Africa. Proceedings of a symposium held at ILCA, Addis Ababa, Ethiopia, 26–30 November 1990.* ILCA (International Livestock Centre for Africa), Addis Ababa, Ethiopia. 392 pp.

FAO (Food and Agriculture Organization of the United Nations). 1998. *Production yearbook, 1998*. FAO, Rome, Italy. 233 pp.

ILCA (International Livestock Centre for Africa). 1991. *A handbook of African livestock statistics*. Working document 15. ILCA, Addis Ababa, Ethiopia. 66 pp.

Jahnke H.E. 1982. *Livestock production systems and livestock development in Tropical Africa*. Kieler Wissenschaftsverlag Vauk, Kiel, Germany. 253 pp.

McIntire J., Bouzart D. and Pingali P. 1992. *Crop–livestock interaction in sub-Saharan Africa*. The World Bank, Washington, DC, USA. 246 pp.

Winrock. 1992. *Assessment of animal agriculture in sub-Saharan Africa*. Winrock International Institute for Agricultural Development, Morrilton, Arkansas, USA. 125 pp.

Module 2: Livestock farming systems research

2.1 Performance objectives

Module 2 is intended to enable you to:

1. List the key concepts of livestock farming systems research.
2. List the steps in the farming systems research process.
3. Describe the components of the livestock systems research process.
4. Describe the four main categories of livestock farming systems.

2.2 Introduction

The farm is a complex system. Often, researchers design experiments without considering the complexity of the system. This chapter is designed to give you an overview of this complex system and ways to approach your research with the needs and goals of resource-poor farmer in mind. It will not cover methods of data collection. Such information is available in two working papers published by ILCA during 1990. A list of these methods is shown in Box 2.1.

Livestock research in SSA needs to address factors that have led to poor performance of the sector during the last two decades: inappropriate policies, institutional deficiencies, resource constraints and a failure to design experiments and technologies applicable to the farmer's situation; we will address the last factor in this chapter. The systems approach to research is recognised as the most appropriate means of gaining knowledge of the factors that influence production decisions at the farm level.

2.3 Livestock farming systems: Key concepts

A farming system is a set of interacting activities which can be synergistic or competitive. The activities are:

- managed towards satisfying the farmer's objectives (short- or long-term objectives)
- decided by one level of management (farmer or family)
- compatible with the environment.

The farmer in this complex system chooses among various resources to produce outputs. Resources and outputs could be:

- synergistic, e.g. nitrogen fixing legumes contribute nitrogen to non-fixing crops
- competitive, e.g. crop residues for feeding sheep vs. crop residues for mulching the soil.

Farmers manage activities in the farming system with a set of goals in mind. A decision can be made by the farmer or collectively by the family and is determined by the objectives and by the risk the farmer is willing to take. When the farmer has complex objectives, she/he makes complex decisions. The farming system can only operate when it is geared towards stability. Therefore we can infer that:

Box 2.1. Livestock farming systems research: Methods and type of data to be collected for various themes

To conduct research on livestock systems, you need to acquire knowledge and skills. To assist you in this endeavour, ILRI published the following manual: *Livestock systems research manual.* ILCA Working Paper 1. Volumes 1 and 2. 1990. If you are interested in this manual, send your request to ILRI.

Information in this box was selected from the manual to give you a glimpse of the list of methods described in the manual and the type of data that you may collect in each theme.

A. Methods

- Informal surveys
- Developing hypothesis about systems relationships/linkages
- Questionnaire design
- Sampling methods
- Methods of data collection for household budgets
- Methods for animal production: aging by dentition, recall surveys, progeny history method, direct observation and measurement
- Methods for assessing the composition of feed, sampling crop residues
- Sampling to detect disease presence and prevalence rates
- Methods for estimating livestock numbers, offtake and acquisition and to understand marketing functions
- Breeding practices
- Organisation, presentation and analysis of results

B. Type of data to be collected

- Baseline data
  - the general characteristics of the study area
  - the specific characteristics of farmer/pastoralist within each target group
  - available technologies which might be applicable to the problems identified
- Data for labour input
  - labour available to the household
  - labour use over a period of time by age and sex categories
- Household budgets and assets
  - assets inventory data
  - income data
  - expenditure data
- Animal production
  - inter-species composition of the household livestock holding
  - herd/flock structure
  - reproductive performance
  - mortality
  - growth and weight gain
  - outputs (meat, milk, hides and skins)
- Animal nutrition
  - 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
  - Feed data: digestibility, energy value of feed, crude protein content
- Animal health
  - Passive data: veterinary records, records of diagnostic or research laboratories, data from slaughter houses, data from quarantine stations and checking points
  - Active data: data supplied by farmers, data from laboratory analysis, productivity data

- a farming system is more than the sum of its components as there is interaction among the components
- introducing an innovation modifies the whole system; it shifts the balance through synergy or competition.

For research results to suit complex farming system and to be accepted by farmers it is essential to understand the system. For the research to be effective (i.e. to meet the needs of the farmers) it should take into account the following issues:

- Research should be geared towards solving the client's problems and therefore a bottom-up approach is best.
- Research should be viewed as an investment for development.
- Information flows between researchers, development agents and farmers should be redefined (Figure 2.1).
- Researchers should recognise the rationale behind farmer's decisions.
- Researchers should consider small farms as complex systems managed by farmers.
- The research should be multidisciplinary.

(1) Classical model

(2) Improved classical model

(3) Interactive model

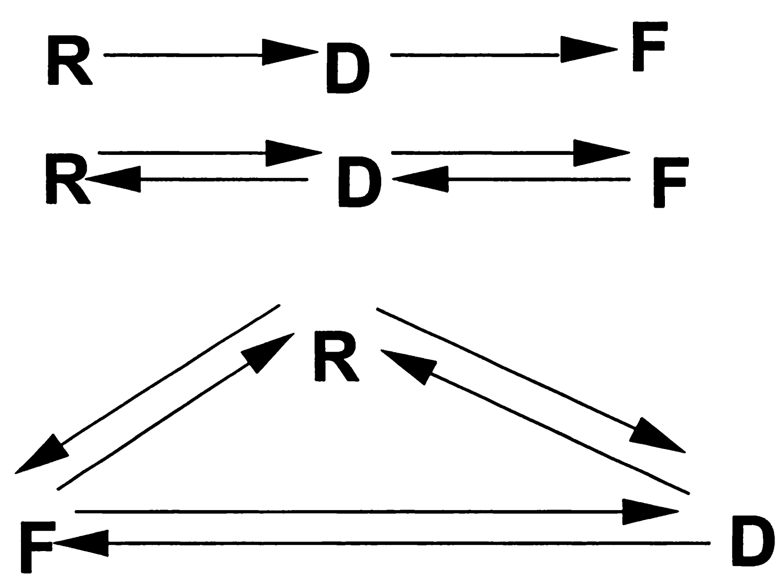


Figure 2.1. *Models for information flow among researchers (R), farmers (F) and development agents (D).*

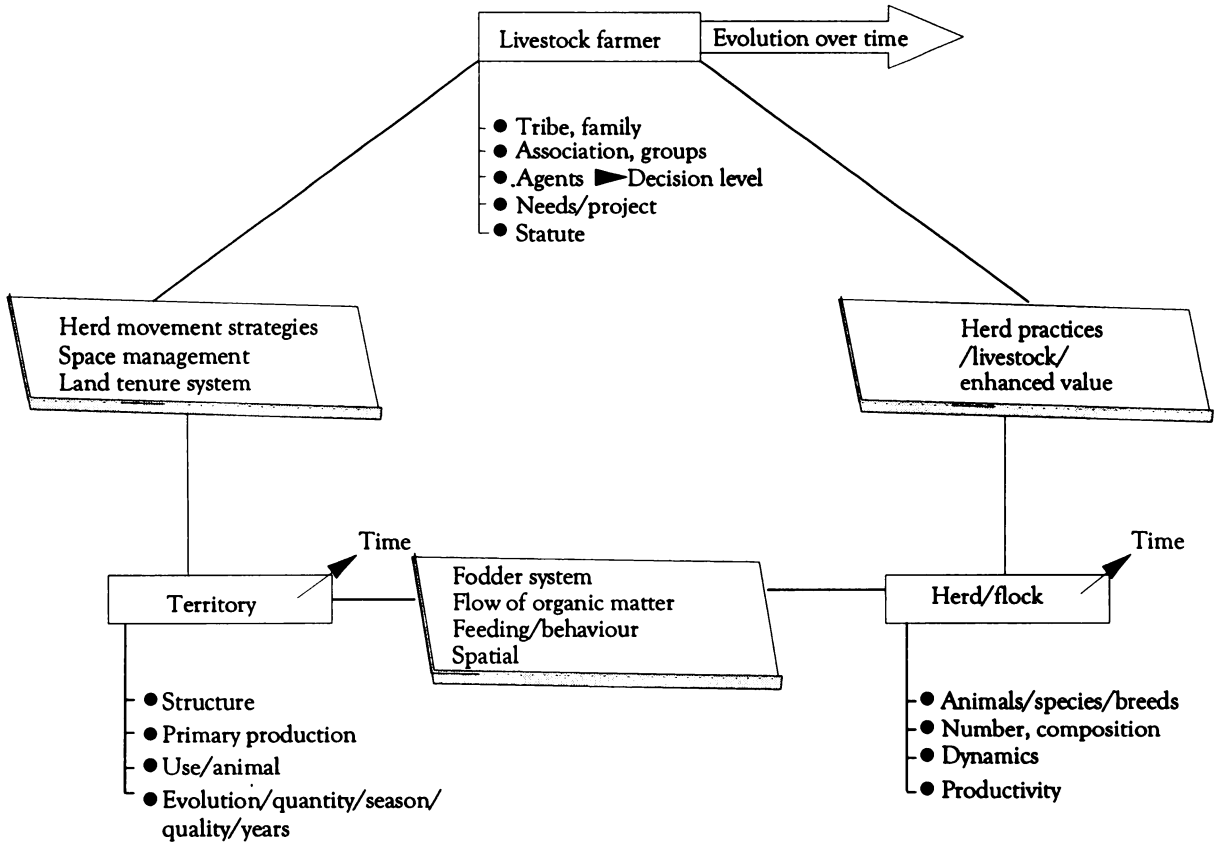
In the past farmers were used to test information without any thought being given to their needs. Recently research has shown that information flow (Figure 2.1) is essential for the scientist to exchange information with the farmer. Starting and ending with the farmer (farmer-to-farmer model) allows for direct exchange of information between the scientist and the farmer. The ideal way to exchange information is to involve the three parties: farmer, researcher and development agent. It is important for the scientist to understand why the farmer does what he/she does because this allows research to provide the solutions needed by the farmer.

2.4 Livestock farming systems conceptual model

As researchers our objectives for following a farming systems research approach are to:

- gain knowledge about farming and livestock systems
- conduct research, based on the knowledge of the system, that will provide the information necessary to design interventions for improving the performance of the livestock system.

Implementing these objectives compels us to look at problems using a more holistic approach. It also leads us to use multidisciplinary teams to conduct the research. A conceptual model was developed by Lhoste (1986) to describe these relationships (Figure 2.2).



Source: Lhoste (1986).
Figure 2.2. *General conceptual model for livestock systems.*

Livestock systems are part of the agricultural systems hierarchy (Figure 2.3). Studying livestock farming systems in isolation will make it difficult to see or deal with the total picture. This approach does not necessarily conflict with scientists' specialisation in specific areas.

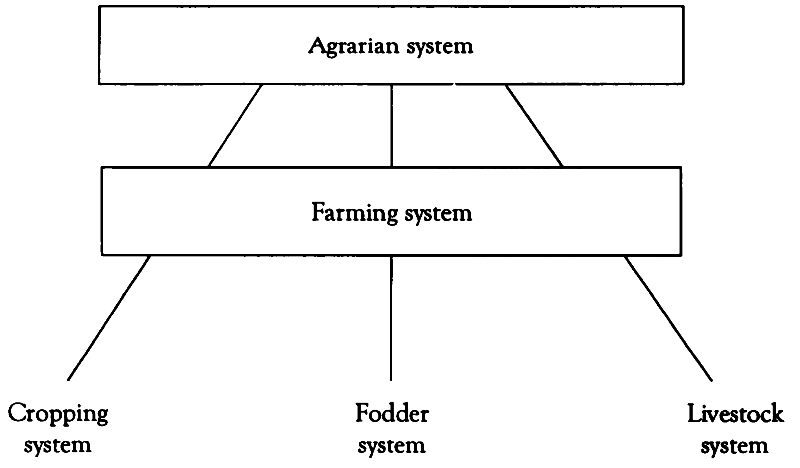


Figure 2.3. *Systems hierarchy.*

2.5 Livestock farming systems process

Livestock farming systems research methodology may be influenced by the nature of the particular system under study but the process involved for all types of farming systems is similar. This includes the terminology used and the sequencing of the process. The following features are prerequisite for the farming systems approach:

- no preconceptions about the system

- it should be improvement oriented
- all factors affecting the household should be examined
- it should involve multidisciplinary teams
- farmer participation is essential
- solutions should be evaluated for productivity, profitability, stability and sustainability.

The livestock farming systems process involves four main phases, namely diagnostic, design, testing and extension. Figure 2.4 illustrates the sequencing and relationships among these phases. Comparing the bottom-up approach to the top-down approach further illustrates the relationship among the phases (Figure 2.5). Farmer involvement is central to the bottom-up approach. It allows us to know the farmer's capabilities when improving existing technologies or proposing new ones. The ability of the farmer to economically afford or socially accept the new technology is easier to identify with this approach. The top-down approach, used by most researchers in the past, contributed among other factors to the high rate of failure in adoption of technologies by farmers. Solutions generated through the top-down approach may not address the needs of the farmer.

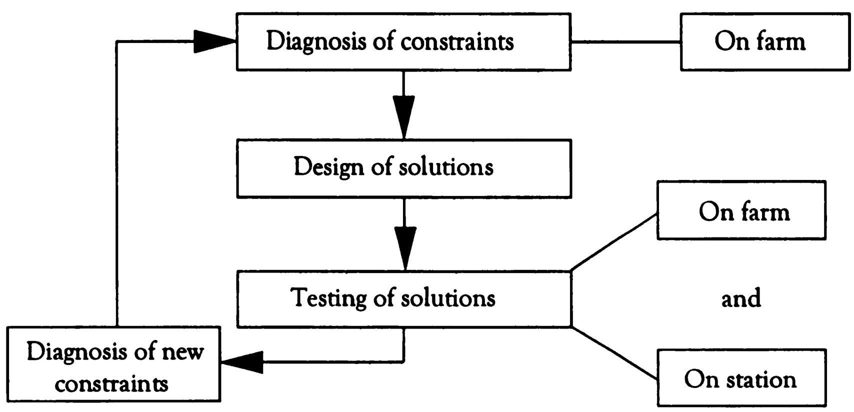


Figure 2.4. *Farming system research process.*

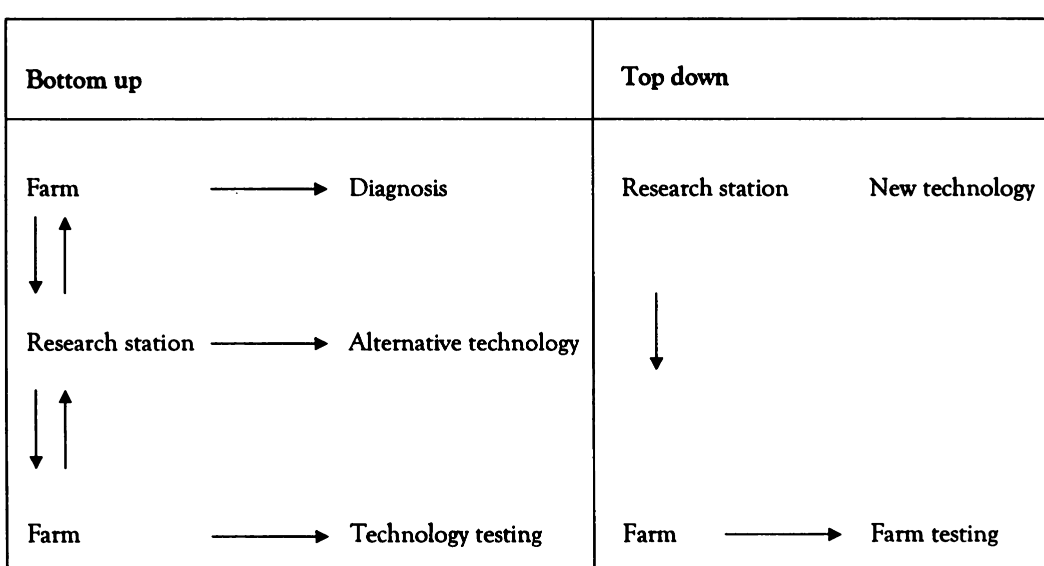


Figure 2.5. *Approaches to research.*

2.5.1 The diagnostic phase

Diagnosis offers answers to the following questions:

1. What is going on? What is the farmer doing? What goes into the system?
2. What is the problem?

3. Why is it a problem?
4. What can be done to solve the problem?

Knowing the answers to the first three questions will allow you to (i) address question 4 using a multidisciplinary approach, (ii) focus your research, (iii) save time and (iv) use the limited resources fruitfully.

The main objectives of the diagnostic phase are:

- To describe the production system.
- Researchers use this phase to highlight the circumstances and practices of the representative farmers. Understanding the household activities and the wider features of the system is necessary for technology design.
- To identify constraints to resource use.
- The main objectives of farmers are to produce for household consumption and sale and to avoid risk and save for bad times. It is important to identify the factors that constrain or limit production or income.
- To understand what causes the constraints.
- Understanding the reasons for constraints will lead to solutions.
- To determine opportunities for further improvement.

This involves screening available technologies for their suitability. This information will allow the researcher to decide on an appropriate course of action. Sometimes improvement on farmers' practices can be a solution, e.g. prevalence of parasites in spite of dipping may be due to resistance of ticks to the dipping solutions, reduced animal resistance due to underfeeding or improper dipping. Surveys of indigenous knowledge are recommended as part of meeting this objective.

Diagnostic tools

1. Surveys

Surveys can be formal or informal and comprise one or multiple visits. To meet the objectives of surveys a researcher should:

- have adequate knowledge about the target population of farmers
- use good questionnaire techniques
- use good sample techniques
- use skilled surveyors with adequate logistic support (transportation, incentives, knowledge of the area, knowledge of local language etc.)
- involve or consult with a biometrician.

The numbers of observations and amount of data per observation are important factors in determining data quality. Equilibrium should be reached so that the number of observations matches the available resources.

The information collected during a survey should be:

- qualitative and quantitative knowledge on the functioning of the livestock system
- knowledge on variability of livestock systems
- quantitative knowledge on systems performance (function of the farmer's memory and confidence).

Lengthy interviews lead to loss of concentration on the part of the farmer which affects the accuracy of the answers given. Respondent fatigue can also be reached when surveys are conducted over a long time.

Formal survey. In a formal survey, a well-structured or semi-structured questionnaire is developed. The questionnaire contains a number of questions to be answered by the farmer. The farmers are randomly selected and the survey is designed to collect data on particular aspects of the production system. Formal surveys can also be used to redefine target groups and identify priorities for research.

Informal survey. In this type of survey no structured questionnaire is needed; information is gathered in an informal way. One need only remember the key issues in asking the questions. The reliability of the information depends on the questions and the way in which they are asked.

Farmers are busy and in both formal and informal surveys we must not waste their time unnecessarily. The best approach is a combination of both structured and unstructured questionnaires. Both formal and informal surveys should be complemented by observations made during farm visits.

Single-visit survey. In some cases one visit may be enough to gather information from a farmer. This is especially so when the farmer is busy during the peak of the seasonal calendar (when the maximum number of activities are being conducted at the same time). This approach is useful for farm inventories and qualitative information.

Multiple-visit survey. Multiple visits are used when we want to verify information or we require more in-depth information. This approach establishes better rapport between researchers and farmers. Researchers have a chance to show interest in the farmer's personal life but they should be careful not to probe matters of privacy or taboo (e.g. income, number of children) directly. This type of survey is particularly useful for semi-structured interviews and for when farmers are less busy.

2. Farm monitoring

In this method the team of monitors visits farmers over an extended period and records detailed data, e.g. reproductive performance, changes in environment and livestock dynamics. This approach involves collecting continuous data. Depending on the nature of the investigation, data collection can take from one month to several years. The main disadvantage of this method compared with surveys is its high cost. Its advantages over the survey method are that it can be used to double-check information from rapid surveys and it relies less on the farmers memory (particularly related to the performance of animals).

To monitor flocks of cattle on a farm:

- choose flocks to be monitored
- collect information on resources (territory, flock and family)
- conduct retrospective studies (female productive history)
- pay regular visits to collect data.

2.5.2 The design phase

Analysis of information during the diagnostic phase allows us to identify the problems and their causes (if lucky). Designing a set of research activities to solve the problems follows diagnosis. The purpose of designing solutions is to develop technologies that will address the constraints and adapt the technologies to suit the situation.

Considerations during design

When designing research activities you should consider the following:

- nature of the farms which vary in location and management
- type of farmers: education and ability to handle technology
- degree of management control: researcher-managed trials (researcher plans and executes), researcher–farmer-managed trials (researcher plans and farmer executes) and farmer-managed trials (farmer plans and executes)
- type of trial
- number of test animals
- type of statistical analysis
- available resources (time, money and expertise).

Research should focus on technologies which are compatible with the resources and objectives of the farmer and are consistent with the features of the system.

Major rules for designing solutions

- adapt technologies already developed
- evaluate all feasible options

- exploit possibilities in the system.

In the short term it is useful to exploit existing options. In any production system major long-term increases can only be obtained by overcoming constraints to production. Whether exploiting existing technologies or developing new ones to improve the system, the economic evaluation is important, as farmers will not use solutions that are not profitable.

2.5.3 The testing phase

The research agenda formulated in the design phase will comprise trials to be carried out at research stations (on-station trials) or in farmers' fields (on-farm trials). The trials may be short- or long-term. Farmers and policy makers are eager for results and research impact. To sustain their participation, we can demonstrate some spin-offs so that they can look forward to the final result. To maintain the interest of farmers, especially in long-term projects, consistent monitoring and spot analysis of data will help identify opportunities for mid-way interventions. Many researchers delay analysis until the end of the project thus missing many opportunities for spin-offs. Looking at the trend of results can help identify some valuable solutions which will satisfy the farming community.

Considerations

- Farmers should be involved in the trial process and evaluation of technology on farm.
- Experiments should be simple.
- The involvement of farmers outside the target area should be considered.
- Farmers' reactions to the alternative technologies should be monitored.

On-station experimentation

On-station research is needed to arrive at the best alternative among the many tested options. The best option is then tested on-farm.

On-farm experimentation

We need to collect data that will lead to technologies that are technically and socially acceptable and allow us to evaluate performance biologically and economically.

2.5.4 The extension phase

The objective of the extension phase is to assess the impact of the new technology in a wider community of farmers. It is essential to monitor:

- production levels and the use of inputs
- resource allocation (e.g. land for crops vs. animals)
- institutions (e.g. markets)
- farmers' opinions—acceptance or rejection of technologies.

Even though this phase is led by the extension service, it requires input from farmers and researchers; such contact should be maintained to ensure feedback.

2.6 Participatory rural appraisal (PRA)

Participatory rural appraisal is:

- An opportunity to learn from the target people about their situation. Target groups can be involved at several points in the process:
  - investigation, identification and prioritisation of needs
  - planning and implementation
  - monitoring and evaluation.
- A method that gives researchers and farmers an opportunity to exchange knowledge. This will enable researchers to design programmes that will meet the needs of the farmers.

2.6.1 Why PRA?

1. The success rate of agricultural projects has been unsatisfactory because:
   - projects fail to adequately acknowledge the interactions among the component parts of farming systems including ecological, biological and socio-economic elements
   - there is limited or no participation by the target groups in conceiving, planning, implementing, monitoring and evaluating the projects.
2. Evolution through the decades
   - It started with rapid rural appraisal (RRA), a technique which ignored participation of the target group.
   - Rural project appraisal was developed as a new form of RRA; it involved rapid assessment procedures and has the same limitations as RRA.
   - PRA overcame the limitations of the two techniques by involving the target group at every stage of the research process.

2.6.2 PRA techniques

Problem identification

PRA techniques are preliminary exercises that provide information about constraints facing the farming system. They complement more formal methods, e.g. surveys.

1. Open discussion (non-structured)
   - Problems are identified through open non-structured discussion. The main features of the discussion are:
     – the clients lead the discussion ('we can do it' attitude) and the researcher acts as a facilitator only
     – the researcher steps in only to seek clarification; otherwise he/she watches, listens and learns.
2. Semi-structured (topic investigation)
   - specific answers are obtained for specific questions
   - the researcher's role is limited to introduction and organisation
   - target group leaders take lead to ensure vigour in the discussion
   - the researcher's role in discussion is catalytic.

Gathering data

There is always a wealth of information embedded in a variety of resources. PRA is a quick way to make this information available to the research before project planning. To simplify the collection of data, it is classified into many types depending on the source, space, time and social considerations.

1. Secondary data: publications, maps, census reports, grey literature and aerial photographs.
2. Field generated data (primary data) is spatial data collected jointly with the farmer. It comprises sketch maps (resources, activities, opportunities and problems), transects (items the sketch map may not have included) and farm sketches which are drawn by farmers and their families.
3. Time-related data (temporal)
   - A time line is developed showing important local, national and international events observed by the community.
   - A trend line is developed showing important changes in the community, why there are changes and the community's attitude to change (since research aims at change, such information is essential).
   - Seasonal calendars are developed to show seasonal problems or opportunities in average years.
4. Social data (people-related information)
   - Farm household interviews are conducted to gather socio-economic information and characteristics of a particular community or farm.

Information is collected about institutions to provide knowledge about various groups and organisations within the community (including churches, schools, women groups etc.). This information gives an insight into the relationship among the institutions and determines how the community views its institutions (e.g. ranking the contribution to development of institutions).

Ranking and scoring

The impact of problems at the farming systems level can be of varying magnitude. Ranking and scoring are ways of prioritising different interventions and technical solutions that are relevant to and adoptable by farmers. This involves placing things in their order of importance at a particular time. Ranking could be done for problems and opportunities.

2.6.3 PRA virtues

The virtues of PRA are that it is:

- participatory and hence client oriented
- enabling, as farmers feel the researcher is interested in them
- empowering because the clients say what needs to be done and the researcher listens
- semi-structured leading to local participation in a systematised fashion
- flexible, gender sensitive and applies to all classes
- iterative and thus exploits all alternatives and possibilities
- exploratory and hence looks at all possible situations
- involves training and orientation which enable the farmer to rationalise and evaluate the products (e.g. weighing cattle, weighing milk)
- focused
- ensures sustainability.

2.7 Categories of livestock farming systems

There are three categories of livestock farming systems.

Category 1: Farming systems research *sensu stricto*

Farming systems research in this sense studies the farming system as is. The studies are academic and scholarly rather than practical.

Category 2: On-farm research

This is research on farmers' fields with farmers participating and with a farming system perspective. In this category the researcher:

- assumes that only the farmers experiences can reveal their needs
- isolates a subsystem and studies it in enough depth to obtain new perspectives
- proceeds to on-farm experimentation with the farmers' contributions.

Category 3: Development of new farming systems

The objective is to invent, test and exploit new systems. This involves radical restructuring of farming systems instead of the step-wise change followed in category 2, e.g. intensified dairy system in place of an extensive pastoral system.

2.8 Exercises

1. Give examples from livestock–crop interactions that show: (i) synergistic effects of resources and outputs and (ii) competitive effects of resources and outputs.
2. Lhoste (1986) developed a global conceptual model for livestock systems research. Does this model fit the themes from your region? Describe the similarities and the differences.
3. The livestock farming systems research process has four phases. List these phases in sequence and explain what will happen to the value of your research results if any of the phases is omitted.
4. List the categories of livestock farming systems research.

2.9 References and reading materials

ILCA (International Livestock Centre for Africa). 1990. *Livestock systems research manual. Volume 1*. ILCA Working Paper 1. ILCA, Addis Ababa, Ethiopia. 287 pp.

ILCA (International Livestock Centre for Africa). 1990. *Livestock systems research manual. Volume 2*. ILCA Working Paper 1. ILCA, Addis Ababa, Ethiopia. 55 pp.

Lhoste P. 1986. Le diagnostic sur les systèmes d'élevage. In: Landais E. and Faye J. (eds), *Méthodes pour la recherche sur les systèmes d'élevage en Afrique intertropicale. Actes de l'atelier, ISRA, Mbour, Sénégal, 2–8 February 1986*. Etudes et Synthèses de l'IEMVT 20:39–59. IEMVT (Institut d'élevage et de médecine vétérinaire de pays tropicaux), Maison-Alfort, France, and ISRA (Institut Sénégalais de recherches agricoles), Dakar, Senegal.

Module 3: Guidelines for reproductive management in cattle

3.1 Performance objectives

Module 3 is intended to enable you to:

1. List the anatomical parts of the cow that are of importance in reproductive functions.
2. List the main events in the reproductive cycle of the cow.
3. Describe factors influencing efficiency of cattle reproduction.
4. Describe embryo transfer techniques.
5. List major constraints to reproductive efficiency in cattle.
6. Define heat and describe how it is detected.
7. Define pregnancy and describe how it is diagnosed.
8. List potential points of intervention to improve reproductive efficiency in a cow.

3.2 Introduction

Several attempts have been made to improve the productivity of cattle in sub-Saharan Africa (SSA). Understanding the physiology of reproduction is essential to achieve this goal. Most important is finding potential points where intervention in the life cycle of the cow or bull can result in more efficient performance and hence higher productivity.

Long dry periods result in reduced milk production and hence economic losses. The number of calves born can be reduced because the periods optimal for conception are missed. In addition, the cost of treatment of reproductive disorders can be high or beyond the reach of smallholder farmers. This module will deal with reproductive management in cattle to achieve the desired goal.

3.3 Concepts of reproductive physiology

3.3.1 Anatomy of the reproductive organs in the cow

It is important you learn the anatomy of the organs that are involved in the reproductive physiology of the cow. This information will help you to understand the various processes involved in reproduction. The ovary and uterus are shown in Figure 3.1. For detailed descriptions of these parts consult veterinary books in your library.

3.3.2 Cycles of reproduction

Most cattle in SSA breed all year round. It is important to understand the basics of the reproductive stages so that management can be applied to attain high productivity. We have divided the life of the cow in four cycles. It is important to understand these cycles because this knowledge is important to formulate strategies to achieve higher productivity.

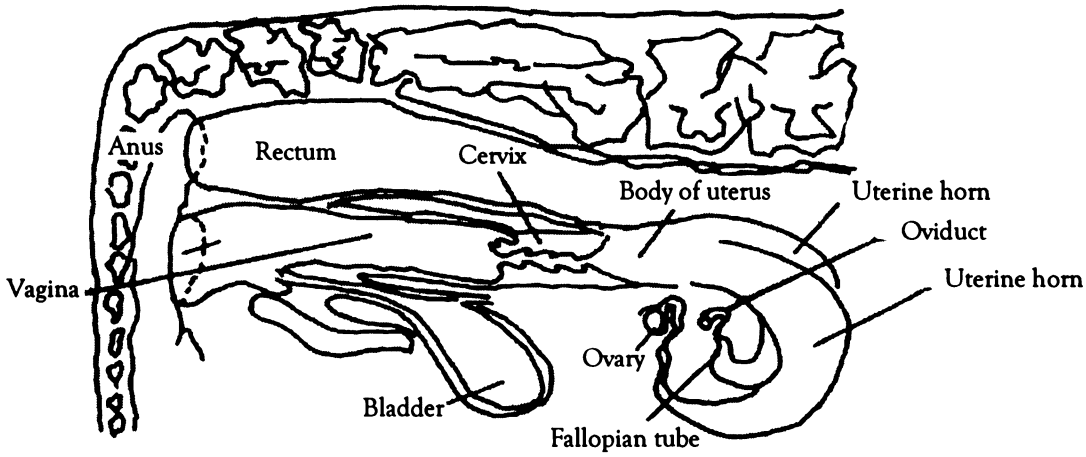


Figure 3.1. *Reproductive tract of a cow showing uterus and ovaries.*

The life cycle

The three main phases in the lifetime of a cow are pre-puberty (before cycling), puberty (initiation of cycling) and the reproductive periods. This module will describe these periods briefly.

Pre-puberty. This is the period before cycling starts. During this period the ovaries are small. Incomplete cycles where ovulation does not occur are detected first. The onset of ovulatory cyclic activity follows and is a gradual process. The luteinising hormone (LH) can be detected in blood plasma at normal adult basal levels and peaks as early as 6 weeks of age and continues up to puberty. In the bull calf, the size of the testicles indicates the approach to puberty and production of viable semen. The changes are associated with androgen rather than LH.

Puberty. Puberty (initiation of cycling) may be defined as 'the time when the reproductive organs become functional'. In the female, it is defined as the time when the first functional oestrus occurs and the earliest age at which reproduction can occur. Usually genotype or breed, nutrition, season and other environmental factors (e.g. climate) determine the age at which puberty is attained. As a consequence, large variations occur between and within breeds. The age at first calf delivery may also vary as a result.

- Puberty is a more dramatic change in the female (heifer) than in the male (bull).
- It is associated with increase in the ovarian size.
- In the 2 months preceding puberty there is no change in follicle stimulating hormone (FSH). However, once the initiation of cycling is attained, eggs develop in the follicle under the stimulation of FSH/LH.
- Sometimes one or two silent cycles precede first oestrus.

Undernutrition results in delay of the onset of puberty in heifers. Heifers that are well fed grow faster and attain puberty at an earlier age.

Reproductive period. Breeding activities in cattle can continue for many years. A cow is born with a full supplement of ova; at the age of 15 to 20 years, a cow will have no primordial follicles. Testicular size is a good indicator of sperm production and reproductive activity and is easy to estimate (Figure 3.2). Males produce sperm continuously. Even though efficiency of sperm production peaks at 11 months, total production continues to increase with increase in testicular size. Both cow and bull reach senescence at about age 15 years but this is of no practical value, as cattle are usually not kept to this age.

3.3.3 The annual breeding cycle

Even though cattle in the tropics can breed all year round, the efficiency of cows and bulls is affected by many environmental factors.

- Bulls show seasonal variation in fertility due to the effect of temperature.

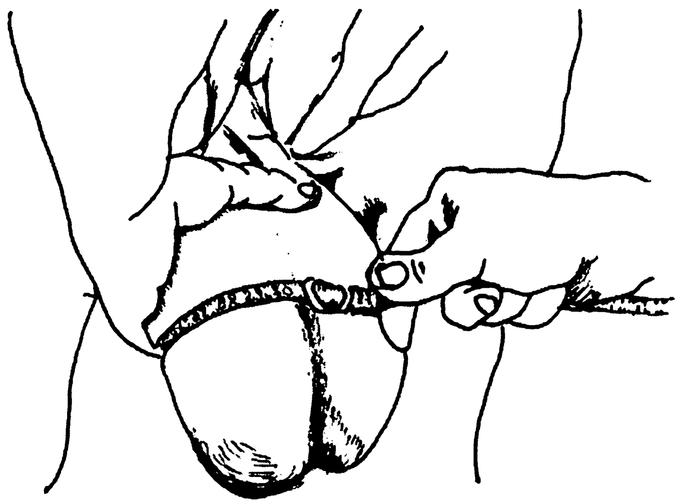


Figure 3.2. *Measuring testicular size.*

- In zebu cattle (*Bos indicus*) other environmental factors, such as temperature and rainfall assume more importance.
- Pubertal heifers conceive during the dry season and calve during the rainy season when there is enough pasture. This synchronisation enables the heifer to build up its body condition during the late phase of pregnancy and before calving.

3.3.4 The oestrous cycle

Oestrus, or heat, is defined as the time when the female is receptive to the male. It occurs in cycles.

Duration of oestrus

The length of the oestrous cycle is 20 days in heifers and 21 days in cows. Oestrus is short, 6–30 hours, but it varies among breeds and the range is considerable. The first day of oestrus is usually designated as day zero. Ovulation occurs after the end of oestrus.

Events in the oestrous cycle

The events in oestrus follow a specific timed sequence (Figure 3.3).

Luteal phase. A corpus luteum is formed under the influence of pituitary LH. The function of the corpus luteum is to secrete progesterone, which reduces the amount of the hormone oestrogen produced. As long as the corpus luteum is functional, oestrogen is unable to trigger formation of the follicle (a large fluid-filled sac containing the egg). By day 18 the corpus luteum degenerates due to prostaglandin (released from the uterus) and goes through a regression phase. Associated with corpus luteum regression is a decline in progesterone (Figure 3.3).

Follicular phase. Following the decline in progesterone, an increase in oestrogen (mainly oestradiol-7) takes place and peaks before the onset of oestrus (Figure 3.3). Oestrogen stimulates the release of gonadotropin-releasing hormone (GnRH) from the hypothalamus. GnRH stimulates the release of FSH and LH from the pituitary gland. LH rises to a peak at the beginning of oestrus. FSH and LH stimulate the development of follicles in the ovary. One follicle predominates which secretes oestrogen and triggers a wide range of anatomical and physiological changes in the cow [see Signs of oestrus, p. 25]. All the changes ensure that if the cow is mated, the sperm will stay alive until one of the spermatozoa will effect fertilisation. The follicle ruptures and releases the egg (ovulation).

Conception. Mating may take place followed by conception. The luteal phase of the cycle starts again (Figure 3.3). In this case the embryo develops and the corpus luteum does not regress but continues to secrete progesterone and remains active throughout the pregnancy. If there is no mating or fertilisation fails to

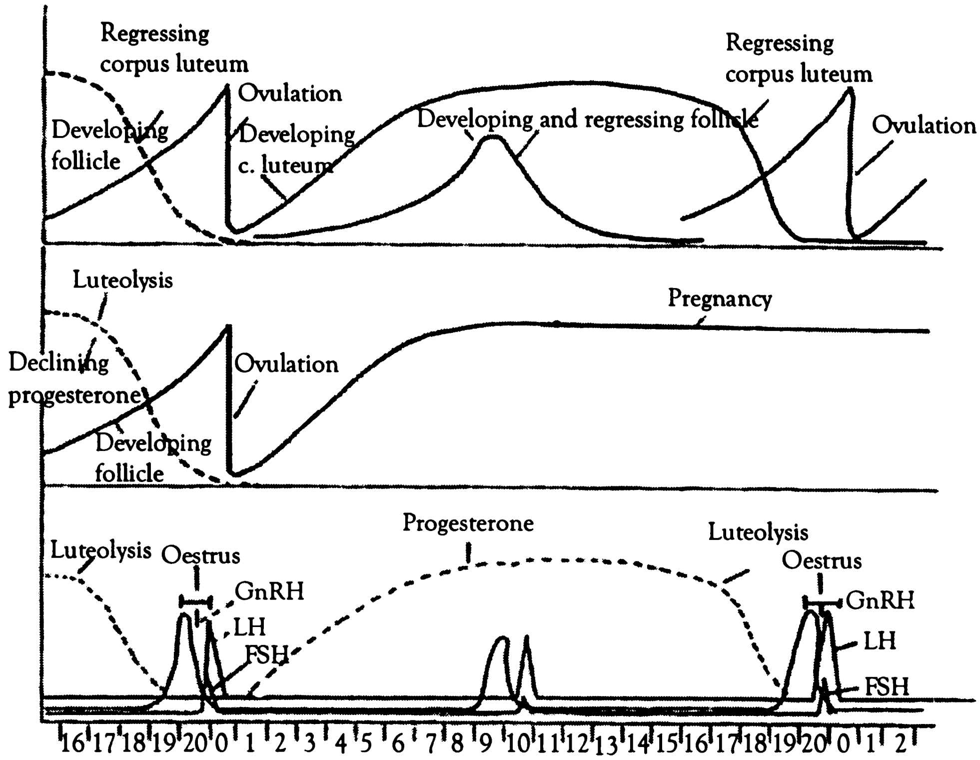


Figure 3.3. *Events in the oestrous cycle of the cow.*

occur, progesterone secretion ceases abruptly on day 17 or 18 of the luteal phase. This is brought about by the uterus releasing uterine luteolysin which initiates the regression of the corpus luteum. The regression is followed by growth and maturation of another follicle and the cycle starts again (Figure 3.3).

Example: How to assess progesterone during oestrous cycles

The enzyme-linked immunosorbent assay (ELISA) technique can be used to assess progesterone levels during the oestrous cycle (Boland et al. 1985). Mukasa-Mugerwa et al. (1990) assessed progesterone with a commercially available ELISA technique in 20 Ethiopian Menz ewes. In their experiment the oestrous cycle averaged 17.2 ± 1.0 days (range 15–20 days). Progesterone values were under 1.0 ng/ml from 2 days before to 4 days after oestrus. Hormone concentrations rose steadily to peak at 5.0–5.6 ng/ml on days 10 to 14. This was followed by a rapid decline to 3.0 ng/ml (53% of day 14 peak value) on day 15; 0.8 ng/ml (15% of peak value) on day 16; and 0.2 ng/ml (3.7% of peak value) on the day before oestrus. It was concluded that ELISA method can be used for progesterone determination in Ethiopian sheep, and also, that progesterone level of under 1.0 ng/ml are indicative of either anoestrus or the follicular and early luteal phases of the oestrous cycle.

Signs of oestrus

The major signs shown by a cow on heat are:

- The cow stands to be mounted (Figure 3.4).
- Ruffled hair and mud on the rump and flanks of the cow on heat can be seen due to mounting by other cows or bulls.
- The cow tends to mount other cows.
- The cow is restless and noisy.
- The cow nudges and butts other cows.
- The cow exhibits chin resting, sniffing and licking other cows.
- The cervix produces clear mucus, which is seen at the vulva.
- The vulva is swollen and pink.

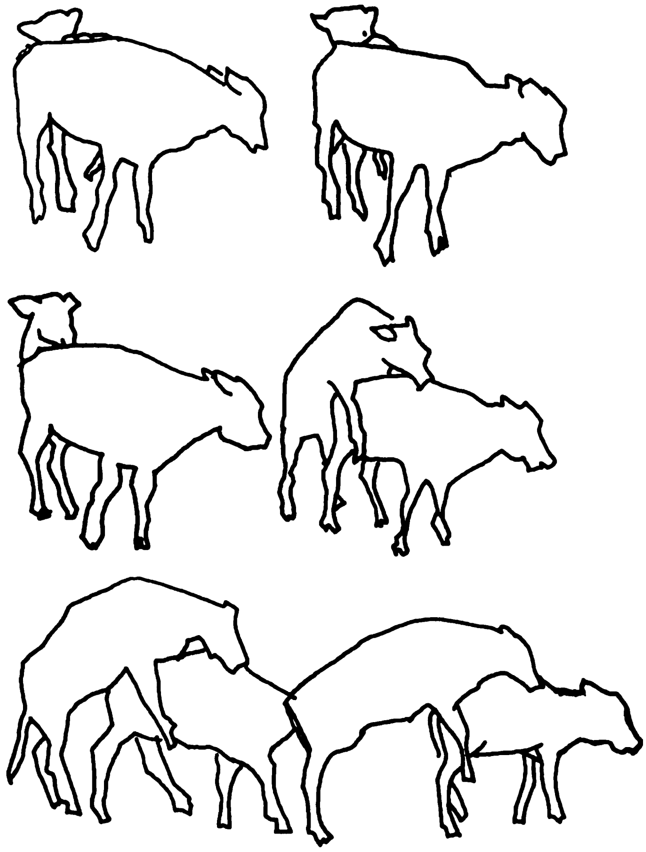


Figure 3.4. *Heterosexual/homosexual behaviour: A major indicator of oestrus in cows.*

Factors affecting cycling in animals

Cycling in animals is affected by physiological, pathological and environmental factors (e.g. high temperature) (Figure 3.5). Prolonged suckling, pregnancy and mummification (foetal death without abortion or resorption) delay oestrus leading to a condition known as anoestrus. Diseases that affect the ovary can lead to a long anoestrus or failure to come to heat.

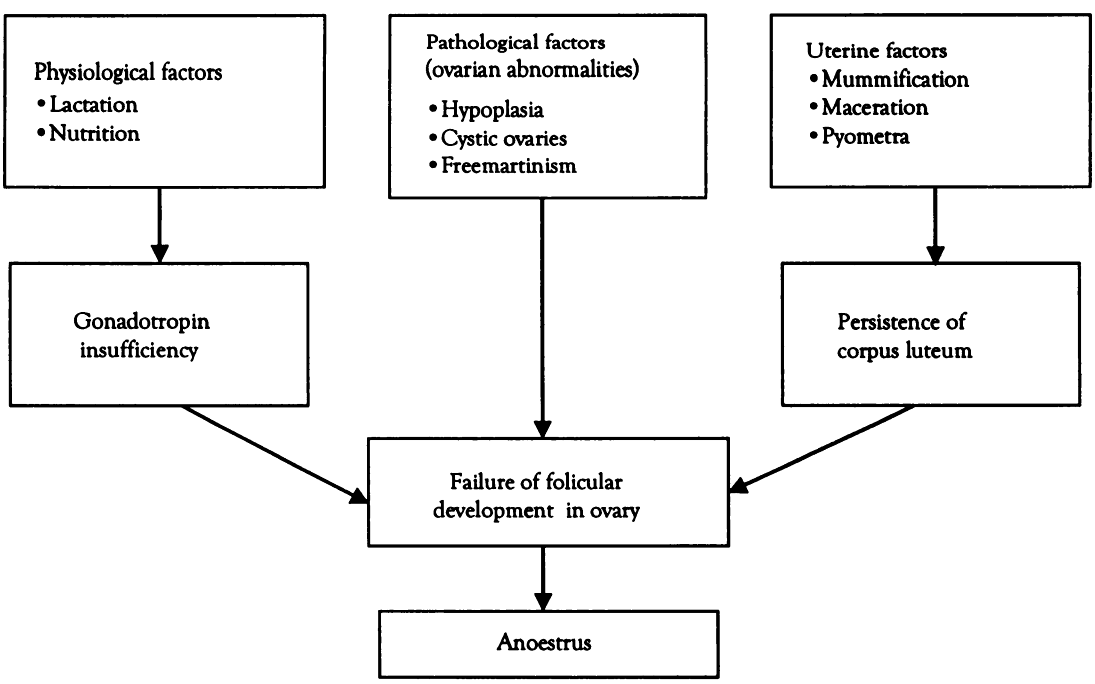


Figure 3.5. *Possible causes of anoestrus in cows.*

3.3.5 The spermatogenic cycle

The production of spermatozoa by a bull is a continuous process. Semen can be collected in successive harvests. The spermatogenic cycle takes 60 days.

Mating and fertilisation

Mating in the heifer is highly sensitive to oestrogen. The egg is normally shed about 10 hours after the onset of oestrus. Oestrogen causes the egg to travel down the oviduct and assists the sperm travel up the oviduct. The union of egg and sperm takes place in the oviduct.

Pregnancy, gestation and parturition

Pregnancy is established after fertilisation. It is defined as the time span between the implantation of a fertilised ovum in the uterus and the expulsion of the foetus and its associated membranes at term. It has three phases:

- the fertilised ovum passes down to the fallopian tube
- differentiation occurs into an embryo
- the embryo enters the uterus two to three days after fertilisation. The embryo will form foetal tissue (called the placenta) that folds with maternal tissue (called carnucles). Even though there is no direct vascular connection between the placenta and the carnucles, the blood vessels of the placenta lie quite close to those of the uterus so that material is interchanged. The placenta produces hormones that ensure the survival of the foetus and development of the mammary glands (udders). The foetus grows rapidly.

Gestation is the interval from fertile service to process of calving (parturition). During parturition the uterus contracts, foetus is delivered and placenta is expelled. Parturition should be completed in about 8 to 12 hours in cattle.

Lactation

Lactation, the final phase of the reproductive cycle of the cow, is the formation and secretion of milk to nourish the young. Man domesticated cattle to produce enough milk for calves and for human consumption. The duration of lactation varies depending on nutrition. The yield of milk in cattle increases steadily until it reaches a peak at 8 or 9 weeks and then declines over the remainder of the lactation period. The composition of milk also changes during lactation. Once colostrum (the first milk) changes to milk, there is a small decline in protein, fat and lactose until peak production. After the peak, these constituents increase slightly until the cessation of lactation.

Resumption of cyclicity

Post-partum is the period following parturition in which lactation starts and reproductive cycles are established. The number of days from parturition to first ovulation averages about 20 days and time to first oestrus averages about 34 days. Ways to manipulate the reproductive cycle to shorten the period between calving and first oestrus include:

Nutrition manipulation. Low nutrition in beef cattle, that reduces weight after calving, prolongs the period to first oestrus. Supplementation is essential to alleviate this constraint. This treatment must be economical for smallholder farmers to accept it.

Example: Effect of nutrition on reproductive activity in cows after a long anoestrus period

Body condition is a major determinant of oestrous activity. This is especially important for female draft animals because their bodies are already stressed by work. Zerbini et al. (1996b) examined 12 low body condition, non-milking, non-cycling (depletion state) F_1 crossbred dairy cows (Friesian × Boran and Simmental × Boran) in the Ethiopian highlands. The cows were fed natural grass hay and offered mineral lick plus 3 kg concentrate (800 g noug cake, 150 g wheat middlings, 30 g salt and 20 g bone meal per kg concentrate) and 7 hours per day natural grazing. The results of this study indicated that healthy cows which had been underfed to the extent that no reproductive events occurred (i.e. ovulation and oestrus) for a period of more than 2 years, rapidly regained reproductive ability under improved nutrition. All cows became pregnant after a relatively short period of repletion and subsequently all calved normally. Despite the exceptionally long period of anoestrus, the cows were able to resume ovarian activity and to cycle within 3 months of dietary repletion.

Remove suckling inhibition. Management of the post-partum period depends on the rationale for raising the cow. If we are raising the cow to produce milk for marketing, then removal of the calf becomes necessary. Nursing delays oestrus and ovulation. Table 3.1 shows the effect of rate of suckling on oestrus. Reduced suckling resulted in more cows experiencing oestrous. Neither calf nor dam weight at weaning was affected by reduction in suckling.

Example: Influence of suckling on resumption of post-partum ovarian function

The effect of suckling on post-partum ovarian function was monitored by determining plasma progesterone weekly (Mukasa-Mugerwa et al. 1991). Enzyme immunoassay was used in 16 Small East African Zebu *(Bos indicus)* cows which were maintained with a fertile bull in Debre Birhan, Ethiopia. The results indicated:

- Continuous suckling or constant cow–calf interaction extended the post-partum anoestrus interval in Ethiopian zebu cows.
- Ethiopian zebu cows calving with average body weight and body condition can cycle and conceive within 100 days post-partum under natural mating conditions, provided calves do not suckle continuously.
- Prompt post-partum ovarian cyclycity can be achieved through improved nutrition during the last trimester to ensure that cows calve with good weight and in good condition. In addition, minimal suckling and better oestrus detection are needed to achieve the goal.
- Early weaned calves or those on restricted suckling would need extra nutritional supplementation to ensure continued growth.

Table 3.1. *Effect of suckling on first calf heifer.*

	Normal daily suckling	Suckling once a day
Post parturition interval (days)	124–168	32–69
Oestrus at 90 days (%)	10	75
Cow weight at weaning (kg)	335	360
Calf weight at weaning (kg)	147	147

3.3.6 Factors influencing efficiency of cattle production

Nutrition

Inadequate nutrition is a major constraint to productivity of cattle in SSA. Nutrition stress can influence a cow in the following ways:

- cow fertility during the service period can be lowered by poor nutrition
- low energy content in the feed results in low liveweight gains and low milk yield in early lactation
- poor nutrition leads to delay in resumption of ovarian activity and a lowered conception rate.

Example: Effect of nutrition on onset of puberty and conception

The dry season in SSA is associated with poor quality feed. Tegegne et al. (1992a), working in Ethiopia during the dry season, fed Boran and Boran × Friesian crossbred heifers a diet containing 1.5 kg/head per day of a 2:1 mixture of wheat bran and noug cake (*Guizotia abyssinica*) which contained 16% crude protein and 10.8 MJ/kg dry matter energy. The results led to the following conclusions:

- the growth rates of Boran and Boran × Friesian heifers could be improved through strategic supplementation during the dry season
- supplementation resulted in reduced age at puberty and at conception
- supplementation improved the pregnancy rate.

Stress factors

High ambient temperature imposes adverse effects on conception rates in cattle. It shortens the duration of oestrus. In hot weather most cows come to heat during the night when no one observes them, thus missed heats are common in the summer. High temperature can also prolong anoestrus in lactating cows. A simple measure to lessen the effect of high temperature is to provide shade and air movement. High temperatures also affect the fertility of the bull by affecting both the libido of the bull and the quality of semen collected for artificial insemination (AI).

Management

- Mating should coincide with or occur just before ovulation since ovulation occurs at a definite time and lasts for only a few hours. This is to ensure that the sperm will have the maximum chance to meet the egg.
- To plan mating, it is important to know the length of the heat period.
- Even though the first occurrence of heat is determined mainly by environmental factors, there is considerable variation among breeds and individuals within a breed. This information will be valuable for managing reproduction.
- Accurate detection of heat is important for the efficient management of reproduction.

3.4 Reproduction in genetic improvement

3.4.1 Embryo transfer techniques

Embryo transfer is the process in which a breeder allows a cow to become temporarily pregnant, recovers the embryo in early pregnancy, and transfers it to the reproductive tracts of another cow to complete gestation. This section of the module will briefly describe the rationale for embryo transfer and the steps to do it. For details of the process, refer to listed reference material.

Advantages of embryo transfer technique

1. Cows with superior genetic traits are limited by the long duration of gestation, and hence few progeny. Embryo transfer will increase the reproductive potential of these cows.
2. If the donor cow is prolific in ovulation, then the number of ova supplied is large and this will expand the breeding programme.
3. Embryo transfer accelerates genetic selection.
4. Superior females may be injured or reach old age before their genetic potential is fully tapped; embryo transfer technique is the most useful means of tapping this potential.
5. A high proportion of cows in the herd can produce twins which is desirable for research purposes.
6. When introducing pure breeds into different environments, animals can bring diseases or be stressed by local environment and diseases. In embryo transfer, the embryos are less likely to transmit disease than live animals are. The new born obtains passive immunity from the cow's colostrum.
7. Embryo transfer helps, through long-term storage of cattle eggs to preserve rare germplasm.
8. Embryo transfer makes manipulation for cloning possible.

Steps to follow during embryo transfer

1. Superovulation, synchronisation and fertilisation

Superovulation. This technique aims at increasing the yield of viable ova. Injections of pregnant mare serum gonadotropin (PMSG) or follicle-stimulating hormone (FSH) are given to stimulate the growth of additional follicles. This is followed by injection of luteinising hormone (LH) to induce ovulation. It is recommended that the treatment start 8–12 days into the oestrous cycle and corpus luteum degeneration.

Synchronisation. To succeed in embryo transfer, it is essential to synchronise the donor and recipient reproductive phases. This ensures the right environment for the embryo. Recipients should be in oestrus one day after the donor. Oestrus can be either natural or induced (using appropriate hormones).

Fertilisation. Superovulated donors are inseminated often with more sperm per inseminate. This is to safeguard against damage to sperms during transportation.

2. Embryo collection, evaluation and culture

Ova can be removed from the animal surgically or non-surgically. The non-surgical method is safer and preferred. Currently, catheters (e.g. Foley catheters) are used to recover embryos. After collection, ova are examined under the microscope with a magnification 10 × to 15×. A fine pipette is used to remove them into a culture medium for evaluation. Morphologically normal ova are selected to use in embryo transfer.

3. Transfer

Implantation. Usually ova of more than eight cells are transferred. This process is done non-surgically. There are many techniques for implantation of the ova in the recipient reproductive tracts (see the list of references for details).

Pregnancy. The highest pregnancy rates are achieved when one embryo is transferred into each uterine horn of the recipient cow.

Example: Practical application of embryo transfer in sub-Saharan Africa

Although the embryo transfer technique has potential, its application in SSA is limited to research stations. Government and large commercial enterprises may use it to import exotic breeds. For example, frozen embryos of N'Dama cattle from West Africa have been transferred into zebu cattle in Kenya, East Africa.

One of the limiting factors in developing embryo transfer in SSA is control of the technique to induce donors to shed several ova instead of one through superovulatory treatment (a regime of hormone treatment). Breed, age, physiological condition, season and nutrition affect it. A number of gonadotropin treatments have been used in superovulation programmes. Tegegne et al. (1994) studied the response in Boran cattle (*Bos indicus*) after treatment with either pergovet (human menopausal gonadotropin) at 1050 or 1350 IU of pulset (porcine gonadotropin) at 500 or 1000 IU. The results showed that both perovet and pulset could effectively be used to superovulate Boran cows. Although both hormones resulted in good embryo yield, pergovet tended to yield more embryos in Ethiopian Boran cows. Pergovet given at 1050 IU and Pulset at 1000 IU resulted in 19.4% and 39.0% more transferable embryos than at 1350 and 500 IU, respectively.

3.5 Physiological constraints

Reproductive failure leads to low productivity in cows. In this module we shall cover more common causes of reproductive failure.

3.5.1 Lactational anoestrus

When oestrus is not manifested in a cow during lactation for an extended period, this is termed lactational anoestrus. Even though lactational anoestrus is not a disease, it is a sign of temporary depression of ovarian activity. It can be caused by (Figure 3.5):

- inadequate nutrition: low energy level in diet, deficiency of minerals and vitamins
- lactation stress: the more the period of suckling by a calf (nursing) is extended, the more the chances of anoestrus
- ageing: mostly associated with abnormal corpora lutea in cows 14 to 15 years old
- diseases of the ovaries such as cystic ovaries.

3.5.2 Failure of ovulation

Failure to ovulate may be due to failure of the follicle to release the egg due to cystic ovaries. Follicles with cysts grow and regress but fail to ovulate.

3.5.3 Fertilisation failure

Fertilisation may fail due to:

- death of the egg before sperm entry

- abnormality in sperm or egg
- physical barriers in female genital tract that prevents the sperm or egg to reach the site of fertilisation
- diseases of the reproductive tract.

3.5.4 Embryonic mortality

Fertilisation in cows may take place successfully but the embryo does not complete its cycle to delivery. Embryo mortality in cattle usually occurs during rapid growth and differentiation of embryo. This can be due to:

- diseases of the reproductive tract, e.g. campylobacteriosis, trichomoiasis, vibrosis
- progesterone deficiency caused by genetic infertility or lack of proper embryo development
- inbreeding
- poor nutrition
- old age
- heat stress.

Embryonic mortality can be determined in the following ways:

- progesterone profiles are measured during early pregnancy
- rectal palpation is performed
- slaughter records, which show dead embryos, can be used to estimate incidences/frequency of embryonic death.

3.5.5 Abortion

Abortion is defined as the spontaneous expulsion of the foetus. Abortions can be caused by diseases such as brucellosis or by genetic, hormonal or nutritional factors. It also occurs in some heifers when bred immediately after puberty.

3.5.6 Perinatal and neonatal mortality

Perinatal mortality refers to the death of the offspring shortly before or during parturition. It also includes mortality within the first 24 hours after parturition. In cattle it can range from 5% to 15% of births. Perinatal mortality can be caused by old age or poor nutrition of the cow. Neonatal mortality refers to the death of the offspring during the first few weeks of life. Nutritional deficiencies in the calf result in this disorder, e.g. disturbance in selenium metabolism may cause the disorder.

3.5.7 Reproductive failure in the bull

Failure in the fertility of the male can be due to:

- Poor sperm production: abnormalities in testes (e.g. undescended testes or those that are not fully developed) can lead to suppression of sperm formation.
- Viability of the sperm: defective semen results in failure to fertilise and it is therefore essential to examine the semen quality. Semen analysis is simple to perform. It includes recording volume, colour, density of ejaculate, sperm concentration, forward motility of spermatozoa (%) and examining smears for sperm abnormality. In general, most laboratories adopt the following standards for classification of semen as probably fertile: over 500 million sperms per millilitre, more than 50% of motile sperm make a forward progression, more than 80% of the sperms conform to the normal shape.
- Poor sexual desire: lack of sexual desire (or libido) may be hereditary, due to environmental stresses, e.g. high temperature or hormonal imbalance.
- Inability to mate: physical disabilities may cause certain bulls to be unable to mount the cow, fail to achieve intromission (penis fails to enter vagina) or fail to ejaculate.

3.5.8 Reproductive infections

Infectious diseases in cattle can cause abortion. The following are diseases which generally cause abortion: brucellosis, bluetongue virus, foot-and-mouth disease, rinderpest, tick-borne fever, bovine petechial fever, trypanosomosis. For details see Hafez (1980).

Example: Reproductive problems in crossbred cattle in central Ethiopia

Crossbred cattle, the progeny of zebu and Holstein-Friesian cattle are mainly used for milk production in Ethiopia in dairy farms around the major cities, e.g. Addis Ababa, Gondar and Jimma. The major constraints to production facing these cattle are inadequate nutrition, poor management and genital diseases. Tekelye Bekele et al. (1991) studied reproductive problems facing these cattle. They found that calving intervals were much longer than the optimum 360 days expected from dairy cows. This was due to the extended calving to conception interval owing to anoestrus. Longer calving intervals were also caused by stress due to tick-borne diseases such as heartwater and babesiosis. Abortion rate ranged from 1.7% to 20.2%. The researchers concluded that cattle in the dairy farms under study had low reproductive efficiency because of inadequate oestrus detection, poor artificial insemination services, semen deterioration owing to lack of liquid nitrogen, insufficient feed supply and diseases.

3.6 Practical applications

3.6.1 Heifer management

It is essential to know when to improve reproductive management in cows. The first opportunity for intervention is during the period between birth and first conception (interval 1 in Figure 3.6). We can reduce the period to first conception by adequate nutrition, breeding and proper health management. Failure to detect heat can lead to delayed first conception. The second opportunity for intervention is to reduce the interval between delivery and subsequent conception. This opportunity offers itself in a cyclic manner. During this period (interval 2 in Figure 3.6) heat detection is vital. Other factors that can help in reducing interval 2 include good nutrition and calf removal.

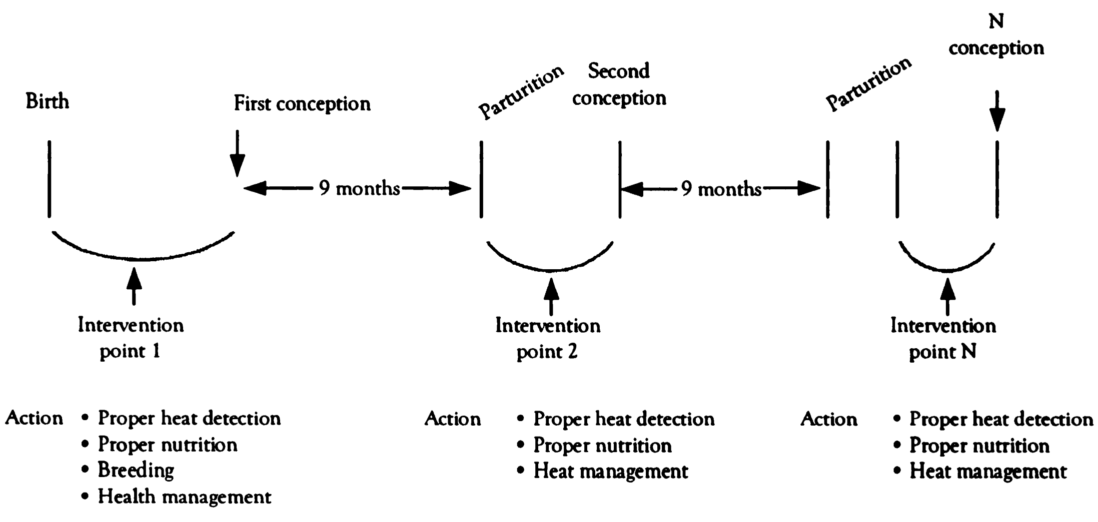


Figure 3.6. *Intervention points for improving reproductive performance in cows.*

Heat detection

We have described the signs of heat. But how do we identify a cow which is on heat? The following are tips to help you use the heat signs more efficiently:

- Observe the cows when they are not disturbed.
- Use standing to be mounted as the best criterion.
- Make as many observations as possible per day.

- Use a team approach (i.e. more than one person) to detect heat.

There are special methods and aids to help detect heat:

1. Vasectomised bulls: If there is a bull in the herd, it may mount a cow on heat. A vasectomised bull can therefore be used to detect heat. The bull mounts the cow on heat but fertilisation does not occur. Coloured markers are used in this method and skill is required in detecting the coloured marks on a cow on heat.
2. Tail paint: A paint paste, which is water-based emulsion, is used. It is cheap and easy to use. The paste can be put on the clean tail head using a paintbrush. The paint paste should be brushed to reach the skin level and the final product should be a smooth strip (about 12 × 4 cm). When the cow is mounted, the paint strip will be scuffed, removed or cracked. The cow should be checked regularly, otherwise the heat may be missed.

There can be errors in detecting heat. It is costly to wrongly diagnose a cow on heat because it leads to wrong management (e.g. AI) decisions. In general in SSA 36% of the cows presented for breeding are not in heat. These cows had ovarian and uterine changes indicating they were not on heat but still the farmers will judge them as being on heat. Incorrect detection of heat leads to irregular heat cycles.

Errors in detecting heat occur by:

- selecting cows that stand involuntarily
- selecting the mounting cow
- use of incorrect criteria for heat detection
- faulty identification.

False or irregular heats are caused by:

- Errors in detecting heat.
- Cystic ovarian degeneration: when ovulation is delayed, the mature follicle may shrink, degenerate or it may form a large ovarian cyst (large fluid-filled sac). This condition can lead to infertility and to prolonged anoestrus (a period where oestrus is not shown).
- Inflammation of the uterus
- Follicle producing low levels of oestrogen: this may lead to failure of appearance of heat or to a very short oestrous cycle.

Example: oestrus synchronisation using a prostaglandin analogue in Ethiopia

Tegegne and Franceschini (1993) used 32 Boran × Friesian heifers in Ethiopia to evaluate oestrus synchrony using a prostaglandin analogue, Prosolvin. Plasma samples were obtained periodically and used to determine progesterone levels. Oestrus was shorter in treated heifers than in controls. Pregnancy rates were 91%, 73% and 60% in heifers that received full and split doses of Prosolvin, and in the control group, respectively.

Pregnancy diagnosis

To successfully manage cattle fertility, it is important to diagnose whether pregnancy has occurred or not. The following are common methods to diagnose pregnancy:

1. Palpation: This is the most reliable method. A veterinary surgeon will perform rectal palpation. The disadvantage of this method is that it is difficult to diagnose early pregnancy.
2. Progesterone assay: In this method, the milk is tested for progesterone on day 24 after insemination. At this time the hormone is absent in non-pregnant cows. Progesterone is secreted by the corpus luteum in early pregnancy and is passed into the milk from the blood plasma. If fertilisation has taken place, then the corpus luteum will not degenerate and progesterone levels will continue to be high. Radio-immunoassay is used to accurately measure levels of progesterone in the milk.

Target body weight

In temperate climates, the target body weight at first mating (which is critical minimum weight) for *Bos indicus* is 280–300 kg at 24–27 months of age. This cannot be widely applied to tropical heifers. Target weight for tropical cattle should be developed taking into consideration the nutritional plane that farmers can afford.

3.6.2 Bull fertility management

In many cases farmers focus more on managing the fertility of heifers and give little attention to the fertility of bulls. In this module we will briefly focus on bull fertility aspects as they affect productivity of cattle in SSA.

General concepts

Bull fertility is dependent upon total sperm production which is highly correlated with testis size. The best measure for testis size in live animals is the scrotal circumference. Why are the testes so important? They produce sperm which is vital in fertilisation and hence fertility of the herd. The testes also produce sex steroids (male sex hormone testosterone) which are vital for the reproduction process.

Bulls with small scrotal circumferences may end up with poor fertility and hence are recommended for rejection for breeding. It is important to note that for any given age there is a standard scrotal circumference. This simple measure can contribute significantly to bull fertility improvement research. Scrotal circumference can be measured on the live animal using either a flexible plasticised cloth or metal tape while testes length and diameter can be measured using caliphers.

The reproductive performance of bulls is influenced by the genetic constitution of the breed, climate, nutrition, age and disease. It is important to manage the fertility of bulls because they graze alongside cows in the animal agricultural systems of SSA. Often little attention is paid to bulls, as the myth is 'all bulls are good bulls!' For *Bos indicus* herds, bull fertility can influence herd fertility.

Fertility problems in *Bos indicus* bulls include:

- Fertility is lower in 2-year-old than in 3-year-old bulls in standard bull evaluation procedures.
- Bulls may inherit testicular hypoplasia, a congenital disease in which the potential for development of the spermatogenic epithelium is lacking leading to reduced fertility or sterility. Studies on 18-month-old *Bos indicus* cross bulls showed that testicular hypoplasia incidence (17%) lowers fertility.
- Nutritional stress can lower bull fertility by suppressing growth of the testes. This can happen during 6–9 months (post-weaning) and during 18–20 months age. It is important to supplement the feeding of growing bulls to ensure future fertility. Supplementation can prevent decline in sperm production by about 40%. Since feed is mostly short during the dry season in SSA supplementation should be provided during this period. Studies should be done to assess availability of feed and the economic feasibility of supplementation.
- *Bos indicus* bulls experience decline in libido. There are no satisfactory field tests for testing this limitation.

Selection for enhanced fertility in bulls

Selection criteria are now available for growth rate and reproductive traits. For bull fertility, some of the criteria are:

- clinical normality
- functional testis tissue
- daily sperm production potential
- libido and service capacity
- testis size.

Heritability for testis size in *Bos indicus* bulls is high (estimates 0.55–0.65). Thus one of the important selection criteria for improved fertility is testis circumference. The relationship between live weight and scrotal circumference of bulls at puberty in different breeds is given in Table 3.2.

Table 3.2. *Age, live weight and scrotal circumference of bulls of different breeds at puberty.**

Breed	Age (months)	Live weight (kg)	Scrotal circumference (cm)
Brown Swiss	8.7	295	27.2
Charolais	9.4	396	28.8
Angus	9.7	273	28.0
Brahman	15.9	432	34.4
African Zebu	16.0	155	22.1

* Puberty is defined as the age of first ejaculate containing 50×10^6 spermatozoa with 10% motility.

Example: Comparison of sperm reserves in two breeds of zebu bulls

The bull plays an important role in influencing herd fertility and contributes to genetic improvement. Gonadal and extragonadal sperm reserves were determined in Small Highland Abyssinian Zebu (SHAZ) and Boran bulls (Tegegne et al. 1992b). Mean scrotal circumference was 27.9 and 30.7 cm for SHAZ and Boran bulls, respectively. Daily sperm production did not differ between SHAZ (2.89 × 10^9 sperms) and Boran (3.67 × 10^9 sperms) bulls. Corpus sperm reserves were higher in Boran than SHAZ bulls. The researchers concluded that:

- Some variation exists between *Bos indicus* bulls in reproductive potential and should be taken into account when planning mating programmes and using the bulls for artificial insemination.
- Bulls used for draft power may have lower reproductive potential.
- Good management and selection will lead to improvements in herd fertility by emphasising breed characteristics, better growth and reproductive potential.
- Improvement of testes size through better feeding might improve capacity for sperm production.
- Boran bulls tend to have better reproductive potential than SHAZ bulls in Ethiopia.

3.6.3 Use of dairy cows for draft

Farmers use oxen for draft to plough land. The oxen are fed all year round but their work output is utilised for only part of the year. The use of the cow for draft is more efficient because:

- cows produce milk
- males can be fattened and sold younger
- farmers cull old cattle and cows provide progeny that can be used for replacement
- since oxen are eliminated, there is a reduction in stocking rates and hence reduction in overgrazing.

ILRI and the Ethiopian Agricultural Research Organization (EARO) conducted joint research on the performance of crossbred dairy cows (Friesian × Boran and Simmental × Boran) used for draft. The main treatments were varying workloads and supplements (Zerbini et al. 1996a).

Work output

Farmers are sceptical about using their cows for draft work. For farmers to adopt this technology, it is therefore essential to determine the optimum workload that dairy cows can undertake. Feed and body energy stores have to be channelled to different productive tasks such as milk production and/or pregnancy and work. Research in the joint EARO–ILRI project found that in the Ethiopian highlands work efficiency of the cow increased from about 7% to 26% as the workload increased to its maximum (Zerbini et al. 1996a).

Metabolism

Zerbini et al. (1996a) found that in working cows, glucose is an important energy source for the muscles; it is also important during reproduction. Fatty acids were found to be important for the synthesis of milk fat as well as reproductive hormones. Non-esterified fatty acids (NEFAs) and β-hydroxybutyrate were found to increase in working cows whereas glucose, magnesium and inorganic phosphorous decreased.

Zerbini et al. (1996a) found a greater loss in body weight in working non-supplemented cows than in working supplemented ones. Glucose was decreased in non-supplemented cows, which stimulated the release of NEFAs from adipose tissue (150% increase in the plasma). Fatty acids were mobilised from the fat depots even in well-fed animals. This suggests that NEFAs are the principal fuel for the muscle tissue of working dairy cows. Reduction in NEFAs in poorly fed working cows explains the low conception rate. Energy restriction affects reproductive performance at the hypothalamic or pituitary level. This could be due to inhibition of gonadotropin-releasing hormone (GnRH).

Post-partum oestrus and conception

Work stress has an effect on fertility. Thus when breeding dairy cows are intended to perform work, the incidence of anoestrus should be studied. Zerbini et al. (1996b) found:

- Diet supplementation significantly reduced days to first oestrus and days to conception in non-working cows. Post-partum anoestrus was longer in working than in non-working cows.

- The combined effect of work and non-supplementation was deleterious to milk production, number of conceptions and number of calving of crossbred cows. There was longer-term effect from supplementation than from work.
- Even though work delayed conception during the first post-partum period by 365 days, post-partum conception rate was similar for supplemented non-working and supplemented working cows. Thus supplementation can negate the deleterious effect of work if sustained for a long time.
- For first oestrus, the supplementation effect is larger than the work effect.
- Body condition at calving affected post-partum reproductive ability of cows. Thus the negative effect of dietary energy restrictions on oestrus and onset of conception can be overcome if the cow has greater body reserves at calving and the ability to use these reserves during the post-partum period.
- Working cows have longer calving intervals. The economic trade-offs between work and calving should be studied.
- Once the cow is pregnant, work does not affect maintenance of the pregnancy.
- Working soon after calving delayed but did not suppress oestrus and conception.

Economic implications

The economic implications indicated that the value of work more than compensated for the small reduction in milk production and longer calving interval. Working cows must be supplemented to ensure adequate nutrition. When working crossbred cows are supplemented, the greater return to investment was due to higher value of work output, in spite of the higher feed costs.

3.7 Exercises

1. List the important events in the life cycle of a cow.
2. A farmer has one cow which he/she keeps in a zero grazing unit. He/she wants to know how to detect when this cow is on heat. Explain to him/her how he/she can do this.
3. A dairy farmer has a cow that delivered today. His/her goal is to produce the maximum amount of milk and at the same time get his/her cow back in cycle for reproduction as soon as possible. He/she has sought your advice. Which of the following options would you recommend to him/her:
   - Milk the cow and leave a small amount of milk in the udder for the calf to suckle. Take the calf away after it feeds.
   - Leave the calf with its mother 24 hours.
   - Remove the calf from the mother altogether and feed it milk from its mother, other cows or powder milk.
4. High temperature can affect the reproductive efficiency of cows and bulls. In many locations in SSA, temperatures can rise above 30°C. What simple measures can be taken to lower the temperature without costing the smallholder much.
5. Embryo transfer is very useful but it is expensive. Describe steps to perform embryo transfer. Describe situations in which you would recommend embryo transfer in spite of the expense.
6. List ways to reduce the occurrence of lactational anoestrus.
7. It is rare for smallholder farmers to keep bulls as it is expensive to feed them. Consider a farmer who keeps bulls for draft and is also interested in using them for mating his/her cows. If this farmer asked you for advice on how to improve the reproductive efficiency of these bulls, what would you advise him?

3.8 References and reading materials

Boland M.P., Foulkes J.A., MacDonnel H.F. and Sauer M.J. 1985. Plasma progesterone concentrations in superovulated heifers determined by enzymeimmunoassay and radioimmunoassay. *British Veterinary Journal* 141:409–415.

Cole H.H. and Cupps P.T. 1977. *Reproduction in domestic animals*. Academic Press, New York, USA. 665 pp.

Esslemont R.J., Bailie J.H. and Cooper M.J. 1985. *Fertility management in dairy cattle.* Collins, London, UK. 143 pp.

Gordon I. 1983. *Controlled breeding in farm animals.* Pergamon Press, Oxford, UK. 436 pp.

Hafez E.S.E. 1980. *Reproduction in farm animals.* Lea and Febiger, Philadelphia, USA. 627 pp.

Mukasa-Mugerwa E., Zere Ezaz and Viviani P. 1990. Plasma concentrations of progesterone during oestrous cycles of Ethiopian Menz sheep using enzyme immunoassay. *Small Ruminant Research* 3:57–62.

Mukasa-Mugerwa E., Tegegne A. and Franceschini R.R. 1991. Influence of suckling and continuous cow–calf association on the resumption of post-partum ovarian function in *Bos indicus* cows monitored by plasma progesterone profiles. *Reproduction Nutrition Development* 31(3):241–247.

Payne W.J.A. 1990. *An introduction to animal husbandry in the tropics.* Longman, New York, USA. 881 pp.

Seidel G.E. 1984. Applications of embryo transfer and related technologies to cattle. *Journal of Dairy Science* 67(11):2786–2796.

Tegegne A. and Franceschini R.R. 1993. Evaluation of luteolysis and oestrus synchronization using a prostaglandin analogue (Prosolvin) in Boran × Friesian crossbred heifers in Ethiopia. *Journal of Applied Animal Research* 4:107–114.

Tegegne A., Entwistle K.W. and Mukasa-Mugerwa E. 1992a. Effects of dry season nutritional supplementation on growth, onset of puberty and subsequent fertility in Boran and Boran × Friesian heifers in Ethiopia. *Theriogenology* 37:1017–1027.

Tegegne A., Taddele Y. and Kassa T. 1992b. Gonadal and extragonadal sperm reserves in two breeds of mature Zebu (*Bos indicus*) bulls in Ethiopia. *Tropical Agriculture (Trinidad)* 69(3): 243–246.

Tegegne A., Franceschini R.R. and Sovani S. 1994. Superovulatory response, embryo recovery and progesterone secretion in Boran (*Bos indicus*) cows after treatment with either Pergovet or Pluset. *Theriogenology* 41:1653–1662.

Tekelye Bekele, Kasali O.B. and Tsion Alemu. 1991. Reproductive problems in crossbred cattle in central Ethiopia. *Animal Reproduction Science* 26:41–49.

Zerbini E., Wold A.G. and Gemeda T. 1996a. Effect of dietary repletion on reproductive activity in cows after a long anoestrus period. *Animal Science* 62:217–223.

Zerbini E., Gemeda T., Wold A.G. and Tegegne A. 1996b. Effect of draught work on the metabolism and reproduction of dairy cows. In: Phillips C. (ed), *Dairy science.* CAB (Commonwealth Agricultural Bureau) International, London, UK. pp. 145–168.

Module 4: Nutrient requirements and feed resources

4.1 Performance objectives

Module 4 is intended to enable you to:

1. List strategies to improve ruminant livestock nutrition.
2. Describe feed intake for ruminant livestock.
3. Describe nutrient requirements (protein, energy, minerals, vitamins and water) for ruminant livestock.
4. Calculate crude protein from nitrogen analysis data.
5. List *in vivo* and *in vitro* methods for measuring digestibility.
6. Describe feed resources: natural pastures and ways to improve them, artificial pastures, fodder trees, crop residues and agro-industrial by-products.
7. Describe methods for conserving forages.
8. List feeding techniques.

4.2 Introduction

Preceding modules described the production systems in sub-Saharan Africa (SSA) and stressed the following facts:

- One of the major factors limiting productivity of livestock ruminants in SSA is poor nutrition.
- Variations in birth weight may be related to the plane of nutrition at the time of conception and during late pregnancy in ruminants.
- Neonatal losses can be closely correlated with birth weight, which is a reflection of maternal nutrition during the last two months of gestation.
- Undernourished animals are more likely to contract diseases.
- Feed supply is limited during the dry season.

The above factors indicate that nutrition must be part of any strategy to increase productivity. In this module we will highlight (i) nutrient requirements and (ii) availability and use of feed resources. More details about ruminant nutrition (methods of feed evaluation and nutrition strategies) can be accessed in manuals produced by ILRI (ILCA 1990; Osuji et al. 1993b).

Insufficient forage during the dry season is a major constraint to ruminant productivity. Forage availability determines the overall carrying capacity of the land. In SSA human population is increasing, forcing farmers to use grazing areas for arable farming. Even though this may have a negative effect on pastoralists, it also results in a symbiotic relationship. Pastoralists can graze their animals on crop residues in the dry season and the settled farmers crops benefit from the animal manure that is left in the fields.

To assist you in learning the following sections, Box 4.1 contains the definitions of some basic concepts of nutrition and feed. Solutions to nutritional constraints depend on the nature of the system. In pastoral systems the scope is limited as the situation is complicated by land tenure and stocking rates. In mixed crop–livestock systems there is potential for improvement. The following are a few strategies to improve ruminant livestock nutrition through technological solutions:

- Crop improvement: This pathway includes (i) selection of crop varieties which yield residues of high nutritive value and/or in large quantity (ii) changing crop combinations, e.g. intercropping with legumes and (iii) changing time of planting.
- Livestock management strategies: This involves changing livestock management to match feed availability with livestock feed requirements.
- Pasture improvement strategies: This involves improving the management of the range principally through increasing the amount and quality of forage.
- Feed supplementation strategies: These involve using fodder banks, fodder trees, by-products such as oilseed cakes and meals, and urea/molasses blocks to supplement shortages of crude protein.

Box 4.1. Definition of concepts related to nutrition and feeds

Crude protein. The amount of protein in the feed available to the ruminant. It is calculated using nitrogen content of the feed corrected by a factor of 6.25 based on the assumption that feed protein contains, on average, 16% nitrogen. Assumes that all faecal nitrogen is in the form of proteins.

Crude fibre. A fraction of feed that contains the cell wall and consists of carbohydrates (hemicellulose and cellulose) and lignin.

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.

Energy. Derived from organic constituents of food and used as fuel for body functions and production.

Maintenance. This is the condition where an animal's energy requirements are in balance (equilibrium) and it is not reproducing or producing output.

Metabolism. The sum of all the physical and chemical processes taking place in living organisms. For example the excretion of waste (manure and urine) products from the body is part of the metabolic process.

Scientists conduct research to develop feeding systems that provide sets of tables that give nutrient requirements of the animal and the nutritive value of feed both expressed according to the feed evaluation system. The feeding systems are prepared to help farmers calculate rations for their animals. Scientists conduct research to find solutions to nutritional problems. This involves studying the relationship between nutrition and performance, management and grazing conditions. To achieve this goal, data are collected to:

- examine the effect of nutrition on production
- determine the amount of feed consumed
- determine the composition of the feed consumed.

This module presents some concepts and methods used to collect these data (Table 4.1). For further details, you are referred to the reading materials.

Table 4.1. *Types of animal data used to diagnose animal nutrition problems.*

Objective	Type of data
Production effects	Liveweight gain, condition scores, traction power, milk and wool production
Amount of feed consumed	Feed intake
Composition of feed consumed	Rumen fistula samples, faecal samples and grazing behaviour

Detailed methods for data collection are described in ILCA (1990).

4.3 Feed intake

Feed intake is the amount of feed an animal consumes. It can be estimated by using either digestibility data or markers.

4.3.1 Using digestibility data

When digestibility data are available, intake can be estimated by multiplying the dry matter (DM) weight of faeces by a digestibility factor. The factor is known as the feed:faeces ratio and is expressed as:

$$\text{DM intake (g/day)} = 100/(100 - \text{digestibility}) \times \text{DM weight of faeces}$$

where digestibility is in per cent.

For example if the dry-matter weight of faeces of an animal is 870 g/day and the percentage digestibility of the feed consumed is 60%, then the amount of dry feed consumed would be:

$$\text{DM intake} = 100/(100 - 60) \times 870 = (100/40) \times 870 = 2175 \text{ g/day}$$

4.3.2 Using 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, iron oxide and barium sulphate). They are used when the measurement of feed intake and faecal output is difficult.
The formula used to estimate faecal output is:

$$\text{Faecal output (g)} = \text{grams of marker in feed per day/concentration of marker in faeces}$$

For example an animal is dosed with 50 g of chromic oxide per day to determine its daily faecal output. The concentration of marker in the dry faeces sample is 5.75% and the dry-matter weight of the faecal output is:

$$\text{Faecal output} = 50/0.0575 = 870 \text{ g}$$

If the proportion of marker in the diet is 3.4%, then we calculate dry-matter intake as follows:

$$\text{DM intake} = 870 \times (5.75/3.4) = 1471 \text{ g/day}$$

4.4 Nutrient value of feed

It is important to know the supply of different nutrients to ruminant livestock in systems in relation to their need for these nutrients. This module will cover energy, protein, water, minerals and vitamins. Methods to estimate amounts of these nutrients can be found in ILCA (1990).

4.4.1 Energy

The energy yield of a source of feed (such as natural pasture) can be estimated from its dry-matter weight per unit area. Feeds with a high biomass per unit area are often low in energy since they also contain a high proportion of indigestible fibrous matter.

4.4.2 Protein

Protein is the basic structural material from which all body tissues (e.g. muscles, nerves and blood cells) are formed. It is therefore essential for production and maintenance and cannot be replaced by other nutrients in the feed. The requirements of the animals are for essential amino acids, which are the building blocks of the protein. This is expressed as protein requirements, where crude protein (CP) is obtained by using this equation:

$$CP = \% \text{ nitrogen} \times 6.25$$

where the value 6.25 is based on the assumption that feed protein contains, on average, 16% nitrogen.

Crude protein is highly related to grain yield at the time of harvest (Church and Pond 1982). On a per hectare basis, grain yield is related to CP in the leaf. Such relationships can be used to indicate the availability of CP in the different sources and/or at different stages of plant growth.

When estimating the CP content of browse plants and crop residues, it should be kept in mind that the presence of certain chemical compounds (e.g. tannins) in these feeds can affect the availability of nitrogen to the ruminant.

It is important to know that ruminants are able to synthesise protein from non-protein nitrogen sources (e.g. urea) by microbial action in the rumen.

4.4.3 Minerals

Calcium, phosphorous, magnesium, sodium, potassium, sulphur, chlorine, iron, copper, cobalt, iodine, manganese, selenium, zinc, chromium, fluoride, molybdenum, nickel, silicon and vanadium are essential for tissue growth and regulation of body functions in ruminants. If one of these minerals is missing in the diet, symptoms of deficiency occur; if any mineral is in excess the animal experiences toxicity. Mineral deficiencies in the soil and flora can lead to these deficiencies in the ruminants. Excess of selenium in the soil may result in levels in plants which are toxic to the animals. Usually under extensive livestock systems in the tropics, mineral imbalances are rarely seen. Analysis for minerals should only be attempted if mineral deficiencies are clearly evident. Even then, if other nutrients such as energy or CP are more limiting (as is likely to be the case in African rangelands), the mineral constraint should be dealt with only after the primary deficiencies have been rectified. A more detailed account of symptoms of mineral deficiency and the role of minerals in ruminant nutrition can be found in basic nutrition texts (e.g. Church and Pond 1982).

4.4.4 Vitamins

Ruminant livestock require vitamins in very small amounts, to regulate body functions. Although vitamin deficiencies do occur in ruminant animals in the tropics, in general they are of minor importance. Under more intensive systems (e.g. peri-urban dairy), vitamin supplements should be provided. Many of the vitamins are synthesised in the rumen especially many of the members of the vitamin B complex and vitamin C. If animals are exposed to the sun, they are able to manufacture vitamin D. Vitamin A is essential during pregnancy; cattle can obtain provitamin A from green forage and convert it into vitamin A. Young herbage and cereal grains contain enough vitamin E to meet livestock needs.

4.4.5 Water

Ruminants require water because:

- it affects voluntary intake: less water leads to inadequate intake of dry matter
- it is needed to maintain the water content of the body.

For animals kept under the pastoralist system, the frequency of watering is very important. During the dry season water is available only from wells or some lakes/streams. This leads to overgrazing around the watering points forcing pastoralists to move their animals far away from water sources to obtain pasture. The situation presents a dilemma to nomads because water intake increases as watering frequency is decreased and food conversion efficiency becomes lower as watering intervals increase.

Heat stress increases the water requirement of cattle. It is recommended that cattle be given water *ad libitum*. The water requirements increase when cows are pregnant or lactating. Lactating cows require 50% more water during early lactation and 25% more during late lactation. The extra water required is equivalent to the amount of milk produced.

4.5 Evaluation of feed

The chemical composition of a feed determines its nutritive value. The difference in energy value of feeds is due to their differing 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. A few methods to evaluate feed for digestibility are listed. [For more details about the methods consult Osuji et al. (1993b)].

4.5.1 *In vivo* measurement of digestibility

Feeding trials

A feeding trial is used to obtain data to calculate digestibility values. Faeces from several animals is collected for at least 1 week following an adaptation period of 2 weeks. The following equation is used:

$$\text{Digestibility} = 100 \times (DM_{food} - DM_{faeces})/DM_{food}$$

where DM_{food} is the dry matter consumed and DM_{faeces} is the dry matter excreted in the faeces.

Nylon bag technique

You place samples of feed in small nylon bags, which are then placed in the rumen through a fistula. The degradation of the feed is recorded after two days.

Indigestible marker technique

An indigestible marker such as chromic oxide is mixed with the feed. The concentration of chromic oxide in the feed and faeces is used to calculate digestibility as follows:

$$\text{Apparent digestibility (\%)} = 100\,[100 - (100 \times \%\ \text{marker in feed}/\%\ \text{marker in faeces})]$$

4.5.2 *In vitro* methods for measuring digestibility

There are several *in vitro* methods for measuring digestibility.

- You can use equations to calculate digestibility from chemical analysis. One of the methods used pepsin enzyme to determine digestibility. You incubate a feed sample in rumen fluid and then transfer it to a pepsin solution. To monitor the accuracy of this *in vitro* method, it is important to include one or two samples extracted from the cow rumen and for which *in vivo* analysis was done.The *in vivo* samples act as standards.
- You can use the Menke *in vitro* gas production technique. In this method gas is produced when feed is incubated in rumen fluid. The amount of gas is correlated with digestibility. This method determines the gas produced over a 24-hour incubation period.

4.6 Feed resources

4.6.1 Natural pastures

Natural pastures are the most important feed resource for cattle in SSA. Pastures differ in their species composition and canopy coverage. The canopy coverage depends on the amount of moisture in the soil and sunlight. UNESCO (1979) adopted the following classification for natural pastures:

- Savannah is composed of grasses and shrubs or trees. The acacia grasslands of East Africa fall into this category.
- Grasslands are composed of pure grasses. There is little true grassland in the tropics. Aquatic grasslands are found in southern Sudan, around Lake Chad and in the seasonal flooding areas of East Africa.

The potential carrying capacity of the pasture is determined by the quantity of vegetation. The productivity of cattle on pasture is affected by the quality of the vegetation. The quantity and quality of pasture is affected by:

- climate and season
- burning: accidental fires or burning for pasture management

- legume content: the mixture of legumes and grass has a better quality than grass alone.

At the start of its growth, natural pasture has high water and protein contents which are not advantageous for animals because of limited energy intake; cellulose increases thereafter. Natural pasture with 30–40% cellulose content is adequate for the maintenance requirements of ruminant livestock. Higher cellulose content is undesirable because rumen micro-organisms are unable to degrade it, thus pasture with high cellulose content is low in nutritive value. Grasses reach their highest quality during stem elongation and the quality decreases after heading.

4.6.2 Improved pastures

The yield and quality of natural pastures can be improved by:

- changing the species composition, e.g. introducing a legume such as *Stylosanthes guianensis* in a natural pasture to increase the protein yield per hectare
- improving management, e.g. grazing control or applying fertilisers.

Improving pasture in the dry zones of the tropics is limited by cost such that only simple measures can be implemented. There is more scope for improvement in the subhumid and humid zones of SSA provided there is a way to control tsetse fly and associated cattle diseases.

Introducing new species to pastures must be done carefully. An aggressive species will dominate the less aggressive ones. Introduced species should be able to:

- grow in soils of low fertility
- withstand stress, i.e. heat, moisture and waterlogging
- withstand severe grazing pressure
- spread on hill slopes to help control erosion.

The list of species and the methods used to establish and maintain pasture are beyond the scope of this manual. Specialised texts can be consulted for more details (see Crowder and Chheda 1982). The successful use of improved pastures depends on grazing control. The use of barbed wire or electric fences is beyond the means of resource poor farmers. The use of fodder trees or non-palatable shrubs as fences has been demonstrated as a possible means of controlling grazing (Charray et al. 1992). However, the use of this technology is limited by lack of enough labour and inadequate knowledge of the management of trees/shrubs.

4.6.3 Cultivated pastures or fodder crops

Even though natural pastures are used extensively in SSA, they can only support the desired productivity of cattle to a certain level and for a short period. Cultivated pasture or fodder crops are grown with the aim of:

- increasing forage production per unit area
- improving the feed value of the grasses.

When choosing a fodder crop we should ask the following questions:

- Is it easy to sow? And establish?
- How is it to be used?
- What is the length of the vegetative cycle?

Fodder crops are not yet widely used in SSA because of the high cost of inputs such as land, labour and fertiliser. These crops are attractive when grown as:

- catch crops growing in a period when the land is otherwise unused
- break crops, which improve the yield of subsequent crops by improving soil fertility or reducing pests and diseases
- intercrops, grown between the rows of another crop to improve soil fertility, provide shade or control erosion.

Fodder crops must give higher yields or have better quality than pastures (Mohamed-Saleem 1985). Legume fodder is known to have these attributes.

Fodder banks were found to improve the nutritional status of livestock during the dry season. These are special plots of legumes grown by pastoralists adjacent to their homes to serve as supplements to dry-season grazing. For Nigerian pastoralists, ILRI developed fodder bank technology packages which use low inputs. The farmers received the technology well and researchers and extension teams worked with them to overcome difficulties related to establishment, utilisation and regeneration.

Supplementation of roughage

Dry natural pastures can only provide low-quality roughage and therefore cattle will benefit from any form of supplementation of the roughage. Supplements usually consist of at least one of the following:

- concentrates
- molasses
- non-protein nitrogen (e.g. urea)
- minerals.

These supplements can be fed to animals separately, incorporated into a complete diet or as feed blocks. When supplementing roughage you must remember that:

- supplementation with molasses must be accompanied with urea
- urea is not palatable to livestock ruminants; mixing it with molasses overcomes this problem.

Supplements to roughage are beneficial to cattle because:

- they provide essential nutrients to the rumen micro-organisms
- the enhanced activity of micro-organisms in the rumen results in better digestibility
- they provide nutrients for cattle.

4.6.4 Conserved forage

During the dry season, the quality of pasture is low and forages are scarce. One way to solve this problem is to conserve forages. Conservation aims at retaining the feed value of the forage. Fodder can be conserved as hay or silage.

Hay

Hay is dried fodder. To produce hay of high quality, it is essential to harvest the fodder at the right time. When fodder is harvested too early, its moisture content is too high resulting in hay with reduced dry-matter content. If fodder harvest is delayed, the plants develop high lignin content. Hay made from fodder with high amounts of lignin is of poor quality because its digestibility is low. In the humid zone, heavy rainfall forces farmers to delay fodder harvest until the dry season resulting in fodder with high lignin content. In addition, at the end of the rainy season, most crops are ready for harvest so hay-making competes with crop harvests for labour.

Hay can be sun dried to 10–15% moisture content. Low air humidity is needed to achieve this level of moisture in the hay. This is easy to achieve in the arid and semi-arid zones but difficult in the humid zone where the rainfall and relative humidity are higher.

There are many methods for making hay. The simplest and cheapest method is drying the forage on the ground. The grass is cut (using a machete) early in the morning and is spread on the ground in the field. The heaps of forage are turned over many times to avoid picking up moisture from the soil. Sophisticated methods for drying forages and haymaking are available but they are costly and beyond the reach of smallholder farmers. Hay should be protected from rain and the sun as exposure to these factors reduces its feed value. Cattle may refuse hay of low quality unless they are starving. Hay can never be equal in feed value to the fresh forage from which it is made.

How do farmers use hay?

- Feed it to animals on maintenance diet.
- Feed it to calves to accelerate rumen development and the rumination process.
- Use it as roughage for calves destined for fattening on rations with large amounts of high-energy, high-protein concentrates.

Silage

Fermenting the sugars in green herbage under anaerobic conditions produces silage. The desired product is reached when enough acids are produced (low pH which prevents bacterial decomposition) and fermentation stops. Silage can be stored for at least a year.

Silage can be made in silos of various shapes. The easiest method is to use pit and trench silos, which can be built using simple materials. The silo and its wall must be completely air tight to prevent the fodder putrefying. The bottom of the silo must be covered with stones to allow the liquids resulting from fermentation to drain off. To ensure successful silage making:

- After harvesting forage, keep it at low moisture by exposing it to the sun. The harvested forage should not be exposed to rain.
- Chop the forage into fine pieces (with a machete) of not more than 10 cm length.
- Compress the forage in the silo to remove as much air as possible (treading with feet can be used to compress forage in small silos).
- Cover the silo as soon as possible with compacted straw or a sheet of plastic (if available) and place soil on top (a layer of about 50 cm). Compact the upper layer of the soil to maintain good coverage.

4.6.5 Crop residues

There are many crop residues which can be used for feeding cattle. Farmers with no animals may use crop residues to improve fertility of the soil or sell the residues.

Straw

Straw is mostly a by-product of cereal crops that is used as roughage for ruminants. Straw of the following crops is used in SSA: maize, millet, sorghum, wheat, barley, rice and teff. Crop residues from other crops are also used on a small scale: sugar-cane, cocoa, banana, cotton, cassava and legume crops.

Straw has low nutritive value. The energy content of straw ranges from 5.5 to 9.6 MJ metabolisable energy (ME)/kg DM. Energy values vary with the cereal variety and the management of the residue after grain harvest. Straw is high in lignin, which lowers its digestibility. Straws of most crops are low in CP and minerals (especially phosphorous). The nutritive value of straw and its coarse physical form limit the activity of micro-organisms in the rumen and contribute to the low rate of passage through the digestive system. All these factors result in low voluntary intake. You can improve the feed value of straw by:

- Adding supplements of energy, protein and minerals, which will give an adequate supply of nutrients to both the rumen micro-organisms and the animal. Research at ILRI (Girma Getachew et al. 1994; Umunna et al. 1995) has shown that supplementation with forage legumes is a sustainable way of improving the feed value of poor quality crop residues especially for resource-poor African smallholders. The results indicated that *Stylosanthes guianensis, Lablab purpureus* and *Sesbania sesban* were useful as supplements for sheep in Ethiopia. A similar effect was found by Khalili et al. (1994) when they supplemented the maize-lablab forage diet of crossbred (*Bos taurus* × *Bos indicus*) with wheat middlings diet. They found that daily mean organic matter intake increased. Milk yield also increased.
- Grinding or chopping the straw or heating it with steam to increase voluntary intake. The cost of treatment is high because it requires labour.
- Treatment with chemicals, particularly alkalis (e.g. sodium hydroxide, potassium hydroxide, calcium hydroxide and sodium carbonate) and nitrogenous compounds (urea and ammonium hydroxide). These treatments will increase digestibility and nitrogen content but they are expensive and the chemicals may not be available, posing problems for small farmers. This practice is therefore suitable only for research stations and a limited number of farmers.

Bran

Bran is produced from cereals and it consists of the outer parts of the hulled grains, some broken grain and germ. Bran is palatable and is a valuable feed for cattle. Its CP content is 12%. The main problem with bran from rice and maize is its relatively high oil content (around 10%). Fatty acids turn rancid with storage and this lowers the nutritive value and palatability of the bran.

4.6.6 Agro-industrial by-products

Cottonseed cake

Cottonseed cake, when available, is an excellent feed for cattle. It has a high content of protein (25–40%), fat (10–23%) and cellulose (25–30%). Once the animal gets used to cottonseed cake, intake increases. Kumwenda and Msiska (1990) fed dairy cows in government research stations in Malawi maize bran in combination with cottonseed cake at the ratio of four parts of maize bran to one part of cottonseed cake. They found that the diet increased milk production and the inclusion of cottonseed cake in maize bran-based dairy rations would raise dairy farmer's profit. Other researchers obtained good results by mixing cottonseed cake with salt and molasses. It had been tried with West African Dwarf ewes and a mixture of 50:50 molasses and cottonseed cake gave good results (Charray et al. 1992). The high protein content allows the amount of cottonseed cake to be reduced without detrimental effects. Unfortunately cottonseeds contain the toxic substance gossypol, which reduces the growth of young animals, but has little effect on adults. However, there are cotton varieties that are glandless and their seeds are free of gossypol.

Oilseed cakes

Oilseed cakes (oilmeals) are by-products of processing a variety of oil crops: groundnut, sunflower and soybean. These cakes are like cottonseed cakes: rich in protein and fatty acids. They can be used alone or mixed with molasses for effective results. Research at ILRI (Osuji et al. 1993a) showed that sunflower cake was utilised effectively by Menz sheep in the Ethiopian highlands in terms of rumen microbial nitrogen synthesis, nitrogen retention and growth. The addition of small amounts of energy such as crushed maize grain increased microbial nitrogen synthesis, nitrogen retention and live weight gain. The cost and availability of the cakes will determine the likelihood of their adoption by farmers.

Brewery by-products

When beer is made, the residues are the spent grains and yeast. Cattle readily accept these as feed. Sources for these by-products are beer factories, which are increasing in SSA (including home made installations). The by-products from home installations are richer in energy and protein than the residues from the factories.

Sugar industry by-products

The by-products from sugar-cane factories are dried sludge, molasses and bagasse. Cattle can be fed all three by-products. Farmers mostly use molasses, a thick dark brown liquid which contains 50–65% sugar with little protein or water. It is thus a high energy feed. When added to cottonseed cakes, it increases the intake of coarse and less readily accepted cakes. It can be added to the herbage during silage production. Molasses therefore is an excellent feed provided it is supplemented with protein and minerals.

Example: Supplementation with molasses

At ILRI's research station in Debre Zeit, Ethiopia, four rumen fistulated crossbred (*Bos taurus* × *Bos indicus*) steers (mean live weight 468 kg) were fed twice daily a basal diet (Diet MO) comprising native grass hay *ad libitum* (free eating) and 4 kg dry matter (DM) of wheat bran. Three other diets were tested: 1. Native grass hay plus 750 g wheat bran per kg DM; and 250 g molasses per kg DM; 2. Native grass hay plus 500 g wheat bran per kg DM and 500 g molasses per kg DM; and 3. Native grass hay plus 250 g wheat bran per kg DM and 750 g molasses per kg DM. The native grass hay was predominantly *Pennisetum* species. Wheat bran and molasses were mixed and fed together from a bucket. Increasing the level of molasses did not affect the intake of hay. There was no effect on digestibility of wheat bran. The researchers concluded that replacing wheat bran with different levels of molasses did not affect the function of microbes in the rumen. Rumen microbes utilised energy equally from molasses fermentation compared with wheat bran.

Source: Osuji and Khalili (1994).

4.6.7 Fodder trees

The integration of cattle with tree crops is common practice in many places in SSA. Farmers in the Kenya highlands feed leaves of *Leucaena* to cattle. The dry-matter yield of *Leucaena* is between 2 and 20 tonnes per hectare per year. The tree leaves contain mimosine which is toxic to cattle. Many other tree species are used for fodder, e.g. *Sesbania sesban*, *Calliandra* spp and *Gliricidia sepium*. Fodder from trees is especially useful during the dry season when it is used to supplement roughage or hay. Fodder trees were found to affect lactation of cows when fed as supplements to Napier grass. *Leucaena* supplementation increased total dry matter intake and milk yield (Muinga et al. 1992). Research at ILRI concluded that *Erythrina abyssinica* has high forage potential and can effectively serve as a cheap source of protein supplement for low quality diets during the dry season for resource-poor farmers with stall-fed sheep and goats (Larbi et al. 1993). Supplementation of pasture in Zimbabwe with 110 g *Acacia angustissima* per goat per day was found to result in an increase of 12 g per goat per day.

Example: Feeding multi-purpose trees as supplements

Many multi-purpose trees have been tested as supplements to feed of livestock ruminants. In this example we will focus on results of an experiment that used *Leucaena leucocephala*. The literature has ample examples of other fodder trees. The feeding value of *L. leucocephala* leaves was evaluated with crossbred cows in Kenya. The crossbred cows were fed Napier grass *ad libitum* and supplemented with 4 or 8 kg fresh *Leucaena* leaves per day from day 15 to 112 of lactation. The results showed that there was an increase in the intake of Napier grass and total dry-matter intake due to *Leucaena* leaves supplementation. Supplementation resulted in significant increases in milk yields. Milk yield increased over the Napier grass *ad libitum* treatment by 0.8 kg and 1.7 kg per day from the 4 and 8 kg *Leucaena* supplementation treatments, respectively.

Source: Muinga et al. (1992).

4.7 Feeding techniques

This module will only provide a list of feeding techniques. For more information consult Charray et al. (1992).

The following are common feeding techniques:

- Grazing: Pastoralists feed their cattle on rangeland for at least 8 hours a day. Pastoralists have developed complex management systems for grazing.
- Continuous grazing: This method is used when an area of forage is allocated for cattle to graze freely. The enclosed area is calculated based on the carrying capacity of the pasture.
- Rotational grazing: This method leaves time for the grass to recover between successive periods of use. The stock grazes a plot for a specified time then moves to another plot, returning to previously grazed plots when they recover.
- Zero-grazing (also known as cut-and-carry): In this method feed is brought to cows which remain confined.

4.8 Exercises

1. A calf is given a diet of 11.0 MJ ME per kg DM. Its DM intake is 511 g per day. Assuming it eats *ad libitum*, and that energy is the limiting nutrient, how fast will it grow?
2. Do farmers in your region conserve forages to feed to cattle? If so, describe indigenous methods used by farmers in your area to conserve feed for their cattle?
3. Mark the correct answer:
   A. Multi-purpose trees are useful as supplements because they can provide nitrogen and they lack toxic substances.
   B. Multi-purpose trees are useful supplements because they can provide nitrogen but a few contain toxic substances.
   C. Multi-purpose trees are useful supplements because they can provide nitrogen in the diet of the ruminant and the rumen can detoxify toxic substances that a few multi-purpose trees may contain.
4. Smallholder farmers use more crop residues than agro-industrial by-products. List two reasons for this behaviour.
5. List the techniques used by farmers to feed their cattle.

4.9 References and reading materials

Charray J., Humbert J.M. and Levif J. 1992. *Manual of sheep production in the humid tropics of Africa.* CAB (Commonwealth Agricultural Bureau) International, London, UK, and CTA (Technical Centre for Agricultural and Rural Co-operation), Wageningen, The Netherlands. 187 pp.

Church D.C. and Pond W.G. 1982. *Basic animal nutrition and feeding.* 2nd edition. John Wiley and Sons Inc., New York, USA. 403 pp.

Crowder L.V. and Chheda H.R. 1982. *Tropical grassland husbandry.* Tropical Agriculture Series. Longman, London, UK. 562 pp.

Girma Getachew, Said A.N. and Sundstøl F. 1994. The effect of forage legume supplementation on digestibility and body weight gain by sheep fed a basal diet of maize stover. *Animal Feed Science and Technology* 46:97–108.

ILCA (International Livestock Centre for Africa). 1990. *Livestock systems research manual. Volume 1.* ILCA Working Paper 1. ILCA, Addis Ababa, Ethiopia. 287 pp.

Jarrige R. 1989. *Ruminant nutrition. Recommended allowances and feed tables.* INRA (Institut national de la recherche agronomique), John Libbey Eurotext, London, UK. 389 pp.

Khalili H., Osuji P.O., Umunna N.N. and Crosse S. 1994. The effects of forage type (maize-lablab or oat-vetch) and level of supplementation (wheat-middlings) on food intake, diet apparent digestibility, purine excretion and milk production of crossbred (*Bos taurus* × *Bos indicus*) cows. *Animal Production* 58:321–328.

Kumwenda M.S.L. and Msiska H.D.C. 1990. On-farm evaluation of maize bran and cottonseed cake and introduction of improved forage technologies for milk production in Mzuzu milkshed area of Malawi. In: Dzowela B.H., Said A.N., Asrat Wendem-Agegnehu and Kategile J.A. (eds), *Utilization of research results on forage and agricultural by-product materials as animal feed resources in Africa. Proceedings of the first joint workshop held in Lilongwe, Malawi, 5–9 December 1988.* ILCA (International Livestock Centre for Africa), Addis Ababa, Ethiopia. pp. 280–299.

Larbi A., Thomas D. and Hanson J. 1993. Forage potential of *Erythrina abyssinica:* Intake, digestibility and growth rates for stall-fed sheep and goats in southern Ethiopia. *Agroforestry Systems* 21:263–270.

MAFF (Ministry of Agriculture, Fisheries and Food). 1975. *Energy allowances and feeding systems for ruminants.* Technical Bulletin 33. HMSO (Her Majesty's Stationery Office), London, UK. 79 pp.

Mohamed-Saleem M.A. 1985. Forage legumes in agropastoral production systems within the subhumid zone of Nigeria. In: Kategile J.A. (ed), *Pasture improvement research in eastern and southern Africa. Proceedings of a workshop held in Harare, Zimbabwe, 17–21 September 1984.* IDRC (International Development Research Centre), Ottawa, Canada. pp. 222–243.

Muinga R.W., Thorpe W. and Topps J.H. 1992. Voluntary food intake, live-weight change and lactation performance of crossbred cows given *ad libitum Pennisetum purpureum* (Napier grass var. Bana) supplemented with leucaena forage in the lowland and semi-humid tropics. *Animal Production* 55:331–337.

Osuji P.O. and Khalili H. 1994. The effect of replacement of wheat bran by graded levels of molasses on feed intake, organic matter digestion, rumen fermentation and nitrogen utilization in crossbred (*Bos taurus* × *Bos indicus*) steers fed native grass hay. *Animal Feed Science and Technology* 48:153–163.

Osuji P.O., Nsahlai I.V. and Khalili H. 1993a. *Feed evaluation.* ILCA Manual 5. ILCA (International Livestock Centre for Africa), Addis Ababa, Ethiopia. 36 pp.

Osuji P.O., Sibanda S. and Nsahlai I.V. 1993b. Supplementation of maize stover for Ethiopian Menz sheep: Effects of cottonseed, noug (*Guizotia abyssinica*) or sunflower cake with or without maize on intake, growth, apparent digestibility, nitrogen balance and excretion of purine derivatives. *Animal Production* 57:429–436.

van Soest P.J. 1982. *Nutritional ecology of the ruminant.* O and B Books Inc., Oregon, USA. 374 pp.

Umunna N.N., Osuji P.O., Nsahlai I.V., Khalili H. and Saleem M.A. 1995. The effect of supplementing oats hay with either lablab, sesbania or wheat middlings and oats straw with lalab on the voluntary intake, nitrogen utilization and live weight gain of Ethiopian Menz sheep. *Small Ruminant Research* 18:113–120.

UNESCO (United Nations Educational, Scientific and Cultural Organization). 1979. *Tropical grazing land ecosystems.* UNESCO, Paris, France. 655 pp.

Module 5: Partial budgeting as a tool for economic analysis in livestock production

5.1 Performance objectives

Module 5 is intended to enable you to:

1. Describe the logic behind partial budgets.
2. Describe the framework for partial budget analysis.
3. List the essential data required for computing partial budget analysis.
4. Compute partial budgets given production parameters data and corresponding cost and prices data.
5. Interpret the results given computed partial budgets.

5.2 Introduction

Agricultural economists are usually members of multidisciplinary teams solving problems of livestock agriculture. The economist applies economic concepts and tools to estimate economic profitability of a technology. This input can be made during any phase of the research process: technology development, testing and evaluation on farm. Details of economic theories and tools are beyond the scope of this module. In sub-Saharan Africa (SSA) most research teams lack an economist because only a few people are specialised in this. Since the majority of the audience for this manual is non-economists, this module will focus on partial budgeting, a tool that we think can be used by non-economists. Partial budgeting allows a quick insight into the profitability of the technologies without having to wait until a detailed analysis of the data is conducted.

5.3 Partial budget analysis

Partial budget analysis is the tabulation of expected gains and losses due to a relatively minor change (marginal) in farming method or technology, e.g. feeding concentrate supplements to cattle. The new technology could be technically feasible but this is not a necessary condition for adoption by farmers; the new technology must be profitable. Therefore it is important for scientists developing a new technology or improving an existing one to determine the profitability of the technology. However, most national research systems do not have enough economists and biological scientists often lack the ability to conduct economic analysis. This module therefore aims at describing a simple technique to determine the profitability of technologies at farmer level—the partial budget analysis. Livestock scientists need to be equipped with basic economic tools to evaluate technologies.

Partial budgets list only those items of income and expenses that change. They (i) measure change in income and returns to limited resources, (ii) provide a limited assessment of risk and (iii) suggest a range of prices or costs at which a technology is profitable. After the changes are determined, the relationship is shown by the following equation:

[Added returns + Reduced costs] – [Added costs + Reduced returns] = [Profit or Loss]

The farmer's goal is to maximise profit and not necessarily only productivity. Determining the farmer's goal is a good start. For example the household may set as a goal, 'to increase income during drought periods' and achieve this goal by introducing cattle in addition to cropping. The advantages and disadvantages of partial budgeting are listed in Box 5.1.

Box 5.1. Advantages and disadvantages and appropriate situations for partial budget analysis technique

Advantages

- The technique is simple (it can be performed with a hand calculator) and easy to learn for non-economists.
- It examines only net changes in costs and benefits, therefore it is effective for assessing economic viability of single interventions technologies.
- It requires less data than whole farm budgeting since fixed costs are not examined.
- The data required for partial budget analysis are collected for almost all other economic analyses.
- It allows early conclusions about the adaptability of the new technology.

Disadvantages

- There is a danger of forgetting that farmer's resources are limited and sometimes knowledge about the resource base may be lacking; this happens as most new technologies require an increase in purchased inputs and additional labour.
- Often scientists do not understand the farmer's objectives; the partial view of a farming system might obscure the secondary character of a given farm component.
- Lack of a time analysis; researchers do not understand the time needed for various farming activities which may overlap with or contradict a new schedule.
- Linearity of factors is assumed by using small-scale input/output data for a large-scale operation. The assumption that an increase in a unit of resource will increase the profit proportionally is questionable. The increase in management skills by many technologies often is not considered.

Appropriate situations for partial budget analysis

Partial budget analysis is appropriate in trials where:

- a single component must be analysed
- inputs and outputs are measurable and easy to price
- animal yields vary little between farms
- profitability is the major concern rather than issues such as equity and income distribution
- fixed cost do not change
- economic evaluation is needed for new technologies which are not yet well developed.

5.3.1 Logic behind partial budget analysis

The farmer's goal is to maximise returns. The following equation describes this relationship:

$$NI = TR - TC$$

where NI is the net income (e.g. from sale of cattle), i.e. the amount of money left when total costs (TC) are subtracted from total returns (TR). Total cost (TC) is composed of the cost of all inputs: variable costs (VC) and fixed costs (FC). Since FC is the same for comparing the new technology and the technology practised by the farmer, then:

$$TC = VC$$

The farmer wants to know if the new technology will increase his income while the researcher wants to know which technology is potentially more attractive economically. The change in income can be expressed as follows:

$$NI = TR - TC$$
$$NI = TR - VC$$

This relationship can be used as a rule of thumb for partial budgeting, since FC = 0 because by definition fixed costs do not vary.

If capital is not a constraint, choose the highest NI. Since higher benefits require higher costs, it is necessary to compare the extra (or marginal) costs with the extra (or marginal) benefits.

Marginal rate of return (MRR) is another way of taking the cost factor into account. It measures the NI which is generated by each additional unit of expenditure (VC):

$$MRR = NI/VC$$

MRR is also a measure of additional capital invested in a new technology and its effect on net return.

Researchers make recommendations to farmers about what to adopt. To make these recommendations, the following economic criteria should be observed (provided the technology is in line with the farmer's goal, sustainable etc.):

- If net income remains the same or decreases, the new technology should not be recommended as it is not more profitable than the farmers' current technology.
- If net income increases and variable costs remain the same or decrease, the new technology should be recommended as it is more profitable than the farmers' current technology.
- If both net income and variable cost increase (the most common case), the MRR should be considered. The greater the increase in NI and the higher the MRR, the more economically attractive the new technology is.

Partial budgets for animal enterprises are essential because:

- animals have a longer life cycle than food crops
- animals use non-market inputs (crop residues, native pastures, labour and land) and market prices often do not exist
- animals have multiple outputs (e.g. meat, milk and manure)
- the life cycle of animals is not synchronised which makes it difficult to measure output.

5.3.2 Data required for partial budget analysis

The most important step in performing partial budget analysis is the proper identification of data on the costs and benefits associated with the alternative technologies. Generally the following are essential data that must be collected:

- quantities of inputs which vary between alternative technologies
- prices of these variable inputs
- yields or productivity levels resulting from the alternative technologies
- prices of the outputs valuing non-market inputs or products opportunity cost (the value of the resource or product in its next best alternative use, e.g. family labour vs. market labour wages).

Important products of cattle include reproductive capacity (offspring), milk yield, meat yield (weight gain), manure and hides.

Inputs depend on the technology being used. Input costs should include cash costs (e.g. feed) and non-cash costs (family labour, capital costs, depreciation costs, crop residues and household wastes).

The breakdown of the benefits and costs for economic analysis of ruminant livestock is shown in Table 5.1. Care should be taken in determining the value to assign to inputs and outputs when calculating partial budgets. In some cases opportunity cost needs to be used. For example, manure provides a low cost fertiliser for crops and in this case it can be given the cost of reduction in fertiliser use. Family labour is another example. Rural wages for hired labour can be used to evaluate family labour. When labour is not an option for household members, it is difficult to evaluate. Animals or animal products that are consumed by the household can be valued against the purchase value in the market. Checklists of costs of and benefits from producing ruminants that must be considered when computing partial budgets are given in Tables 5.2 and 5.3.

Table 5.1. *Breakdown of benefits and costs for economic analysis of livestock.*

Benefits	Costs
Primary	Primary
Increase milk yield	Cash costs
Increase litter size	Feed costs: hay, salt and minerals, concentrates, grains, feeds for the young
Culls (ewes, rams, does, bucks)	Non-feed costs: veterinary medicine and drugs, vaccines
Goat meat and lamb or mutton	Wages for hired labour
	Pasture rent
Mohair and wool	Non-cash costs
Hides	Family labour
Manure	Depreciation facilities (of equipment etc.)
Horn and hooves for processing into feed supplements and other products	Other non-market feed costs
Meat and milk by-products	
Secondary	Secondary
Urine	Carry disease
Weight increase (realised when the animal is sold)	Destruction of crops, trees, trampling of land (which causes ecological damage)
Weeding-grazing	Foul odour
Farmers' preference	Noise pollution
Attractiveness of colour and appearance	
Pet	
Seed distribution	
Research	

Source: Adapted from Amir and Knipscheer (1987).

Table 5.2. *Checklist of costs involved in producing ruminants.*

Type of cost	Form of cost
1. Primary costs	
1.1 Variable costs	
Feed costs	Cash
Concentrates	Cash/non-cash
Grass and hay	Cash
Minerals/supplements	Cash/non-cash
Grain	
Water	
Other costs	
Medicines/vaccines	Cash
Veterinary services	Cash
Breeding fees	Cash/non-cash
Supplies	Cash
Milk hauling/marketing	Cash/non-cash
Transportation	Cash/non-cash
Utilities	Cash
Hired labour	Cash
Other labour (family/exchange)	Non-cash
Stock replacement	Cash/non-cash

cont...

Table 5.2 cont...

Type of cost	Form of cost
1.2 Fixed costs	
Housing/bedding	Cash/non-cash
Beginning stock	Cash
Land rent	Cash/non-cash
Depreciation	Non-cash
Taxes, interest	Cash/non-cash
2. Secondary costs	
Destruction of crops	Cash/non-cash
Trampling of land	Non-cash
Noise, disease	Non-cash
Foul odour (animal and/or manure)	Non-cash
Threat to safety of small children	Non-cash

Table 5.3. *Checklist of benefits of producing ruminants.*

Type of benefit	Form of benefit
Primary benefit	
Milk	Cash/non-cash
Meat	Cash/non-cash
Work (large ruminants)	Cash/non-cash
Hides	Cash/non-cash
Manure	Cash/non-cash
Horn and/or hooves for feeds	Cash/non-cash
Horn and/or hooves for art	Cash/non-cash
Meat and milk by-products	Cash/non-cash
Transport (large ruminants)	Cash/non-cash
Capital asset	Cash
Reproduction	Cash/non-cash
Secondary benefit	
Urine	Non-cash
Weeding/grazing	Non-cash
Aesthetic value	Non-cash
Religious value	Non-cash
Pet value	Non-cash
Entertainment and sports	Non-cash
Research	Non-cash

5.4 Examples of partial budget analysis for cattle

5.4.1 Example 1: Draft management and early ploughing in Botswana

The problem

Botswana agricultural researchers have established the positive effects of double ploughing on moisture conservation and grain yield. Farmers cannot double plough because their draft animals are in poor condition. Providing feed supplements to draft animals in the dry season is costly and hence requires economic analysis.

The experiment

In 1986 the Agricultural Technology Improvement Project (ATIP) in Francistown, Botswana, conducted a researcher-managed, farmer-implemented experiment on draft management and early ploughing. The study was conducted with five farmers. Feed supplements were provided to ensure that the cattle were in good shape for early ploughing. The supplement included wild grasses cut-and-dried as hay and a mineral mix of salt and calcium phosphate. Double and single ploughing were compared, labour data were collected for all operations and costs of feeding were recorded.

Partial budget analysis

A partial budget analysis was done to answer the following questions:

1. Should a farmer double plough or single plough?
2. Should a farmer double plough 1 ha or single plough 2 ha?

The partial budget framework is presented in Tables 5.4 and 5.5. The main costs and benefits were grain yields, labour time, seed costs and supplemental feed to draft cattle. Resources were valued at appropriate opportunity costs; in the case of labour, this was the market wage. For yields, the price received by the farmers in the town market was used.

Table 5.4. *Double vs. single ploughing 1 ha in Botswana.*

Budget items	Value
Reduced costs	
Total labour hours single ploughing (102.85 h × 38 P/h)[a]	39.08
Added benefit	
Double plough yield (347.3 kg × 43 P/kg)[b]	149.34
Subtotal	188.42
Added cost	
Total labour hours double ploughing (185.2 h × 38 P/h)	70.38
Depreciations	1.50
Animal feed attributable to second ploughing	28.53
Reduced benefit	
Single plough yield (165.8 kg)[b]	71.29
Subtotal	171.70
Net gain	16.72

a. Cost of labour valued at market wage. Botswana currency is Pula (P); (US$ 1 = P 2.15).
b. Price used is average price for the nearest town to the trial site.

Table 5.5. *Double vs. single ploughing 2 ha in Botswana.*

Budget items	Value
Reduced costs	
Total labour hours two single ploughings (219.67 h × 38 P/h)[a]	83.47
Seed saving (4 kg × 30 P/kg)	1.20
Added benefit	
Double plough yield (347.3 kg × 43 P/kg)[b]	149.34
Subtotal	234.01
Added cost	
Total labour hours double ploughing (185.2 h × 38 P/h)	70.38
Reduced benefit	
Two single plough yield (342.2 kg)	147.14
Subtotal	217.52
Net gain	16.49

a. Cost of labour valued at market wage. Botswana currency is Pula (P); (US$ 1= P 2.15).
b. Price used is average price for the nearest town to the trial site.

Conclusions

- Double ploughing on 1 ha produced the same yield as the single ploughed 2 ha.
- Comparing double ploughing versus single ploughing 1 ha, the double ploughing provided 8% net gains per hectare.
- The increased cost of labour in the double ploughing system (involving increases in ploughing and weeding) is more than paid for by the increased yields.
- The partial budget showed that feed supplementation for extra ploughing was economically feasible.

5.4.2 Example 2: Profitability of replacing milk with concentrate for calves in Mali

The problem

In Mali calves subsist on milk that farmers leave for them after milking for human consumption. This is usually about half the milk produced (Ouloguem et al. 1994). In Bamako the price for milk is 210 CFA francs (FCFA) to a litre (FCFA 300= US$ 1). The producer in peri-urban dairy units in Bamako is interested in selling as much of the milk as possible. This practice results in malnourished calves leading to increased calf mortality rates. In addition, heifer calves retained in the herd are destined to have fewer lactations with lower output of calves and milk. The problem is to ensure an adequate growth rate for the calf at a reasonable cost.

The experiment

An on-farm trial was carried out for 90 days in a village in the suburbs of Bamako. Eighteen calves were divided into two groups (control and experimental). Both groups were allowed *ad libitum* access to straw, water and mineral blocks. The experimental group were fed maize-groundnut-cake-rice bran concentrate (1 kg concentrate = 500 g maize, 230 g groundnut cake, 200 g rice bran, 60 g meat and bone meal, 10 g salt).

Data were collected for milk and weight gain of the calves in both groups. Value of milk was set at the price paid by a milk processing plant in Bamako. Data were also collected on the costs associated with concentrate, purchase of equipment (calf ropes and buckets) and labour for feeding.

Partial budget analysis

In the experimental group there was a reduction in intake of milk. The control group consumed 32 litres of milk more than the experimental group. Calves in the experimental group gained twice as much weight as those in the control group. Partial budget was done to evaluate relative profitability (Table 5.6).

Table 5.6. *Costs and benefits associated with feeding a concentrate to supplement calves in Bamako, Mali.*

	Experimental group		Control group	
	Amount (kg)	Monetary value (FCFA)[1]	Amount (kg)	Monetary value (FCFA)
Cost				
Concentrates (85 FCFA[2]/kg)	73	6,205	0	0
Milk consumed (210 FCFA/kg)	60	12,600	92	19,320
Straw (25 FCFA/kg)	24	600	41	1,025
Total feed costs		19,405		20,345
Benefit				
Milk sold (210 FCFA/kg)	207	43,470	175	36,750
Weight gained (210 FCFA/kg)[3]	34	7,140	17	3,570
Total benefit		50,610		40,320
Net return on unit feed cost				
On milk sold only		1.24		0.81
On milk sold + weight gain		1.61		0.98

1. FCFA = CFA francs.
2. FCFA 300 = US$ 1.
3. One kg gain in weight is assumed to equal the price of 1 litre of milk.

Conclusions

The results in this study indicated that:

- Calves require supplementary feeding at a young age.
- Replacing milk with concentrate is profitable.
- The cost of feeding concentrates to calves was less than the cost of feeding them milk.
- An additional 32 litres of milk per cow was available for sale during the 90-day trial.

5.5 Exercises

1. The following table shows data for variable amounts of feed used by the farmer and the corresponding milk output.

Feed		Milk		
X (kg)	ΔX (kg)	Y (kg)	ΔY (kg)	Marginal product ( )*
2		10		
4	( )*	30	( )*	( )*
6	( )*	60	( )*	( )*
8	( )*	100	( )*	( )*
10	( )*	150	( )*	( )*

Use your knowledge about production relationships to fill the ( )* with the missing words, letters and numbers after you make the necessary computations.

5.6 References and reading materials

Amir P. and Knipscheer H.C. 1987. A conceptual framework for the economic analysis of on-farm trials with small ruminants. In: Devendra C. (ed), *Small ruminant production systems in South and Southeast Asia. Proceedings of a workshop held in Bogor, Indonesia, 6–10 October 1986*. IDRC (International Development Research Centre), Ottawa, Canada. pp. 308–391.

Amir P. and Knipscheer H.C. 1989. *Conducting on-farm animal research: Procedures and economic analysis.* Winrock International Institute for Agricultural Development, Morrilton, Arkansas, USA, and IDRC (International Development Research Centre), Ottawa, Canada. 244 pp.

Ehui S. and Rey B. 1992. Partial budget analysis for on-station and on-farm small ruminant production systems research: Method and data requirements. In: Rey B., Lebbie S.H.B. and Reynolds L. (eds), *Small ruminant research and development in Africa. Proceedings of the first biennial conference of the African Small Ruminant Research Network, ILRAD, Nairobi, Kenya, 10–14 December 1990*. ILCA (International Livestock Centre for Africa), Addis Ababa, Ethiopia. pp. 91–104.

Heinrich G., Worman F., Masikara S. and Gray. R. 1987. *Draught management and early ploughing trial: Researcher managed/farmer implemented.* Progress Report. Department of Agricultural Research, Ministry of Agriculture, Botswana. 24 pp.

ILCA (International Livestock Centre for Africa). 1990. *Livestock systems research manual. Volume 2.* Working Paper 1. ILCA, Addis Ababa, Ethiopia. 125 pp.

Ouologuem B., Reese A.A., Traoré B. and Debraii S.K. 1994. Profitability of replacing milk with a concentrate for calves of cows requiring calf at foot for milking. *Tropical Animal Health Production* 26:37–48.

Module 6: Biometrics techniques

6.1 Performance objectives

Module 6 is intended to enable you to:

1. Define the basic concepts of biometry.
2. Define descriptive statistical parameters.
3 Compute variance, standard deviation, coefficient of variation, standard error, confidence interval, binomial and Poisson variables.
4. Write statistical models to fit a set of data.
5. Compute analysis of variance.
6. Use the t-test.
7. Compute regression analysis.
8. Compute analysis of covariance.
9. Use the chi square (χ^2) test.
10. Plan experiments.
11. Use randomisation techniques.
12. Describe sample designing in surveys.
13. Present results.

6.2 Introduction to basic biometry

Animal research comprises both experiments and surveys conducted either on station, on farm or in the field. Such research has to be properly designed and conducted, and the results must be statistically analysed and interpreted. Typically, comparable groups of animals are subjected to specified treatments for some predetermined period and the results of these imposed treatments, as measured by one or more variables, are used for estimating different types of responses.

The scope of this module is to introduce some of the basic principles of experimental design and statistical analysis. The purpose of good experimental design is to ensure that the results obtained are free of bias and that interpretations can be made which are uncomplicated by the existence of uncontrolled factors. Procedures for the statistical analysis, from calculation of treatment means and standard errors to the more elaborate techniques of analysis of variance, are useful and necessary tools for researchers. However, only experiments of sound design permit sound statistical analysis and interpretation.

6.2.1 Example data set

The data set that will be used throughout much of this course is from an experiment carried out to study the effect of supplementation of weaned lambs on their health and growth rate (Table 6.1). Sixteen Red Maasai and 16 Dorper lambs were treated with an anthelmintic at weaning (approximately 3 months of age) and assigned at random to supplemented and non-supplement groups. All lambs grazed on pasture for a further 3 months. At night they were housed and lambs in the supplemented group were fed cottonseed cake and bran meal. Data recorded included body weight at weaning and body weight, packed red cell volume (PCV) and faecal egg count (FEC) at 6 months of age.

Table 6.1. *Data set.*

Record	ID	Breed	Sex	Supplement	Block	Weaning weight	Weight at 6 mo. (kg)	PCV (%)	FEC (epg)	Weight gain (kg)
1	349	1	2	1	1	8.0	8.4	10	6500	0.4
2	326	1	2	1	1	9.0	9.6	11	2650	0.6
3	393	1	1	1	2	12.0	12.1	22	750	0.1
4	71	1	1	1	2	12.3	14.1	15	5200	1.8
5	271	1	1	1	3	13.0	13.2	19	4800	0.2
6	382	1	2	1	3	15.5	16.3	24	2450	0.8
7	85	1	2	1	4	16.3	17.7	27	200	1.4
8	176	1	2	1	4	15.9	17.2	21	3000	1.3
9	286	1	2	2	1	11.0	13.1	21	1600	2.1
10	183	1	1	2	1	9.9	11.2	21	450	1.3
11	21	1	2	2	2	11.6	12.6	25	2900	1.0
12	122	1	1	2	2	12.5	14.3	25	300	1.8
13	374	1	1	2	3	14.6	17.4	19	2250	2.8
14	32	1	2	2	3	14.2	16.4	22	2800	2.2
15	282	1	2	2	4	16.3	19.7	20	750	3.4
16	94		1	2	4	16.7	17.2	13	5600	0.5
17	127	2	2	1	1	8.5	9.1	26	1350	0.6
18	216	2	2	1	1	9.2	10.3	19	1150	1.1
19	133	2	1	1	2	11.1	12.7	30	200	1.6
20	249	2	1	1	2	9.8	11.4	28	0	1.6
21	123	2	2	1	3	12.6	13.6	23	600	1.0
22	222	2	2	1	3	12.3	14.5	24	1500	2.2
23	290	2	2	1	4	1303	15.3	22	1950	2.0
24	148	2	1	1	4	14.1	15.9	26	500	1.8
25	142	2	2	2	1	9.2	12.5	25	850	3.3
26	154	2	2	2	1	9.5	13.2	35	700	3.7
27	166	2	1	2	2	10.7	13.8	29	400	3.1
28	322	2	1	2	2	9.6	13.0	26	800	3.4
29	156	2	1	2	3	11.2	14.0	28	1550	2.8
30	161	2	2	2	3	12.2	15.6	22	550	3.4
31	321	2	1	2	4	13.1	16.9	24	1250	3.8
32	324	2	1	2	4	14.8	19.1	24	1100	4.3

Some of the questions we will attempt to answer will be:

- Did supplementation improve weight gain?
- Did supplementation affect PCV and FEC?
- Were there any differences in weight gain, PCV or FEC between breeds?
- Is the experiment well designed?
- Is the size of experiment (number or animals per group) sufficient to detect differences between breeds and diets?

6.2.1 Methods of describing data

Research data consist of recorded observations or measurements made on **experimental units**, e.g. animals. We shall discuss later how to decide what should be the basic experimental unit in a statistical analysis. Measured characteristics such as body weight, growth rate, PCV and FEC are called **variables**.

One of the first steps in analysing research data should be to examine the frequencies of different values recorded for the variables measured. This will help organise data in some way and to summarise their main features and may also help to spot data errors or extreme values.

Frequency table

A useful starting point is to examine the range spanned by the data. To do this one finds the lowest and highest value of a variable (e.g. PCV) and divides the range into a reasonable number of intervals. The numbers of data values that occur within each interval are counted and tabulated (Table 6.2).

Table 6.2. *Number of animals grouped by packed cell volume (PCV) category.*

PCV class interval (%)	Frequency of animals	Relative frequency (%)
10–12	2	6
13–15	2	6
16–18	0	0
19–21	7	22
22–24	8	25
25–27	8	25
28–30	4	12
31–33	0	0
34–36	1	3
Total	32	100

After calculating the number of animals in each class interval, the relative frequency, which is the percentage of values contained in each interval, can then be calculated. This shows how the data are distributed. Table 6.2 shows that a majority of animals have PCVs between 19 and 30. Four animals have PCVs below and one animal has a PCV above this range. The frequency distribution for FEC is very different with the majority of values at the lower end of the range (Table 6.3).

Table 6.3. *Number of animals grouped by faecal egg count (FEC) category.*

FEC class interval (epg)	Frequency of animals	Relative frequency (%)
0–700	12	38
800–1500	8	25
1600–2300	3	9
2400–3100	5	16
3200–3900	0	0
4000–4700	0	0
4800–5500	2	6
5600–6300	1	3
6400–7100	1	3
Total	32	100

epg = eggs per gram.

Histogram

Tables can be presented pictorially by means of a diagram, known as a histogram. A histogram helps identify the shape of the distribution. Sometimes the histogram is more or less symmetrical, with the bulk of the data gathered near the centre and the proportions of data on each side roughly balancing each other. Sometimes the histogram is **skewed**. This means that the data are rather bunched up to one side (Figure 6.1). Biological data often belong to a **normal distribution**; the frequency distribution is **'bell-shaped'**. The distribution of PCV approximates to this shape.

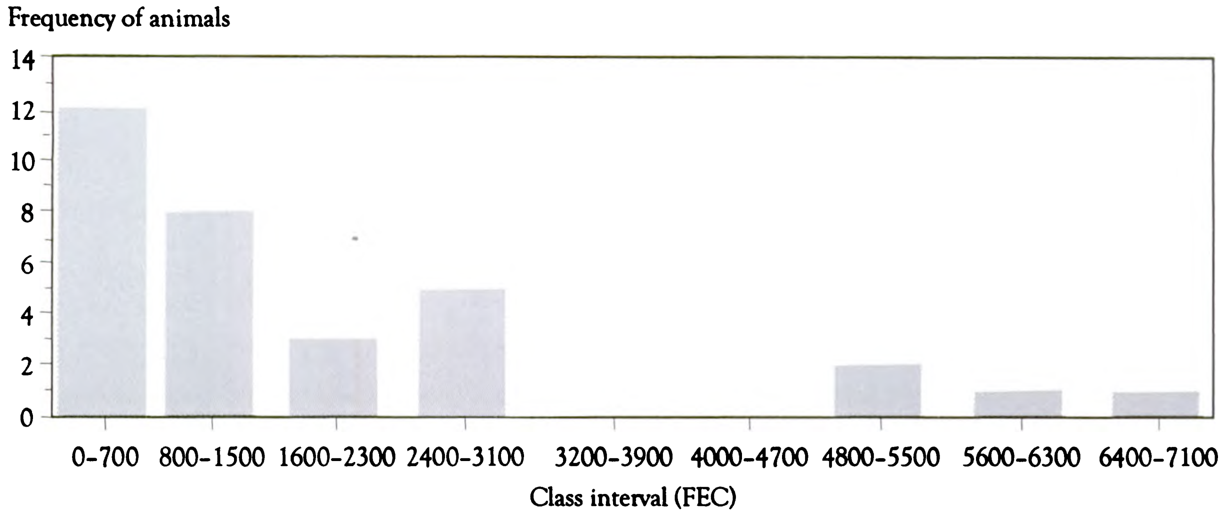
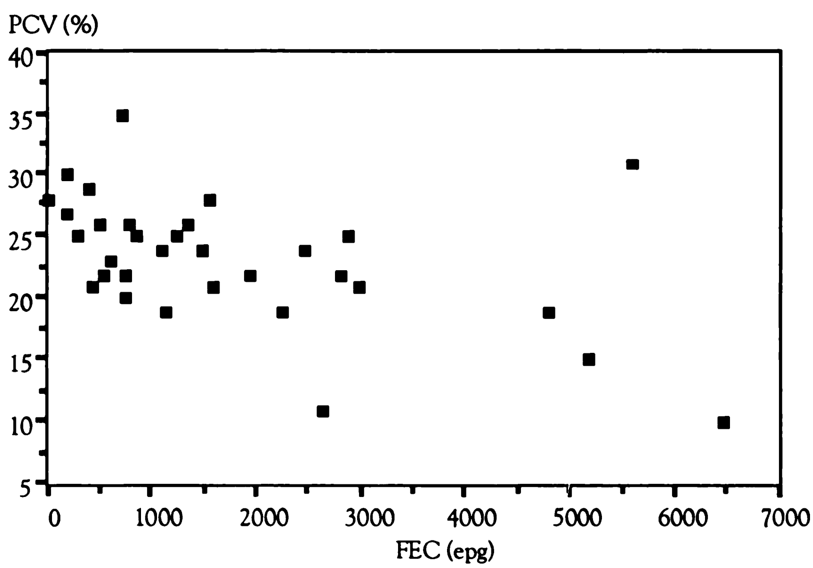


Figure 6.1. *Histogram of frequency distribution of faecal egg count (FEC).*

Scatter plots

Graphs derived by plotting one variable against another are commonly used to examine relationships between two variables. Figure 6.2 shows a scatter plot of PCV and FEC. Such a scatter plot can also indicate outliers (i.e. data values which are rather extreme and appear different from the others) which may be due to data errors. Figure 6.2 shows one possible outlier. Let us assume that during data entry lamb 94 has had its PCV digits transposed by mistake from 13 (see Table 6.1) to 31. With such a high FEC its PCV value is somewhat away from the others towards the top right corner of the diagram. Examining the input data shows that a mistake has been made in data entry.



epg = eggs per gram.

Figure 6.2. *Scatter plot of packed cell volume (PCV) versus faecal egg count (FEC) with mistake in PCV value (31% rather than 13%) for lamb 94.*

Of course, when all the data are described together like this, variations due to diet and breed are hidden. If possible, it is best to summarise the data in each group separately. Quite a nice way is to use what is known as Tukey's box and whisker plot (Figure 6.3), which displays the range, median and quartiles (containing the middle quarter of the data) for each group alongside each other.

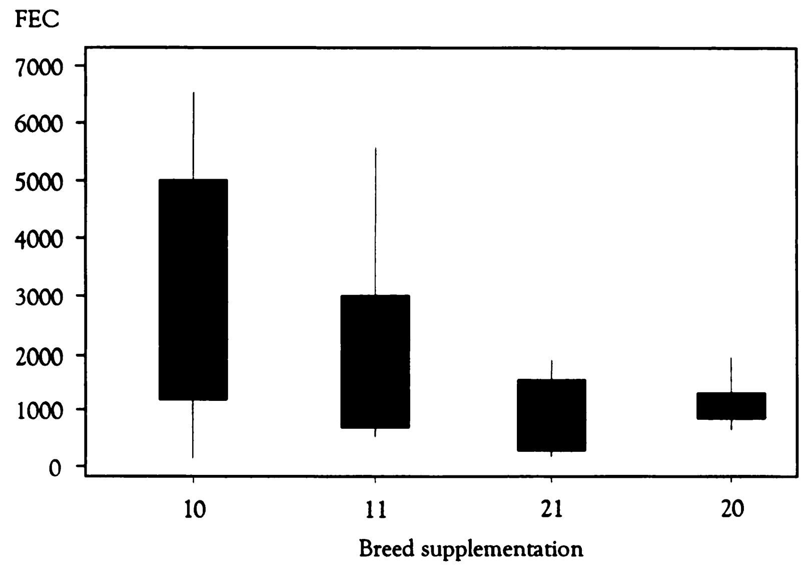


Figure 6.3. *Box plot of faecal egg count (FEC) for each breed–supplementation group.*

6.2.3 Descriptive statistics

Mean

Tables and graphs, such as those already described are often very useful and revealing. They are always the first step in attempting to summarise a set of data and to look at its structure. One of the first items of interest is a measure of a central or representative overall value.

The most commonly used measure is the **arithmetic mean** (usually referred to simply as the **mean**). The mean is obtained by dividing the sum of all the observations by the number of observations.

The calculation of the arithmetic mean may be demonstrated for the Dorper lambs (breed 1) that were non-supplemented (diet 1) by using their weights at 6 months.

$$\text{Mean} = (8.4 + 9.6. + \ldots + 17.2)/8 = 108.6/8 = 13.575 \text{ kg}$$

The mean is a kind of central value. However, the mean can be somewhat misleading if the distribution is skewed, i.e. there is a high proportion of large values or a high proportion of small values. The problem is that a few extreme values unduly influence the value of the mean. In these situations the **median** may be a useful alternative. The median is the value lying in the middle, such that one half of the values are above and one half below. Putting the 6-month body weights in order, we get 8.4, 9.6, 12.1, 13.2, 14.1, 16.3, 17.2 and 17.7 and so the median value is 13.65 kg. If there is an even number of values, the median is the sum of the two middle numbers divided by two. If there are an odd number of values, the median is the middle value. In both cases, the numbers must be arranged in ascending order (from smallest to largest) before calculating the median.

These two values (for mean and median) are in this case very similar. For FEC, however, we might expect the mean and median to be more different. Thus, if we put FECs for the same animals in order, we get 200, 750, 2450, 2650, 3000, 4800, 5200 and 6500. Thus, the median is 2775 while the mean is 3194, which is somewhat higher. For a variable such as FEC, for which the frequency is skewed, the mean will often be greater than the median.

Variance and standard deviation

Biological processes yield variable data. The most common measures of variability are **variance** and **standard deviation**. The variance of a group of observations is calculated as the sum of squares of deviations from the mean divided by one fewer than the number of observations.

The variance of the 6-month body weights for breed 1, diet 1 is thus calculated as:

$$[(8.4 - 13.575)^2 + (9.6 - 13.575)^2 + \ldots + (17.2 - 13.575)^2]/7$$
$$= [(-5.175)^2 + (-3.975)^2 + \ldots + 3.635)^2]/7 = 82.755/7$$
$$= 11.8221 \text{ kg}^2$$

An alternative formula, which is easier to use with a large number of observations, is to calculate the sum of each value squared, subtract the total squared divided by the number of observations, and divide the answer by the number of observations less one.

Using this method the variance becomes:

$$\{8.4^2 + 9.6^2 + ... + 17.7^2 - (108.6^2/8)\}/7$$

$$(1557.0 - 1474.245)/7 = 82.755/7 = 11.8221 \text{ kg}^2$$ and the answer is the same.

While it is often convenient to use the variance based on squared deviations as a measure of dispersion or variation of the data, it is often usual also to think of this variation in terms of the original units. By taking the square root of the variance one returns to the original scale of measurement. The square root of the variance is known as the **standard deviation (SD)**.

Thus the standard deviation $= \sqrt{11.8221} = 3.438$ kg

Coefficient of variation

We have shown that the variation among a set of observations can be measured using variance or standard deviation. There are occasions when we wish to compare the relative variation between two variables having different means, e.g. birth weights of calves and adult weights of cows. Since the adult weights would be expected to have a larger standard deviation because of the larger values involved, a comparison of the two standard deviations may not very helpful. We might also be interested in comparing the relative variation between different characteristics or traits of the same animals, e.g. weaning weights and PCV of calves. For such comparisons the **coefficient of variation (CV)** is calculated as the standard deviation expressed as a percentage of the mean. Thus, for breed 1, diet 1 the coefficient of variation:

$$= (3.438/13.575) \times 100 = 25.3\%$$

The CV is independent of the unit of measurement. For body weight or PCV, for example, coefficients of variation of the order of 10% might normally be expected. Growth rates, however, often have higher coefficients of variation. This example shows that the spread of 6-month weights in this group of lambs is wider than one would normally expect.

The descriptive statistics for the 32 animals in the example data set are summarised in Table 6.4. Note the high CVs for all variables, particularly for weight gain and FEC. The comparatively large CVs for body weight and PCV may have been due to the exposure of these lambs to high levels of helminth infestation.

Table 6.4. *Descriptive statistics of variables measured in the example data set.*

Variable	Mean	Median	Standard deviation	Coefficient of variation
Weaning weight (kg)	12.19	12.25	2.49	20.4
6-month weight (kg)	14.11	13.90	2.82	20.0
Weight gain (kg)	1.92	1.80	1.18	61.4
PCV (%)	22.73	23.50	5.36	23.6
FEC (epg)	1770	1200	1686	95.3

Number of animals = 32.
epg = eggs per gram.

6.2.4 Precision of estimated parameters

Standard error

Suppose the experiment were repeated several times. Each time we would calculate a mean, say for breed 1, diet 1. Each mean would be different. Thus there would be variability among means just as there is variability among individual observations in each sample. However, since each mean is averaged over eight observations, the variation among means would be smaller than the variation among individual observations. The variance of a mean can be calculated as the average of the variances calculated each time the experiment is conducted divided by the number of observations used for calculating each mean. The standard deviation of the mean is known as the **standard error**.

The standard deviation is a useful measure of the variation of an individual observation. The standard error is a useful measure of the variation of a mean.

Normally we would not repeat an experiment to calculate the average variation of the mean. Instead, we pretend that the variance of individual observations will remain constant from experiment to experiment (in practice it will not vary much) and use the value already calculated as an estimate of this average. Thus, we can then calculate, for the 6-month body weights of sheep in breed 1 fed diet 1:

variance of mean = 11.8221/8 = 1.4778 kg^2
standard error = $\sqrt{1.4778}$ = 1.22 kg

The standard error or variance of a mean decreases as the number of observations increases. Thus, for example, if 24 sheep were used for each breed then, for breed 1, diet 1:

variance of mean = 11.8212/12 = 0.9926 kg^2
standard error = 1.00 kg

Note that this standard error is lower than the value calculated above with 8 sheep.

Confidence interval

The standard error can be used to develop what is known as a confidence interval. A **confidence interval** is a range between upper and lower limits, which is expected to include at a given level of probability the true (or population) mean value. This is the value for which the sample in the experiment is providing an unbiased estimate.

Usually we talk about the 95% confidence interval. This is the interval in which the true mean should lie with a 95%, or 19 times in 20, chance of being correct. Similarly, the 99% confidence interval gives the range within which we expect the true mean to lie with a 99%, or 99 times in 100, chance of being correct. The approximate 95% confidence interval can be calculated as the sample mean plus or minus twice the standard error. Similarly, the 99% confidence interval is the sample mean plus or minus approximately 2.6 times the standard error. Thus the approximate 95% confidence interval for the mean 6-month body weight of lambs of breed 1 fed diet 1 is:

$$13.58 \pm 2 \times 1.22 = (11.14 \text{ to } 16.02) \text{ kg}$$

Similarly, the approximate 99% confidence interval is:

$$13.58 \pm 2.6 \times 1.22 = (10.41 \text{ to } 16.75) \text{ kg}$$

As one might expect, the 99% confidence interval is wider than the 95% one. Another way of thinking about this is to say that if the experiment were repeated 100 times then we would expect that on 99 occasions the sample mean would fall within the range 10.41 to 16.75 kg and on the other occasion it would fall outside.

The above formula is only approximate; instead of 2 or 2.6 we should strictly use a t-value with the appropriate degrees of freedom. t-values will be discussed later.

Binomial and Poisson variables

Sometimes response variables take on the values 0 or 1. These could be, for example, mortality or disease. The variables are sometimes described as **discrete** variables, i.e. they can only take on discrete and not continuous values. Variables such as body weight are known as **continuous** variables, i.e. they can take on any value within a reasonable range to a given degree of accuracy. Discrete variables such as mortality and disease often belong to distributions that are not normal distributions, but **binomial** or **Poisson** distributions. Discrete variables taking on values 0 or 1 are also sometimes called **binary** variables. For example, suppose in a sample of 20 lambs, 4 die before weaning. We can record a death as 1, a lamb that survived as 0. The proportion of lambs that died is p = 4/20 = 0.2. This is simply the mean of the 0s and 1s, i.e. (1 + 1 + 1 + 1 + 0.... + 0)/20 = 4/20 = 0.2. Mortality is typical of a variable that is associated with a probability of occurrence p. Such variables typically belong to a binomial distribution.

We have seen that the mean = p, and that this can be calculated in an analogous way to that of a normally distributed variable. The binomial distribution, however, has a special expression for the variance, namely p(1− p). Thus if p = 0.2, then variance = 0.2 × 0.8 = 0.16.

The standard deviation and standard error are similarly calculated, i.e.:

$$\text{standard deviation} = \sqrt{0.16} = 0.4$$

$$\text{standard error} = \sqrt{0.16/20} = 0.089$$

The distribution of certain binary data is often closer to that of a Poisson distribution, a distribution associated with rare events. Incidence of trypanosomosis, for example, can often be considered as being associated with a Poisson distribution, particularly if the prevalence is very low (e.g. <10%). The mean is the same as that for the binomial, namely p. The variance, however, is different from that of the binomial distribution and is also p. Thus, if the prevalence of trypanosome infections is 0.06 in a sample of 100 cattle, (i.e. 6/100 are detected parasitaemic), then the variance is also 0.06 and:

$$\text{standard deviation} = \sqrt{0.06} = 0.24$$
$$\text{standard error} = \sqrt{0.06/100} = 0.024$$

In practice when p is small (<0.1), it does not matter whether one assumes a binomial or Poisson distribution.

6.2.5 Analysis of variance

Statistical models

So far this module has not used mathematical, algebraic equations. This has been deliberate. However, statistical concepts are often presented mathematically and it is important for biologists not to be frightened by the formulae that sometimes appear in scientific papers. Formulae are often the easiest way to describe the statistical methods that have been applied.

If we look at the structure of our example data set we can see that each variable, weaning weight, 6-month body weight, PCV, FEC and weight gain, can be characterised by other attributes. For example, records 1–8 all refer to lambs from breed 1. They are also characterised by the fact that these lambs were not supplemented. Thus, we can say that each record is made up of a component due to breed and a component due to diet. We shall use a letter to refer to each of these components, namely b (breed), d (diet). These components are often referred to as **factors** or **parameters**. It is common to give a subscript to each parameter level. For example, we have 2 breeds. Let us refer to them as b_1, b_2. Similarly, we have 2 diets, d_1, d_2. Thus, for example, records 1–8 are each made up of $b_1 + d_1$.

Similarly, records 9–16 are made up of $b_1 + d_2$ and records 25–32 of $b_2 + d_2$. It is usual to use the letter to refer to the variable to be analysed and to use a combination of subscripts to refer to the particular data value. Thus:

$y_{111} = b_1 + d_1$ for record 1
$y_{124} = b_1 + d_2$ for record 12
$y_{225} = b_2 + d_2$ for record 29

Note that the first subscript refers to breed, the second to diet and third to lamb number (1–8) within each breed–diet category.

Normally b and d are defined as deviations from the overall mean for which the symbol μ is normally used. Also, since there are fewer factor levels (2 + 2) than there are lambs (32), each observation will deviate from the sum of the two parameter levels by an amount usually described by the letter e or ε, known as the **error** or **residual** term.

Thus, the above equations are written in full as:

$$y_{111} = \mu + b_1 + d_1 + e_{111}$$
$$y_{124} = \mu + b_1 + d_2 + e_{124}$$
$$y_{225} = \mu + b_2 + d_2 + e_{225}$$

Thus, each observation is made up of an overall mean, a term for breed, a term for diet and a residual. These equations can be written more generally as:

$$y_{ijk} = \mu + b_i + d_j + e_{ijk} \quad (i = 1, 2;\ j = 1, 2;\ k = 1....8)$$

The purpose of **analysis of variance** is to estimate the overall significance of differences among each set of parameter means. It separates variations due to diet from each other and compares the magnitudes of these different sources of variation with the variation which is left over among residual terms. In using analysis of variance, two main assumptions are used: firstly, that the e_{ijk}s have the same distribution for each parameter or factor (i.e. are not more variable for one than another) and, secondly, they are distributed normally. Thus, it is not strictly valid to use analysis of variance for discrete variables that are associated with binomial or Poisson distributions.

In developing the idea of analysis of variance it will be simplest to start with a model based on just the 4 groups of lambs categorised by breed and diet in the data set, but ignoring the breed–diet structure. The model we shall first use, with g signifying group, is

$$y_{ij} = \mu + g_i + e_{ij} \ (i = 1...4; j = 1....8)$$

It is important to emphasise the need for writing down the statistical model to be fitted to a set of data before embarking on a statistical analysis. It is a great help in deciding the form the analysis of variance should take.

One-way analysis of variance

The model:

$$y_{ij} - \mu + g_1 + e_{ij}$$

is an example of a **one way analysis of variance**. Such an experiment is often referred to as a completely randomised design. The analysis of variance will take the following form:

Source of variation	df	SS	MS	F
Among groups	3			
Residual	28			
Total	31			

The **degrees of freedom (df)** for the variation among groups is calculated as one fewer than the number of groups (i.e. 4 – 1). The total degrees of freedom = 32 (number of lambs) – 1. The residual degrees of freedom is calculated by subtracting the among groups df from the total df.

The following calculations give the **sums of squares (SS)** and **mean squares (MS)**.

Total. This is the same calculation as used previously for the variance, i.e. the sum of squares of individual observations minus the square of the total divided by the number of observations. Mathematically we can write this as:

$$\Sigma y_{ij}^2 - (\Sigma y_{ij})^2/32$$

Thus, if we apply this formula to the weight gains of the 32 lambs, we obtain:

$$\text{Total SS} = 160.78 - 61.4^2/32 = 160.78 - 117.8112 = 42.9688$$

Groups. The formula for the among group sums of squares uses the totals for each group divided by the number of lambs in each group. It is:

$$\Sigma Y_{i.}^2/8 - (\Sigma Y_{ij})^2/32$$

The capital letter Y, together with the dot, means the sum of the individual y_{ij}s summed over the subscript that the dot is replacing, in this case j. Thus:

$$Y_{i.} = y_{11} + y_{12} + ... + y_{18}$$

The among group SS for weight gain is therefore:

$$(6.6^2 + 15.1^2 + 11.9^2 + 27.8^2)/8 - 61.4^2/32$$
$$= 148.2525 - 117.8112 = 30.4413$$

The among group mean square equals the among group sum of squares divided by the among group degrees of freedom: Thus:

Among group MS = 30.4413/3 = 10.1471

Residual. We calculate the residual sum of squares by subtracting the among group sum of squares from the total sum of squares: Thus:

Residual SS = 42.9688 – 30.4413 = 12.5275
Residual MS = residual SS/residual df = 12.5275/28 = 0.4474

Putting the results of these calculations into the analysis of variance table we get:

Source of variation	Df	SS	MS	F
Among groups	3	30.4413	10.1471	22.7
Residual	28	12.5275	0.4474	
Total	31	42.9688		

The residual MS estimates the average variation among individuals within groups and is an estimate of the average within group variance of weight gains. The among group MS represents the additional variation brought about by the differences in mean weight gains among the 4 groups. The magnitude of this additional variation can be assessed by dividing the among group MS by the residual MS to give what is known as the **F-value**. Thus:

F = 10.1471/0.4474 = 22.7

We use this value to compare with values in F-tables with 3 and 28 df. If we look at the column headed 3 df at the top of each of the F-tables at the end of these notes and then come down this column until we reach 28 df on the left hand side, we find the values 2.95, 4.57 and 7.19 for 5%, 1% and 0.1% levels of probability, respectively. If our observed F-value exceeds any of these values then we say it is statistically significant. The value of 22.7 exceeds the value of 7.19. Thus, the analysis of variance shows that there is highly significant variation in liveweight gain among the 4 groups of lambs at the 0.1% level of statistical significance. This is normally described using the notation ($P<0.001$). In other words, the probability of there being no differences among the 4 groups of lambs is less than 1 in 1000.

Factorial analysis of variance

The groups of lambs in the experiment have been chosen with a particular structure. In other words the 4 groups are composed of combinations of 2 diets and 2 breeds, namely:

	Supplementation	
Breed	Yes	No
1	1	2
2	3	4

This design, sometimes described as a 2 × 2 factorial design, is a useful way of getting as much information from an experiment as possible. Thus we can look at the effects of dietary supplementation on weight gain of two breeds at the same time. What is more, we can look at the way that dietary supplementation and breed may interact. If there is no **interaction** then we mean that any effect of dietary supplementation is the same for each breed. If there is an interaction then the effect of supplementation is different for different breeds.

We can rewrite our statistical model as follows:

$$y_{ijk} = \mu + b_i + d_j + (bd)_{ij} + e_{ijk}$$

where $(bd)_{ij}$ is a notation used to signify the interaction of breed and diet.

If the analysis shows there to be no significant interaction then we could express the model as:

$$y_{ijk} = \mu + b_i + d_j + e_{ijk}$$

In other words, the model simply adds to breed the same estimate for diet irrespective of breed. Sometimes we refer to such effects as being **additive**.

To estimate sums of squares for breed and diet we split the sums of squares we have already obtained for groups, namely:

$$\Sigma y_{ij.}^2/8 - (\Sigma y_{ijk})^2/32$$

into a component for breed:

$$\Sigma y_{i..}^2/16 - (\Sigma y_{ijk})^2/32$$

and a component for diet:

$$\Sigma y_{.j.}^2/16 - (\Sigma_{ijk})^2/32$$

The expression we had earlier for the among group SS was:

$$(6.6^2 + 15.1^2 + 11.9^2 + 27.8^2)/8 - 61.4^2/32$$

The between breed SS becomes:

$$(21.7^2 + 39.7^2)/16 - 61.4^2/32$$

(where 21.7 and 39.7 are total weight gains for breed 1 and breed 2, respectively).
The between diet SS becomes:

$$(18.5^2 + 42.9^2)/16 - 61.4^2/32$$

(where 18.5 and 42.9 are total weight gains for diet 1 and diet 2, respectively).

This results in sums of squares of 30.4413, 10.1250 and 18.6050 for group, breed and diet, respectively. The sum of squares for the interaction can be obtained by subtraction of the last two numbers from the first, namely 30.4413 – 10.1250 – 18.6050 = 1.7113. We can then complete the analysis of variance table as follows:

Source of variation	df	SS	MS	F	Probability
Breed (B)	1	10.1250	10.1250	22.63	<0.001
Diet (D)	1	18.6050	18.6050	41.58	<0.001
Interaction (B × D)	1	1.7113	1.7113	3.82	0.06
Residual	28	12.5275	0.4474		
Total	31	42.9688			

This analysis demonstrates a highly significant difference between breeds in average weight gain, a highly significant effect of supplementation of cottonseed cake and bran meal and an interaction approaching statistical significance. But how precisely were these effects manifested? We need to look at the mean values and calculate their standard errors to determine the precision with which they are estimated. We can then apply earlier knowledge we have already gained to calculate confidence limits for each mean.

Mean values for weight gain (kg) are as follows:

Breed	Supplementation		
	No	Yes	Mean
1	0.82	1.89	1.36
2	1.49	3.48	2.48
Mean	1.16	2.68	1.92

Standard errors (SE) can be calculated as the square root of the residual variance divided by the number of observations. From the analysis of variance the residual variance = 0.4474 kg^2. Therefore, SE of any diet mean in the body of Table 6.1 = $\sqrt{(0.4474/8)}$ = 0.236. Similarly, SE of overall mean of supplementation (yes or no) = $\sqrt{(0.4474/16)}$ = 0.167.

SE of overall breed mean = $\sqrt{(0.4474/16)}$ = 0.167

6.2.6 t-test

We now have a good idea from the last exercise that there are highly significant differences between breeds and diets. We shall now formalise the method for analysing these differences when there are more than two breeds or diets. Instead of the F-test, which considers the variation among any number of levels of a factor, we use the **t-test** which looks at the variation between just two levels. The formula for the t-test is:

t = (difference between 2 means)/(SE of difference between 2 means)

The SE of the difference between 2 means (SED) is calculated as the square root of the variance multiplied by $(1/n_1 + 1/n_2)$ where n_1 and n_2 are the numbers of observations respectively making up the two means to be compared. Thus:

SED = [variance × $(1/n_1 + 1/n_2)$]

when $n_1 = n_2$ the formula reduces to:

SED = $\sqrt{(2 \times \text{variance of means})}$ or $\sqrt{2} \times$ SE

To better illustrate the use of the t-test let us return to the one way analysis of variance and pretend that the 4 group means now represent sheep fed 4 different legume species. Thus to compare the difference between weight gains for legume species 1 and 2 we get:

$t = (1.89 - 0.82)/(\sqrt{2} \times 0.236) = 1.07/0.334 = 3.20$

We compare this value with t-values in the t-table using the number of degrees of freedom, namely 28, for the residual variance. With 28 df we get t-values of 2.05, 2.76 and 3.67 at 5%, 1% and 0.1% levels of significance, respectively. The value of 3.20 is less than 3.67 but greater than 2.76 and so the difference in weight gain between these two species is significant ($P<0.01$). However, if we compare species 2 and 3 we get:

$T = (1.89 - 1.49)/(\sqrt{2} \times 0.236) = 1.20$

which is not significant.

Least significant difference

It is sometimes more convenient to calculate the **least significant difference (LSD)** needed for the difference between 2 means to be significant. This is calculated as:

LSD = t × SED

Thus, for the 4 legume species means:

LSD = 2.05 × 0.334 = 0.68 at the 5% level significance
= 2.76 × 0.334 = 0.92 at the 1% level of significance
= 3.67 × 0.334 = 1.23 at the 0.1% level of significance

We can then compare differences between the respective means with these values to determine their significance. Thus, for example,

1.89 – 0.82 = 1.07: significance level $P<0.01$
3.48 – 1.89 = 1.59: significance level $P<0.001$
1.49 – 0.82 = 0.67: not significant

6.2.7 Blocking

One aim of good experimental design is to ensure that the residual mean square is as small as possible. One way to do this is to ensure that animals are as uniform as possible before the experiment starts. Another is to ensure that animals with similar attributes are assigned equally to the different factors being compared. The most common type of design is a **randomised block** for which animals might be blocked or grouped, for example, on the basis of body weight, age, lactational/pregnancy status or herd. An experiment might also be replicated in time; each replicate then constitutes a block.

Because of the wide range of weaning weights among lambs in this experiment it might be sensible to group the lambs on the basis of weaning weight. This in fact is what was done (see Table 6.1). Lambs in each breed were sorted into weaning weight order and formed into four blocks of 4 with the lightest 4 in the first and heaviest 4 in the fourth block. Lambs were then randomly assigned to the two levels of diet within each block. This assignment is shown in Table 6.1. When this is done, the model formula becomes (with r for block):

$$Y_{ijk} = \mu + b_i + d_j + r_{ik} + (bd)_{ij} + e_{ijkm} \ (i = 1, 2; j = 1, 2; k = 1, 2, 3, 4; m = 1, 2)$$

Note that there are eight possible values of r_{ik}: r_{11}, r_{12}, r_{13}, r_{14} for breed 1 and r_{21}, r_{22}, r_{23}, r_{24} for breed 2. The subscript m has two values, one for each of the two lambs assigned to each of the two diets in each block.

The formula for calculating the among block within breed sum of squares is the sum of:

$\Sigma Y_{1jk1}{}^2/4 - (\Sigma y_{1jk1})^2/16$ calculated for lambs of breed 1
$\Sigma Y_{2jk1}{}^2/4 - (\Sigma y_{2jk1})^2/16$ calculated for lambs of breed 2

The new residual sum of squares is then calculated by subtracting this sum of squares from the residual sum of squares previously calculated. The completed analysis of variance for weight gain then becomes:

Source of variation	df	SS	MS	F	Probability
Breeds (B)	1	10.1250	10.1250	21.68	<0.001
Blocks/breeds	6	2.2538	0.3756	0.80	NS
Diet (D)	1	18.6050	18.6050	39.84	<0.001
B × D	1	1.7112	1.7112	3.66	0.07
Residual	22	10.2738	0.4670		
Total	31	42.9688			

This table shows us something about the design of the experiment. If we compare the F-value of 0.80 for among blocks with the 5% value in the F-table with 6 and 22 degrees of freedom, namely 2.55, we see it is much smaller. In other words, differences among blocks were not significant. In this experiment, therefore, assignment of lambs to blocks was of no benefit in reducing, in terms of weight gain, the residual variance. In other words, weight gain post-weaning was unrelated to weaning weight. This does not mean that it was a bad thing to assign sheep to diets on the basis of their initial weight, for in other instances we may find that blocking by initial weight is beneficial.

6.2.8 Heterogeneity of variance

The variances for weight gains among individuals separately for each breed–diet groups were 0.3793, 0.9041, 0.2955, 0.2107 kg^2, respectively. The residual variance used in the analysis of variance was the average of these. Examination of these different estimates shows that the variance was smaller for groups 1, 3 and 4 than for group 2. The analysis of variance we have undertaken assumes that each variance calculated for each group estimates the same 'population' variance. This may not be true. In this example the differences in variances is not much to worry about, and one can assume that the weight gains of lambs in group 2 were by chance more variable than in the other groups. The conclusions are clear. The analysis of variance technique is robust: it handles data for which assumptions, such as homogeneity of variance of symmetric, normal distributions, do not strictly apply. But what alternative methods are at our disposal? FEC, for instance, has a very skewed, non-normal distribution and analysis of variance undertaken on these data may not be justified.

Transformations

Firstly we could transform FEC to a different scale by using a calculation such as log (y), log (k + y) or $\sqrt{y}$. Each of these calculations reduces the skewness of the data and makes the residual variance less dependent on the mean. The logarithm transformation is stronger than the square root one. The log (k + y), where k is a constant >0, is used instead of log (y) when y values occur which equal 0. The disadvantage of this method is that, although it may produce a more valid statistical analysis, it is often not so easy to present the results. This is because the means and standard errors calculated in the statistical analysis are now on a different scale.

Sometimes a transformation is not appropriate and an alternative method would be to split the data into separate parts and to do separate analysis of variance on each part. It is conventional, however, to analyse FEC on the log scale. The arcsin or square root transformation is more appropriate for disease prevalence data, the square root for when the prevalence is low. However, there are now new methods using **logistic regression** or **log linear models** which are more suitable for such data; these will be described later.

Results can be expressed on the original scale by calculating the geometric mean (antilog of the transformed mean) and the antilog of the 95% confidence limits for the transformed mean. Take, for example, the Dorper lambs (breed 1) supplemented with cottonseed cake and bran meal. The mean and standard error for FEC calculated on the log scale (log y) is 7.26 and 0.36, respectively. The 95% confidence range for this mean is $7.26 \pm t \times 0.36$ where t, with 7 degrees of freedom = 2.36. Thus, 95% confidence for mean interval = (6.41, 8.11).

If we transform these values back to the original scale using the antilog (or e^x) transformation, then mean = 1422, range = (608 to 3327). Thus, we can say that the geometric mean is 1422 eggs per gram (epg) and that the 95% confidence interval within which the true 'population' mean lies is between 608 and 3327 epg. Three important points need to be highlighted:

- it is not permitted to calculate an antilog for the standard error to produce a standard error on the original scale
- the upper and lower confidence interval values are not equidistant from the mean
- if log (50 + y) is used for the transformation, then 50 must be taken off the antilogs to calculate the correct geometric mean and range.

Another variable that is often transformed to logarithms is that of antibody titre. Serum is usually diluted in a geometric series, that is with a constant ratio between successive dilutions, e.g. 1/2, 1/4, 1/8, 1/16 etc. Thus, frequency distributions of titres tend to be lognormal and so the logarithmic transformation is to be desired.

6.2.9 Regression analysis and analysis of covariance

Regression analysis

Regression analysis is a form of analysis of variance. The only difference is that the statistical model is written in a form that is based on the relationship between a y variable and one or more other continuous variables, say **x**, z..., often referred to as **independent variables**, rather than with discrete sets of parameter or factor levels.

Thus $y_i = a + bx_i + e_i$ fits a straight line between the y_i and x_i values with slope b, known as the **regression coefficient**, and crossing the y-axis at the point a, known as the **intercept**. We shall not consider methods of calculation here, but they result in a similar analysis of variance table to those derived previously. For example, consider the relationship between PCV and log (50 + FEC) and ignore the fact that lambs were from different breeds and fed different diets. Statistical analysis of these data (using calculations not described) lead to the following analysis of variance.

Source of variation	df	SS	MS	F	Probability
Regression	1	374.5087	374.5087	21.9	<0.001
Residual	30	513.9600	17.1320		
Total	31	888.4688			

Regression equation is y = 46.0 – 3.297x
Regression coefficient = –3.297
SE of regression coefficient = 0.705
Correlation coefficient (r or p) = 0.65

We can test for the statistical significance of the regression coefficient by using the t-test:

$$t = b/SE = -3.297/0.705 = 4.68$$

Comparing with t-values in the t-table with 30 degrees of freedom, we see that the regression coefficient is significant (P<0.001). We come to the same conclusion using the F-value in the analysis of variance table. Thus, there is a highly significant association between PCV and FEC. The degree of this association is described by the correlation coefficient. A correlation coefficient can vary between 0 (no correlation at all) and 1 (perfect association, i.e. the points lie on a straight line). In this case r = 0.65. The scatter diagram of PCV and log (FEC + 50) is illustrated in Figure 6.4 with the regression line imposed. The spread of points illustrates a reasonable association between PCV and logarithm of FEC, although the association between PCV and FEC untransformed (Figure 6.2) may be slightly better.

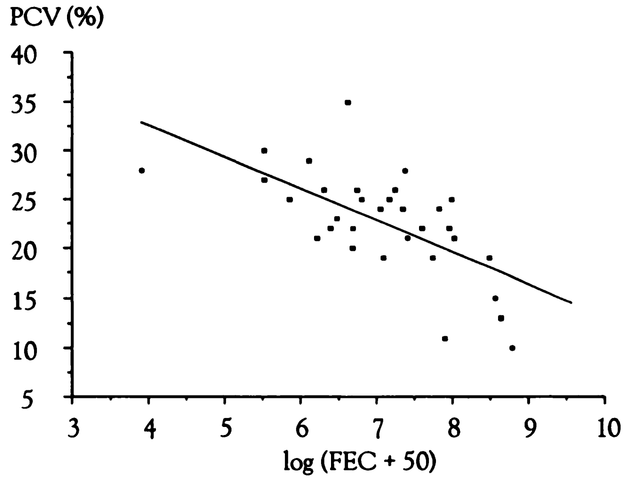


Figure 6.4. *Regression line of packed cell volume (PCV) on log (FEC + 50).*

Analysis of covariance

Analysis of covariance is a simple extension of analysis of variance. Independent variables not incorporated in the design of the experiment, are included as **covariates.** Thus, in the study of the effect of supplementation on the weight gains of the two breeds of sheep, weaning weight was taken into account in the definition of blocks. Sex, however, was not. We can, however, include sex in the model as a covariate with values 1 or 2 for males and females, respectively (Table 6.1). Covariates may also be continuous variables. The full model appears as follows:

$$y_{ijkm} = \mu + r_{ik} + d_j + (bd)_{ij} + \beta x_{ijkm} + e_{ijkm}$$

where β is the regression coefficient of weight gain (y_{ijkm}) on sex (x_{ijkm}). The analysis of covariance appears as follows:

Source of variation	df	SS	MS	F	Possibility
Breeds (b)	1	10.5302	10.5302	23.31	<0.001
Blocks within breed	6	2.9192	0.4865	1.08	NS
Diet (D)	1	19.3548	19.3548	42.84	<0.001
Breed × Diet	1	1.8982	1.8982	4.20	0.05
Sex	1	0.7870	0.7870	1.74	NS
Residual	21	0.4518	0.4518		
Total	31	42.9688			

The analysis adjusts, or corrects, parameter level means for the differences in numbers of males and females making up the mean. The regression on sex, whilst not significant, has nevertheless reduced the residual mean square. Interestingly, when adjusted for sex, the F-value for blocks is now also greater than 1.

Note that the total sum of squares is no longer the sum of the individual squares in the analysis of variance tables. This is because each sum of squares is now corrected for differences between sexes.

When there is a choice to use an independent variable as a covariate or to define it as a blocking factor in a designed experiment, the second option is usually to be preferred, provided adequate numbers of degrees of freedom are retained for the residual term. If there had been equal numbers of females and males for each breed in Table 6.1, then it would have been possible to first block lambs on the basis of body weight for each sex.

6.2.10 Analysis of discrete data

Sometimes response variables measured in an experiment may be discrete, not continuous. Such variables, often referred to as **binary** variables, can take two values, 0 or 1. One example is mortality; others are proportions of animals conceiving, proportions lambing or proportions with a given disease etc. This module briefly mentions two methods of handling such data.

Chi square (χ^2) test

For simple experiments one can group the data into a two-way table and perform a χ^2 test. Thus, for example, if the lambs used in this experiment were drawn from a group of 55 Dorper and 42 Red Maasai lambs and 14 and 4, respectively, died before weaning, then we can compare differences in mortality by forming a table, often known as a **contingency table**, as follows:

Breed	Alive at weaning		
	No	Yes	Total
Dorper	14	41	55
Red Maasai	4	38	42
Total	18	79	97

The above values are the ones observed. The next step is to calculate the values that would have occurred had the mortality rates in the two breeds been the same. These are known as expected values. To do this calculation, expected values for each of the 4 cells in the body of table are obtained by multiplying together the two totals in the corresponding row and column and dividing by the grand total. Thus, expected values are:

55 × 18/97	55 × 79/97
42 × 18/97	42 × 79/97
10.2	44.8
7.8	34.2

The formula for the χ^2 test is:

$$\Sigma(o_i - e_i)^2/e_i$$

where o_i is the observed value and e_i is the expected value (i = 1, 2, 3, 4).

$$\text{Thus } \chi^2 = (14 - 10.2)^2/10.2 + (41 - 44.8)^2/44.8 + (4 - 7.8)^2/7.8 + (38 - 34.2)^2/34.2$$
$$= 1.416 + 0.322 + 1.851 + 0.422$$
$$= 4.01$$

The number of degrees of freedom = (2 – 1) × (2 – 1) = 1

The 5% and 1% values for χ^2 with 1 degree of freedom are 3.84 and 6.63, respectively. Thus we can say that the mortality rate before weaning in the Dorpers of 14/55 (25%) was significantly higher than that of 4/42 (10%) in Red Maasai ($P<0.05$).

When any value of e_i is less than 5, the above formula should be replaced by:

$$\Sigma(|o_i - e_i| - 0.5)^2/e_i$$

where $|o_i - e_i|$ is the positive value of the difference between o_i and e_i. This is because the χ^2 test is only an approximation to the distribution of numbers in a contingency table when the numbers are small.

Logistic regression models

In recent years various more advanced statistical methods have been developed for handling binary variables. The most frequently used of these is the fitting of a logistic regression model. The method is very similar to that used in analysis of variance. However, instead of fitting a model to the y-values themselves, namely:

$$y_{ijkm} = \mu + b_i + d_j + r_{ik} + (bd)_{ij} + e_{ijkm}$$

the logit transformation log [(y/1 – y) is applied and the model:

$$\log [y_{ijkm}/(1 - y_{ijkm})] = \mu + b_i + d_j + r_{ik} + (bd)_{ij} + e_{ijkm}$$

fitted instead. This method also takes into account the fact that the e_{ijkm}s are distributed as binomial and not normal distributions.

It is not possible to carry out this analysis on a hand calculator and the method is therefore outside the scope of this module. Advanced computer programs have been developed for this analysis. If you come across scientific papers using this method, all that you need to appreciate is that a model, similar to that used in an analysis of variance, has been used. The method carries out an analysis known as **analysis of dispersion**; this is analogous to analysis of variance. Both these analyses evaluate how much of the variation is accounted for by each of the factors in the model.

In the past some authors analysed binary data by analysis of variance assuming that their data are normally distributed. With the advent of the modern computer methods mentioned above, this method is no longer statistically acceptable in many journals.

When data are considered to have come from a Poisson distribution, a log linear model can be used instead. It has the same form as the logistic regression model, except that the term on the left hand side of the equation is log (y_{ijkm}).

6.3 Planning experiments

So far we have considered in some detail the statistical analysis of experimental results. We have encountered the concept of blocking to help improve the precision of an experiment. Now we shall discuss in more detail general aspects of good experimental design. Careful planning of any experiment is obviously important, but it is even more essential for certain types of livestock trials and for on-farm experiments. Experiments involving lambs or kids may be particularly awkward since it may be difficult to control birth dates. This means that different animals may enter the experiment at different times. In addition, livestock trials are often fairly long term, when compared with crop trials, and need intensive data recording. Animals are also valuable. This makes detailed planning essential.

6.3.1 Stages in planning experiments

Objectives

All experiments should have clear, well-defined and realistic objectives. This may seem obvious, but is frequently overlooked. An example of a vague objective is: 'To examine the effect of nutrition on reproductive performance'. More precise objectives might be: 'To quantify the response to treatment with Samorin in early pregnancy on conception rates of goats exposed to a high trypanosomosis risk' or 'To determine the effect of anthelmintic treatment on weight gains of lambs to weaning in different breeds of sheep'. The scope of the experiment should also be clear: which breed(s) will be used, what weight and age/parity ranges will be studied, what management system will be followed etc.

Data collection

At the planning stage, one needs to decide what data to collect and how they should be measured. For example, sera samples may need to be stored and frozen. Is this practically feasible in an on-farm trial? With large on-farm trials in particular, it might be useful to run a small pilot study before the main trial to reveal and resolve any unexpected problems in data collection. Data recording sheets should be designed before data are collected. They should ideally allow for both easy field recording and easy statistical analysis without the need to copy data from one sheet to another. The main methods of statistical analysis should be decided before the trial is started. There is little point in collecting a mass of data if you do not know how you are going to analyse them.

Some guidelines (not necessarily rules) for good practice in data recording are as follows:

1. As far as possible data that are collected manually should be entered on the same recording sheet, i.e. do not put body weight on one sheet, PCV on another etc. Results of subsequent automated analysis (e.g. ELISA antigens) should not, however, be copied to this sheet. It is better to devise a system for entering these data separately and merging with the manually recorded data in the computer.
2. Do not transcribe data from one sheet to another. This is a time when many errors occur.
3. Try to involve two people in measurement and recording so that they can crosscheck each other.
4. Decide beforehand on accuracy required for data recording (e.g. to the nearest kg, 0.5 of a kg etc.), and take care when reading values from an instrument recorder. Values of 25% or 30% for PCV, for example, are, in practice more often recorded than values of 26% or 29% when using a gauge to measure the height of the packed red cell volume in a straw after centrifugation.
5. Enter animal identification on the recording sheet in the order in which animals are weighed and the samples collected. This may be preferable, particularly in field trials, to using recording sheets on which animal numbers have already been written.
6. When recording information on breed, age etc., think how you might want to use it. Information is usually better recorded numerically when the numerical code is easy to remember (e.g. 1 = male; 2 = female). Remember, however, that the computer can easily recalculate values, so do not do mental arithmetic in converting names to numbers if you are likely to make mistakes.
7. Do not do calculations by hand that the computer can do for you, e.g. weight gain.
8. If entering data into the computer preferably get someone else to verify the data you have entered.

The way a recording sheet might be produced is illustrated in Table 6.5.

Table 6.5. *Example of a recording sheet.*

Sample no.	Animal ID	Breed	Calf/ adult	Age	PCV	*T. congolense*	*T. vivax*	*T. brucei*
1	301	1	1	12 mo.	26	0	0	0
2	126	1	2	4 y	24	0	2	0
3	313	2	2	6 y	29	0	0	0
4	219	2	1	9 mo.	27	0	0	0

Note that numbers have been used where possible. Age is a difficult variable to record in a mixed aged population. One way around the problem is illustrated in the table. It might be preferable to separate trypanosome species in the recording sheet as shown, rather than to list species under one column headed 'trypanosomes'. This is easy to do and means that you do not have to get the computer to separate species later. The value 2 represents a score for intensity of infection (1–5), in this case for *T. vivax*. Note that all variables and attributes are entered together in columns on the same sheet with animals listed down the left hand side of the page.

Experimental design

You will need to decide how many animals or farms to use based on previous knowledge of the likely variation you might expect. If you do not have sufficient resources you will have to consider either a modification of your objectives, carrying out the trial in stages over a number of years or abandoning the trial altogether. There is little point in proceeding with a trial if you are fairly sure that it cannot meet your objectives!

Experiments should be kept as simple as possible in terms of design, execution and analysis. The most efficient designs are often the most simple to analyse. For simplicity of analysis there should be equal numbers of experimental units assigned to each treatment. Such designs are known as **balanced** designs. While this is usually relatively easy to organise for crops, it is not always so easy with livestock and on-farm trials. Unbalanced experiments need sophisticated statistical analysis which cannot readily be done without a powerful computer program. Sometimes the analysis has to be done that way, either because it was not possible to make the experiment completely balanced in the first place or because animals may have died during the course of the experiment.

Assignment of animals. Practical arrangements should be simple to avoid problems, confusion and errors when implementing an experiment. However, this should not be at the expense of other considerations, such as avoiding systematic errors. For example, with an on-station trial in individual pens, it might be convenient to put all animals on the same diet in adjacent pens. Animals on different diets will then be in different parts of the barn. However, the barn may not be a uniform environment; some regions may be more exposed to, say, wind and cold air. The differences between diets may be confounded with differences in environment, making the results impossible to interpret. Randomisation should be used to overcome these sorts of problems, even though it may introduce some practical complications.

Precision. An experiment will give an estimate of the difference between two treatments, e.g. the difference in their effects on mean growth rate. The precision of an estimate reflects how close the estimate is likely to be to the true or population value and, as we have already seen, this is measured in statistical terms by its standard error. The smaller the standard error the greater the precision.

The precision of an experiment will depend on the size of the experiment (e.g. the number of animals involved). Precision increases as the number of experimental units per treatment increase. It also depends on the inherent variability of the experimental material. An experiment with large variation among experimental units will have less precise estimates than one for which there is very little variation among units.

Replication or blocking. Estimating the precision of an experiment depends on the amount of random variation. Therefore, it is essential to be able to calculate the standard deviation of the data. To do this there must be data from more than one experimental unit in each treatment. Thus the treatments must be replicated.

Very low levels of replication such as two experimental units per treatment may not be sufficient to give an adequate estimate of the standard deviation nor to give reliable estimates of treatment means. As a general guide one should always try to ensure that at least 6 degrees of freedom are available for estimating the residual variance in the analysis of variance. Increasing the number of times each treatment is replicated also increases the precision of an experiment.

A good choice of blocks will make the variation among replicates greater than the residual variation within blocks. This is also a good way of improving the precision. In the data example (Table 6.1), blocking based on initial weight did not reduce the residual variance. In other situations, however, blocking based on body weight will be beneficial and, therefore, is a good principle to adopt. Sometimes there may be several choices for suitable replicates or blocks, e.g. body weight, age, sex. Research workers are often tempted to make treatment groups similar in all respects by balancing such attributes across treatments. This is wrong and can introduce systematic errors. This method gives no scope for randomisation of animals to treatments.

It is essential to allocate treatments at random to experimental units. This is to eliminate any subjective bias which may occur (no matter how honest one tries to be). Randomisation minimises the risk of systematic errors and helps to ensure that each treatment is represented fairly in the trial. The idea of randomisation is that it gives each experimental unit an equal chance of being allocated to any of the treatments.

6.3.2 Experimental units

The best formal definition of an **experimental unit** is that it corresponds to the smallest division of the experimental material such that any two units may receive different treatments in the actual experiment. For example, in an on-station feeding trial, if animals can be fed individually, then any one animal can receive any of the feeds. An animal is the experimental unit in this case, and animals are randomised to treatments. However, if individual pens are not available, then animals must be group fed. Any animal must then be given the same diet as its pen mates, will compete with its pen mates for food and therefore cannot be considered independent of them. In this case, a pen must be considered as the experimental unit, the pen is randomised to treatments and all statistical calculations to compare treatments should be carried out on a pen basis. Group feeding may have the advantage, though, of being closer to farm practice.

Experimental units need to be carefully thought about and defined in on-farm trials. With many types of treatments it will not be possible for a farmer to give one treatment to some animals and a different treatment to others. All animals in one herd or flock will be given the same treatment. In many such cases a herd or flock will need to be considered as the experimental unit. Data will have to be summarised on a herd or flock basis before statistical analysis is undertaken.

The correct definition of the experimental unit is crucial for the validity of most statistical analyses.

Split-plot designs

Split-plot designs are more common in crop than animal experiments. They involve two levels of experimental units, a 'main plot' and a 'subplot'. Thus, for example, an experiment might use a number of flocks, half of which receive regular anthelmintic treatments. Within each flock, sheep might be randomised into two groups, one receiving trypanocidal prophylaxis, the other not. For anthelmintic comparisons, flock is the experimental unit while for trypanocidal comparisons, the individual animal is the experimental unit. When using split-plot designs one has to be careful to ensure that adequate numbers of replicates are available at the main-plot level since there is more variation among flocks than among sheep within flocks.

6.3.3 Randomisation

Once a suitable method of blocking has been decided, one needs to design an adequate number of blocks which can allow equal numbers of experimental units to be assigned to each treatment. Thus, in the example, lambs were ranked in order of body weight and 8 sets or blocks of 4 lambs formed. The 4 lambs in each block were then assigned at random to each of the 2 diets. There are different mechanisms for assigning experimental units at random.

Drawing lots

A card or piece of paper can be prepared for each treatment or cards can be taken from a pack of playing cards. The cards can then be shuffled and drawn like raffle tickets. The treatment marked on the first card drawn is allocated to the first animal and so on.

Using tables of random digits

Many statistics books give tables of random numbers. Alternatively, the digits from telephone numbers in a telephone directory, for example, could be used.

As an example, suppose we wish to allocate 6 treatments to 6 animals in a block, and suppose the sequence of random digits listed in a table is:

6 7 3 8 2 2 9 0 8 5 6 9 8 3 1 4 7 0 5 8 0 8 1 8 6 1 5 4 3 2....

then the first animal in the block would have treatment 6; the next number, 7, would be ignored since there is no treatment 7. The second animal would get treatment 3, 8 is ignored and the next animal would receive treatment 2. The next 2 in the sequence would be ignored because treatment 2 has already been allocated etc. The full randomisation for the first block would then be

animal	1 2 3 4 5 6
treatment	6 3 2 5 1 4

Continuing, we get for the second block:

animal	1 2 3 4 5 6
treatment	5 1 6 4 3 2

The lines below show again the random sequence and indicate with x which digits are ignored, either because a digit is not in the range 1 to 6 or it has been used before in the block.

```
6 7 3 8 2 2 9 0 8 5 6 9 8 3 1 4    7 0 5 8 0 8 1 8 6 1 5 4 3 2
  x   x   x x x x   x x x x        x x   x x x   x   x x
         Block 1                          Block 2
```

With five or fewer treatments, one can use two or more digits to represent a treatment. For example, with three treatments, digits 1, 4 and 7 could represent treatment 1, digits 2, 5 and 8 treatment 2 and digits 3, 6 and 9 treatment 3. Then only 0 would be ignored. With more than ten treatments, random digits can be taken in pairs giving random numbers from 0 to 99. Again different pairs of digits can be used to represent the same treatment.

Other methods

A die used in children's games can be used instead of random digits for six or fewer treatments. Note though that one should not use 2 dice for up to 12 treatments, since numbers such as 7 (3 + 4, 2 + 5 or 1 + 6) are far more likely to occur than 12 (6 + 6) and the number 1 cannot occur at all.

6.3.4 Designing surveys

An essential component of a survey is a sound sample design. In most cases it is impractical to collect data on all individuals of a population, but a representative subset (**sample**) of the population can allow one to draw inferences about the characteristics of the population. There are several methods to select animals for sampling. The methods can be classified in two types, one type that does not and one type that does rely on random sampling techniques.

Objectives

As in designing experiments you should clearly state the objectives and to list the variables to be estimated. It is also important to define the target population and to ensure that the sampled population is representative of the target population. It would be inappropriate to use data from diagnostic laboratories or abattoirs, for example, and then to make inferences about the occurrence of disease in an animal population of a country.

Sampling frame

The population to be sampled must be divided into **sampling units** before selecting the sample. A unit can vary from an individual animal to an aggregate of individuals, such as pens, farms, dip tanks, villages etc. The list of all sampling units in the sampled population is called the **sampling frame**.

Non-random sampling

Two methods can be used: convenience sampling and purposive sampling. In convenience sampling, a sample is selected because it is easy to obtain, e.g. a herd near the investigator. In purposive sampling, the selection of units is based on known exposure or disease status. It is thus an inadequate technique for obtaining data to estimate the occurrence of disease in a population. Both methods may create serious biases.

These methods are not based on probability sampling techniques and therefore, it is not possible to give a level of confidence to the mean. These methods are not usually to be encouraged since they may produce inaccurate population estimates and are often as expensive to perform as random sampling methods. There may be good reasons on occasions for using such methods, but the experimenter needs to be aware of their limitations.

Random sampling

A number of methods are available, e.g. simple random sampling, systematic random sampling, stratified sampling and cluster sampling. Confidence limits of the population values can be calculated. These designs are more complex to analyse but the validity of the results is worth the investment in time and money.

The objective of random sampling is to select a percentage of the population using a formal randomisation process as has already been described. Such a selection procedure is required for the investigator to calculate the precision of the sample estimate as measured by the standard error of the mean. In practice, random sampling provides the investigator with the assurance that the sample will be representative of the population being investigated.

To obtain a simple random sample of n from a population of N animals to determine the prevalence of trypanosomosis by antigen-ELISA analysis, for example, one would randomly select n numbers from between 1 and N, each number identifying an animal in the sampling frame. Thus, the animals selected would be distributed randomly throughout the sample population.

The estimated standard error of the sample mean:

$$= s/\sqrt{n} \times \sqrt{(1 - n/N)}$$

where s is the calculated standard deviation, which equals p(1 – p) for a binary variable.

Note that this is different from the standard error used previously in the analysis of designed experiments. It has the additional value $\sqrt{(1 - n/N)}$ which is included to take into account that the sample is from a population of finite size N. If the population is infinite (or very large), this term can be ignored.

Systematic random sampling

In systematic sampling the n sampling units are selected from the sampling frame at regular intervals (e.g. every 10 animals). The interval k between animals (in this case 10) is the integer closest to N/n. When systematic methods are used, the starting point in the first interval is selected at random. Systematic sampling is a practical way to obtain a representative sample, and it ensures that the sampling units are distributed evenly over the entire population. It is particularly useful for sampling animals arriving at a dip tank. Then, we can assume that the sample is random and a standard error can be calculated. When sampling animals at a crush on a farm, however, the systematic sample may give an accurate estimate of the mean, but it may not be strictly random because the weaker animals may arrive last at the crush. If there is any doubt about whether one can pretend that a sample is random or not, and the sampling frame is known in detail in advance, then it is advisable to select the whole sample at random.

Stratified random sampling

With this technique, the sampling frame is divided into blocks known as **strata** based on factors (e.g. herd, area, age of animal) likely to influence the level of the variable (e.g. prevalence of helminthosis) being estimated. A simple random or systematic random sample is then selected within each stratum. Stratified random sampling improves the precision of the sample estimate, because only the within stratum variation contributes to the variation (standard error) of the mean. Different sampling percentages can be used in the various strata. For example, if 60% of animals are from the Red Maasai breed and 40% from the Dorper breed, then the sample of size n can be selected from the breeds in the same ratio (e.g. 60:40).

When stratified sampling is used, information on all sampling units, with respect to the factors forming the strata, must be known before drawing the sample. In general, the number of factors used for stratification should be limited to those likely to have a major impact on the mean value of the primary variable to be estimated (e.g. prevalence of helminthosis).

An estimate of the population mean is given by the formula:

$$\bar{y} = \Sigma N_i \bar{y}_i / N = \Sigma N_i / N$$

where $\bar{y}_i$ is the sample mean in stratum i of size N_i:

$$= \Sigma N_i \times \text{sample mean}/N$$

The standard error of sample mean in stratum i of size $\bar{y} = (1/N) \times \sqrt{\Sigma[N_i^2 \times s_i^2/n_i \times (1 - n_i/N_i)]}$.

Cluster sampling

In cluster sampling, the first sampling unit is larger than the particular unit of interest, and sampling takes place at several stages. For example, cluster sampling in two stages could include a sample of primary units (e.g. farms) and then, within the farms, a sample of secondary units (e.g. animals).

Cluster sampling is often used because of its practical advantages and flexibility. The number of primary (n_1) and secondary (n_2) units may be varied to account for different costs of sampling primary versus secondary units, as well as the variability among primary units and among secondary units within primary units.

Whenever possible one should select sampling units at each stage with probability proportional to the number of individuals. This minimises the standard error and stabilises the sample size. Usually cluster sampling generally requires more animals to achieve the same precision as simple random sampling, but the costs will be lower. The formulae for estimates of means and standard errors can be found in statistical textbooks.

6.3.5 Sizes of experiments and sample surveys

Experiment

Before conducting an experiment, we must decide how many animals, flocks etc. we may need to estimate treatment means to a desired precision. In other words, we need to know how many replicates or blocks are needed to have a reasonable chance of detecting a real difference at a given level of statistical significance.

We have already seen that the standard error of the difference between two means, each of n observations, is given by the formula:

$$SED = \sqrt{2} \times variance/n = \sqrt{2}\, SE$$

One might have a preconceived idea of the approximate size of the standard deviation to be expected. Thus, if the experiment described in our example were to be repeated using two different breeds, we could assume that we might expect a residual variance of about 0.5 (it was 0.4670 in the experiment). Suppose we decided that we needed to determine a difference of 1.0 kg in weight gain between two groups to be statistically significant ($P<0.05$). We can then apply the formula:

$$LSD = t \times SED = t\sqrt{(2 \times variance/n)}$$

Squaring both sides and manipulating terms we get:

$$n = 2t^2 \times variance/LSD^2$$

Substituting t = 2 (approximate value with large number of degrees of freedom) we get:

$$n = (2 \times 4 \times 0.5)/1.0^2 = 4.0$$

Therefore we can expect to require 4 animals per group to show a difference in weight gain of 1.0 kg as significant between diets ($P<0.05$).

With a completely randomised design with 4 groups (breed × diet) we would have 12 (i.e. 4 × 3) degrees of freedom for the residual mean square. $t_{12} = 2.18$ where t_{12} is the t-value with 12 degrees of freedom. Replacing t^2 with 2.18^2 in the above formula we can revise our sample size estimate to:

$$n = (2 \times 4.75 \times 0.5)/1.0^2 = 4.75$$

Therefore we would in fact need 5 animals per diet.

Surveys

Suppose we wish to carry out a survey to estimate the trypanosome prevalence in a given population of cattle. To estimate the size of a random sample we follow the same steps as in the previous section. First we decide how accurately we need to determine the population mean μ, i.e. how close to μ we want our sample mean to be. Approximating to a normal distribution, we can write:

$$t = (\text{sample mean} - \mu)/se\,(\text{sample mean} - \mu)$$

$$\text{Write sample mean} - \mu = L$$

Then:

$$SE(L) = SE(\text{sample mean}) \text{ (since } \mu \text{ is fixed, i.e. it is the mean of the population)}$$
$$= \sqrt{[p(1-p)/n]}$$

Therefore:

$$t = L/\sqrt{p(1-p)/n}$$

Squaring both sides and manipulating the equation we get:

$$n = t^2 p(1-p)/L^2$$

As before we first substitute t = 2 for $P<0.05$. It is clear that to estimate n we need to have some idea of p beforehand. If we are sampling from a finite population of size N then we adjust the required sample size to n^1 using the formula:

$$1/n^1 = 1/n + 1/N$$

To demonstrate how to calculate L, suppose $p = 0.4$. If we decide that we want our sample to provide an estimate within 10% of this value, i.e. between 0.36 and 0.44, then:

$$L = 0.40 - 0.36 = 0.04$$

Then:

$$n = 2^2 \times 0.4 \times 0.6/0.4^2 = 600$$

If the population is of size 1200, then:

$$1/n^1 = 1/600 + 1/1200$$

and so:

$$n^1 = 400$$

6.4 Presenting results

A set of numerical results should usually be presented as a table or graph rather than be included in text. Text becomes difficult to read if too many numbers are included. Well presented tables and graphs can concisely summarise information which would be difficult to describe in words alone. Poorly presented tables and graphs, however, can be confusing or irrelevant.

In general, tables are better than graphs for giving detailed numeric information, whereas graphs are better for indicating trends and making broad comparisons.

Tables and graphs should, ideally, be self-explanatory. In other words, the reader should be able to understand them without detailed reference to the text. The title should be informative and rows and columns of tables and axes of graphs should be clearly labelled. Graphs and tables should be as simple as possible, while having sufficient detail to be useful and informative.

In scientific papers, statistical information, such as standard errors and significance levels, is usually required. This may not be necessary for articles for a more general readership or for slides or transparencies for use in a lecture. Such statistical information should always be presented in such a way that it does not obscure the main message of the table or graph.

One often finds tables in scientific papers clustered with little superscripts a, b, c etc. or symbols *, *** to signify significant differences. Authors need to ask themselves whether these are really necessary, as they tend to obscure the main ingredients of the table. Think twice, however, before doing this. Normally tables are much better if they are simple and present the data at their face value. Often only means and standard errors are required. All that is needed to present the mean results for the breed/dietary supplementation example is given in Table 6.6. Provided readers understand standard errors they will be able to draw their own conclusions on how biologically significant the results are. Significance levels can be quoted in the text as a guide to the reader, but readers should be able to draw their own conclusion on how 'significant' they feel the results are.

Table 6.6. *Weight gains (kg) of lambs.*

Breed	Supplementation		
	No	Yes	Mean
1	0.82	1.89	1.36
2	1.49	3.48	2.48
Mean	1.16	2.80	1.92

SE of differences between means in body of table = 0.24.
SE of differences between overall breed and dietary means = 0.17.

The number of digits and decimal places presented in a table should be the minimum number that is compatible with the purpose of the table. Thus, in this example, 3 decimal places, e.g. 0.825 may be too many, since the third decimal place may have little practical significance; conversely, one decimal place, e.g. 0.8, 1.9, could lose too much information. As a general rule, standard errors should be written with the same or one more decimal place than the mean.

The same data is presented in the form of a bar chart in Figure 6.5. Graphical presentation often helps to highlight certain aspects of the results. Individual standard errors for each diet can be presented as a vertical line above a bar. If it is necessary to include standard errors of differences between means, these can be included as a footnote or in the text. A graph should never duplicate the results displayed in a table in the same report.

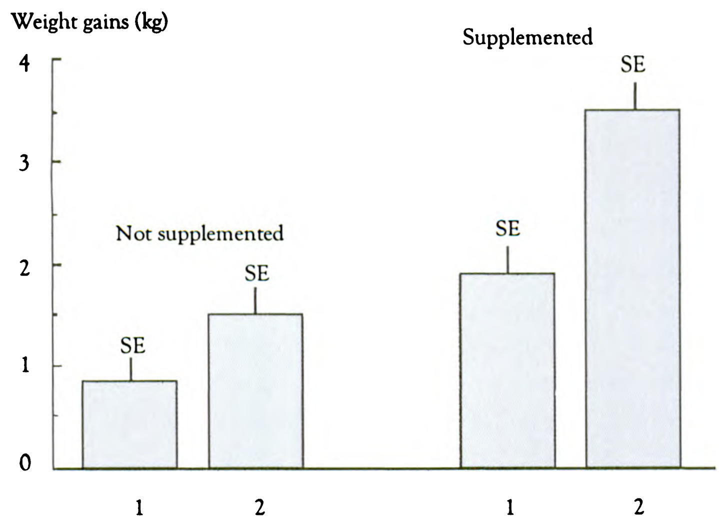


Figure 6.5. *Weight gains (kg) of sheep in form of a bar chart.*

6.5 Exercises

1. Calculate the mean, median, standard deviation and coefficient of variation of the PCVs of the 8 lambs in breed 1 fed diet 1 (Table 6.1).
2. Using the results of Exercise 1, calculate the standard error and 95% confidence interval for mean PCV of breed 1 lambs fed diet 1.
3. In a sample of 80 sheep 5 are detected with trypanosomes. Calculate the standard error of the prevalence assuming first a Poisson distribution and second a binomial distribution. Calculate the 95% confidence interval using the formula given for the normal distribution.
4. Write down a statistical model to describe the factors which you might expect to affect incidence of helminthosis during a 3-year study of 10 flocks of sheep.
5. Calculate the variance for weight gain of the 8 lambs within each group (Table 6.1) and show that the average of these variances is the same as the residual mean square already calculated in the notes.
6. Using the following standard errors and means calculated for the weight gain, calculate approximate 95% confidence intervals for the various means. For example, for breed 1, non-supplemented, you should get a 95% confidence interval of $0.82 \pm 2 \times 0.236 = (0.35 - 1.29)$. Briefly explain what these results show you.

	Supplementation		
Breed	Yes	No	Mean
1	0.82	1.89	1.36
2	1.49	3.48	2.48
Mean	1.16	2.80	1.92

SE of mean in body of table = 0.236.
SE of overall mean by supplementation or by breed = 0.167.

7. Complete the following analysis of variance table for PCV using the data in Table 6.1.

Source of variation	df	SS	MS	F
Breed	1			
Diet	1			
B × D	1			
Residual	28	560.375		
Total	31	888.4688		

Interpret the findings.

8. Using the results of exercise 7 calculate SED for comparing mean PCVs of breeds 1 and 2, calculate the t-value and show that t^2 = F-value for breed in the analysis of variance table.

9. Using only data for non-supplemented lambs (in Table 6.1) carry out a t-test to compare FEC between breeds, firstly using values on their original scale and secondly transforming FEC (y) to log (50 + y). The value of 50 is used, as it is the lowest detectable FEC.

10. Two flocks were sampled for trypanosomosis. In one flock 12 of 32 animals were found to be parasitaemic (38%) and in the other 4 of 19 were parasitaemic (21%). Are these trypanosome prevalences significantly different?

11. Two hundred and forty breeding does (120 Mashona type and 120 Matebele type) bought from communal areas is being used in a 6-year continuous mating study. Does were randomly allocated to eight treatment groups within breed. A 2 × 2 × 2 factorial design was used. Two levels of feed supplementation (no supplementation; supplementation using 300 g of a 12% crude protein concentrate per doe per day), dosing (no dosing; dosing with anthelmintics three times a year) and dipping (no dipping; dipping three times a year) were evaluated.

    Does were mated with five bucks in each of the breeds in single sire flocks. Kids were allowed to graze with their dams. The first kid crop was born three years ago. Deaths within one of the treatment groups have resulted in no does or kids remaining in that group. The experiment has another 3 years to run. Should the researcher fill this group with new does or continue to analyse the experiment with one treatment group missing? Write down any other questions you would like to address to the researcher.

12. You plan to carry out a farm trial to assess the effect of anthelmintic treatment on growth rate of lambs to weaning. You have 10 flocks, each on a different farm, at your disposal. It will be possible to divide four of the flocks so that each half grazes in a different area. The flocks on the other farms cannot be subdivided in this way. It has been decided that it would not be desirable to mix treated and untreated sheep on the same grazing pasture. Design two experiments, one based on just the 4 flocks, the other based on all 10 flocks to carry out the objective. Write down the statistical models in each case and sketch the form of the analysis of variance table. Which are the experimental units in each case?

13. Suppose that the lambs in the example data set (Table 6.1) do not belong to two breeds but that they are all Red Maasai and the code used for breed is instead anthelmintic treatment (yes or no). Redesign the experiment to investigate the effect of supplementation in the presence or absence of treatment and reassign the lambs to treatment and supplementation using the table of random numbers at the end of these notes.

14. Suppose a stratified random sample of 40 cattle is chosen: 20 from 180 zebu and 20 from 120 N'Dama cattle. Suppose 10 of the zebu and 2 of the N'Dama are found with trypanosomes in their blood. Calculate the estimated mean trypanosome prevalence in the population of 300 cattle and its standard error.

15. The mean trypanosome prevalence is to be estimated from 200 cattle in 20 herds, which range in size from 36 to 180 animals. It has been decided to randomly select 10 herds at random with probability proportional to their size and then to select 20 animals at random from each herd. Describe how you would select the 10 herds.

16. Calculate how many replicates you would need to determine a difference of 0.5 kg as significant ($P<0.05$) in the breed × diet experiment described in Table 6.1 if your estimated standard deviation was 0.8 kg.
17. Suppose we wish to estimate the size of the sample needed to estimate antigen prevalence rates of Theileria parva in zebu calves. We estimate that the likely prevalence is 50%. Calculate how many calves we will need to sample if the population mean prevalence in a group of 400 calves is to be estimated to within a 10% prevalence range in accuracy (namely 40–60%). What will be the predicted accuracy of this sample if the actual prevalence turns out to be 80%?
18. There are at least three ways that Table 6.6 could be improved for publication in a scientific paper. List these. Are there any changes that you would make to this table if you were to present it as a transparency in a talk?
19. Using the following analysis of variance table:

Source of variation	df	SS	MS	F	Probability
Breeds (B)	1	10.1250	10.1250	21.68	<0.001
Blocks/breeds	6	2.2538	0.3756	0.80	NS
Diet (D)	1	18.6050	18.6050	39.84	<0.001
B × D	1	1.7112	1.7112	3.66	0.07
Residual	22	10.2738	0.4670		
Total	31	42.9688			

and applying the t-test to the means and standard errors summarised in exercise 6, write (in no more than three sentences) a report of the results.

6.6 References and reading materials

Cochran W.G. and Cox G.M. 1992. *Experimental designs*. John Wiley and Sons, Inc., New York, USA. 634 pp.

Cox D.R. 1987. *Planning of experiments*. John Wiley and Sons, Inc., New York, USA. 296 pp.

Snedecor G.W. and Cochran W.G. 1982. *Statistical methods*. Iowa State University Press, Iowa, USA. 507 pp.

Steel R.G.D. and Torrie J.H. 1960. *Principles and procedures of statistics*. McGraw-Hill, London, UK.

Thrusfield M. 1986. *Veterinary epidemiology*. Butterworth, London, UK. 280 pp.

Module 7: Guidelines to communication

7.1 Performance objectives

Module 7 is intended to enable you to:

1. List the steps for planning the communication requirements of your research project.
2. Use guidelines for (i) oral communication, (ii) interpersonal communication, (iii) visuals and (iv) writing and editing.
3. Write papers for publication in refereed journals.
4. Write review articles.
5. Prepare posters.
6. Prepare overhead projection transparencies.

7.2 Introduction

Scientific research to solve the problems of livestock systems is a prerequisite to generating technologies. It is then the duty of the researcher, extension agent and others in government and non-governmental organisations to communicate this research to farmers, development agents, researchers, donors and the general public.

This module is written for the livestock researcher. It broadly describes ways to communicate and provides reading material that can be consulted for more details.

7.3 Planning communication in a research project

When you plan your research, you should include ways to communicate the results of the work. Communication activities must be planned at the onset of your research project. Most researchers think of communicating their results on an *ad hoc* basis and this usually happens near the end of the project. This behaviour results in poor communication of the results.

- As part of the plan for your project, develop the plan of communication activities. For example: seminars, annual reports, newsletter articles, refereed journal articles, workshop proceedings and project reports.
- Write the objectives for each communication activity.
- Define the expectations and agree on the role of each member of the research team in project.
- Discuss issues with professional communicators (if you have them in your institution).
- List the agenda for action in order of priority.
- Agree on deadlines for outputs.
- Implement the plan.

- Monitor the implementation of the plan.
- At the end of project evaluate the outputs of the communication plan as part of the evaluation exercise.

7.4 Communication guidelines

To communicate properly you need to acquire the necessary skills. In this module we will focus on guidelines for oral presentation, interpersonal communication, visual communication and writing and editing. We hope you learn and use these guidelines to communicate your research results to the various audiences (farmers, general public, researchers, extension agents, other development agents and donors). Depending on the situation, you may find yourself in need of other skills.

7.4.1 Guidelines to oral presentation

To communicate the results of your research, you often need to present your results in scientific meetings or to farmers. In both cases you need to acquire oral presentation skills. You need not fear speaking in scientific meetings or in meetings with farmers provided you learn the skills needed for this purpose (see Tripathi 1991).

What do we mean by presentation? Presentation means communicating your message by sight and sound via the co-ordinated act of mind, body, language and voice. Presentation skills can be divided into stagecraft and delivery.

Stagecraft

Stagecraft is the effective management of stage devices. The stage is the place from where you make your presentation.

- The stage can be set into different configurations. For effective presentations, the front centre and the left side of the stage are the strongest. Movement on the stage should be co-ordinated for the most effective relay of the message. You should move forward if you want to stress a point, backward to show rejection and laterally to signal change in topics.
- The speaking platform on the stage is a table or podium. It is placed on the stage to facilitate placement of notes, transparencies and other material that you may need for the presentation.
- A public address system, composed of speakers and microphones, is sometimes available. If the system is not functioning well, raise the tone of your voice to keep the audience alert to your messages. Tips for using a microphone include talking over the microphone and avoiding speaking to it; do not handle sheets of paper near the microphone.
- You may like to use a board (e.g. whiteboard) or flipcharts.
- You may need to use projection equipment. Learn how to use the projection equipment (overhead or slide projector) before the meeting. You need to check that the equipment is functioning well before your presentation.

Delivery

Delivery is the communication of the message by verbal and non-verbal means. To master some measure of control over your delivery, you need to follow five simple rules:

- Preview the materials
- Practice your presentation
- Prepare the environment
- Prepare your audience
- Present

When you begin your presentation, approach the audience with a confident air. If the presentation is the first for you, you may feel nervous. Tips to feel at ease:

- Prepare or select your illustrations (slides or overhead transparencies) very well. Number your illustrations and arrange them in order before the meeting. Before the meeting load the slides into the projector and do a trial run.
- Feel that the audience is there to learn from you and exchange information with you rather than evaluate you.

- Have no fear that you will lose your status.

It is advisable to show enthusiasm as this will pass to the audience. You need to observe the following tips in your delivery:

- Adopt a simple conversational style in a relaxed and confident composure. Look at the audience no matter how shy you may feel.
- Use an effective voice that is audible, intelligible, expressive and pleasant.
- Use simple and direct language; avoid jargon.
- Speak at a reasonable rate (100 to 125 words per minute) so that your audience can follow you.
- Present in a lively form; avoid dull monotone presentation.
- Avoid distracting mannerisms (e.g. smoothing hair, playing with pens, too many body movement etc.).
- At the beginning of your presentation thank the chair and the audience for giving you the chance to present and at the end thank them for their attention.

If unexpected events happen during your presentation (e.g. bulb of overhead projector burns), do not panic. Always have a contingency plan for such events. The audience will sympathise with you and probably admire you if you can continue the presentation in spite of the problem at hand.

After you deliver your presentation, allow time for discussion. A presentation without discussion will lack interaction with the audience. Tips for your conduct during this important part of the presentation:

- Keep calm while answering the questions.
- Do not evade questions; if you cannot answer the question or do not have the data to support your answer, say 'I do not know' which will gain you the respect of the audience.
- Treat every question or comment seriously even if they appear elementary to you; the listener has the right to learn.

7.4.2 Guidelines to interpersonal communication

Like all communication processes, interpersonal communication is a two-way process. To be successful in your career you need to understand and apply positive interpersonal methods. In this section we will deal with the following tools in interpersonal communication: verbal communication, non-verbal communication and active listening.

Verbal communication

You need verbal communication in every aspect of your career. You need to communicate verbally with your colleague scientists, farmers and development agents. A basic rule in verbal communication is simplicity. Simple language is more effective with most audiences. You can use jargon with listeners who understand it otherwise it will distort your message. Your intention is to communicate and not intimidate. Tips for good verbal communication habits:

- Empathy: Try to put yourself in the other person's place. Do it with an open mind.
- Respect: Show respect to your listener and this will improve exchange of information.
- Eye contact: Establish eye contact with your listeners; this shows confidence and transparency.
- Grammar: Use correct grammar and avoid slang.
- Pace or speed: Speak at a reasonable rate as you may lose the listener if you speak too fast or too slow.

Your listeners often will hear what they want to hear. Factors that lead to this state are different attitudes, cultural backgrounds, educational backgrounds and difficulties with language. The best way to put your message across is to keep trying until you get the proper feedback. Try to understand the factors that may hinder communication first and try to find ways to avoid the problems.

Non-verbal communication

In all cultures, people communicate with gestures, facial expression and body language. You can use non-verbal communication effectively if you understand the cultural background of the listener.

- Positive body language: relaxed appearance, body leaning forward, arms outspread and hands at side.
- Negative body language: tense appearance, chin in hand, hands hidden and hands in pockets.

- Personal distance: If you happen to know the listeners you can speak to them at a distance of 1 m, e.g. person-to-person communication with a colleague or a visiting farmer.
- Social distance: If you are involved in business or formal communication, maintain a distance of about 2 m, e.g. conversation during a meeting or in group discussion.
- Public distance: During exhibition or field days, you can maintain a longer distance while speaking without offending your listener. Use a microphone if available.

Active listening

To understand what the speaker is saying one must actively listen. Passive listening is good in certain circumstances, e.g. psychiatric treatments. Active listening is the active involvement of the listener (receiving the message) with the speaker (sending the message). Active listening can:

- show the speaker that you want to hear what he/she wants to say
- allow you to show the speaker that you are interested in open, honest communication
- lead to effective discussion
- assist in recognising problems
- aid in solving problems

To be an active listener you should avoid the following behaviour:

- When giving feedback do not threaten, preach, blame, ridicule or interrogate.
- When listening, keep attentive and do not become easily distracted.

7.4.3 Guidelines to visual skills

This section of the module is targeted at scientists or extension/development agents who are not necessarily specialists in visuals. It is intended to help you grasp the concepts of visuals so that you may be able to:

- interact with artists while they are preparing visuals for you.
- prepare simple visuals for written papers, posters and slides in the absence of visual specialists in your institution.

For more details about visual skills please refer to the reading materials especially Tripathi (1991).

Role of visuals

Visuals in your scientific writing or presentation can do one or all of the following:

- demonstrate a real situation
- highlight key points
- explain trends
- summarise information
- gain and hold the attention of an audience
- save time by avoiding excessive verbal explanation (a picture is worth a thousand words).

Visual format

There are two visual formats:

- Projected format which includes overhead transparencies and slides.
- Non-projected format which includes posters, flip charts and specimens.

In the following sections we will detail preparation of overhead transparencies and posters. For more details on these or other formats please refer to the reading material.

Considerations in preparing visuals

The two main considerations are (i) clarity of the message and (ii) clarity of the image. The following are tips for clear message and image visuals:

- Your message must be relevant and simple. The projected visual must show what is described. A good effective visual has one fact or idea and is uncluttered. Divide complex information into chunks that are easily understood. It is better to show more visuals than to try and cram every concept into one or a few visuals.
- The recommended maximum number of text lines is nine including title and subtitle.

- The recommended number of words and/or data is 25 to 40.
- Try to use tables of maximum 6 rows × 6 columns.
- If you are to project tables or graphs from journal articles or books, try to produce your own version with summarised information; tables or graphs from books usually contain too much information.
- Each visual must have a simple, short title that conveys the essence of the message and stimulates interest.
- Your image will be more visible if there is clear contrast between content (text, illustration) and background. One way you can achieve contrast is by using colour. You can use light colours for images (content) and dark colours for background. In word slides the following tips can help: white lettering on blue background or yellow on black background is recommended. You can use other combinations to avoid too many colours in one visual.
- Use lower case letters for the text, as they are easier to read than capital letters. You can use capital letters at the beginning of sentences or in short titles.
- Select a readable typeface such as Times New Roman.
- The size of the letters depends on the viewing distance. You can check the legibility of a 35 mm slide by holding it about 35 cm from your eyes. If you can read it, then the audience should be able to read it on the screen. To quickly check the legibility of an overhead transparency lay it on the floor on a white paper. If you can read standing over it, then the audience should be able to read from a screen.
- Sequence your visuals to flow from introduction to the body of your presentation to conclusion.

Graphic design for visuals

It is essential to understand the principles of graphic design for effective communication through visuals. Even though you may not be a graphic specialist, it is useful to learn and use principles of graphic design. For detailed information about graphic design consult Arntson (1988).

Nowadays it is easy to acquire, learn and use computer graphics software. The first step is to learn from good examples which are available in publications in the library.

- Start with a plan and a format.
- Consider the equipment you will use. We recommend computer programs such as Adobe Photoshop and Illustrator.
- Use simple typefaces.
- Learn to use vacant space to add to your message.
- Computers provide default space between the lines. It is easy to change space specifications if there are specific requirements.
- Keep your graphic design simple.
- Try to use illustrations if possible. You can use photos or select from the clip-art in the computer. Beware of copyrighted art material as it may get you into legal entanglement. If you really need to use the material, obtain copyright from the publisher.

Guidelines to writing/editing skills

This section will provide tips on writing and editing. For details refer to the reading material.

Writing tips

- Write short sentences.
- Keep the paragraphs short; editors do not like long paragraphs.
- Use short, simple words in place of long words with the same meaning.
- Use personal words (e.g. you, we, a person's name, direct quote etc.) which will give your writing a human touch.
- Action verbs grab the interest of the reader better than to be verbs. Use verbs in the active rather than the passive voice.

When you have no access to an editor

- Check your paper or report before you submit it.
- Avoid mixed tenses. For example:

Wrong sentence: He planted the seeds and milks the goat.

Correct sentence: He planted the seeds and milked the goat.

- Avoid redundancy. For example:

  Wrong sentence: The farmer was growing the same identical cultivar as his neighbour.

  Correct sentence: The farmer's cultivar was identical to his neighbour's.

- Be careful of plural and singular verbs. For example:

  Wrong sentence: A mixture of fertiliser, herbicide and inert material are not available to the poor farmer.

  Correct sentence: A mixture of fertiliser, herbicide and inert material is not available to the poor farmer.

- Avoid careless repetition. For example:

  Wrong sentence: You want to emphasise a point, so you repeat it, using different words for emphasis.

  Correct sentence: You want to emphasise a point, so you repeat it using different words.

- Be careful about mixed construction. For example:

  Wrong sentence: We informed the farmer to prepare his field early, that he should plant at the onset of the rains, and he should weed in time.

  Correct sentence: We informed the farmer to prepare his field early, to plant at the onset of the rains and to weed in time.

7.5 Writing scientific papers

We do research to solve the problems of the resource-poor farmer. However, we need to communicate the research results to our colleagues. Communication channels to do so include newsletters, workshops and workshop proceedings, reviews and refereed journals. This section will deal briefly with 'how to write papers for refereed journals'. For more details consult the reading materials section for relevant publications. We recommend you consult O'Connor (1991) and Stapleton et al. (1995).

7.5.1 Planning the paper

The logical time to plan your paper is at the time you planned your research. When you complete the experiments, decide whether your results are suitable for publication. A good rule to follow: aim to publish a few first-class articles than many mediocre ones. Quality will do you more good than quantity. How do you know that a paper is worth publishing? A paper worth publishing meets one or all of the following criteria:

- contributes significantly to experimental or theoretical knowledge
- contributes significantly to observational knowledge
- translates known principles into applications.

If your work measures up to these criteria, then proceed with writing the paper. One way to test whether your results fulfil one of these requirements is to write down the conclusions you have reached. Measure these conclusions against what is known. Discuss them with a colleague. This preliminary exercise will show you whether there are gaps in your arguments and observations. When you reach this stage and are satisfied that your work meets the criteria, find time to write your paper. Simple rules to observe at this stage:

- Do not slice a piece of work into several short paper. Publishing several papers from the same work is suitable only for very large investigations.
- Use your own original work to write the paper. Using other people's work is called plagiarism; this action is fraudulent and unacceptable.
- The paper must be original and the work should not have been published in another journal. This is another form of plagiarism. This rule does not prevent you from publishing a brief note or preliminary communication; if you have done so, you can still submit the work as a full paper.

Choice of journal

The following are important factors in choosing the journal:

- The scope of the journal: Does the journal publish research papers or review articles?

- What type of research papers does the journal publish?
- The audience: Is your work of interest to a wide general audience in your field of research or to a few specialists.
- Which journal is the audience you hope to reach likely to read?
- Which are the well established journals in your field?
- Which journals require authors to be members of the society that owns or sponsors the journal?
- Which journals provide reprints?
- How often is the journal published?
- Does the journal have page charges?

Once you answer the questions, make a list of possible journals. Choose the journal that will publish quickly and that has a style you can cope with. Once the journal is decided upon, obtain and read the 'instructions to the author'.

Outline

An outline will help you write the paper systematically building it step by step. It is an essential part of the plan. The outline can be a topic outline or a sentence outline. The topic outline lists points under the main headings, sorts the points you listed under the main headings into a logical order and gives the points levels using numbers. Example:

1.0. Introduction
1.1. Agro-ecological regions
1.2. Cattle distribution in agro-ecological regions.

A sentence outline uses small short sentences for the outline. Each sentence is then expanded. The example above in the topic outline can be transformed into a sentence outline as follows:

Agro-ecological regions in Africa are five. Distribution of cattle in agro-ecological regions depends on diseases, feed availability, policy issues and population pressure.

Authorship

Research on ruminant productivity is best done by multidisciplinary teams. The contribution of the different members of the team differs. When it comes to publishing, the question of authorship is discussed. Sometimes it can lead to serious disagreements. The following criteria can be used to settle this issue:

- Each author should have participated sufficiently in the work to take public responsibility for the content.
- Credit for authorship should be based on substantial contributions to conception and design, analysis and interpretation of data, drafting the article, reviewing the manuscript critically for important intellectual content and giving final approval of the version to be published.
- Those who should not be included as authors are persons who participated only in the acquisition of funds, participated only in collection of data, only supplied you with research material or only performed general supervision of the research group. To give due credit to such persons, you can mention them in the acknowledgment section.

All those, listed as authors should give their consent. There is need to agree on the order of author's names. The following guidelines may be used:

- The first author is the person who did most of the work and all or most of the writing.
- Co-authors names are listed in an order that reflects the amount of work done by each.
- If the contribution of authors is equal, then list names alphabetically. Another solution to this situation is to assign first author to the members of the team in turn for a series of papers that will be published from the work.
- If you are the first author, find out how exactly each co-author wants their name on the publication.

How to organise writing among the team of authors

The team should agree on the purpose, scope and outline of the paper before writing starts. The following are suggestions on how to handle the process:

- One person in the team should do the writing to be edited and reviewed by others.
- Another approach: Each member of the team should write a section. One person should edit the final draft so that the paper is consistent in style.

- The team can meet to discuss the draft; these meetings should be short.
- All authors should approve the final draft of the paper before it is submitted to the journal.

There is no one style of doing this and teams are free to develop the process that will suit their situation.

Preparing tables and figures

Readers often scan a paper quickly to assess whether they want to continue reading it or not. They most often refer to the abstract, the tables and figures. Therefore attention should be given to these important elements in your paper. Each table or figure must stand on its own and must contribute to the text. Decide whether the data will be presented as a table or a graph. Check the instructions that the journal provides for preparing tables and graphs before you do them. You should prepare the tables and figures before you start writing.

Tables are used to:

- report precise numerical information
- show data for component groups
- present numbers when they are not enough to make a graph.

A table consists of title, column headings, row headings, the rows and columns containing data and explanatory notes when needed.

Tips for designing tables:

- Keep the structure simple.
- Focus on what message you want the reader to get out of the table.
- Arrange the data from left to right and from top to bottom.
- Make the width of the table suitable to fit the columns of the journal.
- Write concise titles for tables.
- Arrange the columns in each table in a way that will show the readers the conclusions you want them to draw.
- Make the column headings brief.
- The rows and columns containing the data should show numbers to accuracy. Numbers should be to the nearest significant figure. When the numbers are large and loaded with zeros, use appropriate factors or units for column headings, e.g. 1,000,000 can be written as 1000 in the field cell and the column heading read $\times 1000$.
- Give the statistics such as probability values, standard error of mean etc. Follow the journal style.
- If there is a need, use footnotes to explain data.

Figures that are often used in papers include graphs, maps, photographs, algorithms and flow charts. For complex illustrations and photographs you need to use the services of a professional. If your institution lacks such services, hire freelance artists or photographers. Most computers have the software required to prepare graphs. Therefore we will provide you with tips on how to prepare graphs. If you want to draw other types of figures on your own, we suggest you consult communication textbooks that deal with these techniques.

Caution: Producing professional quality maps and photographs require expensive equipment and time to master the required skills.

Graphs are used to:

- illustrate trends and the relations between variables in data
- present numbers when there are too many of them.

There are different types of graphs:

- Line graphs are curves demonstrating the relationship between two variables. Line graphs are often used for comparison over time. They show trends more easily than other types of graphs.
- Bar graphs or bar charts show data for one variable. Use bar graphs when there is no continuum (e.g. time) between the experimental points. You can also use them when the results can be subdivided and compared.
- Histograms show the frequency of distribution of the data points for each class of a variable (e.g. Weight).

- Pie charts show the size of component parts.

Tips for drawing graphs:

- Try to use the services of a graphic specialist. If this service is not available to you, use computer software such as Adobe Photoshop and Illustrator. You need to learn the skills necessary to perform this job.
- Do not try to cram your graph with too much data but do not waste space either.
- Three to four curves in one line graph figure should be the maximum.
- When the curves cross, use different line thickness to separate them.
- Draw your curves as straight lines between data points or curves (smooth) fitted by an equation (smooth curves do not have to pass through every point). The computer will fit the curve if instructed to do so.
- You should place the dependent variable on the y-axis (e.g. yield) and the independent variable on the x-axis (e.g. time or fertiliser input).
- Draft short, simple but informative descriptions for the axes; use lower case lettering. Use the labelling to show (i) the variable and (ii) the unit of measurement.
- Use the same symbols when the same entities occur in different graphs.
- Use the same x-axis co-ordinates for different figures if values in them are to be compared.
- Do not draw rectangles around graphs unless the journal instructs you to do so.
- If you extrapolate a curve beyond the observed point, draw the extrapolated part as a dotted line.

To differentiate between curves of similar type of line (e.g. solid) and thickness, use different symbols for points joined by lines (e.g. ∘,•) or similar symbols for points joined by lines of different type or thickness (–, –). Use symbols preferred by the journal.

- Draw a vertical line to show the standard deviation or the standard error of the mean. Make these lines thinner than the other lines. In the legend tell the reader what these lines represent.
- Whenever possible, label curves directly rather than using a key. Position the labels horizontally.
- Choose the scales of the axes carefully. If the axis does not start at zero, mark a break; mark calibrations clearly.

7.5.2 Writing the first draft

After you have prepared the outline, your notes and draft tables and figures, you are ready to write the body text. Leave wide margins and print in double spacing to allow corrections or comments to be written in the empty spaces.

You can start writing the sections in a systematic way or start with easy sections. Most people find the materials and methods the easiest place to start. Follow your outline but it should only be used as an aid.

A typical scientific paper consists of title, authors, postal addressees, abstract, introduction, materials and methods, results, discussion, acknowledgments and references. Most journals follow this order.

The main headings are the reference points that make the structure of the paper clear to the reader. The conventional main headings (abbreviated as an acronym IMRAD) are introduction, methods or materials and methods, results and discussion. Results are often combined with discussion but it is better to keep these sections separate if you can.

Title

The title should answer the question: What is the paper about? Most people find it easier to write the title after they write the first draft. The final version of the title must help the reader and not you. The journal may have specific requirements for the maximum length of the title. Do not use trade names or jargon in your title. If you write a series of papers on the same subject, you can either give each paper a separate title or use a general title with numbered subtitles. Journals differ in their policy on this issue. Some journals may ask you for a shorter version of your title to use as a running head (header) or as footer.

The title of your paper should describe the main subject. It is the part of the paper that is most often read by researchers when scanning the journals or when conducting a computerised literature search. It is used in abstract journals, citation index journals and in databases. Therefore it is important to give it attention. A good title should:

- be brief (around 25 words)

- describe the contents of the papers accurately
- avoid jargon and formulae
- contain key words for indexing and retrieval.

Abstract

An abstract answers the following questions:

- Why did you start?
- What did you do?
- What did you find?
- What do your findings mean?

The abstract usually comes at the beginning of the paper unless the journal states otherwise. Even though the content of the abstract reflects the paper, it is written to stand on its own.

- It is an abbreviated, accurate representation of the contents of your paper, without added interpretation or criticism. It is usually not more than 250 words long.
- It should be informative and should present as much of the quantitative and/or qualitative information contained in your paper as possible. It reports the objective of the research, its scope, the methods used, the main results and the principal conclusions.
- It uses short and simple sentences. Try to write the abstract as a single paragraph. If the abstract is long, you can split it into two or more paragraphs. Write it after the other sections of the paper.

Things not to do in the abstract:

- Do not include information that is not in the paper.
- Do not include tables or diagrams.
- Do not include citations.

Key words

Some journals may ask you to provide key words for indexing and cataloguing entries. Choose the most important and most specific terms you can find in the paper. If you are keen that your work reaches as many scientists as possible, write specific key words; remember that readers search in the libraries using these key words.

Introduction

Readers will first scan the figures and tables and read the abstract. They then move to the introduction. This section must therefore convince them to continue reading.

The introduction answers the following question: Why did you do the work? An introduction should be relatively short and should contain:

- information on what is already known or in use supported by references to the most important publications on the subject
- the hypothesis
- support for the arguments to do the research
- experiments you intend to do to test the hypothesis.

Materials and methods

This section answers the following questions:

- What materials did you use?
- How did you use them?
- Why did you choose these methods?

What do you include in materials and methods section?

- Describe the experimental design.
- Describe what you did and how you did it. A basic rule to follow: Give enough information that anybody who wants to verify your results can repeat your experiment.
- If the methods are already published in widely circulated journals, give the reference instead of repeating all the details. If you used a new method, describe it in full. If you made changes to published methods, describe the changes you made.
- Describe the materials used.

- Describe briefly the geographical area.
- Use generic names for chemicals. Do not use trade or local names unless there are no generic names for them.
- Use the full taxonomic names for animals, plants and micro-organisms.
- For livestock ruminants, give the age and sex, genetic and physiological status.
- Describe the method in a logical order including the procedures.
- State which statistical methods you used. If you used complex statistical methods, explain them.
- Indicate which computer program you used, if any.

Results

The results section answers the question: What did you find or see? What do you include in the results section?

- Write the section so that it can stand on its own.
- Present the results in a logical order. The best order is the one used for the protocol.
- Reduce the massive amount of data you have collected to means along with standard errors or standard deviations.
- Include results from controls as well as treatments.
- Include only results relevant to your argument; these can agree or disagree with your hypothesis. Suppressing negative results is unethical. A negative result is as important as a positive one as it may direct the reader to a new hypothesis.
- You may wish to combine the results and discussion sections. In this case results are to be presented briefly while stating what the findings mean.
- Repeat in text only the most important findings shown in tables and figures.
- Refer to every table and figure by number in the text.

Statistics, to be used in the result section, give estimates of variability or precision of the findings. Follow the journal's policy when presenting statistical parameters in the results section, tables and figures. The following are general tips:

- Use well known statistical tests.
- Report the data such that readers can assess the degree of experimental variation.
- Use standard deviation to show the variability among individuals. Use the standard error of the mean to show the precision of the sample mean. State the number of measurements used to arrive at the mean.
- If data are from a skewed distribution, give the median and the range.

Discussion

The discussion section answers the following questions:

- What do your findings mean?
- What are the implications of these findings for further study?
  What do you write in the discussion section?
- Answer the specific questions you stated in the introduction.
- Show how your findings relate to existing knowledge.
- Describe what is new in your work.
- Discuss the results and hypothesis.
- Present facts and refrain from speculation.
- Focus on the main facts and avoid temptation to refer to every detail of your work.
- Use the end of the introduction as your starting point in the discussion section.
- Use past tense for results and present for the conclusions you draw from them.
- Conclude the section by stating the main results, conclusions and recommendations for future work. You can opt, as many authors do, to write a conclusion section separate from the discussion section. Whatever options you take, follow the directions of the journal.

Reference list

All references in the text should be included in the reference list and vice versa. Follow the reference style of the journal. Avoid secondary citation, i.e. Jones (1953), cited in Black (1994). Cite only those publications you have read yourself. Do not rely on any other author's interpretation.

7.5.3 Style

The rules for grammar and style are well covered in CBE (1994) and Benjamin (1989).

Tips for style

- As often as possible use the first person (I or we).
- Try to use the active voice most of the time. You can use the passive voice on rare occasions.
- Use the past tense for observations and results of completed actions. For example:
  Cow nutrition influenced calf weight.
- Use the present tense for generalisations and conclusions. For example:
  Losses are particularly high in calves born below average weight.
- Avoid jargon.
- Be simple and concise.
- Be sure of the meaning of every word.
- Use verbs instead of abstract nouns (end in -ion). For example:
  Wrong: Investigation of risk factors associated with these problems is needed.
  Correct: The risk factors associated with these problems need to be investigated.
- Break up noun clusters and stacked modifiers. These are strings of adjectives and nouns, with no clues about which modify what. For example:
  Wrong: Guidelines enforcement for laboratory worker safety is a management responsibility.
  Correct: Management is responsible for enforcing guidelines for the safety of laboratory workers.

7.5.4 Review by colleagues

Request your colleagues to review your paper before you submit it to the journal. The following are steps to do so:

- Present your work as a seminar. Feedback will pin-point the strengths and weaknesses in your arguments. Note that tables and figures for a seminar are different from those for a journal.
- Select two to three colleagues and request them to review your paper. Give them a deadline as sometimes it takes a long time for busy colleagues to do the job. If your institute has a review process in place, follow the institute rules.
- You may send your paper to a reviewer from outside your institute.
- Incorporate the comments from the reviewers and then submit the final draft to the journal.

7.5.5 Submission to a journal

The following are steps that may help to submit your manuscript to the journal:

- Write a covering letter to the editor.
- Mail the required number of copies.
- Enquire if you hear nothing in about 8 weeks.
- Reply to the editor appropriately when you receive one of the following answers: (i) paper accepted (ii) paper will be considered if you make the requested change or (iii) paper rejected.

If revision is requested

- If you agree that the changes requested by the editor will improve the paper, then work on the manuscript to make the changes. Always work with your co-authors and get their agreement.
- Return the manuscript with changes incorporated.
- Send a covering letter thanking the editors and attach the list of the changes you have made. If you disagree with one of their suggestions, explain why you disagree. Your reasons must be compelling and clearly argued.
- If you feel the paper is good as it stands and you disagree with all their suggestions, there is no need to waste your time. Submit the paper to another journal.

If the paper is rejected

- If the editor rejects your paper because it is outside the scope of the journal, submit the manuscript to another journal.

- The editor may reject your paper because it is too long and needs changes. If you agree with this and the rejection letter includes an offer to reconsider the article, make the changes and resubmit the paper. Otherwise change the style and submit your manuscript to another journal.
- The editor may inform you that the paper is rejected because of serious flaws or lack of information. If you agree with this assessment, put the manuscript away and obtain more information to fill in the gaps. If you feel the editor is wrong, send the paper to another journal.
- If you are not convinced by the assessment of the editors, write a short polite letter explaining why you think the paper should be reconsidered.

Copyright

You can use published or unpublished information. Since the information is published by others, you need to obtain written permission from whoever has the copyright to this material. If you fail to do so, your paper may not be published by the journal or you will be legally pursued. It is your responsibility to obtain permission to use copyright material.

7.6 Writing review articles

When you are advanced in your career, you may be requested or you may want to write a review article to synthesise information in your field and share your views with your colleagues in your field of specialisation. Review articles have a wider perspective than research papers and writing such articles will help your own development.

7.6.1 Types of review articles

Review articles are detailed summaries of the work published on a specific topic, e.g. feed utilisation by cattle. There are two types of review articles:

- Review articles that evaluate published work on the topic and provide an up-to-date synthesis of it.
- Review articles that summarise the work without evaluating it.

When you accept to write a review article, look at the journal's instructions to authors and at reviews in the current issue. The journal may define the scope of the review. You must be clear on which type you are asked to write.

7.6.2 Literature search

Once you have agreed with the journal on the topic, you need to conduct a literature search before you begin to write. The following are steps to do so:

- Decide on the main headings of the review.
- Make an outline of the article and plan your reading strategies.
- Make notes on your procedures, on the criteria you will use and facts of special interest.
- Use filing cards to keep your notes or you can use a computer. Guard these cards carefully.
- Start with background publications (textbooks and earlier general reviews).
- Do a computer search if the facility is available. In the case of ruminant livestock contact ILRI for assistance.

7.6.3 Writing the review article

- A basic rule is to keep the audience in mind.
- Write a clear introduction that can accommodate both the specialist and the non-specialist. In this section describe the background and state the question your review will examine.
- Write the body of the review that usually focuses on a description of the literature search and ends with conclusions and recommendations for future work. Unlike research papers, review articles do not have standard headings such as materials and methods, results and discussion. The headings in the body of

the review depend on which aspects of the topic are being discussed. In this section inform the reader how you searched the literature: by conventional methods, a computer search or a combination. If the review is a synthesis and analysis of studies, explain how you assessed the reliability of the studies covered. Explain the methods you used to analyse the literature, e.g. statistical methods. Evaluate the selected articles objectively by analysing variations in the findings critically and presenting both sides of a controversy dispassionately and present your position.

- Write your conclusions clearly. In the conclusion section write the summary of the main findings and make recommendations for new research.
- Write the reference list. Observe accuracy by taking details from the original publications. This section is very valuable to researchers and mistakes may waste their time. Write the references in the style of the journal in which you will publish and ensure that all references that you cite in the text are included in the reference list and vice versa.
- If the review journal asks you to write an abstract, try to make it informative by describing briefly (i) the purpose of the review (ii) the search method (iii) the main findings (iv) the main conclusions and (v) the recommendations.

7.7 Posters and overhead transparencies

You may present your visual material using an overhead or a slide projector, flipcharts, films, video clips, computer multimedia or a combination of these. In this section we will limit ourselves to preparing posters for scientific meetings and transparencies for overhead projectors.

7.7.1 Posters for scientific meetings

It is often necessary to communicate information in a display format. Posters will do this effectively. Posters are communication tools used for publicity and advertising purposes. They are linked to meetings, shows and public sales. In meetings they are used to display brief information about a theme. The poster must attract onlookers to view it and stimulate them into further action. This section will deal with posters for scientific meetings.

The content of a poster

After you have decided on the topic for your poster, outline the content of your poster keeping the audience in mind. In general, the following are the main sections of an outline of a poster for livestock research:

- Title
- Introduction (it should be brief)
- Materials and methods used
- Results
- Conclusions

Posters for farmers or the general public will not necessarily have the same sections. They usually present a visual message accompanied by a few words. Whether the poster is for farmers or scientists, the title should be informative, short and meaningful.

Format and design of posters

The format and design of posters depend on the following questions:

- How much space is available?
- What are the vertical and horizontal lengths?
- What shape is the space?
- Are there restrictions on the size of lettering?

You must bear in mind that your audience will not have time to read too many words. So you should convey the meaning through visual means if possible, e.g. striking pictures, use of colour (strongly coloured cards make good background for text in white). There is no single design formula. A basic poster design should organise the shapes following the principles of design: balance, use of space, use of text type, dynamics of colour and layout (see Arntson 1988). If you need to break the rules for a good reason, go ahead.

In all cases, the arrangement of the design elements (title, subheadings, body text and visuals) must be simple and pleasing to the eye. Steps for designing a poster:

- The first step is to find the information about the format before you embark on designing. Posters can have a horizontal (landscape) or vertical (portrait) formats (Figure 7.1).

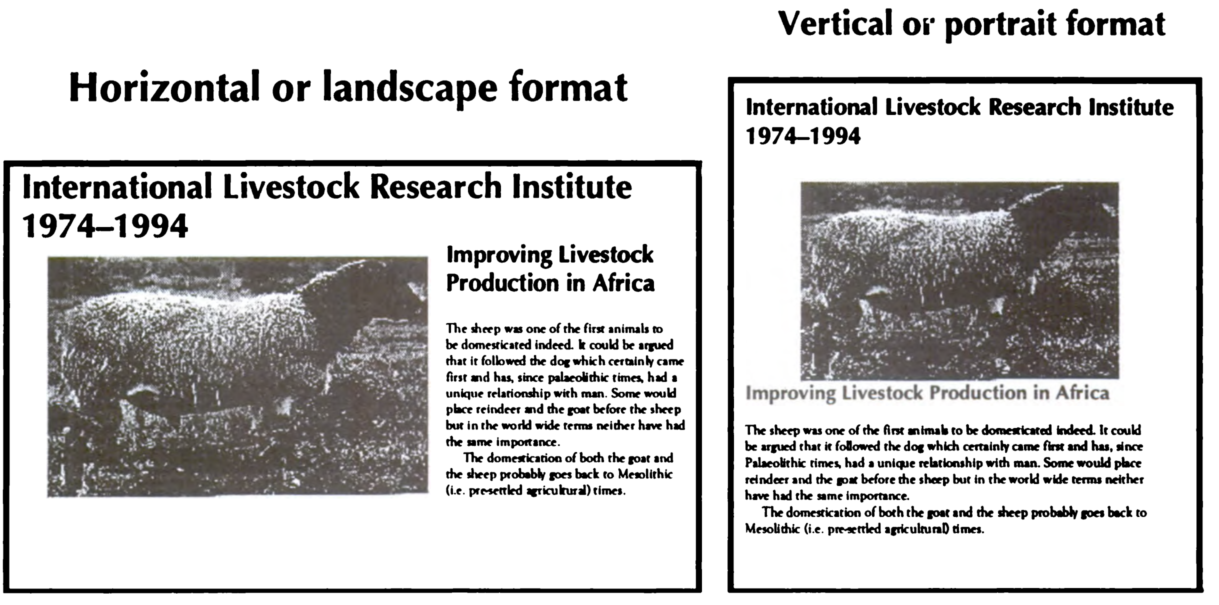


Figure 7.1. *Layout of poster.*

- Draw to scale a sketch plan of the presentation.
- The plan will guide you on how many illustrations and how much text you can fit into the allotted space.
- Make your display easy to carry especially if you have to travel to the meeting place. If you are allotted a space of 185 cm wide by 120 cm long you can have pages of text and figures fixed to 8 pieces of card (38 × 54 cm). The cards will occupy two rows of four pieces each and leave room for a title card. The title card should be large enough to be placed at the top left followed by your name and address (Figure 7.2).

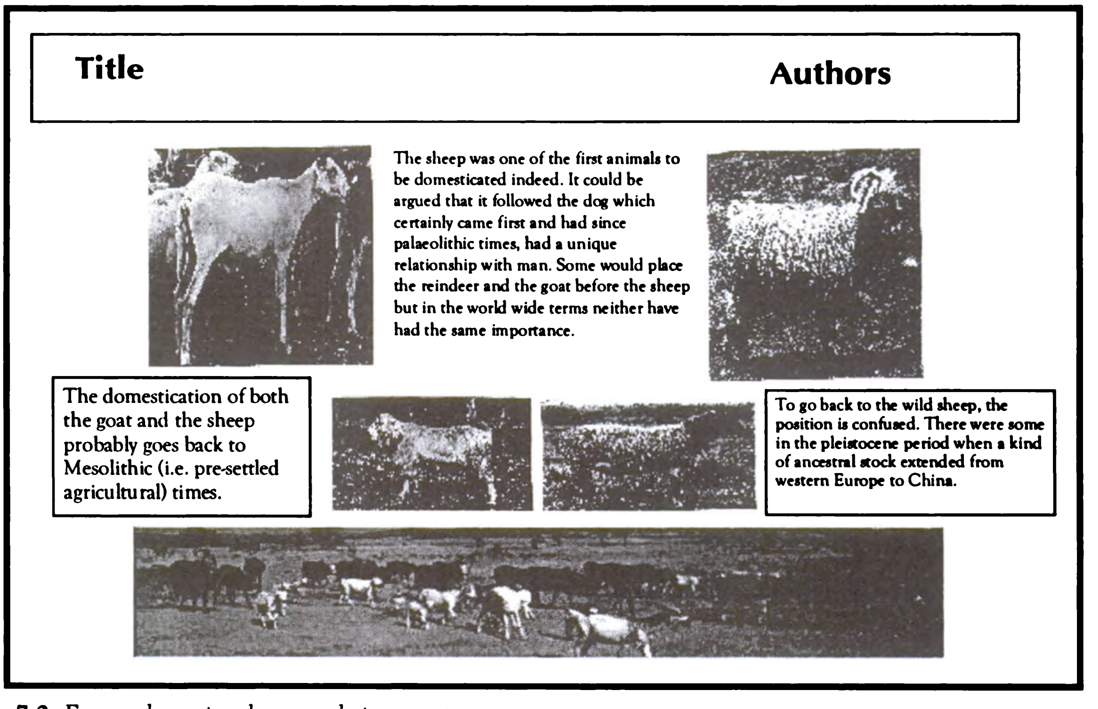
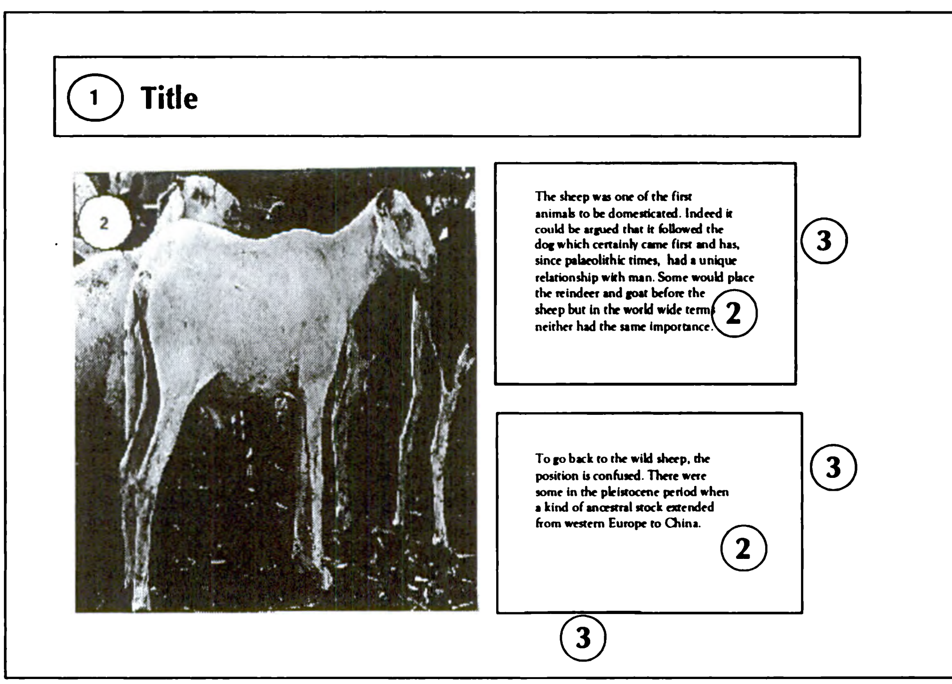


Figure 7.2. *Format determines how you design your poster.*

- Number the text and illustration sheets on the upper right side (Figure 7.2); numbered sheets help readers to find their way quickly through information. It is a good idea also to number the sheets at the back to help you carry them in the right sequence to the conference site. The thin cards (38 × 54 cm) will each hold an A4 sheet containing text or illustrations. Use your own variations but for the best results keep the number of different sizes of texts and illustrations to a minimum.
- Design an uncluttered display; this will help a reader who approaches the poster to stop, read, understand and move on in a very short period.
- When you arrive at the meeting place, fix the text and illustrations to the cards. Use glue or paste that does not dry too fast; this will allow you to adjust positions easily. You can also use double-sided adhesive tape to fix your sheets.
- Prepare a handout for interested viewers who may want to consult the information later. Design the handout to include the title, your name and address and a summary of the poster display. The handout should be short and as beautiful as the poster.

What to consider when designing posters:

- The major design elements are the space occupied by the title, the body of text and the visual. An important element in the design of posters is empty space that surrounds other elements. Empty spaces need not be filled at any cost because this will clutter the poster (Figure 7.3).



1 = title, 2 = body, 3 = open space.
Figure 7.3. *Components of poster design.*

- To create contrast, the size of one of the elements should be larger than the size of the other elements.
- Leave space around the design elements to avoid crowding. The open space area should be 30% to 40% of the poster area.
- It is good practice to balance the elements. For example one large element on one side can be balanced by two smaller elements on the other. You can deviate by creating imbalance or stress that can be desirable to draw attention or direct the eye to certain elements of the design (Figure 7.4).
- Use horizontal lettering, as vertical lettering is difficult to read. To create contrast a large vertical line or illustration can be effective to attract the viewer's attention to the poster.

Materials for preparing posters:

- select the best material you can afford to produce your poster
- try to use smooth hard finish paper if you use ink; this combination will allow you to produce sharp finished lines
- heavy printing paper

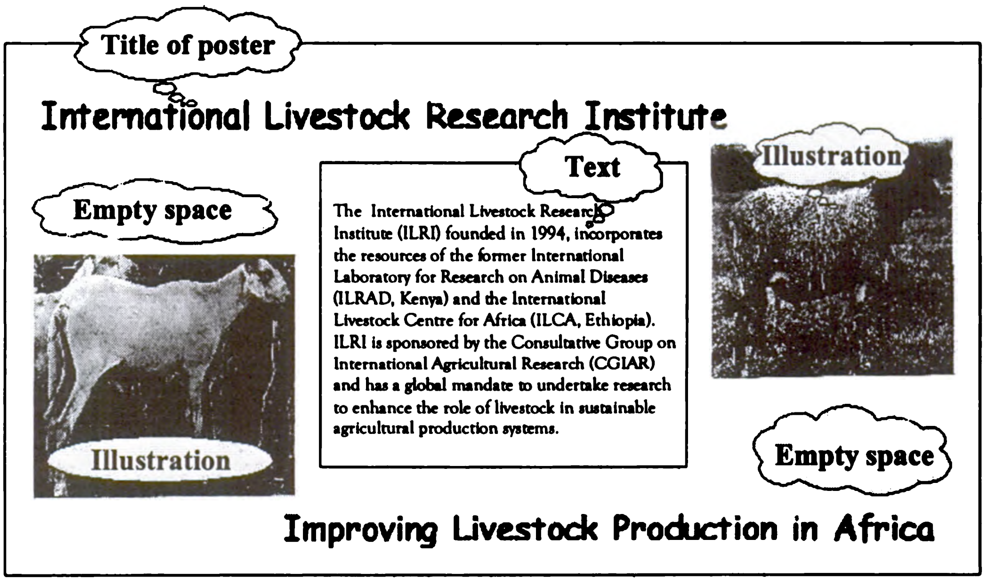


Figure 7.4. *Balance among elements in a poster.*

- cover stock paper
- cardboard
- felt-tipped markers for lettering.

Tables and graphs for posters:

- Use figures rather than tables if you can.
- Write short and informative titles for figures and tables; these titles should be the same size as the subheadings.
- Keep legends short and place them below the figures.
- Make labels on graphs run horizontally.

Lettering for posters:

- Produce lettering for the title and subheadings using a computer if you have the facility. If you do not have a computer, use dry-transfer or stencilled lettering. We suggest you use bold sans serif type for these parts of the poster. Make the capital letters of the title at least 4 cm high and lower case letters about 2.5 cm high.
- Use lower case letters for the body of the text except when it is necessary to use capital letters (start of sentence or genus). Make the capitals 8 mm high and the small letters 4 mm high to facilitate reading from 1 m away. Do not use capital letters for the body of the text because they cannot be easily read from a distance.
- Write your name and address with letters a little larger than letters for the body of the text.
- For subheading titles, use capital letters of 1.0 to 1.6 cm high and lower case letters of 0.6 to 1.0 cm high.
- Line thickness for letters should be reasonably bold for good legibility. Rule of thumb: ideally line thickness should be one-sixth the height of the letter.

The visual (illustration, photograph) is an important part of the poster. Posters for extension purposes usually contain visuals. The visual should:

- present an idea that will appeal to the audience
- be simple, compelling and to the point
- carry or reinforce the message.

Put yourself in place of the viewer and choose the most appealing and informative visual that will communicate the message.

Displaying posters

To display your poster:

- place it where it is highly visible, i.e. at eye level or above
- make sure there is adequate lighting.

7.7.2 Preparing overhead projection transparencies

Transparencies are large transparent acetate sheets on which information can be written and projected. They are handy to use in presenting results during scientific meetings. The overhead projector is widely used and is available in most meeting rooms. It can be used with normal room lights. Tips for using the overhead projector:

- be sure that an electric outlet is available and working
- face the audience while using the projector
- switch the projector light off between transparencies to protect the audience from the glare.

Transparencies contain words or graphics (including illustrations). They are easy to prepare. They range from inexpensive, simply made transparencies to multicoloured transparencies with several parts (or overlays). Acetates of various qualities are available to make transparencies. The equipment used to prepare transparencies ranges from specialised machines to inexpensive thermal and electrostatic copiers.

Preparing transparencies:

- prepare the main points for each transparency
- use 10 lines or fewer with 7 words per line in each transparency
- use a legible typeface
- type text/data first on paper
- prepare illustrations (or obtain from clipart or other sources); illustrations must be few
- design the layout of the transparency
- place text/data and illustrations in place
- photocopy material onto the transparency using the equipment available to you.

7.8 Exercises

1. During your career you will be submitting papers to journals using different reference systems. Write the steps you will take to arrange the huge number of references that will accumulate. Indicate how you will do this using a computer and how you will do it manually.
2. When you start writing your paper, cut yourself off from the outside world. Do you agree with this statement? Elaborate on your reaction and write your own view of how you would go about it.
3. A newspaper editor approached you and asked you to write an article about your research for the newspaper. How would it differ from the style and format you use to write your research paper?
4. Change this title of a research paper to a title for a newspaper article:

   Effects of restricting the water intake of dairy cattle upon their milk yield

7.9 References and reading materials

Arntson A.E. 1988. *Graphic design basics.* Holt, Rinehart and Winston, Inc., London, UK. 214 pp.

Benjamin B. 1989. *Elementary primer of English grammar.* Futura, London, UK.

Calvert P. 1990. *The communicator's handbook:* Techniques and technology. Maupin House, Gainsville, USA. 301 pp.

CBE (Council of Biology Editors). 1994. *Scientific style and format. The CBE manual for authors, editors, and publishers.* 6th edition. Cambridge University Press, Cambridge, UK.

Lindsay D. 1984. *A guide to scientific writing.* Longman, Melbourne, Australia.

Montagnes I. 1991. *Editing and publication: A training manual.* IRRI (International Rice Research Institute), Manila, the Philippines, and IDRC (International Development Research Centre), Ottawa, Canada. 429 pp.

O'Connor M. 1991. *Writing successfully in science.* Chapman and Hall, London, UK. 229 pp.

Reynolds L. and Simmonds D. 1981. *Presentation of data in science: Publications, slides, posters, overhead projections, tape-slides, television–Principles and practices for authors and teachers.* Martinus Nijhoff, The Hague, The Netherlands.

Reynolds L. and Simmonds D. 1982. *Presentation of data in science.* Martinus Nijhoff, The Hague, The Netherlands.

Stapleton P., Youdeowei A., Mukanyange J. and van Houten H. 1995. *Scientific writing for agricultural research scientists: A training reference manual.* WARDA (West African Rice Development Association), Bouaké, Côte d'Ivoire, and CTA (Technical Centre for Agricultural and Rural Co-operation), Wageningen, The Netherlands. 128 pp.

Tripathi B.R. 1991. *Roles of visuals in scientific presentations.* Communication Instruction Series. Audiotutorial Module 1. ILCA (International Livestock Centre for Africa), Addis Ababa, Ethiopia. 24 pp.

Tripathi B.R. 1991. *Speaking at scientific meetings: Organising the message.* Communication Instruction Series. Audiotutorial Module 2. ILCA (International Livestock Centre for Africa), Addis Ababa, Ethiopia. 20 pp.

Tripathi B.R. 1991. *Speaking at scientific meetings: Oral presentation techniques.* Communication Instruction Series. Audiotutorial Module 3. ILCA (International Livestock Centre for Africa), Addis Ababa, Ethiopia. 23 pp.

Tripathi B.R. 1991. *Writing a scientific paper.* Communication Instruction Series. Audiotutorial Module 4. ILCA (International Livestock Centre for Africa), Addis Ababa, Ethiopia. 26 pp.

Youdeowei A. and Kwarteng J. 1995. *Development of training materials in agriculture: A course manual.* WARDA (West African Rice Development Association), Bouaké, Côte d'Ivoire. 104 pp.

Module 8: Research project protocols

8.1 Performance objectives

Module 8 is intended to enable you to:

1. List components of a protocol.
2. Plan for writing a protocol.
3. Write a protocol.
4. Co-ordinate the review process for your protocol.

8.2 Introduction

As a scientist working on cattle production, your goal is to solve the problems of the resource-poor farmer through research. This research should focus on the farmers' problems and must be an integral part of the research of your institution and maybe the region you are in. You may also be a member of a network, e.g. the Animal Agricultural Research Networks (AARNET) in sub-Saharan Africa (SSA). In all these situations, you need to plan, develop and submit your research ideas in a format that can be reviewed and approved by the appropriate body. To achieve this objective, you need to plan your research and develop a protocol. Funds for research are becoming scarce and scientists have to compete for the few resources available. This competition can be for resources provided by your national research institution or by a donor agency; in both cases you need to develop and write a protocol that will convince the donors to fund your research. This module will enable you to obtain the skills to do so. This module will also cover a few topics related to implementation when your protocol is approved: administration, financial information and reporting. These topics are usually not part of a protocol unless the supporting institution wishes them to be.

8.3 Research protocols

What is a research protocol? It is an instrument that captures your intentions to conduct research to solve a problem. It is a document that details what needs to be done:

- It can have one or several proposals.
- It is a project portfolio (including one proposal or several proposals).
- In countries where funding is mostly obtained from donor institutions, it can be called a grant proposal. A protocol is more inclusive than a proposal, a term that is used by many in place of protocol, e.g. ILRI submitted a protocol which contained three grant proposals on small ruminants, cattle traction and nutrition.

8.4 Planning

Several prerequisites will help you in planning, developing and finally writing a good protocol:

- You have good research skills, are experienced and have published articles on previous research.
- You are committed to implementing research.
- You are linked to a stable multidisciplinary team and/or network.
- Your institution is committed to research.

When planning your research, you should:

- be innovative
- provide a clear rationale
- be focused
- be timely
- address specific problems that farmers have.

If the proposal has many experiments, then the experiments should be feasible and presented in a logical sequence. You should know the resources available to you before writing a protocol: personnel, equipment, supplies, land, animals etc. You should also know the study area and the needs of the farmers. Knowledge about other institutions is important as joint protocols may be called for by the complex nature of the problems.

8.5 Components of the protocol

A protocol provides justification, goals and objectives, expected outputs, work plan and budget. A good protocol would include a logical framework that reflects all these components. A protocol should be true to its claim that it can be done and achieve the goals and outputs stated.

8.5.1 Background and justification

This section of the protocol should:

- state the problem and rationale for solving it
- clearly describe the problem
- state what we already know
- state what needs to be done.

This section is used to demonstrate your understanding of the subject and to justify the need to conduct the proposed research. You should show why the information that will be obtained through research would be useful; this means explaining how the information can be used to solve the problems of the farmer. Work done by others that is relevant to your work should be clarified; avoid controversial issues in this section.

8.5.2 Objectives

This section lists and describes the overall objective and the specific objectives. The specific objectives are items in a list that will contribute towards attaining the overall objective. You should describe:

- the research that you intend to accomplish
- the hypotheses that you will test.

8.5.3 Expected outputs

Outputs constitute the terms of reference of the project. Write outputs to reflect the results which the project is held directly accountable for and for which it is given resources. Note that when outputs are achieved, the project is completed. Expected outputs are indicators used to verify whether the objectives have been achieved. To illustrate how outputs are written here are two examples from the protocol submitted by ILRI to fund the Cattle Network:

> **Example**
> Let us use the project 'Collaborative Research Support for Animal Agriculture Development in the Regional Frameworks for Action' that was submitted by ILRI to the European Union to illustrate the two types of objectives.
> - The overall project goal: To improve smallholder dairy/crop productivity and sustainability in order to increase food supplies and reduce imports
> - A specific objective that describes the overall goal in this project: Characterise the epidemiology of the most important diseases of cattle

- Integrated crop–livestock production will be popularised.
- Use of crop residues and by-products will be promoted.

8.5.4 Work plan

The work plan describes the materials needed and the methods to be used. It sets out what will be done and how to achieve it. The description should be clear and detailed for every experiment. There are two different types of work plans:

- A work plan that describes one experiment.
- A work plan that describes more than one experiment.

The second type can be constituted of sequential trials. It can also describe an umbrella project that will cover a series of trials. Whether the work plan is type 1 or 2, each trial should have the following attributes described:

- Objectives: The objective(s) of each trial should relate to the overall and specific objectives of the protocol.
- Expectations: Expectations relate to information on how the objectives will achieve the overall output.
- Time frame: The time frame shows the timetable for the activities in each trial. The targets should be treated as flexible dates but it is important to set such a timetable to guide the team implementing the experiment(s). In such a framework, activities should be listed in chronological order for every year of the lifetime of the protocol. You should be as specific as possible, e.g. feeding schedule, blood sampling dates etc. should be listed.
- Material and methods: The work plan will include the materials needed in every experiment. What goes into this part? In a nutshell it should describe what is to be done and how it will be done. You may find the following terms used but they all mean the same thing:

  Materials and methods ↔ Methodology ↔ Procedures ↔ Activities
- The materials and methods can be described together or separately. The main guideline is that no detail should be left out.
- Statistical analysis: Experimental design refers to various biometrical designs used in experimentation. In the protocol you must:
  - outline the experimental design and procedures
  - for new methods, explain why they are better than the old ones
  - explain control treatments clearly
  - explain how data will be collected and analysed
  - state and describe/define the materials that will be used: crops, animals, feeds etc.
  - list collaborators (scientists, institutions).

8.5.5 Budget

The budget section shows the resources that are needed to implement the protocol. Major features of the budget:

- It has to be based on the real situation. This can be done by surveying the market costs of items in the budget. Past experience can be of great help.

- Inflation rates should be included.
- A percentage for contingency should be included.
  Items that are usually included in protocol budgets are:
- Personnel costs: This includes the list of principal and support staff. Consultants are listed in this section.
- Equipment costs: This can include laboratory, field and office equipment (computers, audio-visual) and vehicles.
- Operation costs include travel, training, communication, information, workshops and office supplies.
- Contingency: This is a line item in the budget to safe guard against unforeseen events such as increases in cost of items.
- An administrative cost: This is a line item that many institutions use to cover overhead costs resulting from the project. Donors view administrative cost differently and a few reject it altogether.
- Budget explanatory notes are placed below the budget table. These notes explain items in the budget that may need further details or qualification.

8.5.6 Logical framework

Many donors require a logical framework to accompany the protocol. The logical framework is a table of information about the protocol that:

- stimulates you to think of what you want to do and how
- can be used as reference to monitor the progress of the project as it provides the indicators to use and the means of verification
- shows the basic assumptions you made before starting the project.

Box 8.1 provides brief descriptions of the components of a generic logical framework. Box 8.2 provides an example of a logical framework.

Box 8.1. Logical framework for projects

The logical framework (logframe is sometimes used for brevity) serves to improve the planning, implementation and performance appraisal processes by clarifying project design and making it transparent to the 'borrower' (the project team) and 'lender' (the source of funding). The main concept underlying the logical framework is cause and effect. The better the cause and effect linkages between objectives, the better the project design. By definition, each project has this if/then or cause and effect logic embedded in it. If we produce certain outcomes under certain conditions, then we can expect to achieve certain other outcomes to result, e.g. IF we supply farmers with improved seed and put a credit system in place, AND ASSUME there is adequate rainfall, THEN production will be increased.

A generic logical framework

The logical framework consists of a 4 × 4 matrix, with a vertical hierarchy of objectives at the goal, purpose, output and activity levels. The horizontal components are summaries of the objectives at each level, performance indicators for achievement of those objectives, the sources needed to verify the indicators and the important assumptions for moving from one level of objectives to the next higher level [see Box 8.2].

Goal: The programme rationale

Usually this will be a programme objective. For example, if farm production is increased (purpose), then farm family income will be increased (goal).

Purpose: Why the project is being done

The purpose is the measurable near-term impact of the project and is the final accomplishment of the project. It describes how the world will be changed as a result of the project's outputs.

Outputs: What the project is to accomplish

These are the deliverables for the project. They are the results for which the project is held directly accountable and for which it is given resources. Together with the objectively verifiable indicators for the outputs, they constitute the Terms of Reference of the project. Note: when outputs are achieved, the project is completed.

cont...

Box 8.1 cont...

Activities

The activities are the key activities undertaken by the project team that together form an action plan for producing the outputs. The activities should also include the basic actions of the project management team: the summary schedule of periodic meetings, monitoring events and evaluations.

Objectively verifiable indicators (OVI)

These are measurements to verify to what extent the objectives at each level are achieved. The elements of an OVI are its description and indications of quantity, quality and time. They must be sufficiently detailed to permit objective assessment of progress and wherever possible they must include numbers. Note: the OVIs at the purpose and output levels must include dates, the OVIs at the purpose level are the end of project status, the OVIs at the activities level are the inputs, i.e., budget, SSYs etc., the OVIs at the outputs level are the Terms of Reference (TOR) for the project.

Means of verification

These are the specific sources of information required to verify the indicators at each objective level.

Assumptions

These are important events, conditions and decisions outside the control of the project that are necessary for meeting the objectives. Assumptions are identified by asking 'What conditions must exist in addition to the objective (activities, output, purpose, goal) to achieve the next level?'

Suggestions for developing logframes

When developing a logframe, involve as many stakeholders as possible in preliminary discussions. Regard it as a very useful exercise, which is essential for the success of the project and an absolute requirement for obtaining funding. Begin with purpose—this is the objective of the project/programme. In developing purpose, ensure it will contribute to goal (which should be predefined). Remember, 'success' is 'purpose achieved'.

Identify important assumptions at the purpose level (i.e. those which must be fulfilled for the project to contribute at a higher level to achieving the goal). It is as well to do this at this stage, because it provides an indication of the realisability of the project. In so doing it may indicate that a project is a 'non-starter', and thus save a lot of further effort in logframe development. Define outputs required to achieve purpose. Remember you are contractually obliged to produce these. When outputs are achieved, the project is completed. Define activities required to achieve outputs. Identify important assumptions at the activities, outputs and goal levels. Do not underestimate the value of this step. It can lead back to a revision of outputs and/or activities.

Detail OVIs for goal, purpose and output, and show a budget summary at the activity level. Identify means of verification at all levels. Use a first draft as a basis for further discussion with all stakeholders, revise draft and provide to selected independent reviewers for comment before finalising.

Source: Rob Eley (International Livestock Research Institute, personal communication).

8.6 Writing strategies

Protocols differ depending on the nature of the problem that needs to be addressed and the format requested by the institution to which you will submit the proposal. This section will provide you with general rules to help you write a good well presented protocol.

- Begin to write your protocol early as it takes time to write a good protocol.
- Set a time outline for yourself. This will leave you ample time to think, plan, prepare, outline, write, revise, have colleagues review, revise, polish, get administrative approval and mail the protocol.
- Use the checklist provided by the donor or network.

8.6.1 Writing guidelines

1. Make an outline for each component of the protocol to safeguard against missing important points.
2. Include well designed and labelled tables and figures.

Box 8.2. Logical framework for the project Collaborative Research Support for Animal Agriculture Development in the Regional Frameworks for Action

Narrative summary	Measurable indicators	Means of verification	Important assumptions
Goal			
1. To improve smallholder dairy/crop productivity and sustainability in order to increase food supplies and reduce imports.	1. Increase the number of high yielding milk cows. 2. Increased milk and meat production. 3. Reduction in dairy and meat imports. 4. Improved nutrition of people in SADC member countries. 5. Increased income to producers.	1. Government and development agency census and survey data 2. Trade figures on imports 3. Ministry of Health reports on family health and nutrition 4. Final project report	1. Livestock research and development given priority by member states of SADC 2. Existence of enabling policy environment 3. Constant government and donor support 4. Private sector and NGOs willing to participate in research and extension
Purpose			
1. Improve feed production and utilisation 2. Characterise the epidemiology of the most important diseases of cattle 3. Characterise factors affecting reproduction, calf mortality and availability of improved genotypes and develop breeding plans 4. Provide socio-economic and policy analysis to policy makers 5. Strengthen NARS capacities in research and technology transfer	1. Number of farmers using improved feeding systems 2. Availability of information on the epidemiology of major cattle diseases 3. Improved herd health and smallholders able to obtain and sustain more productive genotypes 4. Government receptivity to policy recom- mendations 5. Number of trained NARS applying their training	1. Project evaluation reports 2. Annual reports of government institutions and IARCs involved 3. SACCAR annual training reports 4. Annual report to SACCAR board 5. Reports of the Co-ordinating Unit 6. Project evaluation reports	1. Livestock products in demand and livestock production is profitable 2. Producers adopt technologies to improve productivity 3. Governments initiate policy changes, NARS scientists remain in post to use training and experience gained.
Output			
1. Data on the physical, productive and adaptive characteristics of indigenous cattle breeds 2. Improved delivery of AI services 3. Improved breeding strategies 4. Technology for nutrient recycling, feed production and conservation 5. Proven feed production and utilisation technology for smallholders 6. Sustainable herd health delivery systems	1. Number of indigenous breeds characterised and quality of the data 2. Number of animals served and efficiency indicators such as calving intervals and non-return rates. 3. Number of heifers of improved genotypes available for sale 4. Adoption of improved nutrient management and feeding systems 5. Improved herd health amongst target farmers	1. Project research activity reports 2. Publications in peer-reviewed journals and conference proceedings 3. Reports on human resource development 4. Meetings minutes 5. Surveys of extension and beneficiary livestock owners	1. A strong farmer-participatory research programme put in place 2. That all collaborators are committed, especially the farmers 3. A stable working environment exists at country and regional level 4. Timely disbursement of funds allocated for project activities 5. Policy changes stimulate adoption of innovations

cont...

Box 8.2 cont...

Narrative summary	Measurable indicators	Means of verification	Important assumptions
7. Policy recommendations for intensification of animal agriculture 8. Scientists trained in farmer participatory research 9. Strengthened NARS capacity for research in animal agriculture in SADC member countries	6. Government responses to policy recom-mendations 7. Number of NARS scientists, technicians and extension agents trained		
Activities			
1. Formation of Programme Co-ordinating Unit 2. Review of SADC/SACCAR priorities, issue of invitations to compete for research grants and selection of NARS research projects 3. NARS projects implementation, supervision and reporting 4. Formal and informal training of scientists, technicians and farmers 5. Information dissemination through seminars, field days, workshops	1. Technologies 'on the shelf' identified, tested and validated, and recommendations made for their utilisation 2. Demand-led training courses, especially of those related to on-going research projects 3. Newsletters, extension/farmer bulletins and conference proceedings	1. Reports and publications 2. As above 3. As above 4. Number of newsletters, conference proceedings etc.	1. Effect of natural disasters minimal 2. Infrastructure (laboratories, farms etc.) are available 3. Inputs/resources available 4. Project budget ECU 9.35 million over 5 years.

3. Be accurate, clear and consistent:
   - use a logical sequence of presentation of the ideas
   - avoid jargon since your donor reviewer may not be a specialist in your subject
   - avoid ambiguity
   - terminology and abbreviations should be consistent throughout the text
   - appropriate sections of the protocol should agree with each other.
4. Do not include irrelevant information.
5. Use simple words, short direct sentences and short paragraphs.
6. Try to be positive but do not overstate your case.
   If editing facilities are available in your institution, it is a good idea to use them.

8.7 The review process

Discussing your ideas and sharing the first or second drafts of your protocol with your colleagues is a good step to help you avoid pitfalls. It will give you an idea of whether others understand what you want to convey.

If your institution has a review system for all protocols, use it. It is a good idea to set some guidelines for your reviewers on the feedback you need. We suggest the following points:

- scientific and technical significance of the research
- originality
- adequacy of methodology
- suitability of the facilities
- appropriateness of the budget
- appropriateness of time to carry out the research.

Request the reviewers to summarise the strengths and weaknesses of the protocol and provide recommendations.

8.8 Exercises

1. To write your protocol, the following are the main components:
    - Background and justification
    - Objectives
    - Expected outputs
    - Work plan
    - Budget
    - Logical framework

To practice, start with your ideas and answer the following questions for all of the above sections:

- What is the purpose of this section of the protocol?
- What should the scope of this section of the protocol be?
- How should I introduce the subject?
- What are the main ideas to be included in this section?
- Which of the items are essential? Not essential?

8.9 Reference and reading material

Reif-Lehrer L. 1989. *Writing a successful grant application*. Jones and Bartlett Publishers, London, UK. 283 pp.

Module 9: Transfer of technology

9.1 Performance objectives

Module 9 is intended to enable you to:

1. Define transfer of technology.
2. List the types of technology transfer systems.
3. Describe the role of research in the transfer of technology.
4. Explain extension needs of pastoralists and farmers in crop–livestock systems.
5. Describe at least one case study from your region.

9.2 Introduction

As a researcher your job is to develop technologies that will increase livestock productivity. But this effort will not have any impact unless the technologies are transferred to the farmers. Although your main function is research, you cannot afford to ignore linking your research to technology transfer efforts. This module outlines the mechanisms involved in linking your research to transfer of technologies to resource-poor farmers. In most countries of sub-Saharan Africa (SSA) there has been little support from governments for the agricultural sector, and within this sector, small budgets have been allocated to research and extension services. This resulted in failure to transfer new technologies. A few success stories can be cited where extension programmes received good finance, were well structured and targeted high-value commodities. An example of a successful extension effort is dairy development in Kenya.

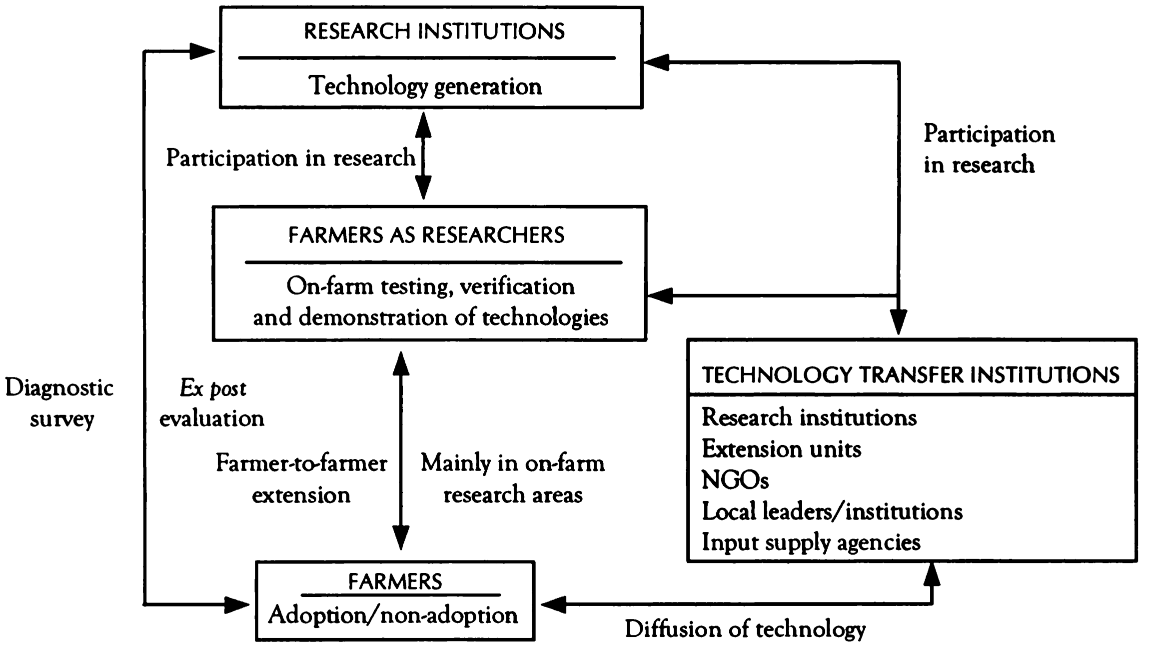
Many factors led to the poor transfer of technologies. Among these is the separation of extension from research programmes. As a consequence many extension agents have little information to share with farmers. This module will focus on research–extension linkages. Your role in the research–transfer of technology continuum will be clarified.

9.2.1 Key concepts

Technology transfer is a two-way flow of technical information and materials among the farmers, researchers and those who disseminate technologies. This definition extends the meaning of extension beyond association with the traditional public sector to involve services provided by other institutions such as non-governmental organisations (NGOs), private firms, educational institutions and producers' associations. Our definition also implies that technologies are generated by all parties and diffused by all. There is a continuum with no hard boundaries (Figure 9.1).

The main processes of research are:

- Discovery: The process of collecting information and/or searching for relationships among variables. This process includes basic and/or strategic research.



Source: M.A. Jabbar, ILRI.
Figure 9.1. *Linking research and technology transfer agencies and farmers.*

- Exploratory development: The process of identifying, understanding and controlling interaction between a proposed technology and the socio-economic and physical environments. This process includes applied research.
- Technology consolidation: Involves transforming the results of research into a new technology package. It includes adaptive research.

The main processes of technology transfer are:

- Technology production: The process of providing materials (inputs and/or information) in sufficient quantities to those who are responsible for delivery.
- Delivery of technologies to farmers: Promoting the technology to farmers; this can be done through many channels.
- Monitoring and evaluating the use of technologies: Studying the adoption rate by farmers and the impact of the technology.

Institutions involved in research and transfer of technology are many. Many researchers may be involved in transferring technology. On-farm research is an important component of transfer of technology. On-farm research:

- applies a problem solving approach
- identifies and describes major farming systems which define the demand for the technology
- adapts technology at farm level for farmers sharing the same problem
- involves farmers participating as partners
- obtains feedback to improve the relevance of research
- involves the collaboration of research, extension and development agencies for effective transfer of technologies

We need to stress the point that technology transfer is used in this module in a broad sense to encompass extension activities. Transfer of technology differs from extension in the following ways:

- It provides inputs and services such as training on use of technologies or inputs, indigenous knowledge, credit, health services, infrastructure, entrepreneurship etc. Extension, the way it is applied in many countries, is mostly limited to information delivery.
- Even though extension is usually limited to government institutions, non-governmental institutions can transfer technologies.
- Transfer of technology facilitates a two-way flow of information. Farmers, development agents and researchers exchange information during the process.

Researchers are involved in the process of technology transfer because:

- research is conducted to solve farming problems
- it is essential to translate research results into action at the farm level
- the researcher needs input from extension and development agents during research planning and implementation and for transfer of technology activities.

Therefore there is a continuum from research to transfer of technology that necessitates the participation of all parties: farmer, researcher and technology transfer (Table 9.1). Studies by the International Service for National Agricultural Research (ISNAR) confirmed the hypothesis that the traditional weakness of the links between research and technology transfer was in part due to lack of awareness of their interdependence (Kaimowitz et al. 1989).

Table 9.1. *Areas of interdependence between research and technology transfer.*

Areas of interdependence	The need for interdependence
Problem definition	Transfer agents > researchers • help them understand farmers' problems • facilitate contact with farmers Researchers > transfer agents • identify the scientific approaches to solve a specific problem
Experimentation	Transfer agents > researchers • identify representative location for trials • develop realistic experimental designs • explain objectives to farmers Researchers > transfer agents • establish proper procedures • provide advice during implementation
Technology adaptation	Transfer agents > researchers • help farmers choose the right option Researchers > transfer agents • propose the options for modifying technology to suit local conditions
Technology verification	Transfer agents > researchers • help manage on-farm trials Researchers > transfer agents • ensure scientific rigour • process data from trials
Technology packaging	Transfer agents + researchers > farmers • inputs required by new technology are available to farmers Researchers > transfer agents • explain the context in which a new technology should be applied
Provision of information	Transfer agents > researchers • produce and deliver effective messages to farmers Researchers > transfer agents • ensure that the messages are accurate
Provision of services	Transfer agents > researchers • provide specialised communication services to disseminate technologies Researchers > transfer agents • provide services such as soil testing, pest identification and seed certification
Provision of feedback	Transfer agents > researchers • provide the feedback of farmers about the new technology Researchers > transfer agents • use feedback to research identified problem

\> means contribution to.

9.3 Technology transfer systems

There is no agreement on the best way to transfer technologies in SSA. The extension systems in the region differ widely because of differences in countries, prior colonial structures and the current interaction with international research and development agencies.

We can group the technology transfer systems practised in SSA as follows:

- Conventional hierarchical approach. This system employs a large number of field staff who work directly with the farmers and are supported by subject-matter specialists.
- Co-operative organisations approach. In this system the organisations provide advice, services and inputs to the farmers.
- Profit-oriented agencies approach. In this system, the agencies provide specialist services in the form of high value crops or livestock to farmers. The agencies make profit selling services or inputs.
- Farming systems research and extension approach. In this system a multidisciplinary approach is followed. The team looks at the total farm unit.

Most of the countries of SSA use the conventional hierarchical approach. Some countries, through funding from the World Bank, modified this system by introducing the training and visit system. A common feature of the conventional hierarchical approach is the separation of technology transfer systems for crops and livestock. If combined, there is a bias towards crops. There is now pressure from farming communities and donor agencies to combine the different crop and livestock extension services into a single service. To achieve any impact, this service must link farmers with researchers.

9.4 Transfer of technology linkages with research

If you conduct research to develop technologies, you need to link your research to farmers and technology transfer groups. Researchers link to farmers through on-farm research (Figure 9.1) to ensure that the results of research solve farmers' priority problems. Researchers link to transfer of technology groups through validation of technologies and pilot projects (Figure 9.1). The link ensures impact through a wider dissemination of technologies. The two links complement each other and one cannot replace the other.

9.4.1 Why do we need links?

Links between researchers, farmers and technology transfer groups ensure that:

- research is focused on priority needs and problems of farmers, therefore results from experiment stations are used to solve farmers' problems
- farmers and technology transfer workers keep up with research developments
- technologies are tailored to suit local conditions
- relevant technologies are widely promoted and adopted
- farmers have access to the information, inputs and services required to adopt technology
- researchers have access to farmers' knowledge.

9.4.2 Organisational issues

To link research to transfer of technology we need to develop an organisational structure. An organisational structure can be achieved through:

1. Grouping research and technology transfer tasks
    - The most important interactions should reflect the grouping. Units should be set up according to the degree of interaction needed to meet a specific objective.
    - Grouping people whose work might overlap.

    The difficulty with this approach is that no group takes responsibility for translating research results into specifications for a new technology, packaging that technology and providing the materials necessary for its use.

2. Merging research and technology transfer units.

   In this approach two or more units in the same institution have a common supervisor who is responsible for integrating their functions and work. Merging is assumed to increase efficiency, facilitate communication and collaboration and promote a shared goal between researchers and technology transfer agents. This approach has its problems and is not as easy to implement as it may sound.

   - Research and transfer of technology share a common goal and area of concern, e.g. to improve productivity of livestock.
   - Financial and human resources are available for linkage activities.
   - The size of the new institution is manageable.
   - The management of the new institution must aim at making the groups work together.

3. Co-ordination units or positions

   - This approach can use subject-matter specialists, research–extension liaison officers or pre-extension services. Unlike direct supervision, these positions have no authority over the units they will co-ordinate. Co-ordination units or positions can handle technical matters better than direct supervision as they have the time and resources to use for integration to develop expertise and to recognise and fill gaps. However, this approach has many disadvantages: (a) institution managers may overlook their responsibilities in the belief that the task is already under control, (b) the co-ordinated groups or units may ignore liaison staff because the co-ordination positions have neither formal authority nor support from management and (c) liaison staff may resent the job of only linking others who are doing the interesting work. This approach may therefore lead to additional barriers (new procedures, objectives and language) rather than removing existing ones.

4. Permanent committees

   These committees promote horizontal and vertical integration. The members may be drawn from various units or institutions. For such a committee to succeed:

   - all parties consider it necessary
   - members of the research–transfer of technology groups have a stake in its work and implement its decisions or recommendations
   - it is action oriented and not only a forum for discussion
   - its mandate is specific
   - senior management in all institutions involved supports it
   - meetings are well planned and chaired and follow agreed upon procedures.

9.4.3 Types of linkage processes

In the previous section we dealt with the structural issues of linkage. This section will deal with the process which will apply to links between on-station and on-farm research as well as between research and transfer of technology.

Planning and review processes

Planning and review meetings have been widely used to forge linkages between research and technology transfer operations. To be successful tools, they require resources (staff time and operating funds). These processes function through:

1. Joint problem diagnosis

   Joint problem diagnosis is best done in the field. Informal diagnostic field survey proved effective in bringing together on-station researchers, on-farm researchers, technology transfer agents and farmers. The survey helps on-station researchers learn about farmers' problems and appreciate the potential benefit of the technology.

2. Joint priority setting

   This exercise is very useful but is difficult to implement. It can be a potential source of conflict as its expected outcome is the work agenda. One group may perceive another as trying to dictate the agenda. The problems can be overcome by including senior managers in the exercise.

3. Joint programming and review meetings

The meetings should be kept small and should concentrate on a particular commodity (e.g. livestock) and region. A meeting is successful when it is attended by people who can take decisions and implement actions.

Collaborative activities

1. Collaboration in trials, surveys and dissemination

   This is a very effective mechanism for linkage. Formal arrangements are needed to facilitate collaboration between on-farm researchers and transfer of technology agents at the field level. Such agents should be trained in skills needed for trials or surveys. Researchers need to be trained in dissemination skills.

2. Joint decision making on recommendations

   This can be a problem for linkages if not treated properly by senior management. Management needs to develop a system for the agencies to reach consensus on recommendations. Management should also assign agencies to implement these decisions. This will ensure that farmers receive similar messages from different groups.

3. Field visits

   Joint field visits are very effective in strengthening linkages. For this activity to be sustained managers should allocate adequate operational funds.

4. Informal consultations and sharing of tasks

   This system is a low cost way of collaborating. It is very effective for links between on-station and on-farm research and should supplement, but not replace formal mechanisms. The system is successful when staff are willing to share additional responsibilities and when institutions are flexible.

Resource allocation

The resources allocated to transfer of technology reflect its importance to managers. The major resources are staff time and operational funds. Research staff rarely allocate time to transfer of technology activities; they prefer to use their time solely for research. Managers need to provide researchers with clear guidelines on the time to be spent on activities for technology transfer: joint meetings, field visits etc. Managers should be careful not to affect the core professional activities of the researcher. Senior management should provide operational funds to meet transport, fuel etc. costs. Lack of funds will slow or stop collaboration. Collaborative activities should be line items in the programme budget and the funds should be the responsibility of those who will use them. Collaborating institutions should share in providing the funds. The rotation or secondment of staff is an effective way of getting the necessary human resources for linkage activities. It is essential to set a clear time frame for rotation or secondment.

Communication

Communication for research–transfer of technology links must be planned at the onset of activities and funds must be provided. Commitment, skills and talents are usually needed.

1. Reports, audio-visual material and publications

   Extension workers are interested in short, easy to read and understand (preferably in local languages and without scientific jargon) publications, e.g. brochures, bulletins and leaflets. Research results should be made available to all involved in the research–technology transfer continuum. Researchers should not wait until the results are published as it takes a long time for papers to appear in journals. In addition, extension agents may not have access to the journals. Institutions should invest in audio-visual resources, human resources and infrastructure. Visuals and radio messages are often more effective than printed material.

2. Seminars and training courses are effective means to foster links. These activities are especially effective among groups that are new to each other or do not understand each other's work.

9.4.4 Management of linkage

Senior management of institutions or units involved in research–transfer of technology links need to:

- participate in research–transfer of technology activities to demonstrate their importance

- build linkage responsibilities into the job descriptions of all involved staff
- provide guidelines to staff on how time and funds are allocated to linkage activities
- provide funds for linkage activities that are shown as budget line items
- reward participation and minimise hardships.

9.5 Extension for integrated crop–livestock systems

The population pressure in SSA is driving the cropping and livestock systems towards integration. Farmers and governments are therefore seeking to integrate the currently separate extension services for crops and livestock. This should lead to efficient delivery of viable technologies and efficient use of financial, physical and human resources. The integrated service should aim at improving farmer-researcher-extension linkages. Unfortunately many livestock departments in Africa are resisting the unification process for fear of being submerged into crop departments. Nigeria took this bold step in 1991 and their experience shows that the integration process will not be easy.

The majority of extension agents in SSA have crop production backgrounds and their education level is low. They advise farmers on animal production. The agents should be able to provide effective advice on common livestock needs such as feeding regimes, calf feeding, clean milk production, fodder production, vaccination, dehorning, castration and deworming.

Animal production specialists working with or in the extension service are essential to provide more advanced advice. They need to work with farmers' training centres. As farmers become sophisticated, the need for more specialised information becomes acute. Training can best be done by the farmers' organisations and newly sprouting businesses. Government services should co-ordinate and encourage these efforts. An example of services that can be provided by private organisations is dipping. There is a need to find new and innovative ways to provide information to farmers. Sub-Saharan Africa can benefit from the example of information dissemination in Asia where progressive farmers have been the most important source of information for other farmers.

9.6 Extension for pastoralists

Pastoralists differ from sedentary farmers in many respects and therefore need different approaches for transfer of technology. The management requirements for livestock differ between pastoralists and sedentary farmers. The acceptance of new technologies also differs between the two groups. There is no specific technique for transferring technologies to pastoralists.

Experts on rangelands should work closely with pastoral groups to improve the systems. The experts should have the knowledge and skills to do the job; they should also have high quality interpersonal communication skills. In addition, they need to be familiar with the communities they serve. Knowledge of the local language is a great advantage.

Pastoralists may need information on the following aspects of livestock improvement:

- animal health
- better feeding technologies
- improved breeding programmes
- seed for food and forage crops
- animal traction
- processing of animal products (milk, meat, hides and skins)
- improving water supplies.

The type of extension work and who should do it will vary depending on the needs and movement of the pastoralist. Usually government services to pastoralists are limited to health services. To remedy this situation governments should provide well trained multi-purpose subject-matter specialists. To solve the problem of movement, these specialists can meet with the pastoralists at watering points or certain camping sites. The pastoralists should be encouraged to select certain extension agents to perform health services and other simple extension requirements. This will relieve the burden of the subject-matter specialists who will limit their intervention to scheduled visits.

9.7 Case studies

In this section of the module we will use case studies to illustrate the concepts of transfer of technology and research-transfer of technology links. As the stories occurred in diverse conditions, they might not cover all the aspects of transfer of technology or the linkage mechanisms. Still we consider them useful and hope you use them as guidelines while pursuing your own activities.

9.7.1 Case study 1: The broadbed maker (BBM) for better management of Vertisols in the Ethiopian highlands

Background

Ethiopia has a land area of 110 million hectares. The Ethiopian highlands represent 45% of the land mass and support 80% of the country's population. Agriculture in the highlands has stagnated due to several factors such as inappropriate land tenure and marketing policies, poor infrastructure and lack of appropriate low input technologies. The main problem is the degradation of the natural resource base and the environment. Use of dung and crop residues for fuel has contributed to further degradation resulting in shallow soils, reduced moisture holding capacity and low soil fertility.

The problem

Ethiopia has 12 million hectares of Vertisols (black cotton soils) which are known to be fertile. The highlands have 8 million hectares of Vertisols. It is estimated that only 25% of the Vertisols in the highlands are cultivated with pulse crops like lentils, chickpea and peas, and cereals such as teff (*Eragrostis tef*). Early planting is not possible because the Vertisols are waterlogged. Farmers practise cropping methods that drain the excess water from the Vertisols, e.g. forming broadbeds and furrows. In certain areas the soil is ploughed at the start of the rainy season and left idle until crops are sown on flat beds later in the season.

Farmers in the Inewari highlands have a unique method of draining excess water. The farmer ploughs the soil to loosen its structure. The loosened soil is manually scooped by women and children to form beds (85 cm wide by 10 cm high, separated by 20 cm furrows). In all cases farmers do not make full use of the growing season and the returns from investment are not enough to meet the food and cash demands of the rising population of the highlands.

Farmers in the Ethiopian highlands plough their land using the traditional plough, the *maresha* or *ard*. The *maresha* is a simple-spiked tilling implement which is usually pulled by a pair of oxen. The traditional plough consists of a metal point fastened to a wooden arm, connected to a pole which is fastened to a wooden neck yoke (see Figure 9.2). The *maresha* weighs 17 to 26 kg which makes it possible for one person to transport it to and from the field. The farmer makes all the wooden parts and buys the metal tine from a blacksmith. The power required to pull the *maresha* depends on the soil moisture content, depth of ploughing desired and the degree of soil compaction. A pair of oxen weighing 300 kg each can provide 0.5 to 0.9 kW of power. The *maresha* has several defects that contribute to the delay in planting such as:

- The *maresha* is a cultivating implement and not a real plough and therefore does not invert the soil and does not provide cutting action. This makes it unsuitable for burying stubble and weeds.
- The *maresha* is not efficient during seed covering. The depth of coverage varies from exposed seeds to shallow coverage; farmers compensate by doubling the seed rate.

Research and technology development

The Joint Vertisols Project (JVP) was started in 1987/88 to develop a low-cost land shaping and seed-covering implement based on local materials. From the beginning, farmers were invited as partners to give their views in the design and testing of the implement. The partners in the project are the Ethiopian Agricultural Research Organization (EARO), Alemaya University of Agriculture (AUA), the Ministry of Agriculture (MoA), the Relief and Rehabilitation Commission (RRC), the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and the International Livestock Research Institute (ILRI).

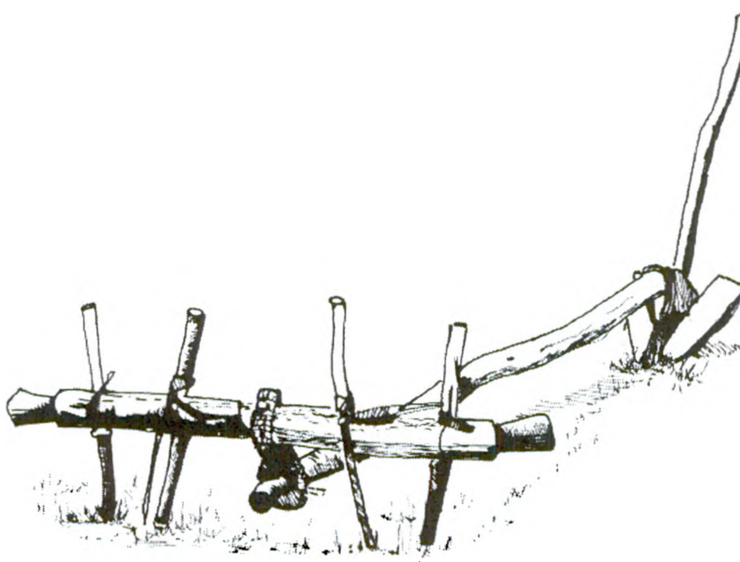


Figure 9.2. *The traditional plough* (maresha) *in the Ethiopian highlands.*

The joint effort of the members of the JVP led to the development of the broadbed maker (BBM). It is made out of a pair of *maresha* (traditional Ethiopian plough) connected in a triangular structure (Figure 9.3a and b). The top ends of the *maresha* are tied together and connected to the yoke in a similar way to the traditional method. To maintain a distance of 1.2 m between the *maresha* tips, a crossbeam is tied between the two poles of the *maresha* at around 1 m from the lower edges of the poles. A steel wing is attached on each of the inner flat wings of the plough to push the soil inside and form the broadbed and furrow. A chain is attached at the edge of the metal wings to shape the beds evenly and cover the seeds. The pulling power required is 0.62 kW.

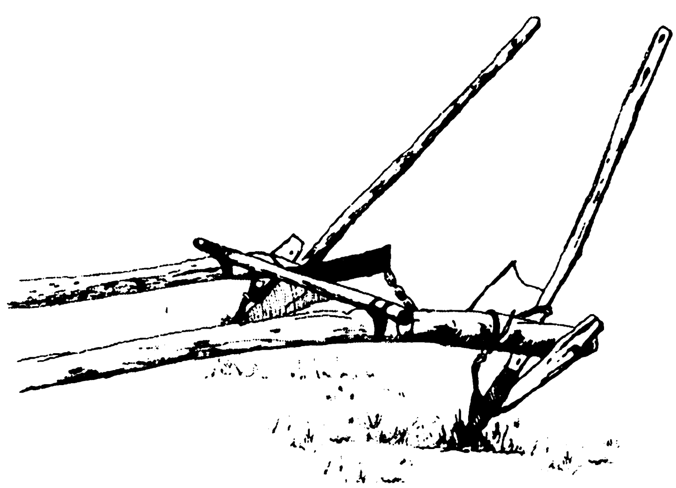


Figure 9.3a. *The broadbed maker.*

The JVP also developed a planter attachment to the BBM. It is a simple hand-metered seeder that is mounted on the BBM (Figure 9.4). The planter consists of a funnel connected to a transparent polythene hose which carries the seed to a steel pipe that leads them into the furrows opened by the metal tines. The planter was tested with maize and wheat and the farmers were able to plant at the recommended seed rate. The tine attachment used for planting can also be used for weeding maize crops.

Tekaligne Mamo et al. (1993) and Saleem (1995) reported that on-station and on-farm testing of the BBM for seedbed preparation has consistently shown that annual productivity of Vertisols increases. The Agricultural Implements Research and Improvement Centre (AIRC) tested the BBM at Debre Zeit, Ethiopia, in June 1990 on ease of construction, availability of construction material and ease of operation.

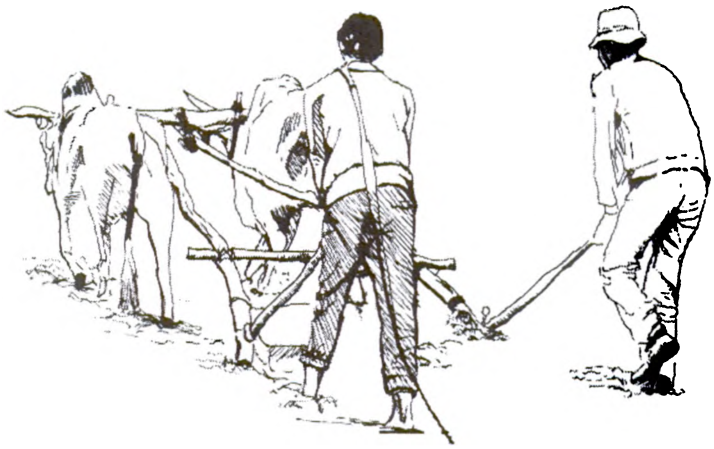


Figure 9.3b. *Farmers ploughing using a broadbed maker in the Ethiopian highlands.*

The results confirmed that the material and skill for construction are within the reach of the farmers and blacksmiths in rural areas. The test found that the draft requirement of the BBM was higher than that of the traditional *maresha.*

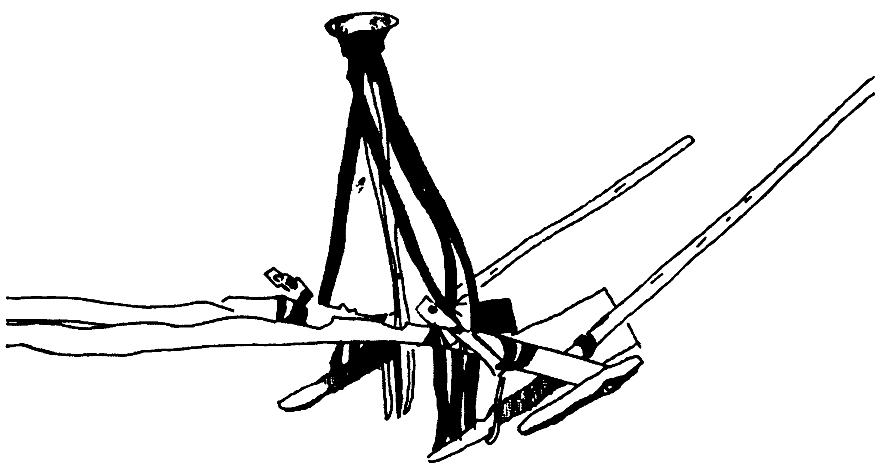


Figure 9.4. *Hand-metered seeder mounted on a broadbed maker.*

Transfer of technology

The JVP tested the BBM technology in a technology package that included the use of appropriate seeds, fertiliser and early planting. Five sites (Debre Zeit, Ginchi, Inewari, Dogollo and Dejen) in the Ethiopian highlands, that are diverse in farming systems, were used for on-farm testing. In this case study we will report only observations on the BBM.

Research with a farming systems perspective was used leading to a two-way flow of information. The BBM technology was designed on station and verified on farm with farmers. Work on draft power was carried out mainly by ILRI at its Debre Zeit Experiment Station. Work on crops was carried by EARO and AUA. Trials to develop new cropping systems were done by the MoA. There was close collaboration among the consortium members. The inter-institutional links achieved:

- mutual information exchange
- minimal duplication
- a critical mass of information in several areas.

The technology was popularised in communities by the MoA and Oxfam-America during 1989 and by Sasakawa Global 2000 during 1998. This was followed by on-farm verification trials. It was then demonstrated on large scale. Adoption was monitored and further socio-economic constraints were identified. The JVP held field days annually just before harvest. Key progressive farmers collaborating with the project visited other farmers to exchange experiences. Policy makers attended field days which were very useful in linking the various partners and providing feedback to researchers.

On-farm testing provided an opportunity for farmers to assess the technology. Seven producer co-operatives with 1500 household membership and 61 individual farmers used the technology during 1986. By 1990 the number of producer co-operatives had increased to 10 with 2500 household members and 158 individual farmers using the technology. There was consistent increase in crop yields and economic gains from using the BBM in place of the *maresha* traditional plough. At Inewari the BBM replaced the drudgery of manual construction of broadbeds and furrows. The use of the BBM reduced labour requirements by 67%. The animal traction time required using the BBM was half that required using the traditional method of seed covering.

Impact

During the early years of transfer of the technology farmers in the on-farm trials were impressed by the results. Feedback, however, highlighted the constraints that still face the adoption of the technology at a wide community scale:

- Farmers were concerned about the weight of the BBM which they perceived as heavy for the oxen and for the farmers who carried it to the fields. As a result the research team constructed a light BBM prototype which solved the problem.
- Farmers were concerned about the availability of the BBM parts. The MoA made inputs available to farmers.
- The BBM technology was linked to early planting and use of fertiliser. Farmers were sceptical about early planting of cereals and it took demonstration to convince them.
- A major drawback is availability of extension staff to spread the technology.

The actual number using this technology at present may appear small. There is no easy method to measure the potential impact. Field days can be used as one indicator as the technology seems to inspire the farmers confidence.

9.7.2 Case study 2: Fodder banks in Nigeria

Background

Cattle are very important in the farming systems of Nigeria. There are 4.5 million cattle in the subhumid zone of Nigeria in the wet season and 4.9 million head in the dry season. The majority of livestock owners are semi-settlers and live in the harsh environment found in the north of Nigeria. During the last two decades pastoralists have settled in the subhumid zone.

The problem

- Natural pastures in the subhumid zone of Nigeria are the main source of feed for ruminants. However, the pastures do not meet the nutrient requirements of the animals throughout the year.
- Even though crop residues are available in large quantities after crop harvest, their nutritive value is low.
- Crude protein is sufficient for three months only.
- By the end of the dry season it is common for animals to have lost 10–20% of their body weight. Losses associated with nutritional stress are reproductive wastage, deaths and prolonged calving intervals.
- Even though feed supplementation can be used to alleviate nutritional stress, supplementation with agro-industrial by-products is beyond the reach of smallholder farmers because these inputs are expensive and in short supply.
- Attempts to increase productivity of the rangeland using conventional methods (bush control, selective burning and rotational grazing) fail because the rangelands are grazed communally and are burned accidentally.

Research

To deal with the problem of poor nutrition researchers introduced the fodder bank concept (de Leeuw et al. 1994; Saleem and von Kaufman 1995). The researchers observed that farmers only grew forages when there was no conflict with crops for labour and when the forages were protected. The researchers also observed that animals were allowed to graze on regerminated legumes. It was therefore hypothesised that a technology that could provide fodder and impose no competition for labour with crops could be appealing to farmers. This was an example of researcher–farmer interaction that led to refinement of the farming system.

In 1980 ILRI started experiments on farmers' fields undersowing the sorghum crops with stylos (*Stylosanthes guinensis* cv Schofield and Cook and S. *hamata* cv Verano). The results of this on-farm research showed that:

- land preparation for sowing stylos was minimal
- intercropping with forage conflicted with weeding of the crop
- itinerant herds attacked the legume pastures and it was necessary to protect the legumes with fencing.

ILRI concluded that the techniques available to integrate forage production with food crops were inadequate, agropastoralists were ready to grow forage crops provided there was adequate protection and there was a need to increase feed resources in arable farming systems and fallow lands.

ILRI conducted different levels of researcher-managed/executed and farmer-managed/executed trials. Various techniques for incorporating forage legumes (mainly Verano and Cook stylo) into compatible cereal–forage crop mixtures were assessed. The sowing date of forage legumes in cereal crops was found to differ for each cultivar. The best crop geometry that produced the highest yield of grain and fodder per land unit was found to be inter-row sowing of stylo with two rows of sorghum and one row of soybean on alternate ridges.

ILRI conducted a series of trials to refine the technology:

- Fodder improvement in the fallow lands
- Nutrient and water-management trials
- Screening of legumes
- Nodulation trials
- Wet-season grazing trials.

The technology

Out of ILRI's research the fodder bank technology emerged. A fodder bank is an 'enclosed area of concentrated forage legumes reserved for dry or wet season supplementary grazing'. Farmers can establish a fodder bank as follows:

1. Fencing fodder banks
    - A good site is selected (stony or waterlogged areas are avoided).
    - A small unit of land is fenced and sown with stylo. The size of the fodder bank (1–4 ha) depends on the number of animals.
    - Materials for fencing include wooden posts and barbed wire metal fences and live fences using suitable trees or shrubs.
    - Fire breaks are established to prevent accidental fires during the dry season.
2. Land preparation for fodder banks

    Land is best prepared using tractors but this is expensive and so the technology uses alternative methods:
    - kraal animals on the fenced site and burn the plot before sowing
    - undersow legumes in crops at the appropriate time, in the last year of the cropping cycle.
3. Sowing to establish a stylo fodder bank
    - Use a seed rate of 15–20 kg per ha
    - Sow after it has rained sufficiently. This ensures that seed-harvesting ants will not gather seeds during dry spells. The ants can also be prevented by sowing a slurry of mixed stylo seed with wood ash or manure.
    - Stylo seeds have hard seed coats and therefore exhibit hardseededness which can be reduced by scarification and hot water treatment to encourage better germination. This is, however, a disadvantage if all the sown seeds germinate at the same time followed by a dry spell. It is better to sow a mixture of softened and hard seeds.

- Mixing stylo seeds with 150 kg superphosphate per ha before broadcasting generally gives satisfactory establishment of a good fodder bank.

4. Weed control

   The herd can graze fodder banks early in the season to selectively control the fast-growing grasses which otherwise smother the slow growing legumes.

5. Dry season management of the fodder bank
   - Grazing begins as required during the dry season.
   - The animals can graze the fodder bank either early in the morning or in the evening after returning from free grazing.

Linkage mechanisms

On-station research by ILRI was followed by on-farm research which led to the fodder bank technology. The researchers and National Livestock Projects Division (NLPD) packaged the technology for transfer to livestock owners. Features of the linkage mechanism used to transfer the fodder bank technology in the subhumid zone of Nigeria:

- extension staff worked closely with researchers
- collaboration was strengthened during a survey and frequent visits to the research sites and farmers' fields
- research staff trained extension staff.

Transfer of technology

- NLPD extension staff in collaboration with researchers from the National Livestock Project and ILRI conducted a rapid appraisal in several states. Results showed that few farmers were aware of the fodder bank technology. To correct for this, NLPD publicised the technology through radio programmes.
- A loan from the World Bank enabled the project to provide credit to farmers for the establishment of fodder banks between 1987 and 1991.

Impact and lessons

The following are highlights of adoption rates and benefits of the technology. Detailed studies and follow-up are needed to document the large-scale impact across Nigeria if any.

- By 1986 about 25 fodder banks were established.
- By 1991 farmers had established 637 fodder banks under the supervised loan scheme of the World Bank Second Livestock Development Project.
- Adoption rates were increased when credit was provided to establish the fodder banks and when pastoralists were allocated land.
- Adoption rates were high among pastoralists who owned land or settled inside grazing reserves.

The benefits of using fodder banks are:

- they provide supplement feed during the dry season
- animals grazing fodder banks have increased growth rates, milk production and calf survival
- pastoralists are forced to sell fewer underfed animals
- fencing increases security by preventing trespassing
- confining animals inside the fenced fodder bank saves on labour costs
- crops following legumes benefit from nitrogen build-up
- the fenced fodder bank can be used for rotational cropping.

The extension package now includes rotational cropping showing beneficial interaction between cropping and the fodder bank technology.

Problems facing adoption are:

- The high inflation rate that followed the devaluation of the Nigerian currency increased the cost of establishing fodder banks. However, many farmers still believe the benefits of fodder banks outweigh the cost.
- Attempts to introduce fodder banks in the semi-arid zones of Nigeria were less successful than in the subhumid zone because of lower rainfall and a shorter growing season.

9.7.3 Case study 3: Women and cattle traction in Tanzania

Background

The Mbeya Oxenization Project (MOP), was located in the southern highlands of Tanzania. It was initiated in 1987 as a joint venture between the Government of Tanzania and the Canadian International Development Agency (CIDA). Its main objective was to promote agricultural development by encouraging smallholder farmers to use animal traction technologies to increase production and alleviate drudgery (Marshal and Sizya 1994).

The problem

Although the project was planned to ensure that both men and women would be effective participants and beneficiaries, this did not happen. A passive approach resulted in project co-ordinators working only with men. Since women represent a sizeable proportion of the farming community, the project staff were frustrated and planned to solve the problem by involving women. Women were excluded from the project because of the misconception that animal traction is a male-dominated activity.

Strategies for integrating women into animal traction

The project co-ordinators started by frequently interacting with women and became clear that women were interested in using oxen. Their major problem was access to oxen, which are owned by men. It was decided that MOP staff would facilitate the process by which women could at least have access to oxen. The Mbeya Oxenization Project adopted two ways to achieve this goal: an awareness campaign and training seminars, and helping women have access to draft animal technology. The awareness campaign was conducted at the household level among contact farmers. This campaign targeted both men and women. Questions such as which members of the household were responsible for what cropping and other activities were addressed. The campaign emphasised that women could use carts to carry water for domestic use and men could use carts for brick making. In addition, women could use an ox-drawn implement to ridge fields for beans and men could use the implement for ridging fields for maize. Training seminars were conducted where husband and wife had to attend together. The second approach was to help women have access to draft animal technology. Women were organised into groups, loans were provided to these groups and the women bought oxen and equipment.

Impact and lessons

By empowering women to have access to animal draft technology and by creating awareness among men to accept this idea, MOP was able to shatter the barriers to women using oxen. Women found themselves empowered enough to counter family, community and cultural constraints. Working with groups allowed MOP to train many women as well as encouraging them to be more confident. This experience created a useful framework, which can be used by other animal traction projects, which need to address gender concerns.

9.8 Exercises

1. Transfer of technology can link with research through formal or informal mechanisms. List mechanisms linking research to transfer of technology in your region. Are the linkages effective? If not, explain why?
2. Agricultural technology systems (ATS) consist of all the individuals, groups, organisations and institutions engaged in developing and delivering new or existing technology. The involvement of the various parties listed in this definition requires various types of skills. List these skills and the basic activities you think the groups should be engaged in.
3. Women play a significant role in agriculture in sub-Saharan Africa yet they are mostly neglected when it comes to project planning or implementation. List two reasons for this neglect of women and ways to overcome this problem.

9.9 References and reading materials

Claar J.B. and Watts L.H (eds). 1983. *Knowledge transfer in developing countries: Status, constraints, outlook. Proceedings of a conference on international extension held at Steamboat Springs, Colorado, July 1983.* Colorado State University, Fort Collins, USA. 59 pp.

Jabbar M.A., Larbi A. and Reynolds L. 1996. *Alley farming for improving small ruminant productivity in West Africa: ILRI's experiences.* Socio-economic and Policy Research Working Paper 20. ILRI (International Livestock Research Institute), Addis Ababa, Ethiopia. 96 pp.

Kaimowitz D., Snyder M. and Engel P. 1989. *A conceptual framework for studying links between agricultural research and technology transfer in developing countries.* Linkages Theme Paper 1. ISNAR (International Service for National Agricultural Research), The Hague, The Netherlands. 30 pp.

de Leeuw P.N., Mohamed-Saleem M.A. and Nyamu A.M. (eds). 1994. Stylosanthes *as a forage and fallow crop. Proceedings of the regional workshop on the use of* Stylosanthes *in West Africa, Kaduna, Nigeria, 26–31 October 1992.* ILCA (International Livestock Centre for Africa), Addis Ababa, Ethiopia. 340 pp.

Marshal K. and Sizya M. 1994. Women and animal traction in Mbeya Region of Tanzania: A gender and development approach. In: Starkey P., Mwenya E. and Stares J. (eds), *Improving animal traction technology. Proceedings of the first workshop of the Animal Traction Network for Eastern and Southern Africa (ATNESA) held at Lusaka, Zambia, 18–23 January 1992.* CTA (Technical Centre for Agricultural and Rural Co-operation), Wageningen, The Netherlands. pp. 266–271.

Merrill-Sands D., Kaimowitz D., Sayce K. and Chater S. 1991. *The technology triangle: Linking farmers, technology transfer agents and agricultural researchers. Summary report of an international workshop held at ISNAR, The Hague, 20–25 November 1989.* ISNAR (International Service for National Agricultural Research), The Hague, The Netherlands. 118 pp.

Saleem M.A. 1995. Fragile East African Highlands: A development vision for smallholder farmers in the Ethiopian highlands. *Outlook on Agriculture* 24:111–116.

Saleem M.A. and von Kaufmann R. 1995. Fodder bank: Improving the nutrition of cattle in the subhumid zone of West Africa. In: Ruiz M.E., Sere C. and Li Pun H. (eds), *Animal production systems global workshop. Proceedings of the global workshop on animal production systems, held in San José, Costa Rica, 15–20 September 1991.* IICA (Inter-American Institute for Cooperation on Agriculture), San José, Costa Rica.

Tekaligne Mamo, Abiye Astatke, Srivastava K.L. and Asgelil Dibabe. 1993. *Improved management of Vertisols for sustainable crop-livestock production in the Ethiopian highlands: Synthesis report 1986–92.* ILCA (International Livestock Centre for Africa), Addis Ababa, Ethiopia. 199 pp.

ISBN 92–9146–081–8 Printed at ILRI, Addis Ababa, Ethiopia Price US$ 10