# Matching feed energy resources to energy requirements of working cattle in semi-arid areas

Stanley Hemed Israel

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The University of Edinburgh

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# Declaration

I hereby declare that this thesis describes research carried out by myself unless otherwise cited or acknowledged. It has not, in whole, or in part, been previously presented for any other degree.

**Signed:** **Date:** 27/07/2000

**STANLEY HEMED ISRAEL**

This thesis is dedicated to my dear mother Pauline-Shari Israel and my late father Israel Tanta Seushi, both of whom ensured that all their children fulfilled their initial ambitions in schooling and/or career.

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# ABSTRACT

The objectives of this thesis were to study the effects of workload and level of feeding on work and live weight changes of draught oxen; to study the effects of energy supply on work performance of oxen; to explore and/or assess strategies to improve the effectiveness of supplementary feeding for draught cattle; and to test the recommended standards for feeding draught cattle under semi-arid conditions in South Africa.

Four experiments were carried out in South Africa. In experiment 1, the effects of three workloads on work and live weight change of three teams each of four draught oxen fed at the same level (1.3 x their ME requirement) were studied. The workloads were: (1) heavy (estimated energy expenditure of 0.9 x maintenance); (2) medium (0.6 x maintenance); (3) low (0.3 x maintenance). Work consisted of pulling sledges loaded differently over different distances for each team.

Experiment 2 studied the effect of level of energy supply during work on the performance of draught oxen. Six pairs of oxen were assigned to two treatments. In treatment 1 oxen were fed on a low energy (0.8 x maintenance) diet during part 1 (week 1-7) followed by a high energy (1.8 x maintenance) diet in part 2 (week 8-13) of the study. In treatment 2 they were fed on the high energy diet throughout. Oxen on both treatments did the same work pulling loaded sledges so that their estimated energy expenditure for work was 0.9 x maintenance.

Experiment 3 assessed two strategies of supplementing draught cattle. In treatment 1 oxen were supplemented for 7 weeks before working and for 7 weeks while working. The supplements were cobmeal (1.5 kg/head/day) and lucerne (0.5kg/100kgLW/day). In treatment 2 the same supplements were fed for the 7 working weeks at twice the amount in treatment 1. Six pairs of oxen were assigned to the two treatments. All oxen were fed on restricted amounts (0.8 x their ME requirements) of *Chloris gayana* hay. Work done was the same as that of experiment 2.

Experiment 4 assessed practices adopted by farmers when using supplements to improve the effectiveness of maize stover as feed for working oxen. Three supplements were fed to 6 pairs of oxen in three periods (a 3x3 latin square design). The supplements were lucerne (2.5 kg/head/day), sunflower cake and cob meal (both at 3.6 kg/head/day). Maize stover was fed *ad libitum*. During each period oxen were fed the diet for two weeks before they worked for two weeks. Work done was similar to that of experiment 3.

The recommended feeding standards for draught cattle were tested by studying the energy balances and live weight changes of oxen in the four experiments.

In experiment 1, live weight changes of oxen under the three treatments suggested that animals subject to the heavy workload utilised dietary energy more efficiently and they were less selective in their eating. The speeds of working of oxen on the three treatments decreased with increase in workload but the differences were not statistically significant ($p>0.05$). Oxen tended to increase their walking speed towards the end of working in the morning when heading home. Within treatment 1, heavy oxen (>400kg LW) lost body weight while light oxen (<400kg LW) registered weight gains during the same period.

In experiments 2 and 3, oxen fed a low energy diet or not supplemented before work lost body weight and condition progressively. The same oxen regained some of their body weight and condition when offered the high energy diet or supplement while working. Oxen that received high energy diet or supplement both before and during work maintained their body weights. In both experiments, there were no significant differences ($p>0.05$) in work done by oxen on low energy or not supplemented before work and those on high energy or supplemented both before and during work, respectively. The experiments showed that loss of body weight and condition in work oxen could occur without affecting their work performance. The results suggest that energy needed for work could be obtained from body energy reserves or equally efficiently directly from offered food. This implies that it may not be necessary to supplement draught oxen during the dry season before work begins provided the oxen do not lose weight to the extent of compromising their capacity for work. Both strategies of feeding supplements to draught oxen in experiment 3 had some effects on weight changes that could be beneficial, but if there is no risk of compromising the working capacity as a result of weight loss, supplementation could be confined to the period of working so as to reduce labour costs.

In experiment 4, methods used by farmers to feed supplements did not take nutritive value into account. Supplementation with sunflower cake, lucerne and cob meal to oxen fed on maize stover had no influence on their work performance. There were statistically significant ($p<0.05$) differences between the three supplements in amount of stover consumed and live weight gain. Oxen supplemented with sunflower cake consumed more stover and attained larger weight gains than the others.

Study of the energy balances of oxen in the four experiments showed that oxen working in a team contribute differently to the overall work done and this leads to inaccurate estimates of energy balance for individual animals working in teams. Estimates of energy balance for whole teams were more reliable. Oxen working in pairs gave better estimates than those of oxen working in teams of four.

Feeding standards for cattle used for work were found to be broadly correct in semi-arid areas.

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Bob Archibald at the CTVM provided great help in laboratory analysis of samples. Keep it up Bob.

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Lastly, I wish to thank my wife Esther, our daughter Pauline and son Chaluvara for their patience and understanding during the whole period I have been away from them to pursue these studies. It was a long and difficult period for the whole of my family.

# LIST OF ABBREVIATIONS

| | |
|---|---|
| ADF | Acid Detergent Fibre |
| AFRC | Agriculture and Food Research Council |
| AI-ash | Acid Insoluble Ash |
| Anova | Analysis of variance |
| AOAC | Association of Official Analytical Chemists |
| ARC | Agricultural Research Council |
| ATC | Animal Traction Centre |
| ATP | Adenosine Tri-Phosphate |
| BC | Body Condition |
| BCS | Body Condition Score |
| $^{o}C$ | Degree Celsius |
| CP | Crude Protein |
| CTVM | Centre for Tropical Veterinary Medicine |
| DF | Draught Force |
| DM | Dry Matter |
| DMI | Dry Matter Intake |
| g | gramme |
| g/d | grammes per day |
| GDP | Gross Domestic Product |
| GLM | General Linear Model |
| h | hours |
| HE | High Energy |
| kg | kilogramme |
| kgf | kilogramme force |
| km | kilometre |
| kN | kiloNewton |
| kW | kiloWatt |
| LW | Live Weight |
| M | Mass |
| m | metres |

| | |
|---|---|
| min | minute |
| $M^{0.75}$ | Metabolic Body Weight |
| ME | Metabolisable Energy |
| m/s | metres per second |
| MJ | MegaJoules |
| MJ/d | MegaJoules per day |
| N | Newtons |
| N/A | Not Available |
| NDF | Neutral Detergent Fibre |
| NE | Net Energy |
| No. | Number |
| s | seconds |
| SAS | Statistical Analysis System |
| sd | standard deviation |
| se | standard error |
| yrs | years |
| W | Watts |

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# CHAPTER 1

## INTRODUCTION

Tremendous advances in science and technology occurred in the 20$^{th}$ century and agriculture received a substantial share of the advancements. However most of the advances in agricultural technology have been fully realised only in the developed world. With few exceptions, farming conditions in developing countries have remained stagnant for a long time and in some cases they are deteriorating. For example, Cleaver and Donovan (1995) showed that in most countries of sub-Saharan Africa, agriculture output has grown more slowly than the population, whilst agricultural income has stagnated in real terms, or fallen. In some developing countries, food production is not sufficient to meet increasing demand and there is an ever-increasing necessity for them to depend on food aid and/or imports. The world population reached 6 billion people in 1999 and Sansoucy, Jabbar, Ehui and Fitzhugh (1995) projected that by 2010 this will increase to about 7.2 billion. The projected increase in population is expected to occur mainly in developing countries, a factor that will worsen the food situation if corrective strategies to ensure food security are not in place. Mohammed-Saleem (1995) cautioned that in sub-Saharan Africa, economic growth had to increase by 4-5% annually if food security was to be achieved in the region. According to Mohammed-Saleem (1995), sub-Saharan Africa is essentially a continent of small holders with cereals/livestock farming as the major agricultural system. With self-sufficiency in food production high on the agenda, any serious campaign to increase crop production so as to attain self-sufficiency in food in the region should therefore pay special attention to the small holder farmers. The sources of farm power for agriculture in the developing countries are human beings, draught animals and agricultural tractors. Sansoucy *et al* (1995) indicated that in the developing countries (excluding China), the estimated relative contribution of farm power for food production from human beings, animals and tractors was 26, 52, and 22%, respectively. Pearson and Vall (1998) noted that the majority of small holder farmers in Africa south of the Sahara practice mixed farming on land areas of less than 4 ha. Total reliance on mechanical power when dealing with farms of this size is not economically justified. This is one of the main reasons why previous efforts by governments to increase agricultural production by encouraging use of tractors in small holder agriculture in many parts of the sub-Saharan region have failed. The average small scale farm area is also too big for the hand hoe, so that where the planting period is short it is very unlikely that sufficient land will be prepared and planted on time, a factor which increases the chances of crop failure or at the very least, reduced yield. The use of draught animal power alone or combined with the other forms of power offers a feasible option for the small holder farmers in the sub-Saharan region. Given the large number of cattle in sub-Sahara Africa, there is considerable potential for increasing small scale agricultural production by promoting increased use of cattle for farm work to replace or complement human power and tractors. However some issues need to be addressed in order to ensure that cattle are used in an efficient and sustainable way for draught work.

A large part of sub-Saharan Africa has semi-arid to arid climatic conditions characterised by low rainfall and long dry periods. Crop production in the region is a risky undertaking because of the uncertain weather. Grazing land in most countries in the region is communally owned, with nobody directly responsible for its management, therefore pastures are overgrazed and degraded with serious soil erosion. According to Dregne, Kassas and Rosanov (1991), the rate of rangeland degradation in African drylands assessed as slight, moderate or severe, was 15, 12 and 31%, respectively. Animals under the small holder farming systems rely mainly on grazing of pasture or crop fields after harvest for their nutrition. During the long dry season when grass is not growing, the animals do not get enough food, therefore they tend to lose body weight and condition. For working animals this could lead to a reduction in working capacity, since preparation of cropland takes place towards the end of the dry period or just after the onset of rains when animals are still in poor condition. The consequences of this situation can mean failure to attain cropping targets or delays in planting, thereby missing the rains and subsequently losing the crop. Therefore, one of the major problems that needs to be tackled in promoting use of draught animals under semi-arid small holder farming systems in many parts of sub-Saharan Africa is the provision of adequate amounts of the right quality of food for the animals at the right time for optimum work performance.

The effects of feeding on body weight and body condition and its subsequent influence on working capacity of oxen have been studied for more than a decade. Results of studies carried out in West Africa in the late 1980s and early 90s (Bartholomew, Khibe, Little and Ba, 1993; Bartholomew, Khibe and Little, 1994;

Fall, 1995) showed that feeding draught oxen during the dry season to increase their body weight and condition had little effect on their capacity for work. Contrary to the findings in West Africa, in Zimbabwe, Francis and Ndlovu (1995) reported improved work performance in work oxen as a result of supplementary feeding during the dry season. There is a need for more research in this area to obtain additional information on how the available feed resources could be used to best effect for draught animals given the discrepancy between food requirements and food available in the areas where draught animals are most needed for work. Information obtained could be used to improve the use of the limited animal feed resources in semi-arid areas and in the process result in improved productivity of draught oxen and livestock in general.

In South Africa, the contribution of agriculture to the total gross domestic product (GDP) was about 7% in the 1980s (Van Rooyen and Osborn, 1988; The World Bank, 1995). More recent figures (National Department of Agriculture, 1999) showed that the contribution of agriculture to the total GDP amounted to 4.7 and 4.5%, in 1996 and 1997, respectively, an indication that it could be decreasing. However in most of the former 'homeland' areas agriculture is one of the main contributors to the local economies. The agricultural industry in South Africa is made up of a fairly well established commercial sector and a small holder sector. The latter is located mainly in areas where farming conditions are marginal with very high risks of losses. This must have contributed to the lack of popularity of agriculture as a means of livelihood in the small holder areas. According to Starkey (1995) many rural South Africans have, over time, come to rely for their livelihoods on remittances from urban wage-earners, pensions and other non-agricultural income. However, with the ongoing rationalisation policy in the public sector and economic reforms, it is becoming increasingly difficult to get jobs in urban areas. As a result agriculture may gain popularity amongst the young and those who become redundant and return to rural areas. There is a need therefore to create the right conditions for improved small holder agricultural production to make it more attractive. One way of doing this is to ensure that affordable farm power is available by encouraging increased use and promoting better techniques of draught animal power application in small holder agriculture.

Animal traction in South Africa dates back to the 17th century (Joubert, 1995; Fowler, 1999). According to Starkey, Njobe and Hanekom (1995), at the beginning of the 20$^{th}$ century draught animal power was extremely important to all sections of South African society for transport, mining and large-scale agriculture. During the middle years of the century (1935-1960), large–scale farming in South Africa moved from almost total reliance on draught animals to dependence on tractors. Starkey *et al* (1995) pointed out that there was total neglect of animal power by authorities during the 1960s and 1970s, with some educational institutions criticising the technology as obsolete and small holder farmers being encouraged to buy old tractors. The result of neglect of animal traction by the authorities, coupled with *ad hoc* mechanisation planning which favoured tractors (Anonymous, 1997) led to many farmers abandoning animal traction. When the viability of tractor schemes proved futile, small holder farmers were left in a difficult situation. This was mainly because the tractor services offered did not meet the user demands for ploughing.

They were also very unreliable in carrying out other farm operations like planting and weeding therefore farmers continued to make use of draught animals to fill the gap that was left. It has been estimated that despite the negative publicity on animal traction that was staged by previous governments in South Africa (before 1994), 40-80 % of families engaged in small holder farming still make use of animal power for transport and/or cultivation (Starkey, 1995). Survey findings (Starkey, 1995) form a valuable source of background information for use by both development and research scientists with the intention of conducting draught animal projects in South Africa.

The results of another survey on the use and management of draught animals by small holder farmers in the Eastern Cape Province (former Ciskei and Transkei), Republic of South Africa (see Appendix 6.24), showed widespread use of draught animal power. Draught cattle were the most popular animals used for work in the area. Average span sizes used for ploughing and harrowing ranged between four and six animals. For most other tasks they used fewer animals. Farmers readily used cows to make their spans when they were short of oxen. Many farmers hired tractors occasionally for primary tillage. All over the surveyed areas, animals grazed on natural pastures that were mostly overgrazed. Almost half of the interviewed farmers described the pastures as poor. The grazing lands were communally owned in all villages surveyed. Half of the interviewed farmers indicated that they do provide supplementary feeding to their animals when they considered their body condition to be poor. The commonest feeds used for this purpose were purchased lucerne and home-grown maize stover. Other types of feeds that some farmers claimed to have used include dairy meal and barley. The farmers indicated that they fed supplements in order of preference as follows: to cows with calves, animals in poor condition, draught animals, fattening cattle for sale or they supplemented all animals. Where maize stover was used as a regular feed or as a supplement, the majority of the farmers left the stover on the field and allowed the animals to graze. Some farmers collected the stover and stored it before use. The farmers' main concerns regarding draught animals were the risks of drought, theft and disease, but they believed the use of these animals to be profitable because of the low capital outlay involved.

On-farm monitoring of the use of cattle for work by selected farmers in two villages in the Eastern Cape Province (Appendix 6.25) revealed that every month there was some ongoing activity involving use of draught cattle. Peak activity was recorded in July-December and transport was a continuous task occurring every month. Borrowing of animals from neighbours to make up spans was a common feature. Although for most of the farmers income from crop production seemed very little compared to inputs, they met most of their domestic needs for food from their own farms. By-products from crops were transported on animal-drawn carts and stored near the homesteads for feeding the animals in winter, or they were left on the fields and grazed by all animals. Contrary to what the farmers reported during the initial interviews, work oxen received no special feeding consideration while working, although some of them were having poor body conditions. Some intervention seem appropriate to improve on feeding strategies and post-harvest handling of crop residues so as to ensure their better use and avoid any decrease in work performance by animals that could result from inadequate feeding.

Until very recently there were no specific guidelines for feeding draught cattle. Lawrence and Pearson (1997) published proposed recommendations for feeding cattle used for work. With these standards, it is possible to estimate the optimum amount of work that could be expected from a given number of draught cattle given the quantity and quality of food available for them. This makes it possible to plan realistic draught power use in farming operations, relying on draught oxen, ensuring improved efficiency and more sustainable use of available animal feed resources. Development of the proposed feeding standards was based partly on research work done on-station under temperate conditions at the CTVM. It is therefore necessary to verify the standards in the field in as many areas as possible before they can be recommended for general use anywhere in the world. The work reported in this thesis aimed to:

1. Study the effects of workload and level of feeding on working and weight loss by draught oxen
2. Study the effects of energy supply from offered food during work on the performance of draught oxen
3. Explore and/or assess the strategies that can be used to improve the effectiveness of supplementary feeding for working cattle in semi-arid crop/livestock systems
4. Test the application of the proposed "*Feeding Standards for Cattle Used for Work*" (Lawrence and Pearson, 1997) under semi-arid conditions of the Eastern Cape Province in South Africa.

In order to accomplish the objectives above, four experiments were conducted on-station at the ATC in the livestock section of the research farm belonging to the University of Fort Hare. Experiments 1 and 2 studied aspects in the first and second objectives, respectively. Experiments 3 and 4 dealt with the third objective. The proposed *"Feeding standards for cattle used for work"* (Lawrence and Pearson, 1997) were tested under the semi-arid conditions of the Eastern Cape Province of South Africa, using information obtained from all the four experiments.

# CHAPTER 2

# EFFECTS OF WORKLOAD AND LEVEL OF FEEDING ON WORK PERFORMANCE, LIVE WEIGHT CHANGE AND ENERGY BALANCE OF DRAUGHT OXEN IN SEMI-ARID AREAS

## *2.1. Introduction*

Draught animals play a major role in smallholder semi-arid crop/livestock farming systems. Agriculture under this system increasingly relies on draught animal power for most farm activities. However, in many areas animal feed resources are decreasing and farmers find it difficult to maintain their animals, especially during the long dry season. The end of the dry season is the time when draught animals are required to plough, ready for the cropping season. Lack of adequate feeding during this time may lead to reduction in work performance of draught animals. For example Ndlovu, Francis and Hove (1996) observed significantly ($p<0.05$) faster ploughing and greater coverage of land by oxen that were provided with extra feed in addition to grazing compared with those that relied on grazing alone. The reduction of speed of working and area covered as a result of inadequate feeding could lead to lower total crop yields due to delays in planting or smaller farmed areas. In Zambia, Shumba (1984) noted up to 3% loss in maize yield for every one day of delay in planting. Ideally, a plentiful supply of food for draught animals is needed to provide the extra energy for working. However it is not an easy task to provide this under the semi-arid farming conditions. One way of addressing the problem of inadequate supply of feed for draught animals during work is to develop strategies that will improve efficiency and sustainability of use of available feed resources. This can only be achieved through investigations into food energy resources available and how to appropriately match them to animal energy requirements.

Lawrence and Pearson (1997) drafted recommendations for feeding cattle used for work by utilising information on energy expenditure of working animals collected under laboratory conditions at the Centre for Tropical Veterinary Medicine and studies of work output of cattle in the field. The *"Feeding standards for cattle used for work"* (Lawrence and Pearson, 1999) have subsequently been published. Pearson, Zerbini and Lawrence (1999) cautioned that some information was still needed to validate these feeding standards. They need to be verified on a wide selection of animals and under different working conditions.

The aim of the present work was: (i) to study the effects of three workloads on work performance, live weight change and energy balances of draught oxen fed on a restricted forage diet; (ii) to study the effects of level of dietary energy supply to draught oxen on their work performance and energy balances; (iii) to verify the *"Feeding standards for cattle used for work"* (Lawrence and Pearson, 1999) in the Eastern Cape Province, Republic of South Africa. To fulfil these objectives, two experiments were conducted.

## 2.2. Experiment 1

## Effects of workload on working, live weight change and energy balance of draught oxen fed on a restricted forage diet

### 2.2.1. Introduction

The purpose of a feeding system for animals is to provide a reliable means of calculating nutrient requirements for given levels of different production needs. Conversely, a feeding system makes possible the estimation of the level of production or performance that could be expected from available feeds, making use of knowledge on nutrient concentration of the foods and possible levels of intake and digestion by the animals. In cattle that are kept primarily for use in work, the most important nutrient for them is energy, required to fuel the muscular exertions necessary for work. The estimation of energy balance for draught cattle could be used as a yardstick for ensuring optimum use of food available for them and safeguarding against any possibility for work to adversely interfere with other vital functions of the body. This is very important because working cattle in most semi-arid crop/livestock systems are multi-purpose producing in addition to work, meat, milk, calves or cash when sold. It is therefore important to ensure adequate feeding so that work does not permanently interfere with growth or gain, reproduction or milk production. This experiment studied the effects of three workloads on live weight change and working of draught oxen fed on a restricted forage diet. It also tested the "*Feeding standards for cattle used for work*" (Lawrence and Pearson, 1999) under semi-arid conditions typified by weather conditions of the Eastern Cape

Province in the Republic of South Africa. To do this, the energy balances and weight changes of the oxen fed on the restricted forage diet and doing three types of work were examined.

### 2.2.2. Literature Review

#### 2.2.2.1. The British ME system for cattle

The AFRC (1993) gave the maintenance metabolisable energy requirement of cattle as:

$$ME = (F + A) / k_m$$

Whereby, ME = Metabolisable energy in MJ/d

F = Fasting metabolism (MJ/d)

A = Activity allowance

The fasting metabolism (F) requirements of cattle were given by ARC (1980) as:

$$F = C\ [0.53(W/1.08)^{0.67}]$$

Whereby, W = Live weight (kg)

C = 1.15 for bulls and 1.0 for other cattle

The factor 1.08 converts live weight to fasted body weight (ARC, 1980).

The ARC (1980) gives additional energy costs for activity (A) as follows:

Horizontal movement 2.6 J/kgW/m

Vertical movement 28 J/kgW/m

Standing 24hrs 10kJ/kgW/d

Body position change 260J/kgW

AFRC (1990) assumed 500m walked, 14 hours standing and 9 position changes for lactating dairy cattle giving activity allowance as:

$$A\ (kJ/d) = (1.30 + 5.83 + 2.34)W = 9.47W$$

Therefore activity allowance for lactating dairy cattle is 0.0095W

For housed beef cattle AFRC (1990) assumed horizontal movement 200m, 12 hours standing and 6 position changes giving activity allowance as:

$$A = (0.52 + 5.00 + 1.56)W = 7.08W$$

Therefore, for beef cattle A (MJ/d) = 0.0071W

The AFRC (1990) recommended a similar activity allowance for pregnant, non-lactating dairy cattle.

Metabolisable energy requirements for lactation were given by AFRC (1990) as:

$$M_l\ (MJ/d) = (Y \times [EV_l]) / k_l$$

Where Y = milk yield in kg/d

$EV_l$ = energy yield of milk (MJ/kg) = 0.0406[BF] + 1.509

(BF is butter fat)

AFRC (1990) gave the energy retained in the animal's body per day ($E_g$) as:

$$E_g\ (MJ/d) = (\Delta W \times [EV_g]).$$

$[EV_g]$ was given by ARC(1980) as:

$$[EV_g]\ (MJ/kg) = C2\ (4.1 + 0.0332W - 0.000009W^2) / (1 - C3 \times 0.1475\Delta W)$$

where C3 = 1 when plane of nutrition , L>1 and =0 when L<1,

C2 corrects for mature body size and sex of the animal.

The AFRC (1990) suggested breed differences for values of C2, classifying them into early, medium and late maturing types, each having a different C2 value.

The British ME system (ARC, 1980; AFRC, 1990) is based on experiments with animal breeds used in temperate regions. Graham (1985) noted that there was no point why the system should not be applicable to all livestock provided the right parameters were used. The only setback was that many such parameters were unknown for cattle in tropical environments. Graham (1985) further noted that the ARC (1980) made no allowance for effects of hot conditions, a factor which was important because many draught animals are exposed to hot climates. Furthermore Graham (1985) criticised the energy values of weight gain or loss given by the ARC (1980) as being too general and lacking any data for draught animals. AFRC (1990) had subsequently taken care of differences of genotypes and stage of maturity but there is still no data specific for draught animals in their recommendation on nutrient requirements of ruminant livestock.

### 2.2.2.2. The factorial method to calculate energy used for work

Lawrence (1985) extended the British Metabolisable Energy system (ARC, 1980) to cater for working cattle. He noted that it was necessary to know the net energy required for work and the heat increment associated with it to quantify the extra metabolisable energy required for work which could be translated into quantities of food. Lawrence (1985) reiterated further that the energy used by a working animal in the field cannot be determined directly, he advocated use of measurable figures of the amount of work done and live weight of the animal to estimate the net energy used for work by using the following relationship:

Energy for work = energy for walking + energy for carrying + energy for pulling

loads + energy for walking uphill.

The relationship can be expressed mathematically as:

$$E = AFM + BFL + W/C + 9.81HM/D$$

Where E = energy used for work (kJ)

F = distance travelled (km)

M = live weight (kg)

L = load carried (kg)

W = work done whilst pulling loads (kJ)

H = distance moved vertically upwards (km)

A = energy to move 1kg of body weight 1m horizontally (J)

B = energy used to move 1kg of applied load 1m horizontally (J)

C = efficiency of doing mechanical work (= work done/energy used)

D = efficiency of raising body weight or applied load (= work done raising body weight or load/energy used).

The quantities F, M, L, W and H could be determined during normal work. The ergometer (Lawrence and Pearson, 1985) can measure the work done (W) and the distance (F) while a balance can measure the load (L) and weight of the animal (M). Estimates of distance (H) could be made from a contour map of the area in which the work is taking place. Values for the factors A, B, C, and D could be obtained from published figures gathered from many experiments that have been done in the laboratory (Ribeiro, Brockway and Webster, 1977; Thomas and Pearson, 1986;

Lawrence and Stibbards, 1990; Lawrence and Pearson, 1993), and more recently in the field (Dijkman and Lawrence, 1997; Fall, Pearson and Lawrence, 1997b; Rometsch, Roser, Becker and Susenbeth, 1997). Some of the published figures for the factors are shown in Table 2.1. Lawrence (1985) assumed that the heat increment associated with work was the same as that for maintenance. He argued that in both cases the heat increment was produced by converting metabolisable energy in the diet to the appropriate form required for use by muscle tissue. The only difference was that the working muscle did the conversion at a much higher rate. Experimental evidence for this hypothesis was obtained from a study done at CTVM (reported by Lawrence, 1985) whereby two cattle performed the same amount of work when they were both fed at maintenance or when starved for 48 hrs. Energy expenditure for work was the same in both cases.

#### 2.2.2.3. Limitations to the application of the factorial method in the field

Lawrence and Pearson (1989) noted that one of the weaknesses in applying the factorial method for calculating the extra energy used for work was centred on the factors used. Values used for the energy costs for carrying and pulling loads as well as efficiency factors for doing mechanical work and raising weight were determined in the laboratory while the animals worked under completely different conditions in the field, which differed from one place to another. This was reaffirmed by Lawrence and Becker (1994) who argued that the most important factor was the energy cost of walking which accounted for 50 % or more of the total energy expended for work and that this factor depended very much on the conditions of working of the animal. They therefore further argued that reliability of the factorial method depended very much on the build-up of data on energy costs for various activities under as much diverse conditions as can possibly be attained. Table 2.1 summarises most of the available data on energy costs for various activities and on different surfaces. The table shows that energy cost of walking increases as the surface on which the animals are walking becomes looser and/or wetter. The table also shows that there could be some variations in the energy cost even for animals walking on the same kind of surface in different areas.

### 2.2.2.4. Effects of the level of feeding and work on basal metabolic rate

Goldberg, Murgatroyd, Davies and Prentice (1989) observed increased basal metabolic rate both during sleep and in the morning on a day following exercise in human beings. A similar phenomenon was observed by Lawrence, Buck and Campbell (1989) in crossbred cattle at a low level of feeding whereby the metabolic rate was on average 8.2 % higher 17 hrs after completing work compared with non-working days. Calculations for 8 hrs after work showed an almost similar increase (9.1 %). However there was no difference in metabolic rate at similar times when the animals were at high level of feeding. The explanation given for this phenomenon was that at the low level of feeding the animals used up more of their body energy reserves during work than they did at the high level of feeding. Metabolic processes necessary for replenishing body energy reserves at the low level of feeding may have therefore been responsible for the rise in metabolic rate.

## Table 2.1. Energy costs for various activities and efficiencies of working of draught cattle on different surfaces

| Activity | Speed(m/s) | Surface | Energy cost | Efficiency (%) | Author |
|---|---|---|---|---|---|
| Horizontal walk | 0.7-1.4 | Treadmill | 2 J/kg/m | | Ribeiro *et al* (1977) |
| Vertical locomotion | | Treadmill | 26 J/kg/m raised | | Ribeiro *et al* (1977) |
| Walk up a slope | | Treadmill | 27-31W/kgM$^{0.75}$ | | Thomas and Pearson (1986) |
| Lift body uphill | | | 26 J/kg/m raised | | |
| Walk up a slope | | | | 30 | |
| Walking | 0.6-1.0 | Treadmill | 2.1 J/m/kgM | | Lawrence and Stibbards (1990) |
| Carrying load | 0.6-1.0 | | 26 J/m/kg carried | | |
| Walking | | Concrete | 1.55 J/m/kgM | | Lawrence and Pearson (1993) |
| | | Concrete | 1.91 J/m/kgM | | |
| | | Mud | 3.34 J/m/kgM | | |
| Walking | 1.20 | Tarmac | 1.75 J/m/kgM | | Rometsch *et al* (1997) |
| | 1.07 | Sandy track | 1.34 J/m/kgM | | |
| Walking | 0.95 | Unploughed sandy soil | 1.59 J/m/kgM | | Fall *et al* (1997b) |
| | 0.86 | Ploughed sandy soil | 2.15 J/m/kgM | | |
| | 1.26 | Laterite track | 1.0 J/m/kgM | | |
| | 0.81 | Sandy soil | | 31 | |
| Walking | 1.13 | Concrete | 1.57 J/m/kgM | | Dijkman and Lawrence (1997) |
| | 0.94 | Concrete | 1.65 J/m/kgM | | |
| | 1.23 | Concrete | 1.27 J/m/kgM | | |
| | 1.06 | Concrete | 1.05 J/m/kgM | | |
| Walking | 0.95 | Mud | 2.89 J/m/kgM | | Dijkman and Lawrence (1997) |
| | 0.69 | Mud | 3.57 J/m/kgM | | |
| Walking | 0.97 | Unploughed upland | 1.47 J/m/kgM | | Dijkman and Lawrence (1997) |
| | 0.83 | Ploughed upland | 2.87 J/m/kgM | | |
| | 0.87 | Unploughed dry fadama | 1.76 J/m/kgM | | |
| | 0.74 | Ploughed dry fadama | 3.76 J/m/kgM | | |
| | 0.80 | Unploughed wet fadama | 3.30 J/m/kgM | | |
| | 0.65 | Ploughed wet fadama | 8.58 J/m/kgM | | |
| Pulling load | 1.04 | Concrete | | 26 | Dijkman and Lawrence (1997) |
| | 0.90 | Concrete | | 32 | |
| | 0.92 | Mud | | 29 | |
| | 0.72 | Mud | | 30 | |
| | 1.26 | Concrete | | 36 | |
| | 1.06 | Concrete | | 34 | |

It appears that the efficiency with which metabolisable energy is used for work, and the effects of level of feeding and work on energy use for maintenance, weight gain and production functions require further research. This together with the variations in energy cost of various activities on different surfaces and different areas, make it necessary to have the feeding standards for cattle used for work verified in different places. Information obtained from this experiment was used to test the following hypotheses:

- Changes in live weight of working cattle in semi-arid areas that are predicted using feeding standards agree with actual recorded changes, hence predicted energy inputs and outputs in working animals in semi-arid areas are valid.
- Net energy expended during work declines in a consistent and hence predictable way during the working day, irrespective of the task undertaken, soil conditions, size, temperament and experience of the animal and environmental conditions during work.
- When draught oxen work as a team, the total amount of work done by the whole team is shared equally between the animals.

## 2.2.3. Materials and methods

### 2.2.3.1. Location and duration of study

This experiment was carried out at the Animal Traction Centre (ATC) in the livestock section of the research farm of the University of Fort Hare, Eastern Cape

Province, Republic of South Africa. The study was conducted for seven weeks during the summer time (from March to May) 1997.

### 2.2.3.2. Animals and their management

Twelve trained draught oxen of local Nguni or mixed breeds were used in the study. The oxen were trained to work in three teams of four, according to their compatibility. Table 2.2 shows the working team, breed, weight and age of each animal at the beginning of experiment. Average live weight of the oxen at the beginning of the study was 456 kg (ranging from 360 to 596 kg). The average live weight of oxen in treatment 1, 2 and 3 were 432, 536 and 399 kg, respectively. The oxen were housed in individual concrete floored pens which had separate concrete feed and water troughs. The pens were roofed with corrugated iron sheets on one end and 75% shade clothing on the other end with an open roof in-between the two. Bedding material in the form of wood shavings, sawdust and wood chipping from a neighbouring sawmill was provided in all pens. Manure was gathered every morning, mixed with the bedding material and allowed to accumulate at one end of each pen for the whole experimental period. All experimental animals were fed on the same diet consisting of a restricted amount (79-82g / kg$M^{0.75}$) of lucerne hay (ME content 6.4 MJ/kg DM). This was supplemented with 14-15g / kg $M^{0.75}$ of a commercial concentrate mixture (ME content 11 MJ/kg DM) so as to provide the animals with a total estimate of 1.3 x maintenance metabolisable energy (chemical composition of the concentrate is shown in Appendix 6.23). The daily hay ration was divided into two portions, one of which was fed in the morning after the work session and the other one after the afternoon work session, or at 0900h and 1600h on non-working days. Concentrate was given in the afternoon before the lucerne hay.

The animals had free access to drinking water when they were not working.

**Table 2.2. Experimental animals, their working teams, breeds, live weights and estimated ages at the beginning of experiment 1**

| Working Team | Ox No. | Breed | Live Weight kg (start) | Age (yrs) |
|---|---|---|---|---|
| **1** | 1 | Brown Swiss/ Nguni Cross | 494 | 5-6 |
| **1** | 2 | Brown Swiss / Nguni Cross | 492 | 5-6 |
| **1** | 3 | Afrikander/Nguni Cross | 362 | 3.5-4 |
| **1** | 4 | Nguni | 378 | 3.5-4 |
| **2** | 5 | Brown Swiss/ Nguni Cross | 526 | 5-6 |
| **2** | 6 | Friesian/Nguni Cross | 596 | >10 |
| **2** | 7 | Friesian/Nguni Cross | 520 | 6-7 |
| **2** | 8 | Friesian/Nguni Cross | 502 | 6-7 |
| **3** | 9 | Nguni | 404 | 4-5 |
| **3** | 10 | Nguni | 360 | 3.5-4 |
| **3** | 11 | Nguni | 380 | 4-5 |
| **3** | 12 | Nguni | 452 | 4-5 |

#### 2.2.3.3. Experimental design

The experiment consisted of three work treatments: (1) heavy workload with high daily estimated energy expenditure of 0.9 x maintenance (team 1), (2) medium workload with daily estimated energy expenditure of 0.6 x maintenance (team 2), and (3) low workload with daily estimated energy expenditure of 0.3 x maintenance (team 3). Work consisted of each team pulling a metal sledge loaded with weights over different distances on farm routes to give the desired energy expenditure. Each working team had its own walking route although some parts of the routes were common to two or all the three teams. An ergometer (Lawrence and Pearson, 1985) was used during the preparation phase of the experiment to measure draught forces for known workloads. From these measurements a regression of force on workload was derived and used to determine the load required for each team so that that the average draught force exerted on the level was equivalent to 8 kgf/kg$M^{0.75}$ (team 1) or 5kgf/kg$M^{0.75}$ (for both team 2 and team 3). Each team of four oxen worked twice a day for 4 days per week, starting at 0800h in the morning session and at 1400h in the afternoon work session. Team 1 was expected to cover about 12 km, team 2 about 10km and team 3 about 6 km per day so as to attain the estimated energy expenditure.

#### 2.2.3.4. Measurements

##### 2.2.3.4.1. Feed intake

Each day a sample of feed was taken while weighing the rations. The daily lucerne samples were pooled to get weekly samples whose dry matter content was determined. Refusals were collected and weighed every day before feeding. The dry matter content of refusal samples collected daily were determined for each animal in order to calculate the daily dry matter intake of each of them. The dried refusal samples from each animal were sub-sampled and pooled over each week. Dry matter content of lucerne, concentrate and refusals from each animal were determined by drying the samples to constant weight in a forced air oven at 60°C. The samples were then ground through a 1 mm screen and stored ready for laboratory analysis.

#### 2.2.3.4.2. Live weight

The live weight of each animal was measured three times every week on Mondays, Wednesdays and Fridays. All the live weight measurements were taken in the morning before working or feeding the animals.

#### 2.2.3.4.3. Work output

The total time taken by each team of oxen to travel around their route was recorded daily as well as the times at which each team passed points marked at intervals of 1 km along all the routes. The times recorded for each interval were used to calculate the walking speed of each team of oxen. On each working day the ergometer was used to record work done, distance travelled and elapsed working time of one of the teams of oxen. Recording of work was done on a rotational basis among the three teams.

#### 2.2.3.5. Digestibility of diets

The digestibility of lucerne hay used in this experiment was determined at the end of the trial. Three oxen were used for this study. The oxen were confined to their individual pens during the whole period. Feed intake was measured and total faecal output was collected for 7 days after a preliminary period of 10 days. Faeces were collected regularly, off the floor from each animal separately. The faeces were weighed and placed into buckets then stored in a cold room. At the end of each day, faeces were mixed and a sample (proportionally 0.05) was taken and frozen. After the 7-day collection period, the daily samples were thawed, mixed and a sub-sample (1 kg) was taken. This sample was oven dried to constant weight at 60°C to determine dry matter. A sub-sample was then taken, ground to pass through 1mm screen and stored ready for analysis.

#### 2.2.3.6. Laboratory analysis

All weekly food samples and the weekly individual refusal samples collected were analysed to determine acid detergent fibre (ADF), neutral detergent fibre (NDF), hemicellulose, crude protein, ash and acid insoluble ash according to AOAC (1990) procedures. For the analysis, feed and refusal samples were pooled together for weeks 1-3 and week 4-7.

#### 2.2.3.7. Energy balances

Energy balance of each individual animal and average balance for each team were calculated using information obtained from the "*Feeding standards for working cattle*" (Lawrence and Pearson, 1999). The ME content of lucerne and concentrate was 6.4 and 11 MJ/kg DM, respectively. Heat increment associated with energy transactions was considered to be 32% of the total ME intake. This is an average heat increment when ME is used to produce ATP for maintenance purposes or for muscular work. Values of the energy costs for walking used in calculating energy balances were 1.5 and 2.0 J/m/kg M. These energy costs were used because of the nature of the surfaces where the animals walked (see section 2.2.4.1). It was not possible to measure with the ergometer the work done by each individual animal. In calculating the energy balances it was therefore assumed that either all animals in any given team worked equally or that only half of the animals in a team worked while the other half just walked without exerting any effort to pull the load. The amount of work done by a team of oxen on those days that direct recording was not done was estimated from distance travelled and the average draught force recorded for the team in the same week. Estimates of live weight change made from the standards were compared with observed live weight changes.

#### 2.2.3.8. Data analysis

One way analysis of variance was done to compare treatment effects on body weight change, speed of working and amount of food consumed and energy balances of each team of oxen. The following statistical model was used:

$Y_{ij} = \mu + \alpha_j + \varepsilon_{ij}$

Where, $Y_{ij}$ was the dependant variable (live weight, speed, amount of food consumed or energy balance)

$\mu$ was the overall mean

$\alpha_j$ was the effect of the $j^{th}$ treatment ($j = 1,2,3$)

$\varepsilon_{ij}$ was the error term

## 2.2.4. Results

### 2.2.4.1. Working conditions

This experiment was conducted during summer time. The average maximum and minimum temperatures on the days that the animals worked were 22$^{o}$C (ranging from 13-26$^{o}$C) and 8$^{o}$C (ranging from 1-15$^{o}$C), respectively. The average relative humidity during the same time was 88 % (ranging from 71-94%). The roads on which the animals walked consisted of a firm gravel surface that had some protruding stones at various places. Some stretches of the routes were muddy when it rained. The walking routes were undulating and animals were constantly going either up or down gradual slopes.

### 2.2.4.2. Intake and digestibility of food and chemical composition of food and refusals

The average daily dry matter intake (± standard deviation) of the oxen on treatment 1 (the heavy workload) was 16.6±0.6 g/kg $M^{0.75}$, on treatment 2 (medium workload) was 15.1±0.7 g/kg $M^{0.75}$ and on treatment 3 (light workload) was 16.5±0.3 g/kg $M^{0.75}$. Table 2.3 shows the nutrient composition of the lucerne hay used in this study and average composition of its refusals from each treatment. The apparent digestibility coefficients for the different food components are also given in the table. Food refusals from the heavy workload treatment (treatment 1) had lower average NDF, ADF and hemicellulose compared with the other treatments. Crude protein content was highest in refusals from the heavy workload treatment. However, none of the differences in chemical composition of refusals from the three treatments was

**Table 2.3. Nutrient content of food offered and refused (g/kg DM), digestibility coefficients (%) of different food components and mean (± sd) dry matter intake (DMI) of cattle on each treatment.**

| | DM g/kg | NDF | ADF | Hemi-cellulose | Crude Protein | Ash | Acid insoluble ash | DMI (kg) |
|---|---|---|---|---|---|---|---|---|
| **Lucerne** | 945 | 626 | 470 | 157 | 148 | 67 | 23 | |
| **Digestibilty Coefficients** | 46±3 | 42±3 | 43±4 | 41±7 | 59±1 | | | |
| **Refusals** | | | | | | | | |
| **Heavy Workload** | 960±5 | 536±36 | 396±21 | 140±22 | 169±17 | 88±3 | 194±53 | 16.6±0.6 |
| **Medium Workload** | 956±3 | 568±42 | 422±34 | 145±19 | 162±24 | 84±6 | 160±75 | 15.1±0.7 |
| **Light Workload** | 958±3 | 564±42 | 419±29 | 145±19 | 155±25 | 85±4 | 195±49 | 16.5±0.3 |

statistically significant (p>0.05). The ash content was high in refusals from all treatments (84-88 g/kgDM) compared to that of the lucerne fed to the animals (67 g/kgDM). Refusals from all treatments showed very high values (160-194 g/kgDM) of acid insoluble ash compared to that of lucerne (23 g/kgDM).

### 2.2.4.3. Work performance

The work performance characteristics of oxen in the three treatments were as shown in Table 2.4. There was no statistically significant difference (p>0.05) in the elapsed working time as percentage of the total time spent working by each team of oxen despite the differences in workloads. The speed of walking of animals in the different treatments followed a trend similar to the workload pattern with the team having the lightest workload walking faster than all the others. However the differences in walking speed between the three teams were not statistically significant ($p>0.05$).

**Table 2.4. Mean daily work performance parameters for oxen on the heavy, medium and light workload treatments (±sd)**

| Treatments | Daily work (MJ) | Distance (km) | EWT (min) | Time worked (%) | Draft force (kN) | Power (kW) | Speed (m/s) |
|---|---|---|---|---|---|---|---|
| Heavy Workload | 14.5±2.3 | 12.0±1.7 | 164±21 | 94.0±2.3 | 1.21±0.07 | 1.47±0.10 | 1.2±0.01 |
| Medium Workload | 9.5±1.7 | 9.8±1.6 | 130±22 | 94.9±1.4 | 0.97±0.05 | 1.23±0.06 | 1.3±0.01 |
| Light Workload | 5.6±0.7 | 6.9±0.7 | 87±10 | 94.5±1.4 | 0.80±0.04 | 1.06±0.07 | 1.3±0.01 |

Changes in walking speed over the whole working day recorded every 15 min. during the working sessions for oxen in the 3 treatments were as shown in Figure 2.1. For animals that had the light workload, their speed increased to a peak of 1.4 m/s and then decreased to their slowest interval before increasing again when the animals were heading back home. In the afternoon work session speed increased to a peak and remained high to the end. Animals in the other two teams (medium and heavy workload) displayed very similar fluctuations in their walking speeds. During the morning work session they increased speed on the last stretch on their way back home while in the afternoon work session this was not observed. Instead, in the afternoon speed increased to a maximum and then dropped continuously up to the end of the work session.

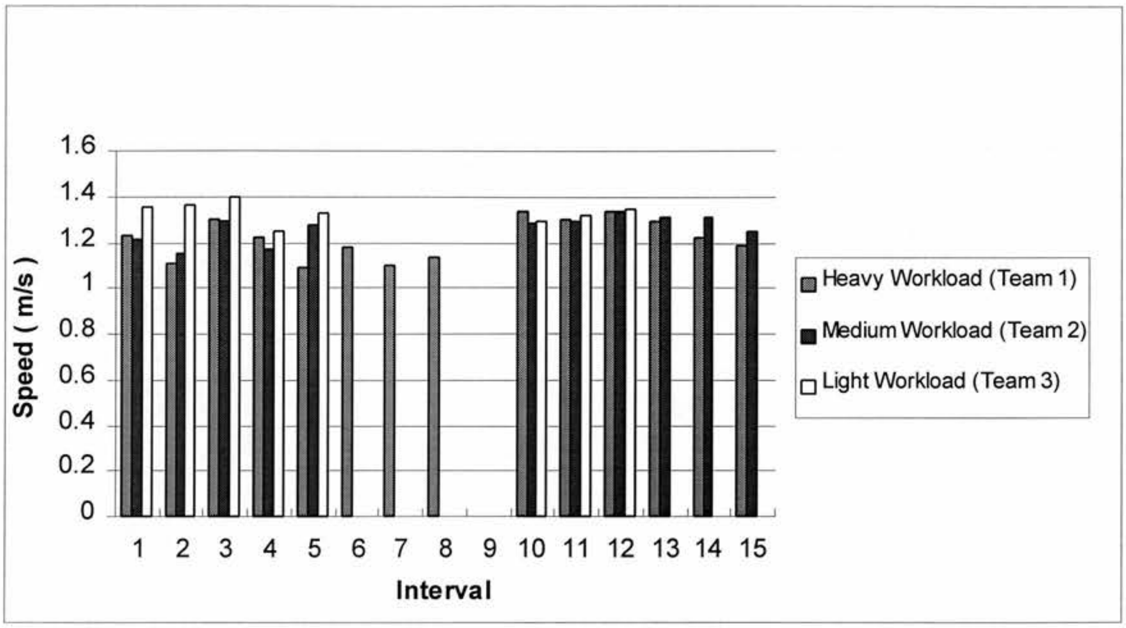


**Figure 2.1. Average walking speed (m/s) of oxen on the heavy (team 1), medium (team 2), and light (team 3) workload recorded at 15 min. intervals in the morning (interval 1-8) and afternoon (interval 10-15) work sessions**

### 2.2.4.4. Live mass change and energy balances

Table 2.5 shows all oxen in their respective working teams (or treatments), the position that was occupied by each animal in its team during working, live weight at start and end of experiment. It also shows the observed live weight change and change in live weight estimated from the "*Feeding standards for cattle used for work*" (Lawrence and Pearson, 1999) under different assumptions. Average changes and estimates for each team are also included in Table 2.5. Animals subjected to the medium workload treatment were heavier than those in the other two treatments at the start of the study. The oxen undertaking the heavy and light workloads had very similar live weights at the beginning of the study. Average total live weight changes of animals over the whole period of study were -8, 68 and 30 kg for the heavy, medium and light workloads, respectively. Expressed as percentages of initial live weights, the average live weight changes were –2, 13 and 8% for the three treatments, respectively. For the oxen team under heavy workload and the one given light workload, the assumption that energy cost of walking was 2 J/m/kgM provided the best estimates for energy balance and subsequent live weight change. For oxen under the medium workload it was the energy cost of 1.5 J/m/kgM that gave reasonable estimates of live weight change.

Estimates of individual weight changes from average energy balances in any particular team showed mixed trends. The two rear (and heavy weight) oxen in the heavy workload treatment lost weight while their two front (and light weight) counterparts gained weight. The proportional weight changes of oxen under the heavy workload treatment were –1.8 and 2.7% for the heavy and light oxen, respectively. This seemed to reasonably agree with estimates of live weight change made under the assumption that only the two rear animals were pulling the load (assumption 2 in Table 2.5). Estimates made under the assumption that all the animals were working equally (assumption 1) appeared to hold more closely for animals that were positioned in the rear of the team during working. The assumptions seem to be most reasonable for individual animals under the heavy workload treatment. If we consider the average observed change in body weight for the treatment (or the whole team), average estimates 1 and 2 (i.e. assumption that all oxen worked equally or that only the rear oxen were pulling) still remain the best. All animals under the medium and light workload treatments gained weight (Table 2.5). Comparing the live weight change of individual animals estimated from feeding standards with observed live weight changes, there were mixed trends

**Table 2.5. Working team and treatment, position in team while working live weight at start, energy cost for walking, observed average daily change in live weight and live weight changes (1-7) estimated from feeding standards under different assumptions for each oxen and average changes for each team**

| Team | Treatment/ Workload | Ox No. | Position | Live Weight (start), kg | Total Live Weight change, kg | Energy cost of walking (J/m/kgM) | Observed change in Weight (g/d) | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Heavy | 1 | Rear Right | 508 | -14 | 2.0 | -286 | -91 | -613 | 306 | -613 | 306 | -613 | 306 |
| 1 | Heavy | 2 | Rear Left | 498 | -4 | 2.0 | -82 | -108 | -646 | 299 | 299 | -646 | 299 | -646 |
| 1 | Heavy | 3 | Front Left | 360 | 6 | 2.0 | 122 | -249 | 260 | -971 | 260 | -971 | -971 | 260 |
| 1 | Heavy | 4 | Front Right | 382 | 4 | 2.0 | 82 | -251 | 245 | -945 | -945 | 245 | 245 | -945 |
| Team 1 Average | | | | 437 | -8 | 2.0 | -41 | -174 | -189 | -328 | -250 | -267 | -260 | -256 |
| 2 | Medium | 5 | Rear Right | 520 | 10 | 1.5 | 204 | 150 | -121 | 382 | -121 | 382 | -121 | 382 |
| 2 | Medium | 6 | Rear Left | 586 | 20 | 1.5 | 408 | -210 | -520 | 54 | 54 | -520 | 54 | -520 |
| 2 | Medium | 7 | Front Left | 524 | 28 | 1.5 | 571 | 208 | 429 | -50 | 429 | -50 | -50 | 429 |
| 2 | Medium | 8 | Front Right | 494 | 10 | 1.5 | 204 | 155 | 393 | -125 | -125 | 393 | 393 | -125 |
| Team 2 Average | | | | 531 | 68 | 1.5 | 347 | 76 | 45 | 65 | 59 | 51 | 69 | 42 |
| 3 | Light | 9 | Front Left | 402 | 12 | 2.0 | 245 | 130 | 294 | -53 | 294 | -53 | -53 | 294 |
| 3 | Light | 11 | Front Right | 384 | 4 | 2.0 | 82 | 135 | 303 | -51 | -51 | 303 | 303 | -51 |
| 3 | Light | 10 | Rear Right | 360 | 2 | 2.0 | 41 | 211 | 27 | 376 | 27 | 376 | 27 | 376 |
| 3 | Light | 12 | Rear Left | 456 | 12 | 2.0 | 245 | 204 | 98 | 350 | 350 | 98 | 98 | 350 |
| Team 3 Average | | | | 401 | 30 | 2.0 | 153 | 170 | 181 | 156 | 155 | 181 | 94 | 242 |

Estimate 1= all oxen work equally; Estimates 2-7= only two oxen pulling load (2=only rear, 3=only front, 4=right front right rear, 5=left front left rear, 6=left front right rear, 7=right front left rear);

amongst oxen working in similar teams. All oxen that pulled the medium workload produced good estimates under the assumption that only two oxen pulled the load (situation 2 on Table 2.5). Except for ox No. 6, the assumption that all oxen worked equally also gave good estimates (situation 2-7 in Table 2.5). When mean estimates of energy balance for the whole team are made, all situations produce similar estimates. Except for ox No. 10, all individual estimates for animals under the light workload treatment made under the assumption that all worked equally were good. Estimates made under the assumption that only two oxen pulled the load gave mixed trends amongst the members of the team. Average estimates of energy balances for the team under all assumptions were good.

### 2.2.5. Discussion

Changes in live weights of animals under the three treatments were different from those anticipated. Given that all animals were fed at the same level (1.3 x maintenance ME requirement) but assigned work demanding different energy expenditures, one would have expected more pronounced differences between treatments in live weight changes. Animals were given the same feed allowance and the amount of food refused by any individual animal was negligible so intake differences are unlikely to account for any of the differences observed in live weight change. The animals in treatment 3 (light workload) were expected to register the highest proportionate gain but this was not the case. A possible explanation for this is that duration of work and the difference in workloads was not sufficient to bring about marked differences in weight changes during the experimental period. There is also a possibility that due to the small demand of energy for work, animals in treatment 3 could have used less efficient metabolic pathways in their energy transactions compared with oxen that were assigned medium and heavy workloads hence the unexpected results. Bamualim and Ffoulkes (1988) suggested that efficiency of utilisation of dietary energy for draught work decreased as digestible energy intake increased. It is possible that in this experiment level of energy demand for work influenced efficiency of feed energy utilisation. It is also probable that the initial live weight and body condition of the animals might have played a part in bringing about the observed changes. The animals that were subject to a medium workload had the highest average initial body mass and they registered the highest average daily gain. These animals may have been depositing more fat compared to the animals that were subject to the light workload, which had lower average initial body mass and registered lower gain despite the fact that they should have expended less energy for work. The animals subject to the light workload treatment were younger than those on the other treatments. This may have accounted for the differences seen.

In this experiment animals tended to walk faster on their last stretch towards the end of the morning work session. During the afternoon work session animals increased their walking speed to a maximum and then slowed down progressively up to the end of the work session. The hypothesis that energy expended during work declines consistently and hence predictably during the working day may therefore not always be true. The type of work that the animals are doing may influence the pattern of net energy expenditure. For example when draught cattle are ploughing a level and regular piece of land they are subject to a very variable workload and keep going backwards and forwards over the same area possibly for the whole working day.

This way their pattern of net energy expenditure over the whole day may decline predictably. Draught animals pulling loads over hilly land may start off their work by going far away before heading back home. When the animals are heading back home, there is an incentive to speed up especially when feed is offered immediately after working. This means that rate of net energy expenditure may increase on the way back home. In this experiment the afternoon work session was shorter than the morning one and the animals had already taken their morning ration, therefore they were not as hungry. This could be one of the reasons for the slowing down observed as the afternoon work session progressed as opposed to the increase in speed that was observed towards the end of the morning work session.

Within the heavy workload treatment, there were differences in the trend in live weight change between light and heavy animals. The heavy oxen registered overall weight loss while the lighter oxen recorded weight gains. This observation seems to agree with findings by Winugroho, Juwarini and Teleni (1989) who reported that when they were subject to the same work, lighter animals lost less weight than heavier ones. Also Fall, Pearson and Fernandez-Rivera (1997a) reported similar results in which heavier animals with good initial body condition lost proportionately more weight (0.099) than lighter animals having medium (0.047) or poor (0.074) initial body condition and subject to the same management and working conditions.

A comparison of the actual live weight changes with the estimation of live weight changes from the feeding standards showed differences between treatments and between individual animals under the same treatments. Estimates of live mass changes for animals under similar treatments tend to indicate that animals in the same treatment were working differently. It is likely that animals which lost weight or registered lower gains compared with their team mates were doing most of the work pulling the load while the others were simply walking or applying very little effort to pull the load. Pearson, Lawrence and Ghimire (1989) and Pearson and Lawrence (1990) pointed out many factors that could influence the work of individual animals, or teams of animals. Estimates made under the assumption that animals worked differently tended at times to be more accurate compared to the actual changes. It is also possible that some of the assumptions made in making estimates of energy balances were not correct. The average energy cost of walking (1.5 or 2.0 J/m/kg M) used for all the estimates might have been either too high or too low for the animals when they walked on the different parts of the track. As pointed out by Lawrence and Stibbards (1990) the accuracy of the factorial method which was used in developing the feeding standards depends very much on similarity of conditions under which cattle are working and those under which the factors used were determined. "*Feeding standards for cattle used for work*" (Lawrence and Pearson, 1999) recommend the energy cost of 1.5 J/m/kg M for smooth flat land. Animals in this study walked on a track with rough gravel and in parts stoney surface and varying but low gradients therefore it is possible that different energy costs for walking on different parts of the routes might have been more appropriate. Rometsch, Newman, Buchenan, Susenbeth and Becker (1994) reported values of 0.8 and 0.6 J/m/kg M for oxen walking downhill for slopes of 6 % and 3 %, respectively. In the estimates made under this experiment, one average figure was applied for walking over the whole route irrespective of slope.

Although the amount of food refused by any individual animal was negligible, refusals from the different treatments showed different chemical composition. The nutrient composition of refusals from the lucerne fed to the animals tends to indicate some differences in selection of food between animals in the three treatments. Animals subject to heavy workload tended to consume more dietary fibre than those in the other two treatments. Their higher demand for nutrients as a result of the extra workload might have resulted in them being less selective in the diet they were consuming than the animals on the other treatments.

From the results of this experiment, the hypothesis that net energy expended during work declines in a consistent and predictable way during the working day irrespective of the task undertaken may not always be true. Observations made in this experiment showed that the type of work being done may influence the pattern of net energy expenditure. This was the case when draught cattle pulling loads increased their speed and hence their rate of energy expenditure when heading home towards the end of working.

The estimates of live weight changes made from the feeding standards under the different assumptions suggest that when draught cattle work in a team, they do not necessarily share the workload equally amongst themselves as hypothesised at the beginning of this study. It would seem that estimation of energy balance from the feeding standards for individual animals working in a team becomes complicated since the contribution of each individual to the overall work done becomes difficult to determine. However the estimates of average energy balance and live weight changes made for whole working teams of draught cattle were reasonable. This means that predictions of energy inputs and outputs in cattle working under semi-arid conditions that are made using the "*Feeding standards for cattle used for work*" (Lawrence and Pearson, 1999) could be relied upon. In order to improve accuracy of the predictions, it would be appropriate to make more determinations of energy costs for various activities related to work so that factors suitable for specific conditions could be applied rather than making use of generalised average factors.

## 2.3. Experiment 2

## Effect of the level of dietary energy supply during work on the performance of draught oxen

### 2.3.1. Introduction

Animals under the small holder farming systems in semi-arid areas almost always lose body weight and body condition or register zero gains during the long dry season typical of the region due to severe shortages of food. When the rainy season sets in, enough food becomes available and the animals quickly regain their body weight as well as condition. With animals that are required to work, this sequence of events poses a serious problem because the period when animals are in their poorest condition occurs at a time when land preparation activities are at their peak immediately before or after the first onset of rains. The loss of body weight and condition of work animals could interfere with their work unless some measures are sought to improve the food situation. One way of dealing with the situation is to provide working animals with supplements to minimise loss of body weight and condition. Given a choice, farmers would like to feed their animals so that they are in good condition in order to perform work well. The problem is that it is not always possible under conditions of small holder farming in semi-arid areas to secure enough supplements necessary to attain the level of animal feeding that is required to maintain the desired condition. The animals therefore tend to lose body weight and condition both before and during work. The objective of this experiment was to investigate the effects of the level of supply of dietary energy before and during work on the work performance of draught oxen.

### 2.3.2. Literature Review

#### 2.3.2.1. Constraints to the feeding of draught oxen in semi-arid areas

In semi-arid areas there are marked changes in both quality and quantity of feed supply between the short growing season and the long dry period. For example Phiri (1994) noted that in the dry season, grazing in the traditional livestock sector of Zambia becomes increasingly scarce and poor, and that the situation is further worsened by overgrazing and indiscriminate bush fires that reduce the natural grazing areas. According to Meinderts, Chibango and Mwenda (1999), farmers in Zambia indicated that the poor condition of draft animals at the onset of rains was a constraint to early and timely planting. The farmers suggested that inadequate grazing during the dry season was the main cause. Grazing animals reared under agricultural systems in the semi-arid areas therefore tend to go through regular cycles of weight loss followed by the well-documented compensatory growth when feed conditions are favourable. The extent of weight loss varies but seasonal changes in live weight of work oxen amounting to 20% have been reported (Wilson, 1987).

The majority of draught oxen in semi-arid areas are kept and used by small holder farmers who in most cases have very limited resources, therefore feeding practices commonly used by them are simple, depending mainly on naturally available feed resources in the various seasons. The most popular method of feeding their animals is through grazing on natural communal pastures or during the dry season after harvesting, the animals can be herded on the crop fields where they graze on a mixture of crop residues and grasses. According to Francis, Ndlovu and Nkuuhe (1994), excessively high stocking rates on communally grazed pastures and crop residues results in low availability of feed biomass. This leads to large weight losses of the animals. Detailed structure of and functioning of farming systems under semi-arid areas are complex and vary from one place to another depending on many factors. In Ethiopia, Mosi and Lambourne (1982) noted that crop residues are available in quantities sufficient to meet nutritional needs for maintenance and work of a pair of oxen and one cow per household. The problem is that the number of animals is bigger and the available quantities cannot meet requirements of productive animals, an important factor since many draught animals serve more than a single purpose. Egan (1989) emphasised the fact that it was not realistic to attempt to exploit the capacity to grow, reproduce and produce by ruminant animals kept under cropping systems relying on draft animal power since high fibre roughage formed the major component of the diets under such systems. Improvement in performance could be achieved through matching of periods of special nutrient requirements with planned allocation of appropriate feed components. Fall *et al* (1997d) cautioned that it was not realistic in most farming systems in semi-arid areas to think of high supplement levels for draft oxen with good quality food since farmers have limited income and their needs for their other animals could prove to be more essential.

Ffoulkes and Bamualim (1989) recommended that feeding strategies prior to working should be aimed at increasing the efficiency of the rumen fermentation process so that sufficient nutrients can be generated to build up stores of body fat and restore body condition. They recommended further that in places where the animals are used on all-year-round basis, they should be fed to avoid weight losses. Where animals are in poor condition and cannot maintain body weight, or are subject to periods of hard work, or are in a productive state, Ffoulkes and Bamualim (1989) insisted on the essence of supplementation with rumen-undegradable concentrates. Egan and Dixon (1992) emphasised that feeding strategies need to ensure that the feed reserved for the period of 4-6 weeks prior to the major drought period is of better quality or if that is not possible supplements should be used during that time.

### 2.3.2.2. Bodyweight and body condition: their significance on work performance

In Mali, Bartholomew, Khibe and Ly (1995) showed that under short periods (maximum 3 weeks) of work, body weight or body condition of the animals had little effect on their work output. Animals that had lost up to 50 kg ($1/5^{th}$) of their body weight over the preceding dry season performed as well as those in good condition. They felt no economic justification for feeding to establish or maintain body energy reserves for use during the working period rather than feeding the extra energy source during working. In a trial to investigate effects of changes in body weight and body condition during the dry season on working capacity of oxen, Bartholomew *et al* (1993) showed increased work capacity of oxen as a result of live weight gain brought about by supplementary feeding in the dry season. However in this study they could not distinguish the effects brought about by changes in live weight from those caused by changes in body condition which occurred at the same time. They argued that if body weight was the essential factor in determining capacity for work then it was possible to determine minimum live weight levels for oxen, irrespective of body condition and define necessary feeding strategies according to individual live weight. Bartholomew *et al* (1994) clearly showed the importance of body weight over body condition in determining the capacity of oxen for work. The practical implications of their findings were that farmers should be advised to use large oxen that could be worked without the necessity for supplementary feeding at the end of the dry season. However, Francis and Ndlovu (1995) demonstrated some benefits of supplementary feeding during the dry season on work output and suggested that farmers should strive to at least maintain live weight of their oxen during periods of nutritional deficiency. Fall *et al* (1997a) came up with findings supporting Bartholomew *et al* (1994) whereby work performance was affected by live weight, but not body condition and live weight losses during work did not have detrimental effect on work performance. They suggested a minimum critical body condition score below which work could irreversibly damage the oxen's health. The published results on the relative significance of body weight and body condition on the working of draught oxen suggest that further research is needed. There is some justification to conduct further investigations on the relative significance of body weight and body condition on work performance. It is also important to seek further clarification on the interaction between quality of the diet and work done. This experiment studied the effects of the supply of dietary energy during work on the performance and energy balance of draught oxen. In addition to testing the proposed feeding standards for cattle used for work, the experiment tested the following hypotheses:

- In draught cattle there is a minimum live weight to force ratio below which work capacity is impaired.
- Work output is a function of body weight rather than condition therefore feeding in order to maintain or improve body condition in draught cattle is not necessary

## 2.3.3. Materials and methods

### 2.3.3.1. Location of study and duration

This study was conducted at the Animal Traction Centre in the livestock section of the research farm of the University of Fort Hare from August to November 1997 (spring/summer season).

### 2.3.3.2. Animals and feeding

Twelve oxen of Nguni or mixed breeds weighing on average 444 kg (range 364-532 kg) were used in this study. The animals were matched according to their live weights and trained to work in pairs. Table 2.6 shows the experimental animals, their breeds, estimated ages, live weights at start of experiment and working team of each. Each animal was individually housed and fed in the same housing facility used for the first experiment. Food for all animals consisted of maize stover, lucerne and a commercial concentrate for beef cattle. Water was available to the animals *ad libitum* when they were in their pens. The animals were dipped once every week to control ticks.

**Table 2.6. Experimental animals, their working teams, breeds, live weights and estimated ages at the beginning of experiment**

| Treatment | Working Team | Ox No. | Breed | Live Weight kg (start) | Age (yrs) |
|---|---|---|---|---|---|
| **1** | 5 | 3 | Afrikander/Nguni cross | 372 | 4 |
| **1** | 5 | 4 | Nguni | 384 | 4 |
| **1** | 1 | 5 | Brown Swiss/Nguni cross | 496 | 6 |
| **1** | 1 | 14 | Nguni | 418 | 4 |
| **1** | 2 | 7 | Friesian/Nguni cross | 520 | 7 |
| **1** | 2 | 8 | Friesian/Nguni cross | 496 | 7 |
| **2** | 4 | 1 | Brown Swiss/Nguni cross | 532 | 6 |
| **2** | 4 | 2 | Brown Swiss/Nguni cross | 490 | 6 |
| **2** | 6 | 9 | Nguni | 418 | 5 |
| **2** | 6 | 11 | Nguni | 394 | 5 |
| **2** | 3 | 10 | Nguni | 364 | 4 |
| **2** | 3 | 12 | Nguni | 438 | 5 |

### 2.3.3.3. Experimental plan

The experiment consisted of two dietary/body condition treatments. In the first treatment (low to high energy diet, low body condition score), three pairs of oxen were fed on low energy (0.8 x maintenance ME requirement) diet for 7 weeks followed by a high energy (1.8 x maintenance ME requirement) diet for 6 weeks. The oxen worked continuously during the 13 weeks pulling loaded sledges. In the second treatment (high to high energy diet, high body condition score), three pairs of oxen were fed on the high energy diet throughout and doing the same work as those in treatment 1. The six pairs of oxen were assigned to the two treatments so that live weight and animal body sizes were balanced between the treatments as far as pairing for work could allow. The first part of the experiment (week 1-7) investigated effects of quality of diet on work performance while the second part (week 8-13) investigated effects of body condition on working.

### 2.3.3.4. Working

All oxen performed the same work in pairs pulling sledges loaded at 10 kgf/100 kg LW over the same route and distance throughout the experiment. The oxen worked twice per day on four days per week starting at 0800 hrs and 1400 hrs daily, every working day.

Working stopped when animals either completed the set distance of 7.5 km in the morning session, 5.2 km in afternoon session or were too tired and reluctant to continue.

### 2.3.3.5. Data collection

Body weights were measured on Monday, Wednesday and Friday of every week. Body condition scoring was done once per week on Fridays. The 0 (lean) to 9 (obese) scale for scoring body condition in cattle by Nicholson and Butterworth (1986) was used. The scheme for body condition scoring is summarised on Appendix 6.22. Using an ergometer (Lawrence and Pearson, 1985) work output, distance travelled and time spent moving was recorded from one team on each working day, while the speed for each team was recorded continuously over every working day as in experiment 1.

#### 2.3.3.5.1. Food intake

Daily rations of maize stover and lucerne for each animal were weighed weekly. During weighing weekly samples of stover and lucerne were collected and their dry matter content determined. Refusals were collected, weighed and sampled every day before feeding. The dry matter content of both maize stover, lucerne and refusals from each animal were determined by drying the samples to constant weight in a forced air oven at 60°C and used to calculate voluntary dry matter intake. Dried refusal samples from each animal were sub-sampled and pooled over each week. The weekly food and refusal samples were then ground through a 1 mm screen and stored for analysis.

### 2.3.3.6. Laboratory analysis

All stover, lucerne and concentrate samples as well as all refusal samples were analysed for NDF, ADF, crude protein, hemicellulose, ash and acid insoluble ash according to AOAC (1990) procedures. The samples were pooled for week 1-3, 4-7, 8-9 and 10-13 before analysis.

### 2.3.3.7. Energy balances

The average daily energy balance for each working team and average balance for each treatment over the whole period of study was calculated using guidelines from the "*Feeding standards for cattle used for work*"(Lawrence and Pearson, 1999). The ME content of lucerne and maize stover used was 6.1 and 7.5 MJ/kg DM, respectively. Heat increment was considered to be 32% of the total ME intake. Other assumptions made in calculating energy balances were the same as those made in experiment 1 (section 2.2.3.7) because of the similarity in working conditions.

### 2.3.3.8. Data analysis

Data obtained from this study was subject to analysis of variance using the generalised linear models (GLM) procedures of the Statistical Analysis Systems (SAS, 1988). The following statistical model was applied:

$Y_{ijk} = \mu + \alpha_j + \beta_k + \alpha\beta_{jk} + \varepsilon_{ijk}$

where $Y_{ijk}$ was the dependent variable ( live weight change, body condition score, work output, speed, power or draught force )

$\mu$ was the overall mean

$\alpha_j$ was the effect of the $j^{th}$ treatment ( j = 1, 2)

$\beta_k$ was the effect of the $k^{th}$ working week ( k= 1, …6 )

$\alpha\beta_{jk}$ was the interaction between the $j^{th}$ treatment and the $k^{th}$ working week

$\varepsilon_{ijk}$ was the error term for the $i^{th}$ team of oxen on the $j^{th}$ treatment in the $k^{th}$ working week

## 2.3.4. Results

### 2.3.4.1. Changes in live weight and body condition

Weight changes of animals and their average weekly body condition scores during the whole period of study were as shown in Figures 2.2 and 2.3. During the first part (week 1-7) of the study, animals on the low energy diet lost weight continuously while those receiving a high energy diet maintained their body weights.

The loss in body weight (Figure 2.2) was accompanied by progressive decline in body condition (Figure 2.3). In the second part (week 8-13) animals with a low body condition score gained weight continuously. Table 2.7 summarises average weekly body weight gains, body condition scores, average daily speed, work, draught force and power. Differences in live weight changes of oxen on the two treatments in both the first and second part of the study were statistically significant ($p<0.05$).

One team of oxen in the low energy treatment (team 1) had to be stopped from working during week seven of the experiment due to the weakness of one animal in the team. Ox No. 5 and 14 in the team had each lost 46.3 and 31.3 kg, respectively (a total of 78 kg for the team). The loss in live weight for each animal in team 1 at the end of week 6, as a proportion of their live weights at the start was 0.09 and 0.07, for ox No. 5 and 14, respectively. The lowest body condition score reached was 2.5 and 3.5, for ox No. 5 and 14, respectively.

### 2.3.4.2. Work performance

Table 2.7 shows the average live weight changes, body condition scores, daily speed, work and power developed by oxen on the two treatments during the first (week 1-7) and second (week 8-13) part of the experiment. Oxen on the high energy diet had slightly higher average speed than those on the lower energy diet. The differences in speed of working of oxen on the two treatments during the first part (week 1-7) of the experiment were not statistically significant ($p>0.05$). In the second part (week 8-13) of the experiment, the average speed of oxen on both treatments increased. Oxen in good body condition had higher average speed of walking than that of oxen with low body condition score. The differences in walking speed between treatments during the second part of the study (week 8-13) were statistically significant ($p<0.05$). There was a statistically significant ($p<0.05$) interaction between treatments and weeks of working.

There were no statistically significant differences ($p>0.05$) in average daily work done, draught force or power developed by oxen on the two treatments despite the fact that animals on the low energy regime were losing weight (therefore their workload was actually increasing the more weight they lost).

### 2.3.4.3 Laboratory analysis of feed and refusals

Table 2.8 shows the nutrient composition of lucerne, stover and their refusals from animals on the different treatments. Results of laboratory analysis show that the

**Figure 2.2. Average weekly live weights of oxen on treatment 1 (low energy for seven weeks then high energy for six weeks) and treatment 2 (high energy diet throughout)**

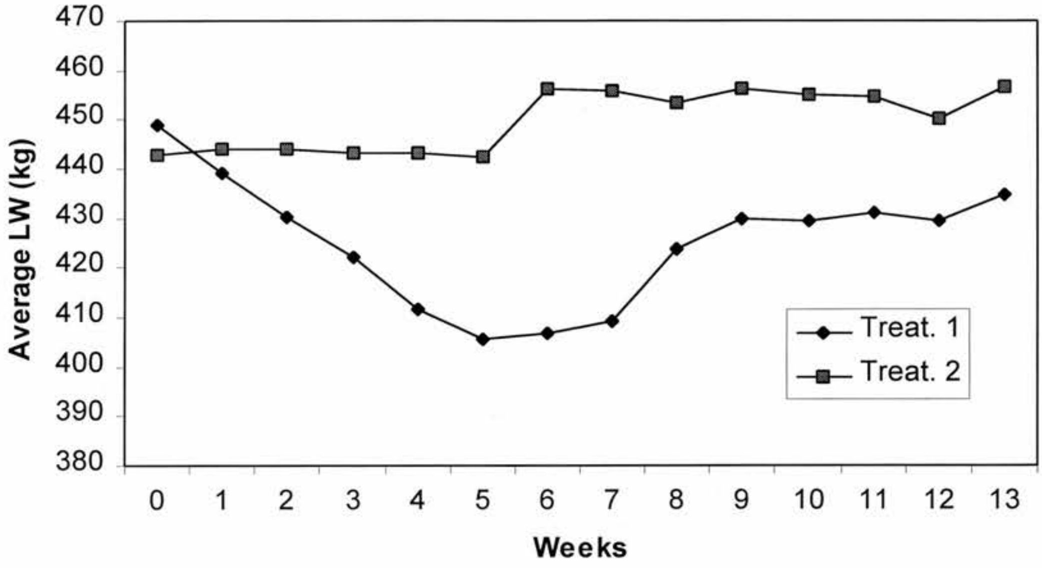


**Figure 2.3. Average weekly body condition scores of oxen on treatment 1 (low energy for seven weeks then high energy for 6 weeks) and treatment 2 (high energy diet throughout)**

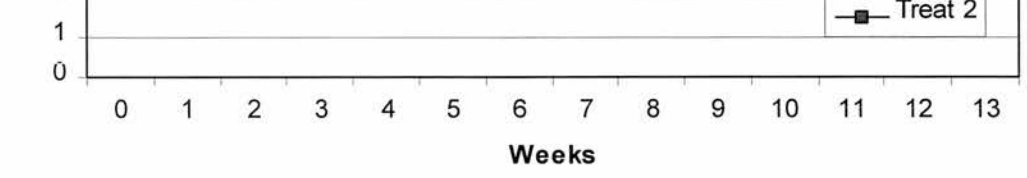

**Table 2.7. Average weekly live weight gains, average body condition scores (BCS) of the individual oxen and average daily working speed and work output, draught force (DF), and power of the ox teams (pairs) in the two treatment groups (±sd)**

| | Week 1-7 | | Week 8-13 | |
|---|---|---|---|---|
| | **High Energy** | **Low Energy** | **High BCS** | **Low BCS** |
| **Average weekly gain (kg)** | 2.4±0.7[a] | -5.2±0.8[b] | -0.4±1.5[a] | 3.7±0.9[b] |
| **Average BC Score** | 7.0±0.1 | 5.0±1.3 | 7.0±0.1 | 4.0±0.3 |
| **Average daily speed (m/s)** | 1.28±0.04 | 1.25±0.08 | 1.31±0.07[b] | 1.27±0.04[a] |
| **Average daily work (MJ)** | 10.0±0.3 | 9.8±0.5 | 8.9±0.3 | 9.8±0.7 |
| **Average DF (kN)** | 0.83±0.04 | 0.85±0.04 | 0.79±0.06 | 0.82±0.03 |
| **Average power (kW)** | 1.05±0.08 | 1.08±0.10 | 1.05±0.03 | 1.10±0.07 |
| **Live weight change (kg/animal)** | 16.5±5.2[a] | -36±5.6[b] | -2.6±9.2[a] | 21.9±5.6[b] |

Means with different superscripts along the same row in weeks 1-7 or weeks 8-13 are significantly different ($P<0.05$)

average NDF, ADF and hemicellulose content of lucerne refusals from animals on the low energy treatment were lower than those of animals on the high energy treatment. The differences between the chemical composition of refusals from the two treatments were statistically significant ($p<0.05$). Average crude protein content of stover refusals from the low energy treatment was significantly ($p<0.05$) lower than that of refusals of the high energy group. The average acid insoluble ash content was very high in Lucerne and stover refusals from the low energy treatment. Animals under the low energy diet consumed more fibre than those on the high energy regime during the first part of study as seen from the lower content of NDF, ADF and hemicellulose in their refusals.

**Table 2.8. Nutrient composition (g/kg DM) of lucerne, stover and their refusals from oxen on treatment 1 (low energy diet for seven weeks, part 1, then high energy for 6 weeks, part 2; HE, Low BCS) and treatment 2 (high energy diet for seven weeks, part 1, then high energy diet for 6 weeks, part 2; HE, High BCS), (±sd)**

| | DM (g/kg) | NDF | ADF | Hemice-llulose | Crude Protein | Ash | AI ash |
|---|---|---|---|---|---|---|---|
| **PART 1** | | | | | | | |
| **Lucerne** | 946 | 633 | 483 | 150 | 139 | 69 | 8 |
| **Refusals:** | | | | | | | |
| **Low Energy** | 950±11 | 462±122[a] | 358±96[a] | 103±28[a] | 140±9 | 71±13 | 211±177[a] |
| **High Energy** | 945±4 | 591±39[b] | 449±53[b] | 142±22[b] | 164±26 | 72±10 | 66±43[b] |
| **Stover** | 954 | 771 | 517 | 254 | 55 | 23 | 48 |
| **Refusals:** | | | | | | | |
| **Low Energy** | 959±6 | 609±132 | 424±72 | 184±65 | 46±2[a] | 41±16 | 235±117 |
| **High Energy** | 957±5 | 692±75 | 478±46 | 215±33 | 67±13[b] | 39±14 | 138±89 |
| **PART 2** | | | | | | | |
| **Lucerne** | 934 | 621 | 461 | 160 | 138 | 68 | 7 |
| **Refusals:** | | | | | | | |
| **HE Low BCS** | 937±6 | 606±86 | 457±78 | 149±13 | 149±49 | 68±9 | 62±55 |
| **HE High BCS** | 937±6 | 579±73 | 430±53 | 149±26 | 167±28 | 71±5 | 97±84 |
| **Stover** | 939 | 771 | 502 | 269 | 52 | 26 | 22 |
| **Refusals:** | | | | | | | |
| **HE Low BCS** | 946±2 | 732±34 | 487±26 | 245±10 | 58±9 | 32±6 | 75±56 |
| **HE High BCS** | 944±8 | 732±36 | 483±26 | 249±16 | 64±9 | 31±6 | 71±45 |
| **Digestibility:** | | | | | | | |
| **Lucerne** | 53±2 | 50±2 | 49±2 | 53±2 | 57±2 | | |
| **Stover** | 54±6 | 57±3 | 56±5 | 63±6 | 39±6 | | |

HE, high energy ratio; BCS, body condition score; Adjacent means down a column with different superscripts are significantly different ($p<0.05$)

#### 2.3.4.4. Energy balances and live weight change

Table 2.9 shows average energy balances of oxen in each of the working teams as well as averages for all teams in each treatment. All oxen that worked under treatment 1 registered negative energy balances. The changes in live weight as calculated from the feeding standards for cattle used for work (Lawrence and

**Table 2.9. Individual means in each team and treatment means (±sd) for live weight at start, daily average net energy transactions (including intake, expenditure and balance), calculated and observed daily average live weight changes.**

| Treatment | Team | LW (start) kg | NE intake (MJ/d) | NE maint. (MJ/d) | NE work (MJ/d) | NE exp. (total) (MJ/d) | NE balance (MJ/d) | Calc. LW change (g/d) | Observed LW change (g/d) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 457 | 34.1 | 36.8 | 10.2 | 47.0 | -12.9 | -1647 | -231 |
| 1 | 2 | 508 | 37.8 | 42.7 | 13.8 | 56.5 | -18.7 | -2946 | 63 |
| 1 | 5 | 378 | 29.8 | 36.9 | 11.5 | 48.4 | -18.6 | -2658 | -183 |
| Treatment Average | | 448 ±66 | 33.9 ±4.0 | 38.8 ±3.4 | 11.8 ±1.8 | 50.6 ±5.1 | -16.7 ±3.3 | -2417 ±682 | -117 ±158 |
| 2 | 3 | 401 | 51.5 | 38.4 | 12.7 | 51.1 | 0.4 | -147 | 194 |
| 2 | 4 | 511 | 60.5 | 43.3 | 12.3 | 55.6 | 4.9 | 94 | 147 |
| 2 | 6 | 406 | 51.0 | 37.5 | 10.8 | 48.3 | 2.7 | 36 | 187 |
| Treatment average | | 439 ±62 | 54.3 ±5.3 | 39.7 ±3.1 | 11.9 ±1.0 | 51.7 ±3.7 | 2.7 ±2.3 | -5.7 ±126 | 176 ±25 |

Pearson, 1999) were different from average changes calculated from measured live weights. Heavy oxen (team 2 in Table 2.9) gained weight (average of 63g/d) compared to the light oxen (team 5) that lost weight (average loss of 183g/d), but estimated live weight changes did not reflect this. For animals under treatment 2, calculated live weight changes provided a good picture of changes that were observed.

### 2.3.5. Discussion

Animals in both treatments in this experiment increased their walking speeds during week 8-13. We could attribute the increase in speed for oxen on treatment 1 to the improved energy supply in the diet. However, the provision of food to animals in treatment 2 remained unchanged throughout the whole period of study and animals in both treatments were managed and worked similarly. The increase in walking speed of oxen in treatment 2 could be attributed to their drovers who could have been inspired by their counterparts driving animals in treatment 1. Pearson *et al* (1989) and Pearson and Lawrence (1990) reported that work output by draught oxen managed and working under same conditions depended mainly on the ploughman and temperament of the animals.

One team of oxen on the low energy treatment (week 1-7) was stopped from working during week 7 because of the difficulty with which the animals worked and their inferior physical appearance compared with their counterparts. The stoppage had nothing to do with actual work output from the team. One animal in the team had reached a body condition score of 2.5 (the average for the team was 3). With a total weight loss of 78 kg probably the team had approached their critical minimum weight for the given workload. Fall *et al* (1997a) suggested that the lowest body condition score that could be attained without the risk of causing permanent damage to working oxen was 3. Observations made in this experiment suggest that for light tasks, it may be possible to work with oxen having condition scores less than 3 provided feeding while they are working is good enough to prevent further weight loss or allow them to regain. The observations above tend to provide proof of the hypothesis that there is a minimum live weight to force ratio below which work capacity is impaired. However it is practically difficult to reach the minimum live weight due to the obvious threat that may be imposed to the animal's life.

The observations made here on the work performance of the animals on the low energy diet (week 1-7) and the low body condition score (weeks 8-14) show the importance of body weight on working capacity. Although the body condition scores of the animals were decreasing during weeks 1-7, this did not affect their working which remained almost uniform throughout the whole experimental period. The animals receiving low energy diet were losing weight continuously during week 1-7. The same animals continued to gain live weight while working when the energy level in their diet was more than doubled during week 8-13. This shows that it is possible to allow animals to lose weight while working without affecting their work performance. It also shows that it is possible to begin working with animals that had previously lost live weight and attain good work performance as long as they are provided with good quality food while working. The results of this experiment seem to agree with the conclusion drawn by Bartholomew *et al* (1994) that body weight is a more useful indicator of capacity for work than body condition. For example, consider draught cattle of two contrasting sizes, a small-sized breed weighing 350 kg (this will be a mature animal having good body condition) and a large-sized breed weighing 350 kg (this could be a growing animal in good condition or a mature animal having poor body condition). In order for draught oxen to work without subjecting them to unnecessary strain, they need to be loaded so that they pull with a draught effort not exceeding 12 % of their body weight. Suppose there is a loaded sledge requiring a draught force of 480 N to be pulled. This means that the small-sized mature ox having good body condition will pull the load with difficulty or even fail to do the work because of being overloaded. The heavier animal having poor or good body condition could however comfortably pull the load because of its weight. Fall *et al* (1997a) made similar observations whereby live weight but not body condition affected work performance and live weight losses did not have detrimental effect on work performance. Although animals could still work with a body condition score as low as 2.5, it would seem appropriate to consider a body condition score of 3 as the minimum for working animals. Findings of this experiment provide proof of the hypothesis that work output is a function of body weight rather than body condition therefore feeding in order to maintain or improve body condition in draught cattle is not necessary. Previous studies (Bartholomew *et al*, 1994; Fall *et al* 1997a) provided similar evidence. Working draught oxen in semi-arid areas could be subject to work without supplementary feeding during the dry season or early rain season when there are very limited amounts of food available for them. It is however important that the animals are properly matched to their implements according to their live weights. If the oxen have reasonable condition at the start of the working period, they could be worked over short periods relying on whatever feed is available for them. Any losses in body weight resulting from such working could be regained when sufficient feed becomes available after the rains. If on the other hand the oxen have poor condition at the beginning of the work season, they could still be used for work if additional feed is available to provide them with the additional energy demanded by the work.

Heavy oxen in treatment 1 gained weight (63g/d) but light oxen in the same treatment lost weight (183g/d). This is different from findings of experiment 1 in this thesis (see section 2.2.5) where heavy oxen lost weight and light oxen gained weight when all were subject to the same feeding regime, management and working conditions. The energy supply to animals in this experiment was lower than that of animals in the experiment 1. Francis and Ndlovu (1995) reported findings that agree with this experiment when oxen were fed on low or high-energy diet, and ploughed in winter or spring. It appears that the effects of level of energy supply on live weight change and working of draught oxen requires further investigation.

The live weight changes calculated from energy balances gave best estimates for oxen in treatment 2. Although there were discrepancies between observed and estimated live weight changes, small teams seem to allow better individual estimates than estimates made from animals working in large teams. When these findings are combined with those of experiment 1 (section 2.2.5) it could be deduced that it becomes increasingly difficult to establish the proportion of work done by each individual animal as the number of animals in a team increases.

# CHAPTER 3

# STRATEGIES TO IMPROVE EFFECTIVENESS OF SUPPLEMENTARY FEEDING FOR WORKING CATTLE IN SEMI-ARID CROP/LIVESTOCK SYSTEMS

## *3.1. Introduction*

Working animals require good quality food in order to meet their maintenance requirements as well as the extra energy needed for work. Failure to supply the extra energy demand for work in the ration may force the animals to mobilise their body tissues for energy, leading to loss in their body weights. Findings from experiment 2 in this thesis as well as previous studies (Fall *et al*, 1997a; Bartholomew *et al*, 1994) showed that work oxen could begin working having lost body weight and/or continue losing body weight while working without affecting their work performance. However severe losses of body weight may adversely affect the working capacity of the animals or endanger their health. In situation where other outputs such as meat, milk and calves are also expected from draught cattle or if they are to be sold for cash after the work is finished, any loss of weight needs to be avoided if all production functions are to be maintained. For example, both Matthewman (1987) and Pearson *et al* (1999) reported the growing use of cows for draught purposes, hence the need to consider milk production and reproductive functions in addition to work output when planning their feeding. In this case a good quality diet may be needed to ensure that work does not compromise the other productive functions of milk production or calf production. Zerbini, Alemu Gebre Wold and Shapiro (1999) pointed out that work with inadequate feeding would not be a feasible option for production systems involving cows for draught. If oxen begin working with poor conditions, then it is better to feed a good quality of diet during work to minimise further weight loss which in an already thin animal may compromise its working capacity or even health. The dietary demands in terms of quality and quantity for feeding draught oxen will be determined mainly by the outputs expected from them.

The main kinds of food available for feeding work oxen in tropical semi-arid areas consist of natural pastures and cereal crop residues. The feeding quality of both of these two feeds is poor and quantities available on the fields during the dry season are mostly not sufficient to meet demand. One strategy that small holder farmers in semi-arid areas could adopt in order to overcome or lessen the problems connected with shortage of food for their work oxen is to conserve some food. Cereal crop residues are one source of food that could be set aside for strategic feeding of working cattle to ensure good work performance during the ploughing season. However most cereal crop residues are poorly digested, they are bulky and ferment slowly in the rumen leading to very slow rates of passage. Animals cannot therefore consume and digest enough to derive adequate amounts of nutrients for maintenance let alone for work and other production functions. In addition, once the residues are stored, it is likely that their quality will deteriorate even further. It would therefore be advantageous to provide supplements when draught cattle are fed on crop residues or other poor quality roughages. An aspect, which needs to be explored, is the appropriate time for supplementing working cattle in relation to work. We also need to consider practical ways of improving consumption and digestibility of the crop residues by working cattle so that energy requirements for work can be met with minimal weight loss. To address the situations, two experiments were conducted: (1)

to investigate the appropriate time for supplementation relative to the working period when cattle are fed on poor quality fodder, and (2) to assess the effects of three supplements on intake and digestibility of maize stover, a poor quality fodder, and their influence on work performance of oxen.

### *3.2. Experiment 3*

### *Assessment of the effects of different strategies of supplementing draught cattle on their work performance*

#### 3.2.1. Introduction and literature review

Provision of supplementary feeding during the dry season to oxen fed on crop residues or other poor quality roughage has often been recommended. Supplements that could be available for this purpose vary from one place to another but in general they take the form of high quality purchased fodder or concentrate mixtures or industrial by-products or poor quality conserved fodder, standing hay on the fields or crop residues. The decision on which supplement to use and when to start feeding the animals relative to the working period will depend on the circumstances surrounding the farmers in terms of resources and the strategy that they have in mind. For example, feeding supplements for a long period before working commences could allow draught oxen to maintain their body weights or to build up their energy reserves and these will become available for mobilisation during working. However this could prove to be an expensive option since it may require large quantities of food and a high demand for labour to handle it. Another possibility is to offer supplements only during the time when the oxen are working. The extra feed will in this case provide part or all the energy needed for work. If the supplement used is bulky, it may not be possible for working animals to consume sufficient quantities to meet their requirements. This may be due to the physical limitation imposed by the capacity of the rumen, slow rate of digestion and hence passage through the gasto-intestinal tract and/or the shorter time in the day available for feeding when the animals are working.

The essence of providing supplements to draught oxen when working for a long time as opposed to working for short periods is a subject that has been debated at length (see section 3.2.1.1). Information that is documented regarding different strategies for feeding supplements to working cattle relative to the working period is not complete. The experiment reported here had the objective of assessing the effects of supplementing working oxen on their work performance and body weight changes when supplements were fed for a period before beginning to work, as well as during work, compared to feeding them the same supplements only during the working period at twice the previous rate.

#### 3.2.1.1. Effects of supplementing draught oxen on work performance

In on-farm supplementation trials in Zambia, Meinderts *et al* (1999) reported that farmers observed faster and harder working, longer working hours and more ploughed land per week when they supplemented their oxen with groundnut stover (2-10 kg fresh weight depending on availability of grass and browse). Bartholomew *et al* (1993) supplemented zebu oxen at different levels before they began working and attained weight changes of –25, +35 and +70 kg. During work all oxen received *ad lib* bush hay and 1 kg cottonseed residue daily. Results showed that supplementation of oxen during the dry season increased their work capacity by 28 % between extreme treatments. They estimated that the energy requirement for weight changes of –25, +35 and +70 kg over the 3 month period was 83, 129 and 163%, respectively of the maintenance energy requirement for an ox of 280 kg. In another study, Bartholomew *et al* (1995) calculated that the estimated energy requirement by oxen working in the field was 1.44 x maintenance. They further noted that the estimated total energy requirement for work for an ox of average live weight (280 kg) assuming 22 days of cultivation was 1080 MJ, an amount of energy that was equivalent to the maintenance requirement of an animal of average live weight of 325 kg for 29 days. Considering the findings of the two studies, it was difficult to justify dry season feeding in order to establish or maintain body energy reserves for use during the working period. They felt that additional energy required during the working period could as well be supplied from conserved forage than from body fat reserve on the animal produced through dry-season supplementary feeding. In Mali, Bartholomew *et al* (1994) reported that oxen of 360 kg live weight and medium body condition achieved 93% of the daily work output of similarly weighed oxen with good body condition, without the need for high levels of supplementation before a working period which lasted 9 days. Fall *et al* (1997a) observed no effect of weight losses on work output when oxen of different body conditions were subject to 28 days of work over a seven week period. They argued that supplementary feeding to prevent the weight losses over short period working was not necessary since the animals could work while losing weight and regain their live weight rapidly after work. The authors noted that there could be justification in favour of dry season supplementation in situations where oxen do heavy work continuously for periods exceeding 6 weeks. Francis and Ndlovu (1995) supplemented working oxen with cob sheath and groundnut stover (3:2 mixture) at a high level (800g/head/day) for a short period (5 weeks) or at low level (400g/head/day) for a long period (10 weeks) before beginning to work. In both cases they reported beneficial results in terms of live weight changes, work and power output, and area ploughed. However their results did not show any significant differences between a long period and low level or a short period and high level of supplementation before work. They concluded that whatever the supplementing strategy, farmers should aim to at least maintain their animals at a reasonable live weight before they start working. Even when considering time of the day to feed a supplement relative to the time for work, Francis *et al* (1994) reached the conclusion that there was no difference on the outcome whether draught oxen fed mainly on crop residues were supplemented with crushed maize grain just before, or a few hours before, working. The supplementing strategy did not have any effect on work performance or body weight change.

### 3.2.1.2. Feeding strategies for draught oxen

Different strategies for feeding draught oxen have been adopted in different areas depending on resource availability and patterns of working. Pearson and Smith (1994) acknowledged the presence of variations in the economics of dry season feeding with location and pointed out that with short working periods, supplementary feeding in the dry season may not be cost effective, but where cattle work for longer periods and spend considerable time moving loads, economic returns may be considerable. Bamualim and Kartiarso (1985) suggested that work animals kept under the rice production systems of Asia could be maintained on rice straw, with or without protein supplement in the form of fodder tree leaves when not working, and then allowed to graze grasses on rice dykes (bunds) or available marginal land during working to obtain additional requirements for work. Where draught oxen are used in year-round cropping systems, Ffoulkes and Bamualim (1989) recommended that concentrates high in rumen-undegradable protein be included in their diets, especially when they are to be subjected to periods of hard work. Egan and Dixon (1993) made a similar recommendation and insisted that supplementation should be done all the time for animals used all year-round. Wanapat (1989) advised on supplementation of work animals grazed on low-quality roughage with urea-treated crop residues during the dry season to ensure better rumen ecology and better body condition at high peaks of workload at the end of the dry season in rain-fed agricultural systems. Egan (1989) emphasised on the objectivity of the animal owners in planning their year-round feeding programmes to realise the full value of crop residues. The author insisted on the farmer's ability to match feeds available anytime with feed requirements for the particular pattern of live weight change projected. Tennakoon (1986) as quoted by Pearson and Smith (1994) advanced the idea of preference in supplementing draught oxen at the expense of other livestock to ensure regularity in working of animals to meet the farmer's cultivation requirements. Fall *et al* (1997d) noted that the feeding strategy for oxen in semi-arid areas will be determined by availability and feeding value of feeds, type and duration of work, climatic environment and farmer's objectives. They questioned use of expensive supplements and insisted on using low-cost feed resources to reduce weight loss during the dry season. They recommended that improvements need to be made in feed conservation, and amounts of poor quality roughage offered to work animals need to be increased so as to improve their selection of more palatable parts. Also they advocated use of urea or other non-protein nitrogen sources to enhance digestion of roughage by improving supply of nitrogen to rumen micro-organisms and advised on the use of supplements only when work period exceeds 6 weeks. This experiment tested the hypothesis that supplementary feeding of draught oxen prior to work during the dry season is not necessary, provided the oxen are assigned tasks demanding draught efforts that fall within their capacity, as determined by their live weights and provided the animals are fed sufficient food to meet their energy requirements during work.

## 3.2.2. Materials and methods

### 3.2.2.1. Experimental site

The experiment was conducted at the livestock section of the research farm of the University of Fort Hare, Alice between May and August (winter season) 1998.

### 3.2.2.2. Experimental plan

The experiment consisted of two treatments. In the first treatment oxen were given supplements for seven weeks before beginning to work and for seven weeks while working. The supplements given were cob meal (1.5kg/head/day) and lucerne (0.5kg/100kgLW/day). Oxen in the second treatment received the same supplements for the seven working weeks at twice the amount given in the first treatment. Amounts of supplements offered to animals in the second treatment were 3kg/head/day of cob meal and 1kg/100kgLW/day of lucerne. Animals in both treatments were fed on restricted amounts (equivalent to 0.8 x their maintenance energy requirements) of the same basal diet of *Chloris guyana* hay.

### 3.2.2.3. Animals and management

Twelve oxen of mixed breeds aged 4–8 years were used for this experiment. The oxen weighed on average 456 kg (380 to 550 kg). Table 3.1 shows the animals, their nutritional treatments, working teams, live weights at start, estimated age and breeds.

**Table 3.1. Experimental animals in their treatments, working teams, and their live weight at start**

| Treatment | Team | Ox No. | Live weight (kg) | Est. age, (yrs) | Breed | Category |
|---|---|---|---|---|---|---|
| 1 | 1 | 31 | 380 | 4 | Nguni | Light |
| 1 | 1 | 34 | 388 | 4 | Nguni | Light |
| 1 | 2 | 7 | 536 | 8 | Friesian-Nguni cross | Heavy |
| 1 | 2 | 8 | 480 | 8 | Friesian-Nguni cross | Heavy |
| 1 | 3 | 10 | 408 | 5 | Nguni | Medium |
| 1 | 3 | 12 | 486 | 6 | Nguni | Medium |
| 2 | 4 | 1 | 546 | 7 | Brown Swiss cross | Heavy |
| 2 | 4 | 2 | 550 | 7 | Brown Swiss cross | Heavy |
| 2 | 5 | 3 | 414 | 5 | Afrikander | Medium |
| 2 | 5 | 4 | 404 | 5 | Nguni | Medium |
| 2 | 6 | 9 | 444 | 6 | Nguni | Medium |
| 2 | 6 | 11 | 448 | 6 | Nguni | Medium |

The oxen were individually housed on concrete floored pens with separate water and food troughs. Feeding was done in the morning after cleaning or on working days after all the animals had completed work.

Drinking water was available to the animals *ad libitum* while penned. The animals were assigned to treatments according to their body weights so that heavy and light animals were balanced in each treatment and as far as their pairing for working could allow. Cleaning of the pens was done daily.

#### 3.2.2.4. Diets

The basal diet which was fed to all oxen consisted of a restricted amount of *Chloris gayana* hay (calculated for each animal to supply 0.8 x maintenance energy requirements). Supplements used in this experiment were lucerne and cob meal, the latter was prepared by hammer milling maize cobs together with their grain. The daily rations for animals on each treatment were as shown in Table 3.2.

**Table 3.2. Composition of the rations used for oxen supplemented before and during working (week 1-14) in treatment 1 and those supplemented only during working (week 8-14) in treatment 2**

| | **Treatment 1** | **Treatment 2** | |
|---|---|---|---|
| | **(weeks 1-14)** | **(weeks 1-7)** | **(weeks 8-14)** |
| ***Chloris gayana* hay** | 0.8 x maintenance energy | 0.8 x maintenance energy | 0.8 x maintenance energy |
| **Lucerne** | 0.5 kg / 100 kg M | 0 | 1 kg/100 kg M |
| **Cob meal[1]** | 1.5 kg | 0 | 3.0 kg |

[1] For each animal mixed with 7 g salt and 100 g monocalcium phosphate per day

### 3.2.2.5. Working

Animals worked in pairs. Working consisted of each pair pulling a loaded metal sledge along the same farm route with all pairs working at the same time four days per week. The load for each team of oxen was calculated so that they all exerted the same draught effort per unit of initial live weight - equivalent to 10% of their weight. Work began at 0800 h daily and continued until a distance of 15 km had been covered or when 4 h of working were completed. A working session for a team was terminated when one or both of the animals began showing signs of distress or refused to continue working.

### 3.2.2.6. Measurements

#### 3.2.2.6.1. Live weight

Live weights were recorded three times per week before working or feeding the animals.

#### 3.2.2.6.2. Food intake

Weighing and sampling of food was done weekly. Every morning before cleaning any food remaining from the previous day ration was collected for each animal separately, weighed and sampled. All feed and refusal samples were dried to a constant weight in a forced air oven at $60^0$C to determine dry matter content from which daily voluntary dry matter intake was calculated. Sub-samples were taken from the dried daily refusal samples and these were pooled every week. Weekly food and refusal samples were ground through a 1 mm screen and stored for laboratory analysis.

#### 3.2.2.6.3. Work

Every working day an ergometer (Lawrence and Pearson, 1985) was used to record work output of one of the teams. This was done on a rotational basis. The distance travelled and speed of each team was calculated daily during work from times which were recorded when each team of working oxen passed set points marked along the route at 1 km intervals.

### 3.2.2.7. Energy balances

The average daily energy balance of each individual animal and average balance for each team over the working period were calculated using information obtained from feeding standards for working cattle (Lawrence and Pearson, 1999). The ME content of *Chloris gayana* hay and lucerne was 7.7 and 7.8 MJ/kg DM, respectively. Energy content of cob meal used in calculating energy balances was 11 MJ/kg DM (Topps and Oliver, 1978). Heat increment was considered to be 32%. Assumptions for energy cost of walking were the same as those made in experiment 1 (section 2.2.3.7) because of similarity in working conditions. The amount of work done by a team of oxen on those days that direct recording was not done was estimated from distance travelled and the average draught force recorded for the team in the same week. Estimates of live weight change made from the standards were compared with observed live weight changes.

### 3.2.2.8. Data analysis

Data collected from this experiment was subject to analysis of variance using the General Linear Models (GLM) procedure of the Statistical Analysis System (SAS) to test effects of treatment, weight category (the blocking factor) and the interaction of weight category x treatment on live weight, work output, speed, power and draught force in the following statistical model:

$Y_{ijk} = \mu + \alpha_j + \beta_k + \alpha\beta_{jk} + \varepsilon_{ijk}$

where $Y_{ijk}$ was the dependent variable ( live weight change, work output, speed, power or draught force )

$\mu$ was the overall mean

$\alpha_j$ was the effect of the $j^{th}$ treatment ( j = 1, 2 )

$\beta_k$ was the effect associated with the $k^{th}$ block ( k= 1, 2; 1= light; 2= heavy )

$\alpha\beta_{jk}$ was the interaction between the $j^{th}$ treatment and the $k^{th}$ block, and

$\varepsilon_{ijk}$ was the error term for the $i^{th}$ team of oxen in the $j^{th}$ treatment and the $k^{th}$ block.

### 3.2.3. Results

#### 3.2.3.1. Live weight change

Figure 3.1 shows average weekly live weights of oxen in the two treatments over the whole experimental period. Oxen that received the supplements throughout the period of the experiment (treatment 1) gained weight during the first 7 weeks when they were not working. During work (week 8-14) oxen in the first treatment at first lost weight (weeks 8-10) and then their average body weight remained stable up to the end of the working period. Animals that received no supplements for the first 7 weeks (treatment 2) lost weight (up to 34 kg or 9 %) during this time but they regained it during the working period when they were fed on supplements.

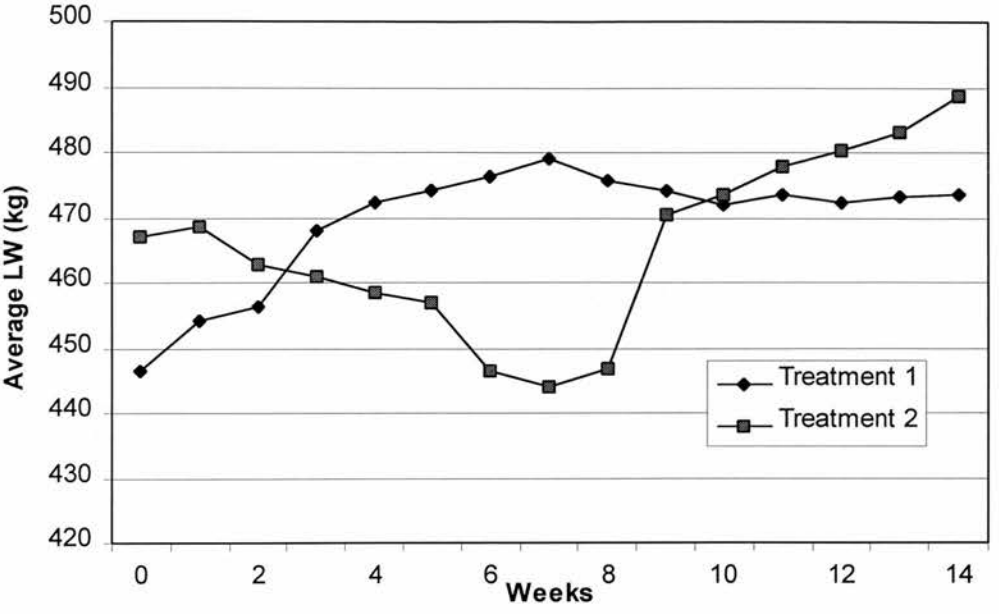


**Figure 3.1: Weekly average live weights of oxen on treatment 1 (supplemented before and during work i.e. week 1-14) and treatment 2 (supplemented during working i.e. last 7 weeks)**

Table 3.3 compares average weekly live weight changes of heavy and light oxen in each treatment as well as the overall change for each treatment. Heavy oxen lost

**Table 3.3. Average live weight at start, weekly average live weight gains (±sd) and proportional weight gain of heavy oxen, light oxen and all oxen in each treatment**

| | Heavy oxen | Light oxen | All oxen |
|---|---|---|---|
| **Treatment 1: LW (start, kg)** | 509± | 384± | 447± |
| **Gain (kg)** | 2.14±4.72 | 1.76±4.03 | 1.95±3.95 |
| **% Gain** | 0.42 | 0.46 | 0.44 |
| **Treatment 2: LW (start, kg)** | 547± | 410± | 479± |
| **Gain (kg)** | 1.60±7.99 | 1.51±7.66 | 1.54±7.66 |
| **% Gain** | 0.29 | 0.37 | 0.32 |

proportionately less weight than light animals in both treatments. The overall average weekly live weight change of oxen in treatment 1 was higher than that of treatment 2 but the difference between the two was not statistically significant ($p>0.05$).

### 3.2.3.2. Chemical composition of feeds and refusals

Table 3.4 shows the average composition of offered feeds and refusals collected. All animals consumed all feed that was offered during the first 7 weeks of the experiment. In the second part of the study (week 8-14), the animals that were given supplements only during this period could not finish their rations between week 8-12. The collected lucerne refusals had higher contents of fibrous material and less crude protein compared to offered material while Rhodes grass refusals had less fibre and similar content of crude protein compared to that offered.

**Table 3.4. Average composition (g/kgDM) of feeds offered to all oxen, lucerne refusals (week 8-9) and Rhodes grass refusals (week 8-12) from oxen supplemented only during work (treatment 2), (±sd)**

| | DM g/kg | NDF | ADF | Hemi-cellulose | Crude Protein | Ash | Acid Insoluble Ash |
|---|---|---|---|---|---|---|---|
| **Lucerne** | 951±4 | 581±35 | 407±29 | 174±8 | 139±11 | 72±2 | 7±5 |
| **Rhodes grass** | 952±4 | 779±28 | 432±6 | 347±25 | 105±2 | 64±2 | 33±3 |
| **Refusals** | | | | | | | |
| **Lucerne (week 8-9)** | 954±2 | 668±73 | 482±49 | 185±34 | 101±19 | 62±9 | 9±6 |
| **Rhodes grass (wk 8-12)** | 958±3 | 745±31 | 417±13 | 328±32 | 102±5 | 62±4 | 48±19 |

#### 3.2.3.3 Work performance

Table 3.5 shows the average work output from oxen in the two treatments. There was no statistically significant difference ($p>0.05$) in the average daily work done, distance covered or speed of walking of oxen on the two treatments. Except for one team of animals (team 6) in treatment 2, all oxen managed to complete the set distance all the time during the experiment. All oxen that were supplemented only during working (treatment 2) completed the working day with some difficulty during the first week of working. There was a tendency for these oxen to become tired compared to their counterparts and they needed more pushing from their drovers. Animals in team 6 (Table 3.1) of treatment 2 could not complete the set distance and moved slowly compared to the other teams of oxen during four out of the first six days of working.

**Table 3.5. Average live weight at start and average work performance parameters (±sd) for oxen in treatment 1 (supplemented before and during) and treatment 2 (only supplemented during work). See text for details of dietary treatments**

| Parameters | Treatment 1 | Treatment 2 |
|---|---|---|
| **Average live weight (start), (kg)** | 446±57.8 | 468±58.9 |
| **Average daily work (MJ)** | 11.2±1.2 | 11.7±1.2 |
| **Distance covered (km)** | 14.6±0.2 | 14.2±0.9 |
| **Draught force (N)** | 776±72.2 | 832±47.9 |
| **Power (W)** | 1042±71.0 | 1078±76.5 |
| **Speed (m/s)** | 1.4±0.04 | 1.3±0.02 |

The animals in teams 5 and 6 of treatment 2 (Table 3.1) appeared weak with visibly poor body condition compared to their counterparts in team 4 of the same treatment. While oxen in team 5 improved in their physical appearance, animals in team 6 remained weak throughout the working period although this was not reflected in the body weights that were increasing. Differences in the overall average daily work output, power developed and average daily speed of oxen teams in the two treatments were not statistically significant ($p>0.05$).

### 3.2.3.4. Energy balances

Table 3.6 shows the average daily energy balances for oxen teams under the two dietary supplementary treatments and the average daily balance for each treatment over the working period. All live weight changes calculated from energy balances

**Table 3.6. Average daily energy balances over the working period of oxen teams in treatment 1 (supplemented both before and during work) and those in treatment 2 (supplemented only during work) and average daily balance (±sd) for each treatment**

| Treatment | Team | LW start kg | NE intake MJ/d | NE maint MJ/d | NE work MJ/d | Total NE exp. MJ/d | NE balance MJ/d | Est. LW change g/d | Observed LW change g/d |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 (ox31,34) | 384 | 42.7 | 37.9 | 13.4 | 51.3 | -8.5 | -783 | -149 |
| 1 | 2 (ox 7,8) | 508 | 53.3 | 46.7 | 17.6 | 64.3 | -11.0 | -857 | -208 |
| 1 | 3 (ox10,12) | 447 | 48.4 | 42.4 | 16.8 | 59.1 | -10.7 | -934 | 54 |
| Team av. (± sd) | | 446.3± 50.6 | 48.1± 4.3 | 42.3± 3.5 | 15.9± 1.8 | 58.2± 5.3 | -10.1±1.1 | -858±62 | -101±112 |
| 2 | 4 (ox 1,2) | 548 | 69.9 | 47.5 | 18.9 | 66.4 | 3.6 | 183 | 834 |
| 2 | 5 (ox 3,4) | 409 | 60.9 | 39.2 | 15.8 | 55.0 | 6.0 | 365 | 792 |
| 2 | 6 (ox 9,11) | 446 | 62.6 | 41.2 | 15.7 | 56.8 | 5.8 | 337 | 768 |
| Team av. (± sd) | | 467.7 ±58.8 | 64.5 ±3.9 | 42.6 ±3.5 | 16.8 ±1.5 | 59.4 ±5.0 | 5.1 ±1.1 | 295 ±80 | 798 ±27 |

were lower than the actual recorded changes. Oxen fed supplements both before and during the working period (treatment 1) showed negative average energy balances. Two teams of oxen in treatment 1 (team 1 and 2) lost weight while team 3 gained weight. All animals in treatment 2 gained weight and all their live weight estimates were also positive.

### 3.2.4. Discussion

This experiment showed no difference in work performance between oxen supplemented before and during work and those supplemented only during work, although the latter had lost up to 9% of their initial live weight. The animals that were not supplemented before work had began the working period with relatively inferior body conditions, and they completed the working day with some difficulty during the first week. The oxen were slow and needed more push, the effect being particularly observed on animals that had smaller body sizes compared to their counterparts on the same treatment. Bartholomew *et al* (1995) made similar observations whereby during the dry season, oxen over a wide range of live weights lost on average 50 kg of their rainy season live weights without it adversely affecting their working performance. When assessing the effects of live weight and body condition on working capacity of Zebu oxen, Bartholomew *et al*. (1994) concluded that body weight as indicated by body size was the main indicator of capacity for work rather than body condition under short season working conditions. In this experiment all animals were subject to the same stress of work by making each team pull a load that was proportional to their combined live weight at the start of the experiment. It would seem therefore that oxen that worked erratically during the first week had a lower capacity for the given work until after the first week when they gained weight and restored their capacity for working. The ox teams that seemed to be affected had lower initial body weights (smaller body sizes) compared with the team (on the same treatment) that was not affected. Francis and Ndlovu (1993, 1995) made similar observations, whereby heavy oxen lost less weight and out-performed light ones in working.

In this experiment oxen that were not given any supplement before the beginning of the working period lost up 9 % of their initial live weight within the first seven weeks. The same group of animals regained their initial body weights within two weeks of supplementation and continued to gain while they were working. This shows that it may not be essential to feed on supplement to work oxen fed on poor quality roughage before the work period begins. As long as feeding during working is adequate, the animals that might have lost body weight before beginning to work could quickly regain it while working. Feeding supplements to work oxen in semi-arid areas could therefore be planned to ensure that the animals are ready for work at the appropriate time, avoiding supplementation over a long period because that may not be essential to the animals. Fall *et al* (1997d) and Bartholomew *et al* (1994) recommended that oxen should be supplemented when the working period exceeds six weeks to avoid impairment of work capacity. In this study it would have been very unlikely for some of the oxen that were not supplemented before working, to withstand the given workload if they were not fed supplements during working, even if the working period was short. Evidence for this could be deduced from observations made in experiment 2 (section 2.3.4.1. and 2.3.5.) in this thesis in which animals had to be withdrawn from work due to weight loss that threatened their capacity for working. Work performance of some of the oxen that were not given supplements before the work period was erratic during the first week of work. Without supplementary feeding it is unlikely that these animals would have improved their work output. An important consideration to be taken into account is the condition of the animals at the beginning of work. Even if the working period is short, the results of this experiment suggest that the condition of the animals is crucial in determining whether supplementation is necessary or not. If the animals available at the start are in poor condition, they may not be able to work. There was no differences in overall work performance of animals that were fed supplements only during working and that of those fed supplements both before and during working. This could be attributed to the rapid rate at which the oxen regained lost weight and restored their capacity for work.

Results of this experiment show that both strategies of supplementation had some effects on weight changes that could be beneficial depending on the conditions under consideration. If the aim of supplementing is to ensure that body weight is maintained in order to preserve working capacity, as will probably be the case when dealing with small-sized oxen, it is appropriate to provide supplements for a period before working begins. If on the other hand, there is no risk of lowering capacity for work or dry season feed is difficult to obtain then it would prove more beneficial to use feed resources to supplement only during work, so as to supply only the extra energy needed for work. However, care needs to be taken when deciding on which strategy to adopt. If for example the combination of the basal diet and the supplement is too bulky, the physical limitation posed by the capacity of the rumen may make it impossible for the animals to consume sufficient daily quantities.

Reliable estimates of actual amounts of supplement that could be fed in either situation can be made using the "*Feeding standards for cattle used for work*" (Lawrence and Pearson, 1999). When the animals are to be given supplements only during the working season, it might be a good idea to supplement them for a short period (at least 1 week) before actual working begins. This would allow them to boost their energy reserves and avoid the slow-down that could occur at the beginning of working as was observed in this experiment. This would be important in areas with very severe shortage of feed at the end of dry season and where the plant-growing season is short and the oxen are required to work long hours over a short ploughing/cultivation season. Farmers need to make an assessment of available feed resources, type and number of cattle available for work and their condition, duration of the work season and the amount of work expected from the animals. As seen from experiment 2 it is possible to continue working with animals fed on a low quality diet without interfering with their capacity for work. Although the animals lose body weight, they regain their weight within a short time upon improving their diet. The most important aspect that need to be observed is to ensure that the animals do not lose weight to an extent endangering their health.

Findings of this experiment as well as those of experiment 2 tend to prove the hypothesis that supplementary feeding of draught oxen prior to work during the dry season is not necessary provided oxen are assigned tasks that demand drought forces which fall within their capacity as determined by their live weights and provided that the animals are fed sufficiently during work to meet the energy requirements needed. The significance of live weight should not be underestimated, as seen from the results of this experiment, heavy oxen tend to lose proportionately less live weight than light ones when subject to inadequate nutrition and therefore stand a better chance of preserving their capacity for work. Where farmers have a choice they could be advised to make use of heavy oxen.

## *3.3. Experiment 4*

## *Improvement of the effectiveness of maize stover as a feed for working cattle through supplementation*

### 3.3.1. Introduction and literature review

Farmers in the semi-arid tropical areas have often been urged to make better use of cereal crop residues to alleviate the shortage of food for feeding their working cattle during the peak ploughing time at the end of the dry season. One of the most common and abundant crop residues in the region is maize stover. Large quantities of maize stover are available in most semi-arid areas in the tropics. According to Kossila (1984), when maize is compared with other crops, it produces the largest proportion of residues that could be used for feeding to ruminants. However the nature and nutrient content of stover make it impossible for animals to consume enough quantities for them to obtain adequate amounts of nutrients to meet their requirements. Fall (1995) came to the conclusion that oxen fed on crop residues or on mature roughages in general cannot either increase their intake or improve their efficiency of use of the food eaten to compensate for the extra energy used for work. Weight loss is therefore a constant feature in working oxen relying on poor quality roughages. If corrective measures to minimise the weight losses are not in place at the appropriate times, there is a risk of interfering with working of these oxen or even threatening their health. It is normally recommended to make use of rich sources of nitrogen when feeding ruminants on poor quality roughages to improve digestibility and increase consumption. However as pointed out by Mosi and Lambourne (1982) most of the good sources of nitrogen recommended (such as concentrates and non-pasture supplements) are either not available or cannot be afforded by small holder farmers. An example of cost-benefit assessment of providing supplements to oxen relying on grazing natural pasture came from Ogwang and Xaba (1996). They noted that despite the benefits in weight gain and better body condition resulting from feeding supplements, the overall cost was too high and uneconomical to the farmers. The supplement used in their study was compounded from maize bran, brewers' residue, molasses and common salt. There is a need therefore to encourage farmers to make use of simple locally available nitrogen-rich supplements when using maize stover for feeding their draught oxen. This will enhance feeding value of the stover and therefore increase efficiency of use of this important animal food resource in semi-arid areas. The experiment reported here was aimed at assessing the relative effects of farmer practices of including sunflower cake, cob meal or lucerne, all locally available supplements, on the intake and digestion of maize stover by working oxen. At the same time it was intended to assess any effects the supplements might have on work performance of oxen.

### 3.3.1.1. Chemical composition (and feeding value ) of maize stover

Poor nutritional value with low content of available energy, protein, minerals and vitamins have been listed by Maehl (1997) as one of the major constraints in using maize stover and other crop residues for feeding animals. In addition, Maehl (1997) pointed out that maize stover and other crop residues have poor feeding value usually associated with low palatability, intake and digestibility. The nutritive value of maize stover depends on several factors which according to Kossila (1988) include variety, stage of maturity at harvest, harvesting and handling, stem : leaf ratio and degree of weathering in the field between crop harvest and collection of stover. Table 3.7 shows some nutritional attributes of whole plant maize stover from different places in Eastern and Southern Africa. Generally whole plant maize stover contains very little crude protein and high fibre. The nutritional value of maize stover is characterised by a decrease in crude protein content while the proportion of fibrous constituents increase with increasing stage of maturity. Tolera, Sundstol and Said (1998) attribute the variation in composition to changes in morphological composition and to losses in nutrients within the morphological fractions of maize stover.

**Table 3.7. Chemical composition of maize stover from different areas in East and Southern Africa (g/kg DM)**

| Source | DM (g/kg) | NDF | ADF | Hemi-cellulose | CP | Ash |
|---|---|---|---|---|---|---|
| Shem, Orskov and Kimambo (1993), Tanzania | 860 | 881 | | | 41 | 60 |
| Shem *et al* (1993), Tanzania | 850 | 864 | | | 49 | 59 |
| Ocen (1993), Uganda | 880 | | | | 39 | 65 |
| Mtambuki (1999), Tanzania | | 760 | 450 | | 30 | 90 |
| Musimba (1981) | | 760 | | | 23 | |
| Tolera *et al* (1998), Ethiopia | 926 | 789 | 399 | 390 | 37 | 81 |
| Tolera and Sundstol (1999), Ethiopia | 918 | 769 | 408 | 362 | 37 | 85 |

### 3.3.1.2. Strategies to improve feeding value of stover

A number of strategies have been developed and used in efforts to increase efficiency of utilisation of maize stover and other poor quality roughages by working cattle. Bird *et al* (1989) listed 4 such strategies: (i) Pretreatment with chemicals such as sodium or ammonium hydroxide, anhydrous ammonia, hydrogen peroxide and urea. The chemicals increase digestibility through delignification or swelling of plant cell walls so that rumen polysaccharide degrading enzymes have better access to their substrates. This leads to higher dry matter intake by the animals as a result of increased rate of passage through the gastrointestinal tract. Most of the chemicals recommended for the treatment of crop residues are expensive and unaffordable by the smallholder farmers. Kategile (1982) observed that although it was economically feasible to fatten animals on roughage-based diets, the cost of NaOH was one of the main constraints. Amongst all the chemicals recommended for treating roughage, Mathers and Otchere (1993) identified fertiliser grade urea as the most easily available and relatively easy to use and cheap, although it was not the most effective in improving poor quality roughage. (ii) Use of supplements to either correct nutrient deficiency in the rumen, that may limit fermentation, or to provide rumen bypass nutrients to balance products of rumen fermentation. Effective supplements are those that are nitrogen rich sources (Ffoulkes and Bamualim, 1989). (iii) Manipulation of the rumen microbial population to increase efficiency and extent of fermentation. (iv) Physical treatment of poor quality roughage to increase surface area exposed to microbial attack and accelerate rate of passage through the gastrointestinal tract. Processes include chopping, shredding, grinding and pelleting.

Fall *et al* (1997d) added another strategy of increasing the amounts of stover offered to the animals so that they can select more of the digestible parts.

### 3.3.1.3. Maize stover as feed for working oxen

Methods employed in feeding stover vary from one area to another. Most small holder farmers allow animals to graze on the standing residue on the fields after harvesting, a method which has been criticised for low utilisation rates resulting from excessive wastage due to trampling, soiling, termite damage, leaching and destruction by winds (Berger, Peterson and Klopfenstein, 1979; Alhassan, Kallah and Bello, 1987; Jayasuriya, 1993). It is very difficult to control use under the free grazing method. In other places stover is harvested and stored to be hand fed to the animals at an appropriate time. Mlay (1987) and Maehl (1997) pointed out that the bulkiness of stover is a constraint to its transport and storage. Under stall-feeding, maize stover can be fed to draught oxen as the main diet or as a supplement for oxen that are grazed.

Selection and intake in ruminants fed on maize stover depend very much on level of feeding. Aboud, Owen, Reed and Said (1994) reported a higher level of selection and intake when animals were fed at a level such that the amount of food refused was 50% of the amount offered, compared to those fed at a level such that the amount refused was 20% of the amount offered. The high feeding levels allow the animals to select the more desirable and less fibrous parts of the plants. Aboud *et al* (1994) also reported lower nutritive values of refusals than offered food. When quality of food offered is higher, level of selection by animals tends to decrease. Mtambuki

(1999) reported the same crude protein content in offered maize stover and refusals probably due to the high quality of maize stover.

Some studies have shown that working oxen fed on cereal crop residues alone are unlikely to consume quantities that will be sufficient to provide the extra energy required for working. In one of such studies, Soller, Reed and Butterworth (1991) observed that zebu and crossbred oxen fed *ad libitum* on a diet consisting of 72% cereal straw and 28% grass hay consumed less feed over the working period compared to their consumption of food when not working, although their digestibility of organic matter and neutral detergent fibre were 3% higher during work periods. In another study, Fall *et al* (1997c) reported similar intakes of poor quality food by oxen before and during the working period. The food consisted of millet stover offered *ad libitum,* and each animal was also supplemented with a concentrate mix made up (g/kg) of wheat bran (600), groundnut cake (300) and bone meal (100) at a rate of 21.3 g/kg $M^{0.75}$. In both of these studies, the authors attributed the results on intake to the low nitrogen content of the crop residues and low levels of rumen degradable nitrogen, the latter limiting microbial synthesis in the rumen, the capacity for fibre digestion and hence dry matter intake. Leng (1985) pointed out the low fermentation rate in the rumen, due to low ammonia concentration, as the primary constraint to feed intake of ruminants on cereal crop residues. The low voluntary food intake has been identified as an important constraint to work output by oxen (Mathers and Otchere, 1990). In some studies (Ndlovu *et al*, 1996; Prasad, Khombe and Nyathi, 1996), work oxen were allowed to graze and offered, as a supplement, maize stover with or without a source of nitrogen. Where a source of nitrogen was included there was reduced weight loss and improved work performance.

## 3.3.2. Materials and methods

### 3.3.2.1. Duration and location of experiment

This experiment was conducted between August and November (spring/summer) 1998 at the livestock section of the research farm of the University of Fort Hare.

### 3.3.2.2. Animals and their management

The same twelve working oxen used in experiment 3 were used in this study but their teaming in this experiment was different. Table 3.8 shows the oxen in their working teams, their live weight at the beginning of the study and allocation of treatments during each period of the experiment. The oxen weighed on average 505 kg (ranging between 412 kg and 600 kg). Management of the animals was similar to that in experiment 3. During summer, dipping of all animals was done fortnightly for the control of ticks.

### 3.3.2.3.Experimental design

The experiment was arranged in a 3x3 replicated Latin square design as shown in Table 3.8 with the rows of each square formed by oxen teams (pairs) and the time periods forming the columns. The treatments consisted of three dietary supplements: A) Lucerne B) Sunflower cake C) Cob meal. All oxen were fed on a basal diet of maize stover. The ox teams were allocated in such a way that there was an equal distribution of heavy and light animals in each treatment. Each period lasted four weeks. Animals worked during the last two weeks of each period.

**Table 3.8. Experimental animals, their working teams, live weight at start and allocation of treatments (supplements: A= lucerne, B= sunflower cake, C= cob meal) during each experimental period**

| Team | Ox No. | Live weight (start), kg | Treatment Period 1 | Treatment Period 2 | Treatment Period 3 |
|---|---|---|---|---|---|
| 1 | 1 | 592 | A | B | C |
| 1 | 2 | 596 | A | B | C |
| 2 | 9 | 490 | A | B | C |
| 2 | 11 | 494 | A | B | C |
| 3 | 3 | 458 | C | A | B |
| 3 | 31 | 412 | C | A | B |
| 4 | 7 | 600 | C | A | B |
| 4 | 8 | 536 | C | A | B |
| 5 | 4 | 456 | B | C | A |
| 5 | 34 | 432 | B | C | A |
| 6 | 10 | 452 | B | C | A |
| 6 | 12 | 534 | B | C | A |

### 3.3.2.4. Working

Working consisted of each pair of oxen pulling a loaded metal sledge along the same farm route with all pairs working at the same time four days per week. The load for each team of oxen was calculated so that they all exerted the same draught force per unit of initial live weight - equivalent to 10kgf/100kg LW. Work began at 0830 h daily and continued until a distance of 16.5 km had been covered or when 4 h of work were completed. A working session for a team was terminated when one of the animals began showing signs of distress or refused to continue working.

### 3.3.2.5. Measurements

#### 3.3.2.5.1. Live weight

Weighing of animals was done on Mondays, Wednesdays and Fridays. This was done in the morning before working or feeding.

#### 3.3.2.5.2. Food intake

The amount of stover offered to each animal was estimated to be 30% above the amount consumed on the previous day. Supplements were offered before the basal ration. The amounts of supplements offered per animal were 2.5 kg (approximately 0.25 of a bale) of lucerne or 3.6 kg of either cob meal or sunflower cake. Determination of the amount of each supplement offered was based on information obtained from farmers in the Eastern Cape Province, Republic of South Africa regarding practices they employ in feeding their animals. A sample of stover offered was collected daily and pooled for each week. Every morning the refusals from the previous day's feeding were collected from each animal and weighed. Refusal samples were taken daily. All feed and refusal samples were dried to a constant weight in a forced air oven at 60°C to determine dry matter content. The voluntary dry matter intake of each animal was then recorded as the difference between the dry matter of food offered and the refusal dry matter. The dried daily refusal samples were sub-sampled and pooled for each week. Weekly samples of each supplement were collected in a similar manner. All weekly stover, supplements and refusal samples were ground through a 1 mm screen before being stored for laboratory analysis.

#### 3.3.2.5.3. Work

During each working day the work output of one team of animals was recorded using the ergometer (Lawrence and Pearson, 1985). This was done on a rotational basis and all work and speed measurements were done as in experiment 1.

### 3.3.2.6. Energy balances

The average energy balance of oxen in each team was calculated using information obtained from "*Feeding standards for cattle used for work*" (Lawrence and Pearson, 1999). The ME content of lucerne used was 6.9 MJ/kg DM. Published ME contents of maize stover, sunflower cake and cob meal for South Africa were used in the energy calculations. The values used were 8, 11.1 and 11.0 MJ/kg DM for maize stover, sunflower cake and cob meal, respectively. Heat increment associated with energy transactions and the energy cost of walking used in calculating energy balances was the same as that used in experiment 1 (section 2.2.3.7) and experiment 2 (section 2.3.3.7). The amount of work done by a team of oxen on those days that direct recording was not done was estimated from distance travelled and the average draught force recorded for the team in the same week. Estimates of live weight change made from the standards were compared with observed live weight changes.

#### 3.3.2.7. Statistical analysis

Live weight changes, daily food intake, distance travelled, speed and work output data were subject to analysis of variance for a Latin square design using the following model:

$$Y_{ijk} = \mu + \alpha_j + \beta_k + \gamma_i + \varepsilon_{ijk}$$

where $Y_{ijk}$ was the dependent variable (team live weight change, feed intake, work output, speed, power or draught forces) for the $i^{th}$ team on the $j^{th}$ supplement in the

$k^{th}$ period

$\mu$ was the overall mean

$\alpha_j$ was the effect of the $j^{th}$ supplement ( $j = 1,2,3$ )

$\beta_k$ was the effect of the $k^{th}$ time period ( $k = 1,2,3$ )

$\gamma_i$ was the effect associated with the $i^{th}$ team ( $i = 1,\ldots,6$ )

$\varepsilon_{ijk}$ was the error term for the $i^{th}$ team on the $j^{th}$ supplement and in the $k^{th}$ period

### 3.3.3. Results

Intake of maize stover by oxen on the three treatments was as shown in Table 3.9. The daily mean voluntary dry matter intake of stover was significantly different ($p < 0.05$) between treatments. Treatment x work interaction was not statistically significant ($p > 0.05$). For all treatments average daily intake of stover was significantly higher ($p < 0.05$) on non-working compared to working days.

Table 3.10 shows the results of the laboratory analysis of stover, lucerne, sunflower cake and cob meal that were used for feeding animals in this experiment. The average chemical composition of maize stover refusals collected from animals in each of the three treatments over the whole duration of study are also shown in the table. There were no statistically significant differences ($p>0.05$) in the chemical composition of maize stover refusals from the three treatments.

**Table 3.9. Overall daily average voluntary dry matter intake (DMI) of stover, DMI on working and non-working days, and work parameters (±sd) for ox teams receiving the different supplements (see text for details of amounts given)**

| Parameter | **Treatment A (Lucerne)** | **Treatment B (Sunflower)** | **Treatment C (Cob meal)** |
|---|---|---|---|
| **Intake of stover (kg DM/team)** | $12.5\pm 2.3^{a}$ | $14.9\pm 3.3^{b}$ | $13.6\pm 2.3^{c}$ |
| **DMI stover (g/kg $M^{0.75}$)** | $57.8\pm5.1^{a}$ | $69.2\pm5.9^{b}$ | $64.56\pm2.2^{c}$ |
| **DMI stover work days (kg DM/team)** | $10.9\pm1.4^{a}$ | $13.3\pm1.5^{b}$ | $12.9\pm0.8^{c}$ |
| **DMI stover non-work days (kg DM/team)** | $13.2\pm1.2^{a}$ | $15.7\pm2.2^{b}$ | $14.1\pm0.6^{c}$ |
| **Average team weekly gain (kg)** | -0.46 | 0.54 | 0.33 |
| **Average daily team work (MJ)** | 11.5±1.9 | 13.4±2.1 | 12.6±2.1 |
| **Speed of working (m/s)** | 1.3±0.02 | 1.3±0.03 | 1.3+0.1 |
| **Average draught force (N)** | 835±44 | 862±55 | 831±34 |
| **Average power (W)** | 1060±68 | 1127±105 | 1056±5 |

Means with different superscripts along a row are significantly different ($p<0.05$)

The average working speed of oxen in treatment B was higher than that of oxen in the other treatments, however the differences in average daily speed were not statistically significant ($p>0.05$). Similarly animals in treatment B tended to have higher draught forces and developed more power compared to those in the other treatments, but the differences between treatments were not statistically significant ($p>0.05$).

The differences in average live weight changes of oxen in the three treatments were not statistically significant ($P>0.05$). Oxen in treatment A lost some weight while oxen in the other two treatments gained some weight.

**Table 3.10. Chemical composition (g/kg DM) of maize stover, lucerne, sunflower cake and cob meal used in feeding animals and composition of maize stover refusals collected from animals in each treatment (±sd)**

| Treatment | DM g/kg | NDF | ADF | Hemi-cellulose | Crude Protein | Ash | Acid Insoluble Ash |
|---|---|---|---|---|---|---|---|
| **Refusals** | | | | | | | |
| **A (lucerne)** | 929±5 | 756±29 | 497±18 | 259±22 | 65±4 | 43±1 | 37±14 |
| **B (SFC)** | 931±6 | 751±38 | 494±18 | 256±33 | 67±6 | 45±5 | 48±34 |
| **C (Cob meal)** | 929±4 | 759±31 | 498±10 | 261±22 | 64±6 | 42±4 | 39±21 |
| **Feedstuffs** | | | | | | | |
| **Maize stover** | 929.94 | 746.47 | 485.25 | 261.22 | 68.11 | 41.22 | 34.00 |
| **Lucerne** | 928.81 | 584.58 | 447.01 | 137.58 | 142.12 | 72.27 | 7.53 |
| **SFC** | 968.76 | 377.27 | 267.67 | 109.59 | 352.20 | 61.46 | 2.21 |
| **Cob meal** | 963.58 | 229.28 | 90.31 | 138.97 | 87.44 | 14.37 | 2.05 |

The average daily energy balance calculated for the worked parts of the experiment for oxen in each working team was as shown in Table 3.11. With the exception of one team of oxen (team 6), all teams of oxen irrespective of treatment lost weight during working. Energy balances and changes in live weight calculated using the feeding standards for cattle used for work (Lawrence and Pearson, 1999) were negative for all oxen teams. Except for team 6, live weight changes calculated from energy balances and observed live weight changes were very similar.

**Table 3.11. Average net energy balances of individual oxen in each team during working**

| Team | Aver. Live weight (start), kg | NE intake (MJ/wk) | NE maint. (MJ/wk) | NE work (MJ/wk) | NE exp. (MJ/wk) | NE bal. (MJ/wk) | NE bal. (MJ/d) | Est. Live weight change (g/d) | Actual Live weight change (g/d) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 594 | 416.2 | 342.2 | 173.8 | 516.0 | -99.8 | -14.3 | -1248 | -1536 |
| 2 | 492 | 404.2 | 304.2 | 147.8 | 452.0 | -47.9 | -6.8 | -563 | -965 |
| 3 | 435 | 397.9 | 292.8 | 144.4 | 437.2 | -39.3 | -5.6 | -515 | -333 |
| 4 | 568 | 495.0 | 346.3 | 173.1 | 519.3 | -24.4 | -3.5 | -401 | -441 |
| 5 | 444 | 399.7 | 294.1 | 145.7 | 439.9 | -40.2 | -5.8 | -607 | -667 |
| 6 | 493 | 387.1 | 309.1 | 157.9 | 466.9 | -79.9 | -11.4 | -1085 | 179 |

### 3.3.4. Discussion

It has been established that maize stover alone cannot provide enough nutrients for working oxen to cater for their maintenance and work energy requirements and that nitrogen-rich supplements are needed when stover is the main diet (Ffoulkes and Bamualim, 1989). Considering the live weight changes observed in this experiment as the criterion for assessing the three supplements used in feeding the oxen, they could be listed as sunflower cake, cob meal and lucerne in the order of their relative effects. The average weekly live weight changes showed that animals supplemented with lucerne lost a little weight while those supplemented with either sunflower cake or cob meal gained a little weight. The superior performance of animals supplemented with sunflower cake could be attributed to its higher crude protein and energy content compared to cob meal and lucerne. Normally lucerne hay has a higher crude protein content than cob meal, but its energy content was lower in this experiment than the cob meal. This might have been the reason for loss of weight when stover was fed with lucerne. Among the three supplements, cattle fed on lucerne showed the lowest intake of maize stover. This could be attributed to the bulky nature of Lucerne limiting space available for stover in the rumen.

Voluntary dry matter intake is one of the key factors to be considered when using crop residues to feed working oxen. In this experiment voluntary dry matter intake of stover by animals in all treatments tended to be higher on non-working days. Pearson and Smith (1994) observed that daily dry matter intake of animals prevented from feeding for four hours everyday was not affected. Similarly Fall *et al* (1997c) noted that work did not influence intake of stover when oxen worked for 4 hrs per day (as in this experiment) pulling weights equal to 12.5kgf/100kg LW. The number of hours worked per day in this experiment was at most four hours, and all animals worked for the same duration, therefore there is no reason to suspect any connection between amount of maize stover consumed by animals in any treatment with time of available access to feed. This means that any differences in amount eaten are likely to be due to the effects of the supplements on utilisation of maize stover. At a daily food allowance adjusted to 30 % higher than the amount consumed the previous day, intake was 57.8-69.2 g/kg $M^{0.75}$ . Fall *et al*. (1997c) obtained very similar intakes (65.5 g/kg $M^{0.75}$) when feeding millet stover to oxen working for 5 hr/day at a daily allowance adjusted for refusals that amounted to 50 % of food offered. The similarity of intake in this case (Fall *et al,* 1997b), where animals worked longer than that observed in this experiment, could be due to the higher allowance (50%) in the former compared to the 30% allowance in the latter. In order to allow working oxen enough time to feed, it could be good practice to ensure that work begins early so that it also ends early enough to give the oxen enough time for feeding before dark. This is especially relevant where the animals are able to graze only during daytime, and are kraaled at night.

The supplementation with sunflower cake, lucerne or cob meal to the oxen fed on maize stover had no influence on their work performance. The results showed that the farmers' practices of feeding led to sunflower cake being relatively more effective than cob meal which was in turn more effective than lucerne in improving utilization of maize stover and live weight gains by working oxen.

# CHAPTER 4

## CONCLUSIONS AND RECOMMENDATIONS

### *4.1. Effects of workload on working and live weight change*

The experiment with draught oxen that were fed at the same level, doing different kinds of work in teams of four suggested that the efficiency of use of dietary energy for work increased with the increase in workload. It was established that heavy workload led to the oxen becoming less selective in the diet they were consuming. The speed of working decreased with the increase in workload. It was also established that oxen tended to increase their speed of working on the last stretch towards the end of the morning working session irrespective of their workload. This suggested that the hypothesis that energy expenditure for work declined in a consistent and predictable manner as the working day progressed irrespective of work being done was not valid. It seems that the type of work being done can influence the pattern of energy expenditure over the working day. Individual energy balances of oxen doing the different workloads suggested further that there was unequal distribution of the total work done amongst the members of a team.

### *4.2. Effects of the supply of energy on working*

During studies on the effects of energy supply on working, oxen responded to increased energy supply by increasing their speed of working. Observations made tended to support the hypothesis that there is a critical minimum live weight for a given workload below which work capacity is impaired. It was not possible however to reach this minimum because of the potential danger to the animal's health. A body condition score of 2.5 could be regarded as the cut-off point before an animal is no longer capable of working safely. In order to ensure a reasonable health safety, it is recommended that a body condition score of 3 be considered as the lowest permissible for working oxen.

When working begins with oxen having low body condition scores, it is necessary to ensure that they are fed sufficiently to supply the energy needed for work to prevent further weight loss. The workloads given to the oxen should correspond to their live weights.

The study showed that energy needed for work could be drawn from body energy reserves or from offered food with equal efficiency. Farmers could therefore feed their draught cattle to ensure that they build enough body reserves for use during working or ensure that the supply of energy during work is sufficient to meet requirements. In the former situation, it means that the oxen will start the working period with good body condition scores and could be fed whatever feed is available while they are working. In the latter situation, the oxen will likely start the working period with poor body conditions and depending on the amount of food offered, they may gain body weights while working. This is important if the animals are intended for sale immediately after the working period or if young animals are being used, in which case the extra supply of food will be used for growth. Where cows are used for work, it is necessary to ensure sufficient feeding both before and during work if the cows are pregnant or lactating. If oxen reach the working period with low body condition scores, they could still be used for working without supplementing them, provided they have not reached their minimum live weights for work. This may be achieved by making use of large teams of oxen so that the amount of energy drawn from each animal is reduced.

It could be concluded that whether energy required for doing work is stored in the animals or supplied through feeding depend on prevailing circumstances. If the pre-work conditions are such that animals will begin working with very poor conditions that may threaten their health or capacity for working, it may be reasonable to feed them so that they build their body reserves for use during work.

### *4.3. Some ways of improving the effectiveness of supplementary feeding for working cattle*

It is clearly evident from the results of these studies that in semi-arid areas, the strategy adopted for supplementary feeding of draught oxen will influence the outcome. When one group of draught oxen were fed supplements before and during working and the other group fed a similar quantity only while working, there was no difference in their work performance. This may have been due to the quick rate at which the oxen that were fed supplements only during working gained their body weights. The oxen fed supplements only during the work period were slow and could not complete the set distance at the beginning. A situation of this kind could be avoided by starting to offer supplements to the animals at least 1 week before working begins. The latter strategy could prove to be very important in those areas where the working period is short and very intense with loss of even a single day of working leading to substantial losses in yields. The results showed that each of the two strategies of supplementation had its advantages, but care needs to be taken when opting for the strategy of supplementing only during work. Although there are advantages of saving on labour costs or even reducing the total amount of food needed, if the supplement combined with the basal ration is too bulky, animals may fail to consume adequate quantities to meet their requirements. If there is a risk of lowering capacity for work as a result of weight loss (it could be the case when dealing with small sized oxen), the option of choice could be to supplement before and during work. If weight loss poses no risk of lowering capacity for work and if it is difficult to get enough food, farmers can opt to supplement their cattle only during work. Clearly farmers need to make their own assessment of available feed resources, number of animals available for work and their condition, the duration of the working period and the daily amount of work to be done. For example if a farmer is having large oxen with reasonable body conditions, it may not be necessary to supplement them if the working period is short or they could be supplemented while working if the working period is long. With animals having low body condition scores, even if the working period is short, supplementation may be necessary if interference with working is to be avoided.

The practices employed by farmers in feeding the three supplements used with maize stover as the basal diet in this study produced different results on the utilisation of stover and live weight gain by working oxen. Amongst the supplements, sunflower cake produced the best result followed by cob meal because of their higher nutritive value. Supplementation with lucerne showed relatively the lowest consumption of maize stover and body weight gain. The voluntary dry matter intake of maize stover was less on working days compared with the non-working days. Where animals rely on grazing and they are kraaled at night, farmers are advised to start their work early so that they also finish early in the day thereby increasing the time available for their animals to graze before it gets dark. If the oxen are fed on stored crop residues or poor quality roughages alone, feeding should preferably be *ad libitum* and any supplement fed first to ensure that it is all consumed. The overall time for feeding work oxen could also be increased by using small spans for short periods as opposed to the use of large spans of oxen continuously for a long duration. If several supplements are available for use it would be a sound idea to combine them so as to take advantages of each and possibly reduce the overall cost. More experiments are needed to identify and test other supplements that are available in the area. There is also a need to test the use of graded levels of supplements and try different combinations when feeding poor quality roughage to working cattle. This will lead to identification of suitable mixtures of supplements and recommendation of optimum levels of inclusion in rations for draught oxen working under semi-arid conditions in the Eastern Cape and other areas with similar conditions. For example oats could be grown in winter and used as a supplement to oxen fed on maize stover and other poor quality roughages. Where farmers have access to appropriate milling facilities, cob meal could be used alone or combined with other supplements available. This will convert the otherwise useless maize cob cores into animal feed and later to manure after being degraded in the rumen. The farmers need to be sensitised on the importance of the nutritive value of supplements so as to ensure that they offer the correct amounts.

### 4.4. Use of the "Feeding Standards for Cattle used for Work" in semi-arid areas

The results of the study of energy balances of working oxen in the four experiments suggested that there was unequal distribution of the total work done amongst the members of a working team of animals. Due to the unequal distribution of work, estimates of energy balances and live weight changes for individual animals working in pairs or in the teams of four were not as accurate as the estimates done for the whole working teams. It appears that accuracy of the estimates made using the feeding standards decrease with increase in the size of the working team. Evidence for this was obtained from estimates of energy balance and live weight change made for oxen working in pairs which were more accurate than those of oxen working in teams of four. Where precise estimates of food requirements, energy balance or expected live weight changes for individual draught oxen working in teams are needed, they will be difficult to attain unless there were some means of measuring the exact amount of work done by each.

Accuracy of estimates of energy balance and live weight changes made by using the feeding standards was not influenced by workload, the level of energy supply in the diet or the kind of food and/or supplement fed. Despite the discrepancies in estimates of live weight changes made from the feeding standards and actual changes, the feeding standards seem to be applicable for practical purposes. This could be true of the day to day use of the feeding standards by researchers and/or planners for application to feeding working cattle under conditions which do not require precise levels of accuracy but rather give a solid basis for making decisions on feeding plans.

Average values for energy costs of walking were used in calculating the net energy used for work. In order to increase accuracy of these estimates, it would be appropriate to make more determinations of energy costs for various activities related to work in semi-arid areas so that factors suitable for specific conditions could be applied rather than using generalised average factors.

### *4.5. The role of draught cattle in small holder agriculture in the Eastern Cape Province, South Africa*

The results of the survey (Appendix 6.24) and on-farm monitoring (Appendix 6.25) showed that animal traction was still alive and its use widespread in the Eastern Cape Province. Although a few farmers could afford to hire tractors for primary tillage, the majority of the small holder farmers still relied on draught animals for all their farming activities and transport of goods within the villages. The data obtained were not enough to work out the exact contribution made by draught oxen to the farmer's income. However the importance of draught animal power to the small holder farmers in the Eastern Cape Province may be underlined by the fact that all the food consumed in the families that were monitored was produced within the farms. What was evident from the results of this study was that there was insufficient support for the farmers from the government authorities for issues related to draught animal power and agriculture in general. Areas that need improvement include support for animal health matters, better linkages between farmers and their extension staff to facilitate dissemination of information on better management of animals and agriculture in general. Effectiveness of local remedies used for treating animals need to be assessed and the farmers need to be educated on public health issues relating to their animals. For example there is a need to educate them on correct ways of dealing with animal diseases of public health significance like tuberculosis. One way of easing the shortage of veterinary services could be to train paravets in the villages who could deal with minor ailments so that qualified veterinarians could be contacted only when there are serious conditions to be attended.

Improvements in post-harvest handling and use of crop residues need to be made. Maize stover was the only crop residue available in considerable quantities and those farmers who were feeding it to their animals *in situ* are advised to adopt the methods used by their colleagues who collect and store the stover. By harvesting and storing the maize stover, it will be possible to control its use and to reduce losses that occur when it is grazed on the fields by all animals. Techniques to improve feeding value of stover could also be applied when it has been harvested. Farmers should therefore be encouraged to chop it and where possible use additives such as molasses to improve its palatability.

It is possible to increase animal food supply in the areas monitored during this study if some measures are taken to improve management of communally owned animal grazing areas. One possible way of achieving this is by erecting new or repairing old fencing around the pastures so that grazing is planned and controlled. This is an area that requires support from the government because the farmers themselves do not have enough resources to accomplish the task. With the fences in place and animal movement controlled, it will be possible for the farmers to sow winter crops like oats specifically for feeding their animals.

The practice of using large spans of oxen by many farmers in the Eastern Cape Province is sometimes not justified. Given the large size of cattle found in the province, small ox teams could accomplish most of the ordinary farm work. By using small spans, animals may get more time for grazing and fewer people will be needed to work with them thereby helping to ease the problem of labour shortage in the area.

### 4.6. General conclusions

The importance of body weight and energy supply in the working of draught cattle needs to be considered when making draught power use plans. Farmers in semi-arid areas should be encouraged to use large cattle for work in pairs or small teams rather than small oxen in big spans. The big oxen can withstand working "off their backs" better than small sized cattle.

Multipurpose use of draught cattle in the Eastern Cape Province is likely to increase in future due to obligatory reduction in numbers of animals kept as a result of concern over environmental degradation caused by overstocking. Alternatives to livestock as a wealth guarantee need to be identified so that farmers can agree to reduce the numbers of animals they keep and match them to available grazing. Research work on the effects of work and energy supply on reproductive efficiency, milk production and growth in cattle will be needed.

The "*Feeding standards for cattle used for work*" (Lawrence and Pearson, 1999) were found to be practically applicable under semi-arid conditions in the Eastern Cape Province in South Africa. Researchers and/or planners can now approach the feeding of draught cattle in the area in a more objective way. It is unlikely however that extension officers and farmers can make use of the feeding standards in the present form. The feeding standards need to be simplified further to make them more user-friendly for application by farmers and /or extension officers who in most cases have limited or no theoretical background on animal nutrition.

With the feeding standards available, more accurate information on the time spent by oxen in the field and duration of working seasons is needed in making estimates of food requirements for different kinds of farm operations. Build-up of a data bank on this could be undertaken and the ATC at the University of Fort Hare in South Africa can start this. Additional research is needed to improve accuracy of estimates made using the standards.

Draught animal power makes an important contribution to small holder agriculture in the Eastern Cape Province and it can play a highly significant role in the efforts to revitalise agriculture in the area. Mechanisation plans including the marriage between tractors and draught animals can work in the area and should be considered along with the options requiring draught animals alone when making decisions. It is concluded that draught animal power contributes significantly to agriculture and other sectors of the rural economies of the Eastern Cape Province by providing valuable transport thereby simplifying work and raising the living standards of the people. If this technology is strengthened, we can hope for better future prospects for life in the rural areas of the Eastern Cape Province.

With the feeding standards for cattle used for work available, feed requirements for draught cattle should be considered together with other livestock productions relying on the limited feed supplies when making farm plans. Efforts to match feed energy resources in the small scale farming enterprises to the energy requirements by livestock in general should be given the attention it deserves in order to attain profitability and sustainability in the farming systems.

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# 6. APPENDICES

## 6.1. Weekly average live weights of oxen in experiment 1

### 6.1.1. Weekly average live weights of oxen with the heavy (team 1), medium (team 2) and light (team 3) workloads in experiment 1

| Ox No. | Week 1 | Week 2 | Week 3 | Week 4 | Week 5 | Week 6 | Week 7 |
|---|---|---|---|---|---|---|---|
| 1 | 508.00 | 496.00 | 506.67 | 501.33 | 506.67 | 499.33 | 502.67 |
| 2 | 497.33 | 482.00 | 496.00 | 492.67 | 488.00 | 487.33 | 489.33 |
| 3 | 360.67 | 348.00 | 362.67 | 360.67 | 365.33 | 362.00 | 370.00 |
| 4 | 376.00 | 368.00 | 377.33 | 384.00 | 385.33 | 384.00 | 385.33 |
| **Team1 av.** | **435.50** | **423.50** | **435.67** | **434.67** | **436.33** | **433.17** | **436.83** |
| 5 | 520.67 | 509.33 | 527.33 | 522.00 | 522.00 | 522.67 | 530.00 |
| 6 | 588.00 | 583.33 | 602.00 | 601.33 | 592.67 | 591.33 | 606.67 |
| 7 | 528.67 | 519.33 | 533.33 | 535.33 | 536.67 | 538.00 | 548.67 |
| 8 | 497.33 | 492.67 | 502.00 | 502.00 | 492.00 | 497.33 | 506.67 |
| **Team2 av.** | **533.67** | **526.17** | **541.17** | **540.17** | **535.83** | **537.33** | **548.00** |
| 9 | 402.67 | 386.67 | 402.00 | 405.33 | 404.67 | 406.00 | 411.33 |
| 10 | 362.67 | 354.00 | 360.67 | 361.33 | 363.33 | 362.67 | 362.67 |
| 11 | 385.33 | 378.00 | 386.67 | 384.67 | 386.00 | 389.33 | 392.00 |
| 12 | 455.33 | 441.33 | 451.33 | 454.00 | 453.33 | 457.33 | 457.33 |
| **Team3 av.** | **401.50** | **390.00** | **400.17** | **401.33** | **401.83** | **403.83** | **405.83** |

### 6.1.2. Average weekly live weights of heavy/rear (1&2) and light/front (3&4) oxen with the heavy workload (team 1) treatment in experiment 1

| Ox No. | Week 1 | Week 2 | Week 3 | Week 4 | Week 5 | Week 6 | Week 7 |
|---|---|---|---|---|---|---|---|
| 1 | 508.00 | 496.00 | 506.67 | 501.33 | 506.67 | 499.33 | 502.67 |
| 2 | 497.33 | 482.00 | 496.00 | 492.67 | 488.00 | 487.33 | 489.33 |
| **Aver.** | **502.67** | **489.00** | **501.33** | **497.00** | **497.33** | **493.33** | **496.00** |
| 3 | 360.67 | 348.00 | 362.67 | 360.67 | 365.33 | 362.00 | 370.00 |
| 4 | 376.00 | 368.00 | 377.33 | 384.00 | 385.33 | 384.00 | 385.33 |
| **Aver.** | **368.33** | **358.00** | **370.00** | **372.33** | **375.33** | **373.00** | **377.67** |

**6.1.3. Average weekly live weights of rear (5&6) and front (7&8) oxen with the medium workload (team 2) treatment in experiment 1**

| Ox No. | Week 1 | Week 2 | Week 3 | Week 4 | Week 5 | Week 6 | Week 7 |
|---|---|---|---|---|---|---|---|
| 5 | 520.67 | 509.33 | 527.33 | 522.00 | 522.00 | 522.67 | 530.00 |
| 6 | 588.00 | 583.33 | 602.00 | 601.33 | 592.67 | 591.33 | 606.67 |
| **Aver.** | **554.33** | **546.33** | **564.67** | **561.67** | **557.33** | **557.00** | **568.33** |
| 7 | 528.67 | 519.33 | 533.33 | 535.33 | 536.67 | 538.00 | 548.67 |
| 8 | 497.33 | 492.67 | 502.00 | 502.00 | 492.00 | 497.33 | 506.67 |
| **Aver.** | **513.00** | **506.00** | **517.67** | **518.67** | **514.33** | **517.67** | **527.67** |

**6.1.4. Average weekly live weights of rear (10&12) and front (9&11) oxen in the light workload (team 3) treatment in experiment 1**

| Ox No. | Week 1 | Week 2 | Week 3 | Week 4 | Week 5 | Week 6 | Week 7 |
|---|---|---|---|---|---|---|---|
| 9 | 402.67 | 386.67 | 402.00 | 405.33 | 404.67 | 406.00 | 411.33 |
| 11 | 385.33 | 378.00 | 386.67 | 384.67 | 386.00 | 389.33 | 392.00 |
| **Aver.** | **394.00** | **382.33** | **394.33** | **395.00** | **395.33** | **397.67** | **401.67** |
| 10 | 362.67 | 354.00 | 360.67 | 361.33 | 363.33 | 362.67 | 362.67 |
| 12 | 455.33 | 441.33 | 451.33 | 454.00 | 453.33 | 457.33 | 457.33 |
| **Aver.** | **409.00** | **397.67** | **406.00** | **407.67** | **408.33** | **410.00** | **410.00** |

**6.2. Analysis of variance for weight gains of oxen in the heavy(team 1), medium(team 2) and light(team 3) workload in experiment 1**

**Summary**

| Treatments | N | Total | Mean | Variance |
|---|---|---|---|---|
| Heavy workload | 21 | -2.00 | -0.10 | 44.84 |
| Medium workload | 21 | 9.50 | 0.45 | 52.77 |
| Light workload | 21 | 7.50 | 0.36 | 43.20 |

**Anova Table**

| Source of Variation | SS | df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Between Treatments | 3.60 | 2 | 1.80 | 0.04 | 0.96 | 3.15 |
| Within Treatments | 2816.33 | 60 | 46.94 | | | |
| | | | | | | |
| Total | 2819.93 | 62 | | | | |

### 6.2.1. Analysis of variance for weight gains of heavy and light oxen with the heavy workload (team 1) treatment in experiment 1

**Summary**

| Groups | N | Total | Mean | Variance |
|---|---|---|---|---|
| Heavy oxen | 21 | -18.00 | -0.86 | 221.83 |
| Light oxen | 21 | 10.00 | 0.48 | 177.96 |

**Anova Table**

| Source of Variation | SS | Df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Between Groups | 18.67 | 1 | 18.67 | 0.09 | 0.76 | 4.08 |
| Within Groups | 7995.81 | 40 | 199.90 | | | |
| | | | | | | |
| Total | 8014.48 | 41 | | | | |

## 6.3. The speed of walking (m/s) of oxen with the heavy (team 1), medium (team 2) and light (team 3) workload recorded every 15 minutes of the working time in experiment 1

### 6.3.1. Heavy workload (team 1)

| Interval | Day 1 | Day 2 | Day 3 | Day 4 | Day 5 | Day 6 | Day 7 | Day 8 | Day 9 | Day 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.22 | 1.36 | 1.23 | 1.19 | 1.15 | 1.22 | 1.24 | 1.42 | 1.14 | 1.17 |
| 2 | 1.10 | 1.21 | 1.05 | 1.25 | 1.10 | 1.20 | 1.00 | 1.33 | 0.94 | 0.89 |
| 3 | 1.29 | 1.41 | 1.41 | 1.19 | 1.30 | 1.44 | 1.24 | 1.40 | 1.14 | 1.19 |
| 4 | 1.25 | 1.21 | 1.25 | 1.18 | 1.11 | 1.29 | 1.23 | 1.31 | 1.15 | 1.24 |
| 5 | 0.89 | 1.10 | 1.04 | 1.09 | 1.05 | 1.26 | 1.05 | 1.17 | 1.07 | 1.20 |
| 6 | 1.11 | 1.14 | 1.26 | 1.18 | 1.05 | 1.28 | 1.30 | 1.23 | 1.02 | 1.18 |
| 7 | 0.98 | 1.11 | 1.00 | 1.04 | 0.93 | 1.41 | 1.15 | 1.15 | 1.04 | 1.17 |
| 8 | 1.11 |  | 0.96 | 1.06 | 1.07 |  | 1.24 | 1.29 | 1.09 | 1.25 |
|  |  |  |  |  |  |  |  |  |  |  |
| 9 | 1.14 | 1.33 | 1.44 | 1.36 | 1.36 | 1.40 | 1.25 | 1.56 |  | 1.18 |
| 10 | 1.20 | 1.28 | 1.41 | 1.33 | 1.32 | 1.31 | 1.29 | 1.31 |  | 1.28 |
| 11 | 1.36 | 1.21 | 1.39 | 1.30 | 1.30 | 1.34 | 1.40 | 1.44 |  | 1.25 |
| 12 | 1.23 | 1.13 | 1.37 | 1.19 | 1.18 | 1.50 | 1.26 | 1.49 |  |  |
| 13 | 1.19 | 1.15 | 1.25 | 1.24 | 1.15 | 1.29 | 1.22 | 1.30 |  |  |
| 14 | 1.25 | 1.15 |  |  | 1.17 |  | 1.18 |  |  |  |

### 6.3.2. Medium workload (team 2)

| Interval | Day 1 | Day 2 | Day 3 | Day 4 | Day 5 | Day 6 | Day 7 | Day 8 | Day 9 | Day 10 | Day 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.20 | 1.26 | 1.18 | 1.20 | 1.18 | 1.26 | 1.12 | 1.27 | 1.30 | 1.25 | 1.12 |
| 2 | 1.20 | 1.25 | 1.19 | 1.12 | 1.12 | 1.14 | 1.08 | 1.16 | 1.30 | 1.11 | 0.98 |
| 3 | 1.30 | 1.31 | 1.29 | 1.23 | 1.29 | 1.25 | 1.26 | 1.36 | 1.42 | 1.31 | 1.19 |
| 4 | 1.24 | 1.15 | 1.17 | 1.15 | 1.13 | 1.07 | 1.09 | 1.20 | 1.26 | 1.18 | 1.19 |
| 5 | 1.35 | 1.27 | 1.33 | 1.31 | 1.26 | 1.28 | 1.20 | 1.36 | 1.23 | 1.34 | 1.09 |
| | | | | | | | | | | | |
| 6 | 1.29 | 1.23 | 1.33 | 1.35 | 1.33 | 1.27 | 1.20 | 1.26 | | 1.41 | 1.18 |
| 7 | 1.27 | 1.25 | 1.31 | 1.33 | 1.32 | 1.26 | 1.23 | 1.29 | | 1.37 | 1.28 |
| 8 | 1.32 | 1.35 | 1.30 | 1.31 | 1.34 | 1.32 | 1.31 | 1.34 | | 1.42 | 1.31 |
| 9 | 1.35 | 1.29 | 1.32 | 1.33 | 1.34 | 1.32 | 1.22 | 1.39 | | 1.35 | 1.23 |
| 10 | 1.36 | 1.29 | 1.32 | 1.37 | 1.35 | 1.25 | 1.25 | 1.28 | | 1.36 | 1.26 |
| 11 | | 1.17 | | | | | 1.36 | 1.31 | | | 1.16 |

### 6.3.3. Light workload (team 3)

| Interval | Day 1 | Day 2 | Day 3 | Day 4 | Day 5 | Day 6 | Day 7 | Day 8 | Day 9 | Day 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.18 | 1.59 | 1.34 | 1.42 | 1.48 | 1.34 | 1.37 | 1.34 | 1.17 | 1.35 |
| 2 | 1.38 | 1.66 | 1.29 | 1.38 | 1.37 | 1.36 | 1.46 | 1.23 | 1.17 | 1.29 |
| 3 | 1.47 | 1.37 | 1.46 | 1.38 | 1.39 | 1.39 | 1.51 | 1.36 | 1.25 | 1.36 |
| 4 | 1.23 | 1.39 | 1.17 | 1.21 | 1.43 | 1.23 | 1.39 | 1.19 | 1.11 | 1.09 |
| 5 | 1.35 |  | 1.44 | 1.25 | 1.42 | 1.21 | 1.23 | 1.42 | 1.24 | 1.39 |
|  |  |  |  |  |  |  |  |  |  |  |
| 6 | 1.22 | 1.36 | 1.35 | 1.33 | 1.26 |  | 1.28 | 1.51 | 1.19 | 1.13 |
| 7 | 1.23 | 1.39 | 1.37 | 1.30 | 1.29 |  | 1.45 | 1.5 | 1.16 | 1.17 |
| 8 | 1.25 | 1.38 | 1.36 | 1.32 | 1.33 |  | 1.37 | 1.51 | 1.17 | 1.43 |

**6.4. Analysis of variance for the speed of walking of oxen on the heavy (team 1), medium (team 2) and light (team 3) workload in experiment 1**

**Summary**

| Treatments | N | Total | Mean | Variance |
|---|---|---|---|---|
| Heavy workload | 14 | 17.04 | 1.22 | 0.01 |
| Medium workload | 11 | 13.88 | 1.23 | 0.004 |
| Light workload | 8 | 10.64 | 1.33 | 0.002 |

**Anova Table**

| Source of Variation | SS | df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Between Treatments | 0.06 | 2 | 0.03 | 6.45 | 0.005 | 3.32 |
| Within Treatments | 0.15 | 30 | 0.01 | | | |
| Total | 0.22 | 32 | | | | |

## 6.5. Laboratory analysis results of food offered and refusals from oxen in experiment 1

### 6.5.1. Laboratory analysis results (* g/kg DM) for lucerne hay offered and refusals from individual oxen in the heavy (team 1), medium (team 2) and light (team 3) workload treatments during week 1-4 of experiment 1

| | DM g/kg | NDF* | ADF* | Hemice-llulose.* | Protein* | Ash* | AI Ash* |
|---|---|---|---|---|---|---|---|
| Hay | 944.45 | 672.17 | 531.64 | 140.54 | 122.05 | 61.48 | 24.82 |
| **Refusals** | | | | | | | |
| 1 | 953.33 | 596.13 | 429.64 | 166.48 | 147.60 | 87.37 | 108.89 |
| 2 | 955.61 | 577.87 | 421.18 | 156.69 | 147.03 | 84.11 | 129.90 |
| 3 | 954.25 | 551.29 | 401.19 | 150.10 | 166.37 | 92.32 | 175.76 |
| 4 | 957.66 | 538.46 | 397.58 | 140.88 | 155.3 | 85.79 | 171.87 |
| ***Heavy WL aver.*** | ***955.21*** | ***565.94*** | ***412.40*** | ***153.54*** | ***154.08*** | ***87.40*** | ***146.61*** |
| 5 | 954.57 | 583.99 | 416.60 | 167.39 | 149.46 | 89.21 | 155.40 |
| 6 | 950.710 | 560.610 | 417.83 | 142.78 | 170.16 | 84.09 | 63.77 |
| 7 | 954.72 | 646.510 | 487.58 | 158.92 | 125.45 | 76.46 | 112.15 |
| 8 | 954.77 | 602.99 | 461.78 | 141.20 | 134.59 | 82.56 | 101.66 |
| ***Medium WL aver.*** | ***953.69*** | ***598.53*** | ***445.95*** | ***152.57*** | ***144.92*** | ***83.08*** | ***108.25*** |
| 9 | 953.91 | 614.51 | 460.15 | 154.36 | 128.40 | 84.82 | 107.10 |
| 10 | 959.17 | 583.50 | 437.83 | 145.68 | 122.32 | 82.41 | 171.04 |
| 11 | 959.30 | 615.34 | 451.4 | 163.95 | 127.68 | 80.53 | 170.06 |
| 12 | 959.35 | 582.15 | 432.76 | 149.39 | 146.44 | 85.88 | 176.79 |
| ***Light WL aver.*** | ***957.93*** | ***598.88*** | ***445.54*** | ***153.35*** | ***131.21*** | ***83.41*** | ***156.25*** |

**6.5.2. Laboratory analysis results (* g/kg DM) for lucerne hay offered and refusals from individual oxen in the heavy (team 1), medium (team 2) and light (team 3) workload treatments during week 5-7 of experiment 1**

| | DM g/kg | NDF* | ADF* | Hemice-llulose.* | Protein* | Ash* | AI Ash* |
|---|---|---|---|---|---|---|---|
| Hay | 950.25 | 627.89 | 447.29 | 180.60 | 132.29 | 61.10 | 24.67 |
| Refusals | | | | | | | |
| 1 | 965.92 | 506.29 | 373.20 | 133.09 | 185.95 | 85.04 | 253.62 |
| 2 | 964.68 | 527.84 | 387.74 | 140.10 | 184.88 | 88.64 | 257.74 |
| 3 | 964.65 | 501.29 | 360.78 | 140.51 | 190.80 | 88.74 | 214.47 |
| 4 | 963.57 | 486.20 | 397.55 | 88.64 | 175.45 | 92.63 | 237.99 |
| | 964.71 | 505.41 | 379.82 | 125.59 | 184.27 | 88.76 | 240.96 |
| 5 | 961.15 | 573.38 | 408.32 | 165.06 | 166.61 | 78.85 | 226.03 |
| 6 | 956.23 | 521.68 | 373.25 | 148.42 | 205.52 | 83.31 | 90.70 |
| 7 | 957.98 | 538.65 | 408.59 | 130.06 | 161.94 | 83.32 | 260.27 |
| 8 | 961.33 | 512.44 | 405.21 | 107.23 | 180.18 | 96.25 | 266.07 |
| | 959.17 | 536.54 | 398.84 | 137.69 | 178.56 | 85.43 | 210.77 |
| 9 | 953.41 | 550.86 | 384.72 | 166.13 | 184.19 | 94.50 | 186.11 |
| 10 | 961.15 | 481.84 | 378.57 | 103.27 | 182.87 | 85.85 | 270.05 |
| 11 | 959.91 | 532.50 | 400.20 | 132.30 | 173.86 | 85.79 | 247.44 |
| 12 | 956.85 | 551.54 | 403.11 | 148.43 | 175.93 | 82.11 | 228.76 |
| | 957.83 | 529.19 | 391.65 | 137.53 | 179.21 | 87.06 | 233.09 |

## 6.6. Analysis of variance for the composition of refusals from oxen on the heavy (team 1), medium (team 2) and light (team 3) workload treatments in experiment 1

### 6.6.1. NDF content of refusals

**Summary**

| Treatments | N | Total | Mean | Variance |
|---|---|---|---|---|
| Heavy workload | 8 | 4285.37 | 535.67 | 1463.11 |
| Medium workload | 8 | 4540.25 | 567.53 | 1974.21 |
| Light workload | 8 | 4512.24 | 564.03 | 1995.31 |

**Anova Table**

| Source of Variation | SS | df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Between Treatments | 4884.10 | 2 | 2442.05 | 1.35 | 0.28 | 3.47 |
| Within Treatments | 38028.40 | 21 | 1810.88 | | | |
| | | | | | | |
| Total | 42912.50 | 23 | | | | |

### 6.6.2. ADF content of refusals

**Summary**

| Treatments | n | Total | Mean | Variance |
|---|---|---|---|---|
| Heavy workload | 8 | 3168.86 | 396.11 | 517.99 |
| Medium workload | 8 | 3379.16 | 422.40 | 1279.13 |
| Light workload | 8 | 3348.74 | 418.59 | 957.33 |

**Anova Table**

| Source of Variation | SS | df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Between Treatments | 3229.51 | 2 | 1614.76 | 1.76 | 0.20 | 3.47 |
| Within Treatments | 19281.16 | 21 | 918.15 | | | |
| | | | | | | |
| Total | 22510.67 | 23 | | | | |

### 6.6.3. Hemicellulose content of refusals

**Summary**

| Treatments | n | Total | Mean | Variance |
|---|---|---|---|---|
| Heavy workload | 8 | 1116.49 | 139.56 | 538.12 |
| Medium workload | 8 | 1161.06 | 145.13 | 396.88 |
| Light workload | 8 | 1163.51 | 145.44 | 403.69 |

**Anova Table**

| Source of Variation | SS | df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Between Treatments | 175.14 | 2 | 87.57 | 0.20 | 0.82 | 3.47 |
| Within Treatments | 9370.87 | 21 | 446.23 | | | |
| Total | 9546.01 | 23 | | | | |

### 6.6.4. Crude protein content of refusals

**Summary**

| Treatments | n | Total | Mean | Variance |
|---|---|---|---|---|
| Heavy workload | 8 | 1353.38 | 169.17 | 313.05 |
| Medium workload | 8 | 1293.91 | 161.74 | 650.89 |
| Light workload | 8 | 1241.69 | 155.21 | 716.77 |

**Anova Table**

| Source of Variation | SS | df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Between Treatments | 780.76 | 2 | 390.38 | 0.70 | 0.51 | 3.47 |
| Within Treatments | 11764.99 | 21 | 560.24 | | | |
| Total | 12545.75 | 23 | | | | |

### 6.6.5. Ash content of refusals

**Summary**

| Treatments | n | Total | Mean | Variance |
|---|---|---|---|---|
| Heavy workload | 8 | 704.64 | 88.08 | 10.03 |
| Medium workload | 8 | 674.05 | 84.26 | 37.58 |
| Light workload | 8 | 681.89 | 85.24 | 18.14 |

**Anova Table**

| Source of Variation | SS | df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Between Treatments | 63.12 | 2 | 31.56 | 1.44 | 0.26 | 3.47 |
| Within Treatments | 460.25 | 21 | 21.92 | | | |
| Total | 523.37 | 23 | | | | |

### 6.6.6. Acid-insoluble ash content of refusals

**Summary**

| Treatments | n | Total | Mean | Variance |
|---|---|---|---|---|
| Heavy workload | 8 | 1550.24 | 193.78 | 3163.72 |
| Medium workload | 8 | 1276.05 | 159.51 | 6491.42 |
| Light workload | 8 | 1557.35 | 194.67 | 2693.49 |

**Anova Table**

| Source of Variation | SS | Df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Between Treatments | 6431.68 | 2 | 3215.84 | 0.78 | 0.47 | 3.47 |
| Within Treatments | 86440.46 | 21 | 4116.21 | | | |
| Total | 92872.14 | 23 | | | | |

## 6.7. Weekly Body Condition Scores for oxen during experiment 2

### 6.7.1. Weekly body condition scores of oxen on the low energy treatment in experiment 2

| Ox No. | Week 0 | Week 1 | Week 2 | Week 3 | Week 4 | Week 5 | Week 6 | Week 7 | Week 8 | Week 9 | Week 10 | Week 11 | Week 12 | Week 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 6.00 | 6.00 | 5.50 | 5.00 | 4.50 | 4.00 | 3.50 | 3.50 | 3.00 | 3.00 | 3.00 | 3.00 | 3.50 | 3.50 |
| 4 | 7.00 | 6.50 | 6.00 | 5.50 | 4.00 | 3.50 | 3.50 | 3.50 | 3.50 | 3.50 | 3.50 | 3.50 | 3.50 | 4.00 |
| 5 | 7.00 | 6.00 | 4.50 | 4.00 | 3.00 | 2.50 | 2.50 | 3.00 | 3.00 | 3.00 | 3.00 | 3.50 | 3.50 | 3.50 |
| 6 | 7.00 | 6.50 | 6.50 | 6.00 | 5.50 | 4.50 | 3.5 | 3.50 | 4.00 | 4.00 | 4.00 | 4.00 | 4.00 | 4.50 |
| 7 | 7.00 | 6.50 | 6.50 | 6.00 | 5.50 | 4.00 | 4.00 | 4.00 | 4.50 | 4.50 | 5.00 | 5.50 | 5.50 | 5.50 |
| 8 | 7.00 | 6.50 | 6.50 | 6.00 | 5.50 | 4.00 | 4.00 | 4.00 | 4.50 | 4.50 | 5.00 | 5.50 | 5.50 | 5.50 |
| **Average** | **6.83** | **6.33** | **5.92** | **5.42** | **4.67** | **3.75** | **3.50** | **3.58** | **3.75** | **3.75** | **3.92** | **4.17** | **4.25** | **4.25** |

### 6.7.2. Weekly body condition scores of oxen on the high energy treatment in experiment 2

| Ox No. | Week 0 | Week 1 | Week 2 | Week 3 | Week 4 | Week 5 | Week 6 | Week 7 | Week 8 | Week 9 | Week 10 | Week 11 | Week 12 | Week 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 |
| 2 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 |
| 9 | 7.00 | 7.00 | 6.50 | 6.50 | 6.50 | 6.00 | 6.00 | 6.00 | 6.00 | 6.50 | 6.50 | 6.50 | 6.50 | 6.50 |
| 10 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 6.50 | 6.50 | 6.50 | 6.00 | 6.50 | 6.50 | 6.50 | 6.50 | 6.50 |
| 11 | 6.00 | 6.00 | 6.50 | 6.50 | 6.50 | 6.50 | 6.00 | 6.00 | 6.00 | 6.00 | 6.00 | 6.00 | 6.50 | 6.50 |
| 12 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 |
| **Average** | **6.83** | **6.83** | **6.83** | **6.83** | **6.83** | **6.67** | **6.58** | **6.58** | **6.50** | **6.67** | **6.67** | **6.67** | **6.75** | **6.75** |

## 6.8. SAS programme for the analysis of variance of body condition scores for oxen on the low and high energy treatment during week 1-7 of experiment 2

```
Data BCScore2;
Input Treat animal week score@@;
Cards;
proc anova data = BCScore2;
class treat week;
model score = treat week treat*week
means treat/reg wf;
title 'Analysis of variance for weekly body condition scores2';
run;
```

**Analysis of variance procedure**

Class Level Information

| Class | Levels | Values |
|---|---|---|
| Treat | 2 | 1 2 |
| Week | 7 | 1 2 3 4 5 6 7 |

Number of observations in data set = 84

**Dependent variable :** Score

| Source | DF | SS | MS | F value | Pr > F |
|---|---|---|---|---|---|
| Model | 13 | 152.65 | 11.74 | 26.80 | 0.0001 |
| Error | 70 | 30.67 | 0.44 | | |
| Corrected Total | 83 | 183.32 | | | |

| R-Square | C.V. | Root MSE | SCORE Mean |
|---|---|---|---|
| 0.83 | 12.44 | 0.66 | 5.32 |

**Dependent variable :**Score

| Source | DF | Anova SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Treat | 1 | 149.33 | 149.33 | 340.87 | 0.0001 |
| Week | 6 | 2.40 | 0.40 | 0.91 | 0.49 |
| Treat*Week | 6 | 0.92 | 0.15 | 0.35 | 0.91 |

Ryan-Einot-Gabriel-Welsch Multiple F Test for variable : Score

NOTE: This test controls the type I experimentwise error rate.

Alpha= 0.05 df= 70 MSE= 0.44

Number of Means 2

Critical F 3.98

Means with the same letter are not significantly different.

| REGWF Grouping | Mean | n | Treat |
|---|---|---|---|
| A | 6.66 | 42 | 2 |
| B | 3.99 | 42 | 1 |

## 6.9. Weekly average live weights of oxen on treatment 1 and treatment 2 in experiment 2

### 6.9.1. Low energy/low body condition treatment

| Ox No. | Week 0 | Week 1 | Week 2 | Week 3 | Week 4 | Week 5 | Week 6 | Week 7 | Week 8 | Week 9 | Week 10 | Week 11 | Week 12 | Week 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 371.33 | 363.33 | 355.33 | 346.67 | 336.67 | 326.00 | 326.67 | 326.00 | 342.67 | 350.67 | 354.00 | 353.3 | 349.3 | 354.0 |
| 4 | 386.00 | 374.67 | 370.00 | 360.00 | 348.00 | 344.00 | 345.33 | 347.00 | 362.67 | 364.67 | 365.00 | 366.7 | 371.3 | 370.0 |
| 5 | 503.33 | 488.67 | 476.67 | 464.00 | 456.00 | 445.33 | 445.33 | 457.00 | 472.00 | 472.67 | 468.00 | 462.0 | 460.0 | 472.0 |
| 14 | 407.33 | 399.33 | 388.00 | 382.00 | 368.67 | 374.67 | 373.33 | 376.00 | 380.00 | 386.67 | 386.00 | 387.3 | 389.3 | 396.7 |
| 7 | 530.67 | 518.00 | 511.33 | 506.00 | 498.00 | 489.33 | 492.67 | 494.00 | 514.67 | 525.33 | 520.00 | 529.3 | 524.0 | 526.7 |
| 8 | 495.33 | 492.00 | 479.33 | 473.33 | 461.33 | 454.67 | 456.67 | 454.00 | 471.33 | 479.33 | 484.00 | 487.3 | 482.7 | 488.0 |
| | 449.00 | 439.33 | 430.11 | 422.00 | 411.45 | 405.67 | 406.67 | 409.00 | 423.89 | 429.89 | 429.50 | 431 | 429 | 435 |

### 6.9.2. High energy/good body condition

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 521.33 | 524.00 | 521.33 | 522.00 | 524.00 | 525.33 | 536.00 | 531.00 | 535.33 | 530.67 | 513.00 | 514.67 | 506.00 | 522.67 |
| 2 | 500.67 | 500.00 | 504.00 | 503.33 | 499.33 | 498.00 | 516.00 | 511.00 | 514.67 | 516.67 | 521.00 | 517.33 | 513.33 | 513.33 |
| 9 | 417.33 | 414.00 | 413.33 | 412.00 | 404.00 | 407.33 | 420.67 | 429.00 | 421.33 | 422.00 | 425.00 | 423.33 | 424.00 | 429.33 |
| 11 | 397.33 | 405.33 | 402.00 | 402.00 | 401.33 | 400.00 | 422.00 | 417.00 | 408.67 | 412.00 | 412.00 | 415.33 | 406.67 | 419.33 |
| 10 | 380.67 | 378.67 | 379.33 | 380.00 | 382.00 | 377.33 | 385.33 | 389.00 | 386.00 | 390.00 | 392.00 | 388.00 | 391.33 | 388.67 |
| 12 | 438.67 | 442.67 | 444.00 | 440.67 | 448.00 | 447.33 | 458.00 | 458.00 | 454.67 | 466.00 | 467.00 | 468.00 | 460.00 | 466.00 |
| | 442.67 | 444.11 | 444.00 | 443.33 | 443.11 | 442.55 | 456.33 | 455.83 | 453.45 | 456.22 | 455.00 | 454.44 | 450.22 | 456.56 |

### 6.10.1. SAS programme for the analysis of variance of weekly live weight gains for oxen on the low and high energy treatment during week 1-7 of experiment 2.

```
Data Gains21;
Input Treat animal week gain@@;
Cards;
proc anova data = Gains21;
class treat week;
model gain = treat week treat*week
means treat/reg wf;
title 'Analysis of variance for weekly liveweight gains21';
run;
```

**Analysis of variance procedure**

Class Level Information

| Class | Levels | Values |
|---|---|---|
| Treat | 2 | A B |
| Week | 7 | 1 2 3 4 5 6 7 |

Number of observations in data set = 84

**Dependent variable :** Gain

| Source | DF | Sum of Squares | Mean Square | F value | Pr > F |
|---|---|---|---|---|---|
| Model | 13 | 3576.60 | 275.12 | 15.12 | 0.0001 |
| Error | 70 | 1273.30 | 18.19 | | |
| Corrected Total | 83 | 4849.90 | | | |

| R-Square | C.V. | Root MSE | Gain Mean |
|---|---|---|---|
| 0.737458 | -301.08 | 4.26 | -1.42 |

**Dependent variable :** Gain

| Source | DF | Anova SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Treat | 1 | 1196.22 | 1196.22 | 65.76 | 0.0001 |
| Week | 6 | 2077.97 | 346.33 | 19.04 | 0.0001 |
| Treat*Week | 6 | 302.41 | 50.40 | 2.77 | 0.0178 |

Ryan-Einot-Gabriel-Welsch Multiple F Test for variable : Gain

NOTE: This test controls the type I experimentwise error rate.

Alpha= 0.05 df= 70 MSE= 18.19

Number of Means 2

Critical F 3.98

Means with the same letter are not significantly different.

| REGWF Grouping | Mean | N | Treat |
|---|---|---|---|
| A | 2.36 | 42 | B |
| B | -5.19 | 42 | A |

### 6.10.2. SAS programme for the analysis of variance of weekly live weight gains for oxen with low body condition and good body condition during week 8-13 of experiment 2.

```
Data Gains22;
Input Treat animal week score@@;
Cards;
proc anova data = Gains22;
class treat week;
model score = treat week treat*week
means treat/reg wf;
title 'Analysis of variance for weekly liveweight gains22';
run;
```

**Analysis of variance procedure**

Class Level Information

| Class | Levels | Values |
|---|---|---|
| Treat | 2 | A B |
| Week | 7 | 1 2 3 4 5 6 |

Number of observations in data set = 72

**Dependent variable :** Gain

| Source | DF | Sum of Squares | Mean Square | F value | Pr > F |
|---|---|---|---|---|---|
| Model | 11 | 1572.90 | 142.99 | 5.86 | 0.0001 |
| Error | 60 | 1463.02 | 24.38 | | |
| Corrected Total | 71 | 3035.92 | | | |

| R-Square | C.V. | Root MSE | Gain Mean |
|---|---|---|---|
| 0.52 | 307.37 | 4.94 | 1.61 |

**Dependent variable :**Gain

| Source | DF | Anova SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Treat | 1 | 300.17 | 300.17 | 12.31 | 0.0009 |
| Week | 5 | 639.81 | 127.96 | 5.25 | 0.0005 |
| Treat*Week | 5 | 632.92 | 126.58 | 5.19 | 0.0005 |

Ryan-Einot-Gabriel-Welsch Multiple F Test for variable : Gain

NOTE: This test controls the type I experimentwise error rate.

Alpha= 0.05 df= 70 MSE= 24.38

Number of Means 2

Critical F 4.00

Means with the same letter are not significantly different.

| REGWF Grouping | Mean | N | Treat |
|---|---|---|---|
| A | 3.65 | 36 | A |
| B | -0.44 | 36 | B |

### 6.10.3. SAS programme for the analysis of variance of weekly liveweight gains amongst heavy and light oxen on the two treatments during week 1-13 of experiment 2.

```
Data Gain23;
Input Treat animal week gain@@;
Cards;
proc anova data = Gain23;
class treat week;
model score = treat week categ treat*week treat*categ week*categ;
means treat/reg wf;
title 'Analysis of variance for weekly gains among weight groups';
run;
```

**Analysis of variance procedure**

Class Level Information

| Class | Levels | Values |
|---|---|---|
| Treat | 2 | A B |
| Week | 7 | 1 2 3 4 5 6 7 8 9 10 11 12 13 |
| Categ | 2 | H L |

Number of observations in data set = 156

**Dependent variable :** Gain

| Source | DF | SS | MS | F value | Pr > F |
|---|---|---|---|---|---|
| Model | 39 | 5709.01 | 146.38 | 6.71 | 0.0001 |
| Error | 116 | 2531.12 | 21.82 | | |
| Corrected Total | 155 | 8240.13 | | | |

| R-Square | C.V. | Root MSE | Gain Mean |
|---|---|---|---|
| 0.69 | -9999.99 | 4.67 | -0.02 |

**Dependent variable:** Gain

| Source | DF | Anova SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Treat | 1 | 185.21 | 185.21 | 8.49 | 0.0043 |
| Week | 12 | 3072.09 | 256.01 | 11.73 | 0.0001 |
| Categ | 1 | 0.00 | 0.00 | 0.00 | 0.9910 |
| Treat*Week | 12 | 2246.50 | 187.21 | 8.58 | 0.0001 |
| Treat*Categ | 1 | 0.03 | 0.03 | 0.00 | 0.9727 |
| Week*Categ | 12 | 205.17 | 17.10 | 0.78 | 0.6663 |

Ryan-Einot-Gabriel-Welsch Multiple F Test for variable : Gain

NOTE: This test controls the type I experimentwise error rate.

Alpha= 0.05 df= 116 MSE= 21.82

Number of Means 2

Critical F 3.92

Means with the same letter are not significantly different.

| REGWF Grouping | Mean | N | Treat |
|---|---|---|---|
| A | 1.07 | 78 | B |
| B | -1.11 | 78 | A |

### 6.11.1. SAS programme for the analysis of variance of average speed of walking of oxen on the two treatments during part 1 of experiment 2.

```
Data Speed2;
Input Treat team week speed;
Cards;
proc glm;
class treat week;
model speed = treat week treat*week ;
means treat/reg wf;
title 'Analysis of variance of average speed for each team';
run;
```

**Analysis of variance procedure**

Class Level Information

| Class | Levels | Values |
|---|---|---|
| Treat | 2 | A B |
| Week | 6 | 1 2 3 4 5 6 |

Number of observations in data set = 144

Note: Due to missing values, only 119 observations can be used in this analysis

Dependent variable : Speed

| Source | DF | SS | MS | F value | Pr > F |
|---|---|---|---|---|---|
| Model | 11 | 0.12 | 0.01 | 1.45 | 0.16 |
| Error | 107 | 0.78 | 0.01 | | |
| Corrected Total | 118 | 0.90 | | | |

| R-Square | C.V. | Root MSE | Speed Mean |
|---|---|---|---|
| 0.129626 | 6.754284 | 0.085325 | 1.26327731 |

**Dependent variable :** Speed

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Treat | 1 | 0.02457284 | 0.02457284 | 3.38 | 0.0690 |
| Week | 5 | 0.08 | 0.02 | 2.06 | 0.08 |
| Treat*Week | 5 | 0.02 | 0.00 | 0.45 | 0.81 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Treat | 1 | 0.03 | 0.03 | 4.73 | 0.03 |
| Week | 5 | 0.08 | 0.02 | 2.19 | 0.06 |
| Treat*Week | 5 | 0.02 | 0.00 | 0.45 | 0.81 |

Ryan-Einot-Gabriel-Welsch Multiple F Test for variable : Speed

NOTE: This test controls the type I experimentwise error rate.

Alpha= 0.05 df= 107 MSE= 0.007

WARNING: Cell sizes are not equal.

Harmonic Mean of cell sizes= 59.29

Number of Means 2

Critical F 3.93

Means with the same letter are not significantly different.

| REGWF Grouping | Mean | N | Treat |
|---|---|---|---|
| A | 1.28 | 63 | B |
| A | 1.25 | 56 | A |

### 6.11.2. SAS programme for the analysis of variance of average speed of walking of oxen on the two treatments during part 2 of experiment 2

```
Data Speed22;
Input Treat team week speed;
Cards;
proc glm;
class treat week;
model speed = treat week treat*week ;
means treat/reg wf;
title 'Analysis of variance of average speed for each team';
run;
```

**Analysis of variance procedure**

Class Level Information

| Class | Levels | Values |
|---|---|---|
| Treat | 2 | A B |
| Week | 6 | 1 2 3 4 5 6 |

Number of observations in data set = 144

Note: Due to missing values, only 111 observations can be used in this analysis

**Dependent variable :** Speed

| Source | DF | SS | MS | F value | Pr > F |
|---|---|---|---|---|---|
| Model | 11 | 0.20 | 0.02 | 2.74 | 0.0039 |
| Error | 99 | 0.67 | 0.01 | | |
| Corrected Total | 110 | 0.88 | | | |

| R-Square | C.V. | Root MSE | Speed Mean |
|---|---|---|---|
| 0.23 | 6.39 | 0.08 | 1.29 |

**Dependent variable :** Speed

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Treat | 1 | 0.05 | 0.05 | 7.48 | 0.007 |
| Week | 5 | 0.13 | 0.03 | 3.72 | 0.004 |
| Treat*Week | 5 | 0.03 | 0.01 | 0.81 | 0.542 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Treat | 1 | 0.05 | 0.05 | 6.69 | 0.011 |
| Week | 5 | 0.12 | 0.02 | 3.55 | 0.005 |
| Treat*Week | 5 | 0.03 | 0.01 | 0.81 | 0.542 |

Ryan-Einot-Gabriel-Welsch Multiple F Test for variable : Speed

NOTE: This test controls the type I experimentwise error rate.

Alpha= 0.05 df= 99 MSE= 0.007

WARNING: Cell sizes are not equal.

Harmonic Mean of cell sizes= 55.13

Number of Means 2

Critical F 3.94

Means with the same letter are not significantly different.

| REGWF Grouping | Mean | N | Treat |
|---|---|---|---|
| A | 1.31 | 51 | B |
| B | 1.27 | 60 | A |

## 6.12. Average weekly body weights of oxen supplemented before and during work (treatment 1) and those supplemented only during work (treatment 2) in experiment 3

### 6.12.1. Treatment 1

| Ox No. | Week 0 | Week 1 | Week 2 | Week 3 | Week 4 | Week 5 | Week 6 | Week 7 | Week 8 | Week 9 | Week 10 | Week 11 | Week 12 | Week 13 | Week 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 31 | 381.00 | 392.00 | 394.67 | 407.33 | 412.67 | 414.00 | 412.67 | 418.67 | 408.00 | 405.33 | 399.33 | 396.67 | 396.67 | 401.00 | 402.00 |
| 34 | 387.00 | 398.00 | 398.00 | 402.67 | 406.00 | 409.33 | 408.00 | 414.67 | 410.00 | 406.67 | 405.33 | 404.00 | 404.67 | 408.00 | 408.00 |
| 7 | 539.00 | 539.00 | 544.67 | 553.33 | 564.00 | 570.67 | 573.33 | 574.67 | 570.67 | 568.00 | 567.33 | 575.33 | 571.33 | 568.00 | 570.00 |
| 8 | 480.00 | 489.00 | 491.33 | 504.00 | 509.33 | 512.00 | 516.00 | 524.00 | 523.33 | 523.33 | 520.00 | 524.00 | 522.00 | 519.00 | 508.00 |
| 10 | 406.00 | 413.00 | 412.00 | 421.33 | 422.67 | 420.67 | 423.33 | 422.00 | 422.67 | 421.33 | 422.00 | 424.67 | 430.67 | 434.00 | 438.00 |
| 12 | 485.00 | 494.00 | 498.00 | 518.67 | 519.33 | 518.00 | 524.67 | 520.67 | 519.33 | 520.00 | 518.00 | 516.67 | 509.33 | 510.00 | 516.00 |
| Average | 446.33 | 454.17 | 456.45 | 467.89 | 472.33 | 474.11 | 476.33 | 479.11 | 475.67 | 474.11 | 472.00 | 473.56 | 472.45 | 473.33 | 473.67 |

### 6.12.2. Treatment 2

| Ox No. | Week 0 | Week 1 | Week 2 | Week 3 | Week 4 | Week 5 | Week 6 | Week 7 | Week 8 | Week 9 | Week 10 | Week 11 | Week 12 | Week 13 | Week 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 547.33 | 551.00 | 546.00 | 544.67 | 538.00 | 538.00 | 526.00 | 525.33 | 532.00 | 551.33 | 558.00 | 560.00 | 563.33 | 563.33 | 570.00 |
| 2 | 546.00 | 546.00 | 536.00 | 532.67 | 530.00 | 530.00 | 525.33 | 519.33 | 527.33 | 556.67 | 559.33 | 560.00 | 562.00 | 566.00 | 568.00 |
| 3 | 415.33 | 416.00 | 406.00 | 402.67 | 400.67 | 398.67 | 390.67 | 388.00 | 390.67 | 410.00 | 418.67 | 427.33 | 432.00 | 433.33 | 438.00 |
| 4 | 404.00 | 407.00 | 405.50 | 402.00 | 401.00 | 400.00 | 391.33 | 389.33 | 389.33 | 410.00 | 411.33 | 415.33 | 414.67 | 420.00 | 428.00 |
| 9 | 443.33 | 446.00 | 443.00 | 442.67 | 442.00 | 440.67 | 424.00 | 422.67 | 426.67 | 446.00 | 450.00 | 454.00 | 457.33 | 460.00 | 472.00 |
| 11 | 446.67 | 446.00 | 440.00 | 441.67 | 438.67 | 433.33 | 420.67 | 419.33 | 415.33 | 448.00 | 444.67 | 450.00 | 452.67 | 456.00 | 456.00 |
| Average | 467.11 | 468.67 | 462.75 | 461.06 | 458.39 | 456.78 | 446.33 | 444.00 | 446.89 | 470.33 | 473.67 | 477.78 | 480.33 | 483.11 | 488.67 |

### 6.13. Analysis of Variance of weekly average live weight gain of oxen on treatment 1 and 2 in experiment 3

**Summary**

| Treatments | N | Total | Mean | Variance |
|---|---|---|---|---|
| Treatment 1 | 14 | 27.33 | 1.95 | 15.62 |
| Treatment 2 | 14 | 21.56 | 1.54 | 58.65 |

**Anova Table**

| Source of Variation | SS | df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Between Treatments | 1.19 | 1 | 1.19 | 0.03 | 0.86 | 4.23 |
| Within Treatments | 965.48 | 26 | 37.13 | | | |
| Total | 966.67 | 27 | | | | |

### 6.14. Working speed (m/s) of oxen teams during each period in experiment 4

| Period | Team 6 | Team 1 | Team 2 | Team 5 | Team 3 | Team 4 |
|---|---|---|---|---|---|---|
| **1** | 1.19 | 1.19 | 1.14 | 1.27 | 1.24 | 1.28 |
| | 1.11 | 1.06 | 0.93 | 1.07 | 1.11 | 1.16 |
| | 1.18 | 1.12 | 1.09 | 1.25 | 1.16 | 1.17 |
| | 1.21 | 1.21 | 1.46 | 1.18 | 1.26 | 1.20 |
| | 1.27 | 1.21 | 1.05 | 1.23 | 1.18 | 1.27 |
| | 1.26 | 1.31 | 1.37 | 1.31 | 1.35 | 1.44 |
| | 1.34 | 1.33 | 1.28 | 1.49 | 1.45 | 1.39 |
| **2** | 1.24 | 1.24 | 1.24 | 1.36 | 1.29 | 1.27 |
| | 1.21 | 1.28 | 1.29 | 1.31 | 1.26 | 1.39 |
| | 1.25 | 1.25 | 1.28 | 1.20 | 1.26 | 1.33 |
| | 1.25 | 1.32 | 1.34 | 1.36 | 1.36 | 1.41 |
| | 1.24 | 1.19 | 1.20 | 1.22 | 1.24 | 1.22 |
| | 1.15 | 1.15 | 1.20 | 1.32 | 1.27 | 1.31 |
| | 1.25 | 1.30 | 1.37 | 1.37 | 1.33 | 1.37 |
| | 1.16 | 1.16 | 1.29 | 1.31 | 1.22 | 1.26 |

**6.14. (continued)**

| | | | | | | |
|---|---|---|---|---|---|---|
| **3** | 1.23 | 1.22 | 1.20 | 1.34 | 1.27 | 1.29 |
| | 1.13 | 1.11 | 1.12 | 1.14 | 1.12 | 1.21 |
| | 1.09 | 1.09 | 1.22 | 1.19 | 1.17 | 1.13 |
| | 1.08 | 1.11 | 1.27 | 1.26 | 1.16 | 0.99 |
| | 1.16 | 1.21 | 1.26 | 1.34 | 1.26 | 1.41 |
| | 1.24 | 1.28 | 1.40 | 1.28 | 1.29 | 1.31 |
| | 1.33 | 1.31 | 1.39 | 1.37 | 1.40 | 1.24 |
| | 1.22 | 1.21 | 1.32 | 1.30 | 1.29 | 1.28 |

**6.15. Analysis of variance of average daily working speed of oxen teams supplemented with lucerne (A), sunflower cake (B) and cob meal (C) in experiment 4**

Analysis of Variance Procedure

Class level information

| **Class** | **Levels** | **Values** |
|---|---|---|
| TREAT | 3 | A B C |
| PERIOD | 3 | 1 2 3 |
| TEAM | 6 | 1 2 3 4 5 6 |

Number of observations in data set = 126

**Dependent variable :** Speed

| **Source** | **DF** | **Sum of Squares** | **Mean Square** | **F value** | **Pr > F** |
|---|---|---|---|---|---|
| Model | 9 | 0.16 | 0.02 | 1.89 | 0.060 |
| Error | 116 | 1.09 | 0.01 | | |
| Corrected Total | 125 | 1.24 | | | |

| R-Square | C.V. | Root MSE | Speed Mean |
|---|---|---|---|
| 0.13 | 7.76 | 0.10 | 1.25 |

**Dependent Variable :** Speed

| **Source** | **DF** | **Anova SS** | **Mean Square** | **F Value** | **Pr > F** |
|---|---|---|---|---|---|
| Treat | 2 | 0.00 | 0.00 | 0.09 | 0.91 |
| Period | 2 | 0.06 | 0.03 | 3.39 | 0.04 |
| Team | 5 | 0.09 | 0.02 | 2.01 | 0.08 |

Ryan-Einot-Gabriel-Welsch Multiple F Test for variable : Speed

NOTE: This test controls the type I experimentwise error rate.

Alpha= 0.05 df= 116 MSE= 0.009359

| Number of Means | 2 | 3 |
|---|---|---|
| Critical F | 3.92 | 3.07 |

Means with the same letter are not significantly different

| **REGWF Grouping** | **Mean** | **N** | **Treat** |
|---|---|---|---|
| A | 1.25 | 42 | C |
| A | 1.24 | 42 | B |
| A | 1.24 | 42 | A |

## 6.16. Average weekly live weights and live weight gains of oxen teams in experiment 4

### 6.16.1. Average weekly live weights (kg) of oxen teams in experiment 4

| | Week 0 | Week 1 | Week 2 | Week 3 | Week 4 | Week 5 | Week 6 | Week 7 | Week 8 | Week 9 | Week 10 | Week 11 | Week 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Team 1** | 1192.00 | 1194.00 | 1184.00 | 1164.00 | 1135.00 | 1138.00 | 1173.00 | 1160.00 | 1138.00 | 1134.00 | 1148.00 | 1144.00 | 1103.00 |
| **Team 2** | 986.00 | 1003.00 | 984.00 | 964.00 | 949.00 | 966.00 | 982.00 | 971.00 | 956.00 | 956.00 | 964.00 | 958.00 | 944.00 |
| **Team 3** | 864.00 | 872.00 | 892.00 | 881.00 | 892.00 | 908.00 | 931.00 | 917.00 | 912.00 | 911.00 | 919.00 | 914.00 | 910.00 |
| **Team 4** | 1149.00 | 1124.00 | 1134.00 | 1139.00 | 1150.00 | 1158.00 | 1182.00 | 1169.00 | 1156.00 | 1169.00 | 1196.00 | 1185.00 | 1169.00 |
| **Team 5** | 879.00 | 900.00 | 917.00 | 896.00 | 893.00 | 901.00 | 912.00 | 906.00 | 905.00 | 911.00 | 950.00 | 935.00 | 925.00 |
| **Team 6** | 981.00 | 985.00 | 973.00 | 963.00 | 959.00 | 975.00 | 995.00 | 967.00 | 972.00 | 991.00 | 1029.00 | 1015.00 | 1009.00 |

### 6.16.2. Average weekly live weight gains (kg) of oxen teams in experiment 4

| | Week 1 | Week 2 | Week 3 | Week 4 | Week 5 | Week 6 | Week 7 | Week 8 | Week 9 | Week 10 | Week 11 | Week 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Team 1** | 2.00 | -10.00 | -20.00 | -29.00 | 3.00 | 35.00 | -13.00 | -22.00 | -4.00 | 14.00 | -4.00 | -41.00 |
| **Team 2** | 17.00 | -19.00 | -20.00 | -15.00 | 17.00 | 16.00 | -11.00 | -15.00 | 0.00 | 8.00 | -5.00 | -14.00 |
| **Team 3** | 8.00 | 20.00 | -11.00 | 11.00 | 16.00 | 23.00 | -14.00 | -5.00 | -1.00 | 8.00 | -5.00 | -4.00 |
| **Team 4** | -25.00 | 10.00 | 5.00 | 11.00 | 8.00 | 24.00 | -13.00 | -13.00 | 13.00 | 27.00 | -11.00 | -16.00 |
| **Team 5** | 21.00 | 17.00 | -21.00 | -3.00 | 8.00 | 11.00 | -6.00 | -1.00 | 6.00 | 39.00 | -15.00 | -10.00 |
| **Team 6** | 4.00 | -12.00 | -10.00 | -4.00 | 16.00 | 20.00 | -28.00 | 5.00 | 19.00 | 38.00 | -14.00 | -6.00 |

**6.17. Analysis of variance of average weekly team live weight gain for oxen supplemented with lucerne (A), sunflower cake (B) and cob meal (C) in experiment 4**

Analysis of Variance Procedure

Class level information

| Class | Levels | Values |
|---|---|---|
| TREAT | 3 | A B C |
| PERIOD | 3 | 1 2 3 |
| TEAM | 6 | 1 2 3 4 5 6 |

Number of observations in data set = 72

**Dependent variable :** Gain

| **Source** | **DF** | **Sum of Squares** | **Mean Square** | **F value** | **Pr > F** |
|---|---|---|---|---|---|
| Model | 9 | 1659.33 | 184.37 | 0.64 | 0.76 |
| Error | 62 | 17935.28 | 289.28 | | |
| Corrected Total | 71 | 19594.61 | | | |

| **R-Square** | **C.V.** | **Root MSE** | **Gain Mean** |
|---|---|---|---|
| 0.08 | 9999.99 | 17.01 | 0.14 |

**Dependent Variable :** Gain

| **Source** | **DF** | **Anova SS** | **Mean Square** | **F Value** | **Pr > F** |
|---|---|---|---|---|---|
| Treat | 2 | 13.36 | 6.68 | 0.02 | 0.98 |
| Period | 2 | 395.86 | 197.93 | 0.68 | 0.51 |
| Team | 5 | 1250.11 | 250.02 | 0.86 | 0.51 |

Ryan-Einot-Gabriel-Welsch Multiple F Test for variable : Gain

NOTE: This test controls the type I experimentwise error rate.

Alpha= 0.05 df= 62 MSE= 289.28

| Number of Means | 2 | 3 |
|---|---|---|
| Critical F | 4.00 | 3.15 |

Means with the same letter are not significantly different

| REGWF Grouping | Mean | N | Treat |
|---|---|---|---|
| A | 0.54 | 24 | B |
| A | 0.33 | 24 | C |
| A | -0.46 | 24 | A |

## 6.18. Daily Intake of maize stover by oxen in experiment 4

### 6.18.1. Daily intake of maize stover by oxen on treatment A (lucerne) in experiment 4 (kgDM)

**Period 1** **Period 2**

| | Ox 1 | Ox 2 | Ox 9 | Ox 14 | | Ox 3 | Ox 31 | Ox 7 | Ox 8 |
|---|---|---|---|---|---|---|---|---|---|
| **31Aug** | 7.43 | 6.54 | 4.54 | 6.03 | 28-Sep | 6.44 | 4.67 | 8.29 | 8.39 |
| 1-Sep | 8.28 | 5.91 | 4.82 | 5.53 | 29-Sep | 5.71 | 5.66 | 8.03 | 6.68 |
| 2-Sep | 6.72 | 5.80 | 4.82 | 7.20 | 30-Sep | 5.92 | 6.10 | 7.23 | 7.32 |
| 3-Sep | 4.30 | 4.45 | 5.46 | 5.88 | 1-Oct | 7.52 | 5.29 | 7.85 | 8.48 |
| 4-Sep | 3.88 | 6.17 | 6.41 | 4.19 | 2-Oct | 6.86 | 6.04 | 7.84 | 8.21 |
| 5-Sep | 6.90 | 7.06 | 5.18 | 4.96 | 3-Oct | 4.89 | 4.07 | 5.86 | 6.74 |
| 6-Sep | 8.52 | 6.62 | 5.76 | 7.31 | 4-Oct | 7.60 | 5.91 | 8.11 | 10.27 |
| 7-Sep | 5.04 | 5.90 | 4.72 | 6.91 | 5-Oct | 6.11 | 5.43 | 8.54 | 8.55 |
| 8-Sep | 4.70 | 5.76 | 3.64 | 6.04 | 6-Oct | 6.50 | 5.69 | 7.83 | 8.24 |
| 9-Sep | 6.13 | 5.94 | 4.58 | 5.30 | 7-Oct | 5.80 | 6.11 | 8.39 | 8.31 |
| 10-Sep | 6.93 | 5.80 | 5.05 | 6.01 | 8-Oct | 6.54 | 5.40 | 8.74 | 8.60 |
| 11-Sep | 6.80 | 7.89 | 7.16 | 6.42 | 9-Oct | 7.31 | 6.47 | 8.88 | 8.05 |
| 12-Sep | 8.01 | 6.84 | 7.58 | 6.42 | 10-Oct | 5.48 | 8.84 | 7.17 | 8.52 |
| 13-Sep | 6.46 | 8.04 | 8.05 | 5.21 | 11-Oct | 6.72 | 6.66 | 8.90 | 9.03 |
| 14-Sep | 4.73 | 6.38 | 5.31 | 3.56 | 12-Oct | 4.44 | 4.27 | 7.00 | 5.95 |
| 15-Sep | 3.72 | 3.50 | 4.71 | 2.18 | 13-Oct | 5.90 | 5.21 | 6.71 | 6.32 |
| 16-Sep | 5.99 | 4.34 | 5.76 | 4.87 | 14-Oct | 6.53 | 6.51 | 7.13 | 7.44 |

**6.18.1. (continued)**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 17-Sep | 3.58 | 5.51 | 3.57 | 4.97 | 15-Oct | 6.20 | 7.00 | 7.37 | 7.81 |
| 18-Sep | 6.08 | 5.31 | 5.05 | 2.88 | 16-Oct | 4.98 | 5.99 | 6.86 | 5.48 |
| 19-Sep | 7.18 | 5.77 | 6.35 | 6.83 | 17-Oct | 6.99 | 6.57 | 7.37 | 8.03 |
| 20-Sep | 6.19 | 5.39 | 6.01 | 5.02 | 18-Oct | 7.35 | 6.67 | 8.00 | 9.45 |
| 21-Sep | 5.84 | 4.55 | 3.71 | 4.09 | 19-Oct | 5.38 | 5.89 | 6.90 | 5.91 |
| 22-Sep | 5.68 | 5.13 | 5.39 | 4.83 | 20-Oct | 5.60 | 6.58 | 6.67 | 8.63 |
| 23-Sep | 5.71 | 5.45 | 6.79 | 5.29 | 21-Oct | 6.24 | 6.16 | 7.34 | 6.31 |
| 24-Sep | 5.58 | 5.43 | 6.78 | 5.94 | 22-Oct | 6.90 | 6.20 | 8.36 | 7.92 |
| 25-Sep | 5.60 | 5.07 | 6.68 | 5.18 | 23-Oct | 5.91 | 5.96 | 7.58 | 8.97 |
| 26-Sep | 6.63 | 6.46 | 6.61 | 6.56 | 24-Oct | 5.95 | 6.05 | 8.48 | 9.29 |
| 27-Sep | 6.14 | 5.77 | 5.82 | 6.25 | 25-Oct | 6.79 | 5.74 | 8.35 | 8.59 |

**Period 3**

| | Ox 4 | Ox 34 | Ox 10 | Ox 12 |
|---|---|---|---|---|
| 26-Oct | 6.42 | 4.98 | 5.22 | 9.20 |
| 27-Oct | 7.08 | 6.87 | 5.90 | 6.12 |
| 28-Oct | 7.24 | 5.94 | 4.87 | 7.81 |
| 29-Oct | 6.92 | 5.93 | 7.20 | 7.10 |
| 30-Oct | 6.76 | 6.84 | 5.70 | 6.97 |
| 31-Oct | 6.96 | 5.80 | 5.26 | 6.53 |
| 1-Nov | 6.66 | 7.26 | 6.68 | 8.23 |
| 2-Nov | 6.31 | 6.75 | 5.35 | 6.62 |
| 3-Nov | 4.65 | 7.66 | 5.62 | 7.11 |
| 4-Nov | 6.47 | 6.24 | 5.29 | 7.57 |
| 5-Nov | 6.74 | 5.57 | 6.12 | 7.26 |
| 6-Nov | 5.92 | 5.26 | 5.63 | 7.29 |
| 7-Nov | 7.43 | 6.51 | 6.00 | 6.70 |
| 8-Nov | 7.21 | 6.64 | 5.73 | 7.75 |
| 9-Nov | 4.99 | 7.14 | 4.56 | 7.17 |
| 10-Nov | 5.07 | 6.40 | 3.99 | 6.08 |

**6.18.1. (continued)**

| | | | | |
|---|---|---|---|---|
| 11-Nov | 6.46 | 5.39 | 5.06 | 5.98 |
| 12-Nov | 4.24 | 3.00 | 5.11 | 5.87 |
| 13-Nov | 3.31 | 4.78 | 4.81 | 5.03 |
| 14-Nov | 6.81 | 5.61 | 5.68 | 4.67 |
| 15-Nov | 5.99 | 6.69 | 2.38 | 8.09 |
| 16-Nov | 4.48 | 5.61 | 6.75 | 6.77 |
| 17-Nov | 5.19 | 5.67 | 5.78 | 6.21 |
| 18-Nov | 7.46 | 6.23 | 6.38 | 6.61 |
| 19-Nov | 5.26 | 5.60 | 4.81 | 6.79 |
| 20-Nov | 3.44 | 3.91 | 4.52 | 4.63 |
| 21-Nov | 5.75 | 6.38 | 5.91 | 7.78 |
| 22-Nov | 4.90 | 6.21 | 5.10 | 6.69 |

**6.18.2. Daily intake of maize stover by oxen on treatment B (sunflower cake) in experiment 4 (kgDM)**

**Period 1** **Period 2**

| | Ox 4 | Ox 34 | Ox 10 | Ox 12 | | Ox 1 | Ox 2 | Ox 9 | Ox 14 |
|---|---|---|---|---|---|---|---|---|---|
| **31Aug** | 7.13 | 6.54 | 5.10 | 5.43 | 28-Sep | 7.13 | 6.96 | 6.86 | 7.57 |
| 1-Sep | 7.51 | 5.90 | 3.43 | 5.95 | 29-Sep | 7.57 | 8.08 | 7.48 | 6.91 |
| 2-Sep | 7.12 | 6.47 | 6.72 | 5.57 | 30-Sep | 8.22 | 5.46 | 6.05 | 6.86 |
| 3-Sep | 4.42 | 6.45 | 6.32 | 5.03 | 1-Oct | 7.75 | 7.37 | 6.68 | 8.39 |
| 4-Sep | 7.44 | 8.08 | 6.44 | 6.07 | 2-Oct | 9.18 | 7.25 | 6.97 | 8.45 |
| 5-Sep | 7.85 | 7.57 | 6.90 | 6.31 | 3-Oct | 7.53 | 6.13 | 5.04 | 5.99 |
| 6-Sep | 8.01 | 7.32 | 7.27 | 5.48 | 4-Oct | 10.18 | 8.68 | 7.35 | 9.66 |
| 7-Sep | 7.46 | 6.72 | 4.91 | 6.12 | 5-Oct | 9.70 | 7.99 | 7.50 | 8.16 |
| 8-Sep | 6.47 | 6.41 | 4.87 | 4.94 | 6-Oct | 8.55 | 7.93 | 8.29 | 8.77 |
| 9-Sep | 7.89 | 6.79 | 5.99 | 4.61 | 7-Oct | 9.08 | 8.36 | 7.70 | 7.91 |
| 10-Sep | 6.99 | 6.89 | 5.24 | 4.67 | 8-Oct | 8.65 | 8.14 | 7.18 | 8.72 |
| 11-Sep | 7.56 | 6.64 | 5.44 | 6.83 | 9-Oct | 9.24 | 8.04 | 7.46 | 8.70 |
| 12-Sep | 8.09 | 7.80 | 4.75 | 5.57 | 10-Oct | 8.57 | 7.86 | 6.57 | 7.32 |

**6.18.2. (continued)**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 13-Sep | 6.89 | 6.72 | 5.57 | 5.45 | 11-Oct | 8.60 | 8.68 | 7.16 | 9.08 |
| 14-Sep | 5.44 | 6.12 | 4.35 | 6.10 | 12-Oct | 7.84 | 5.96 | 6.13 | 5.02 |
| 15-Sep | 6.10 | 5.64 | 4.71 | 3.90 | 13-Oct | 8.21 | 7.65 | 6.33 | 4.94 |
| 16-Sep | 7.49 | 6.21 | 5.15 | 4.90 | 14-Oct | 9.02 | 7.77 | 6.88 | 8.21 |
| 17-Sep | 6.33 | 5.96 | 4.68 | 4.82 | 15-Oct | 8.81 | 8.25 | 7.66 | 7.86 |
| 18-Sep | 6.81 | 5.90 | 4.63 | 5.53 | 16-Oct | 9.65 | 8.36 | 6.58 | 5.91 |
| 19-Sep | 7.04 | 7.07 | 5.86 | 5.99 | 17-Oct | 8.73 | 8.64 | 7.50 | 9.51 |
| 20-Sep | 6.91 | 6.26 | 5.48 | 5.80 | 18-Oct | 7.50 | 8.87 | 7.63 | 8.74 |
| 21-Sep | 6.24 | 6.30 | 5.75 | 5.48 | 19-Oct | 5.10 | 6.00 | 5.59 | 6.06 |
| 22-Sep | 6.51 | 6.67 | 5.28 | 6.05 | 20-Oct | 7.49 | 6.12 | 4.43 | 5.88 |
| 23-Sep | 6.78 | 5.86 | 6.08 | 6.45 | 21-Oct | 8.77 | 7.66 | 6.74 | 7.69 |
| 24-Sep | 7.59 | 7.04 | 5.84 | 6.24 | 22-Oct | 8.66 | 9.76 | 8.25 | 8.91 |
| 25-Sep | 6.17 | 6.84 | 3.62 | 4.96 | 23-Oct | 7.86 | 7.29 | 6.50 | 8.12 |
| 26-Sep | 7.14 | 6.37 | 6.58 | 6.93 | 24-Oct | 8.53 | 7.58 | 7.70 | 8.93 |
| 27-Sep | 7.32 | 6.83 | 6.11 | 7.18 | 25-Oct | 9.43 | 8.68 | 7.54 | 8.50 |

**Period 3**

| | Ox 3 | Ox 31 | Ox 7 | Ox 8 |
|---|---|---|---|---|
| 26-Oct | 6.52 | 6.57 | 7.98 | 8.58 |
| 27-Oct | 7.51 | 6.95 | 8.90 | 9.49 |
| 28-Oct | 7.13 | 5.76 | 9.88 | 10.20 |
| 29-Oct | 7.59 | 7.26 | 11.06 | 9.43 |
| 30-Oct | 8.26 | 6.48 | 10.56 | 10.53 |
| 31-Oct | 7.80 | 6.57 | 10.94 | 11.19 |
| 1-Nov | 8.81 | 7.23 | 10.08 | 12.11 |
| 2 Nov | 8.03 | 6.31 | 10.36 | 10.44 |
| 3-Nov | 8.29 | 6.38 | 10.50 | 10.13 |
| 4-Nov | 7.40 | 6.18 | 9.93 | 11.16 |
| 5-Nov | 8.98 | 6.87 | 8.78 | 10.65 |
| 6-Nov | 8.13 | 6.66 | 11.43 | 12.35 |

## 6.18.2. (continued)

| | | | | |
|---|---|---|---|---|
| 7-Nov | 6.78 | 6.80 | 10.55 | 11.32 |
| 8-Nov | 8.16 | 7.53 | 10.82 | 11.05 |
| 9-Nov | 6.75 | 3.15 | 8.26 | 8.59 |
| 10-Nov | 6.10 | 6.41 | 4.84 | 7.77 |
| 11-Nov | 8.34 | 6.89 | 8.63 | 12.13 |
| 12-Nov | 7.33 | 6.22 | 5.09 | 10.47 |
| 13-Nov | 5.24 | 5.57 | 6.88 | 8.53 |
| 14-Nov | 7.86 | 6.92 | 12.16 | 11.09 |
| 15-Nov | 8.68 | 6.34 | 10.96 | 11.17 |
| 16-Nov | 6.51 | 5.24 | 8.88 | 11.28 |
| 17-Nov | 9.36 | 4.59 | 10.37 | 9.63 |
| 18-Nov | 7.65 | 5.90 | 9.38 | 9.80 |
| 19-Nov | 6.76 | 6.93 | 10.29 | 9.88 |
| 20-Nov | 3.37 | 4.87 | 7.89 | 10.14 |
| 21-Nov | 7.22 | 6.91 | 10.52 | 11.30 |
| 22-Nov | 7.36 | 5.04 | 10.37 | 11.29 |

## 6.18.3. Daily intake of maize stover by oxen on treatment C (cob meal) in experiment 4 (kgDM)

**Period 1** **Period 2**

| | Ox 3 | Ox 31 | Ox 7 | Ox 8 | | Ox 4 | Ox 34 | Ox 10 | Ox 12 |
|---|---|---|---|---|---|---|---|---|---|
| **31Aug** | 5.29 | 7.16 | 8.17 | 7.90 | 28-Sep | 6.11 | 6.86 | 6.41 | 6.63 |
| 1-Sep | 3.79 | 6.00 | 9.25 | 8.26 | 29-Sep | 6.19 | 5.23 | 4.68 | 4.69 |
| 2-Sep | 4.40 | 6.91 | 6.38 | 7.72 | 30-Sep | 6.56 | 6.91 | 6.17 | 6.00 |
| 3-Sep | 5.44 | 5.5 | 6.67 | 5.68 | 1-Oct | 6.04 | 5.95 | 6.58 | 5.88 |
| 4-Sep | 4.38 | 6.99 | 9.24 | 8.08 | 2-Oct | 6.65 | 7.05 | 5.61 | 5.82 |
| 5-Sep | 6.75 | 8.31 | 9.24 | 8.24 | 3-Oct | 5.16 | 5.02 | 4.68 | 7.52 |
| 6-Sep | 5.52 | 7.07 | 8.45 | 8.36 | 4-Oct | 7.93 | 6.55 | 6.02 | 6.65 |
| 7-Sep | 5.92 | 2.18 | 9.06 | 8.18 | 5-Oct | 7.93 | 6.05 | 6.02 | 6.76 |
| 8-Sep | 5.17 | 6.92 | 8.01 | 8.16 | 6-Oct | 7.98 | 6.98 | 6.18 | 6.61 |

**6.18.3. (continued)**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 9-Sep | 4.42 | 7.05 | 8.61 | 8.92 | 7-Oct | 6.87 | 6.24 | 6.38 | 6.43 |
| 10-Sep | 5.41 | 7.76 | 9.13 | 8.70 | 8-Oct | 7.94 | 5.76 | 6.33 | 6.41 |
| 11-Sep | 4.93 | 7.67 | 9.76 | 9.23 | 9-Oct | 7.56 | 7.13 | 6.60 | 5.72 |
| 12-Sep | 6.42 | 8.20 | 9.4 | 8.69 | 10-Oct | 6.42 | 9.73 | 5.91 | 6.09 |
| 13-Sep | 4.26 | 6.90 | 8.51 | 7.91 | 11-Oct | 7.79 | 7.28 | 6.39 | 6.90 |
| 14-Sep | 5.06 | 6.24 | 8.13 | 7.56 | 12-Oct | 6.93 | 6.43 | 5.46 | 6.66 |
| 15-Sep | 4.42 | 5.66 | 6.17 | 8.59 | 13-Oct | 5.47 | 5.42 | 5.04 | 5.87 |
| 16-Sep | 5.77 | 6.59 | 8.58 | 8.98 | 14-Oct | 7.16 | 5.14 | 5.84 | 6.30 |
| 17-Sep | 5.41 | 6.24 | 7.78 | 9.02 | 15-Oct | 6.99 | 7.54 | 6.43 | 7.26 |
| 18-Sep | 4.60 | 6.93 | 7.54 | 8.36 | 16-Oct | 6.97 | 6.41 | 5.89 | 6.00 |
| 19-Sep | 5.48 | 7.19 | 8.60 | 9.25 | 17-Oct | 7.41 | 6.70 | 6.53 | 6.62 |
| 20-Sep | 4.59 | 5.50 | 8.71 | 8.58 | 18-Oct | 8.20 | 7.60 | 6.79 | 7.10 |
| 21-Sep | 5.01 | 5.73 | 9.23 | 8.83 | 19-Oct | 6.61 | 5.41 | 5.71 | 5.76 |
| 22-Sep | 4.80 | 6.36 | 9.08 | 8.98 | 20-Oct | 6.06 | 5.57 | 6.00 | 6.26 |
| 23-Sep | 3.25 | 6.26 | 10.62 | 8.89 | 21-Oct | 6.33 | 6.27 | 6.62 | 6.66 |
| 24-Sep | 5.65 | 6.86 | 10.32 | 9.06 | 22-Oct | 7.19 | 6.77 | 6.50 | 7.43 |
| 25-Sep | 5.33 | 6.59 | 9.51 | 8.58 | 23-Oct | 7.57 | 6.47 | 5.70 | 7.04 |
| 26-Sep | 5.29 | 6.75 | 9.68 | 10.03 | 24-Oct | 6.97 | 6.16 | 6.30 | 6.66 |
| 27-Sep | 6.46 | 6.83 | 8.32 | 9.61 | 25-Oct | 6.33 | 6.36 | 5.86 | 7.53 |

**Period 3**

| | Ox 1 | Ox 2 | Ox 9 | Ox 14 |
|---|---|---|---|---|
| 26-Oct | 7.77 | 7.20 | 5.99 | 7.10 |
| 27-Oct | 6.61 | 7.59 | 6.62 | 7.06 |
| 28-Oct | 6.04 | 6.60 | 5.37 | 6.88 |
| 29-Oct | 7.40 | 7.26 | 6.52 | 6.92 |
| 30-Oct | 5.42 | 7.22 | 5.38 | 7.45 |
| 31-Oct | 7.31 | 7.15 | 6.51 | 6.52 |
| 1-Nov | 8.19 | 8.04 | 7.27 | 7.93 |
| 2-Nov | 8.48 | 8.08 | 5.55 | 7.56 |

**6.18.3. (continued)**

| | | | | |
|---|---|---|---|---|
| 3-Nov | 9.60 | 8.53 | 6.54 | 7.28 |
| 4-Nov | 7.84 | 7.94 | 6.34 | 7.52 |
| 5-Nov | 8.04 | 8.17 | 6.56 | 6.86 |
| 6-Nov | 7.82 | 6.91 | 5.64 | 6.55 |
| 7-Nov | 7.08 | 7.93 | 5.39 | 7.17 |
| 8-Nov | 8.77 | 7.41 | 7.62 | 8.63 |
| 9-Nov | 6.56 | 7.27 | 6.50 | 7.65 |
| 10-Nov | 4.46 | 4.61 | 6.34 | 6.51 |
| 11-Nov | 4.64 | 6.63 | 6.83 | 7.26 |
| 12-Nov | 4.50 | 6.68 | 5.64 | 6.55 |
| 13-Nov | 4.96 | 6.54 | 5.48 | 5.79 |
| 14-Nov | 6.55 | 7.16 | 5.39 | 6.52 |
| 15-Nov | 5.88 | 7.25 | 4.99 | 7.56 |
| 16-Nov | 7.68 | 7.24 | 5.25 | 8.06 |
| 17-Nov | 6.80 | 7.22 | 6.50 | 7.47 |
| 18-Nov | 7.08 | 7.40 | 6.77 | 6.83 |
| 19-Nov | 6.68 | 7.53 | 5.31 | 6.53 |
| 20-Nov | 4.74 | 2.12 | 5.13 | 5.87 |
| 21-Nov | 6.70 | 8.14 | 7.02 | 7.48 |
| 22-Nov | 6.46 | 6.80 | 5.27 | 7.56 |

**6.19. Analysis of variance of the daily average intake of maize stover by oxen teams supplemented with lucerne (A), sunflower cake (B) and cob meal (C) in experiment 4**

**Analysis Variable :** Intake

**Treat=A**

| N Obs | N | Minimum | Maximum | Mean | Std Dev |
|---|---|---|---|---|---|
| 168 | 168 | 6.89 | 18.38 | 12.47 | 2.25 |

**Treat=B**

| N Obs | N | Minimum | Maximum | Mean | Std Dev |
|---|---|---|---|---|---|
| 168 | 168 | 8.24 | 23.78 | 14.85 | 3.28 |

**Treat=C**

| N Obs | N | Minimum | Maximum | Mean | Std Dev |
|---|---|---|---|---|---|
| 168 | 168 | 6.86 | 19.71 | 13.63 | 2.31 |

Analysis of Variance Procedure

Class level information

| Class | Levels | Values |
|---|---|---|
| TREAT | 3 | A B C |

Number of observations in data set = 504

**Dependent variable :** Intake

| **Source** | **DF** | **Sum of Squares** | **Mean Square** | **F value** | **Pr > F** |
|---|---|---|---|---|---|
| Model | 2 | 475.65 | 237.83 | 33.73 | 0.0001 |
| Error | 501 | 3532.72 | 7.05 | | |
| Corrected Total | 503 | 4008.37 | | | |

| **R-Square** | **C.V.** | **Root MSE** | **Intake Mean** |
|---|---|---|---|
| 0.118665 | 19.46 | 2.66 | 13.65 |

**Dependent Variable :** Intake

| Source | DF | Anova SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Treat | 2 | 475.65 | 237.83 | 33.73 | 0.0001 |

Ryan-Einot-Gabriel-Welsch Multiple F Test for variable : Intake

NOTE: This test controls the type I experimentwise error rate.

Alpha= 0.05 df= 501 MSE= 7.051332

| Number of Means | 2 | 3 |
|---|---|---|
| Critical F | 3.86 | 3.01 |

Means with the same letter are not significantly different

| **REGWF Grouping** | **Mean** | **N** | **Treat** |
|---|---|---|---|
| A | 14.85 | 168 | B |
| B | 13.63 | 168 | C |
| C | 12.47 | 168 | A |

## 6.20. Laboratory analysis results of maize stover refusals from oxen supplemented with lucerne (A), sunflower cake (B) and cob meal (C) during each period in experiment 4

### 6.20.1. PERIOD 1

| | DM g/kg | NDF* | ADF* | Hemicell.* | Protein* | Ash* | AI Ash* |
|---|---|---|---|---|---|---|---|
| Ox 1 | 929.61 | 762.29 | 498.40 | 263.89 | 62.24 | 42.59 | 34.01 |
| Ox 2 | 931.00 | 773.94 | 504.22 | 269.72 | 56.40 | 42.08 | 17.18 |
| Ox 3 | 929.11 | 777.15 | 502.02 | 275.13 | 53.30 | 38.41 | 23.94 |
| Ox 4 | 930.45 | 752.43 | 485.20 | 267.23 | 67.09 | 42.26 | 29.44 |
| Ox 31 | 930.26 | 776.98 | 506.52 | 270.45 | 60.54 | 39.58 | 24.94 |
| Ox 34 | 932.37 | 778.78 | 498.98 | 279.80 | 57.87 | 35.91 | 26.85 |
| Ox 7 | 931.95 | 770.54 | 497.45 | 273.08 | 62.60 | 41.95 | 20.63 |
| Ox 8 | 933.79 | 794.36 | 505.54 | 288.82 | 54.64 | 33.72 | 18.69 |
| Ox 9 | 933.25 | 749.24 | 473.87 | 275.36 | 68.01 | 45.97 | 36.46 |
| Ox 10 | 932.74 | 777.95 | 484.86 | 293.09 | 58.51 | 40.22 | 29.54 |
| Ox 14 | 932.72 | 752.62 | 473.03 | 279.59 | 66.72 | 43.42 | 42.47 |
| Ox 12 | 935.72 | 753.44 | 465.83 | 287.61 | 72.16 | 43.48 | 60.17 |

### 6.20.2. PERIOD 2

| | DM g/kg | NDF* | ADF* | Hemicell.* | Protein* | Ash* | AI Ash* |
|---|---|---|---|---|---|---|---|
| Ox 1 | 936.88 | 749.89 | 480.53 | 269.36 | 73.84 | 44.9 | 37.00 |
| Ox 2 | 919.26 | 772.6 | 495.36 | 277.24 | 68.72 | 43.57 | 27.47 |
| Ox 3 | 921.18 | 776.64 | 511.96 | 264.68 | 62.45 | 41.68 | 35.85 |
| Ox 4 | 921.33 | 767.00 | 495.91 | 271.09 | 66.90 | 41.16 | 23.25 |
| Ox 31 | 923.61 | 774.32 | 508.46 | 265.87 | 60.57 | 42.03 | 31.80 |
| Ox 34 | 924.07 | 776.08 | 506.77 | 269.31 | 62.62 | 43.97 | 44.85 |
| Ox 7 | 923.27 | 778.68 | 504.42 | 274.26 | 62.94 | 42.92 | 18.96 |
| Ox 8 | 922.23 | 809.94 | 525.44 | 284.5 | 60.48 | 43.91 | 22.72 |
| Ox 9 | 924.63 | 784.36 | 522.95 | 261.41 | 68.44 | 47.86 | 56.46 |
| Ox 10 | 925.26 | 788.27 | 516.31 | 271.97 | 59.15 | 45.06 | 24.81 |
| Ox 14 | 925.64 | 801.37 | 527.60 | 273.78 | 61.19 | 43.01 | 32.29 |
| Ox 12 | 923.50 | 777.3 | 498 | 279.30 | 69.94 | 39.96 | 29.48 |

### 6.20.3. PERIOD 3

| | DM g/kg | NDF* | ADF* | Hemicell.* | Protein* | Ash* | AI Ash* |
|---|---|---|---|---|---|---|---|
| Ox 1 | 930.57 | 718.24 | 490.11 | 228.12 | 68.58 | 45.41 | 65.75 |
| Ox 2 | 931.70 | 703.64 | 476.37 | 227.27 | 72.34 | 48.69 | 69.50 |
| Ox 3 | 935.26 | 722.93 | 505.58 | 217.35 | 65.63 | 46.28 | 88.10 |
| Ox 4 | 930.28 | 712.08 | 493.28 | 218.8 | 70.13 | 42.65 | 46.08 |
| Ox 31 | 929.95 | 750.58 | 502.71 | 247.87 | 64.23 | 40.55 | 43.94 |
| Ox 34 | 934.07 | 723.51 | 494.57 | 228.94 | 68.04 | 43.99 | 53.02 |
| Ox 7 | 933.85 | 692.66 | 476.98 | 215.68 | 76.79 | 50.28 | 75.89 |
| Ox 8 | 940.25 | 671.56 | 484.76 | 186.8 | 70.5 | 55.84 | 140.53 |
| Ox 9 | 932.35 | 712.49 | 487.74 | 224.75 | 71.29 | 45.93 | 73.37 |
| Ox 10 | 931.97 | 738.2 | 505.55 | 232.65 | 69.54 | 44.91 | 62.41 |
| Ox 14 | 932.39 | 745.83 | 495.76 | 250.07 | 60.99 | 42.00 | 52.03 |
| Ox 12 | 931.47 | 716.31 | 466.42 | 249.89 | 68.73 | 45.76 | 43.26 |

## 6.21. Analysis of variance of content of various components in refusals from oxen in experiment 4

### 6.21.1. NDF content of maize stover refusals

**Summary**

| Treatments | N | Total | Mean | Variance |
|---|---|---|---|---|
| Treat. A | 12 | 9067.77 | 755.65 | 861.75 |
| Treat. B | 12 | 9008.55 | 750.71 | 1465.93 |
| Treat. C | 12 | 9107.88 | 758.99 | 967.84 |

**Anova Table**

| Source of Variation | SS | df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Between Treatments | 416.17 | 2 | 208.09 | 0.19 | 0.83 | 3.28 |
| Within Treatments | 36250.79 | 33 | 1098.51 | | | |
| Total | 36666.97 | 35 | | | | |

### 6.21.2. ADF content of maize stover refusals

**Summary**

| Treatments | N | Total | Mean | Variance |
|---|---|---|---|---|
| Treat. A | 12 | 5959.62 | 496.64 | 309.91 |
| Treat. B | 12 | 5931.34 | 494.28 | 337.62 |
| Treat. C | 12 | 5978.50 | 498.21 | 109.30 |

**Anova Table**

| Source of Variation | SS | df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Between Treatments | 93.90 | 2 | 46.95 | 0.19 | 0.83 | 3.28 |
| Within Treatments | 8325.14 | 33 | 252.28 | | | |
| Total | 8419.04 | 35 | | | | |

### 6.21.3. Hemicellulose content of maize stover refusals

**Summary**

| Treatments | N | Total | Mean | Variance |
|---|---|---|---|---|
| Treat. A | 12 | 3108.15 | 259.01 | 462.72 |
| Treat. B | 12 | 3077.22 | 256.44 | 1092.22 |
| Treat. C | 12 | 3129.36 | 260.78 | 498.79 |

**Anova Table**

| Source of Variation | SS | df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Between Treatments | 114.59 | 2 | 57.29 | 0.08 | 0.92 | 3.28 |
| Within Treatments | 22591.08 | 33 | 684.59 | | | |
| Total | 22705.66 | 35 | | | | |

### 6.21.4. Crude protein content of maize stover refusals

**Summary**

| Treatments | N | Total | Mean | Variance |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| Treat. A | 12 | 776.25 | 64.69 | 19.39 |
| Treat. B | 12 | 804.97 | 67.08 | 35.02 |
| Treat. C | 12 | 762.89 | 63.57 | 39.61 |

**Anova Table**

| Source of Variation | SS | df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Between Treatments | 77.06 | 2 | 38.53 | 1.23 | 0.31 | 3.28 |
| Within Treatments | 1034.23 | 33 | 31.34 | | | |
| Total | 1111.29 | 35 | | | | |

### 6.21.5. Ash content of maize stover refusals

**Summary**

| Treatments | N | Total | Mean | Variance |
|---|---|---|---|---|
| Treat. A | 12 | 521.91 | 43.49 | 2.09 |
| Treat. B | 12 | 534.16 | 44.51 | 26.68 |
| Treat. C | 12 | 505.84 | 42.15 | 16.09 |

**Anova Table**

| Source of Variation | SS | df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Between Treatments | 33.62 | 2 | 16.81 | 1.12 | 0.34 | 3.28 |
| Within Treatments | 493.42 | 33 | 14.95 | | | |
| Total | 527.04 | 35 | | | | |

### 6.21.6. Acid insoluble ash content of maize stover refusals

**Summary**

| Treatments | N | Total | Mean | Variance |
|---|---|---|---|---|
| Treat. A | 12 | 444.22 | 37.02 | 183.06 |
| Treat. B | 12 | 647.68 | 53.97 | 1152.50 |
| Treat. C | 12 | 471.24 | 39.27 | 431.34 |

**Anova Table**

| Source of Variation | SS | df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Between Treatments | 2034.92 | 2 | 1017.46 | 1.73 | 0.19 | 3.28 |
| Within Treatments | 19435.88 | 33 | 588.97 | | | |
| | | | | | | |
| Total | 21470.80 | 35 | | | | |

## 6.22. Scheme used for body condition scoring

(adapted from Nicholson and Butterworth, 1986)

| Score | Condition | Features |
|---|---|---|
| 1 | L- | Marked emaciation (animal would be condemned at ante mortem examination). |
| 2 | L | Individual lumbar processes project prominently, neural spines appear sharply. |
| 3 | L+ | Individual vertebral spines are pointed to the touch ; hips, pins, tail-head and ribs are prominent. Lumbar processes visible. |
| 4 | M- | Ribs, hips and pins clearly visible. Muscle mass between tuber coxae and tuber ischii concave. |
| 5 | M | Ribs usually visible, little fat cover, spinous processes barely visible. |
| 6 | M+ | Animal smooth and well covered; spinous processes cannot be seen, but are easily felt. |
| 7 | F- | Animal smooth and well covered, but fat deposits are not marked. Spinous processes can be felt with firm pressure(rounded not sharp). |
| 8 | F | Fat cover in critical areas can be easily seen and felt; lumbar processes cannot be seen or felt. |
| 9 | F+ | Heavy deposits of fat clearly visible on tail-head, brisket and cod; spinous processes, ribs and pins fully covered and cannot be felt even with firm pressure. |

### 6.23. Chemical composition of concentrate used in experiment 1 and 2 (in g/kg, except for energy)

| | |
|---|---|
| Energy | 11 MJ/kg DM |
| Protein | 120* |
| Fat | 25 |
| Fibre | 110 |
| Calcium | 8 |
| Phosphorus | 3 |
| Urea | 12 |
| Moisture | 20 |

* = of which 28.7 % is derived from urea

## 6.24. Paper on draught animal use by small holder farmers in the Eastern Cape Province, Republic of South Africa

*Development Southern Africa* *Vol 16, No 2, Winter 1999*

# The use and management of draught animals by smallholder farmers in the former Ciskei and Transkei

David H O'Neill, John Sneyd, Nkosi T Mzileni, Lulamile Mapeyi, the late Moses Njekwa & Stanley Israel[1]

*A survey was undertaken on the use and management of draught animals in the Eastern Cape province. Information was elicited by means of semi-structured interviews with 94 rural households, most of which owned livestock and were engaged in farming activities. Most farmers relied on draught animal power, which was provided by their cattle, and preferred it to tractor power for most of their agricultural tasks. Span sizes of four or six animals were used for ploughing and harrowing (the preference being six), but for the lighter tasks such as cultivation, seeding and carting, only one pair of animals was usually used. Farmers readily used cows to make up their spans when they were short of oxen. Many of the farmers used tractors occasionally when they needed to open up new land. Most animals grazed on communal land (natural pasture), receiving supplements, usually stover or lucerne, only when farmers considered their body condition to be poor. Priority was given to milk animals over working animals for supplementary feeding. The farmers' main concerns regarding draught animals were the risks of drought, theft and disease, but they believed the use of these animals to be profitable because of the low outlay.*

## 1. INTRODUCTION

Despite the promotion of motorised forms of power for use in crop production and transport in South Africa, tractors remain an unaffordable and uneconomic technology for many farmers with small landholdings. These farmers have the option of cultivating their crops using manual labour alone or in combination with animal power. A recent appraisal covering a large part of South Africa indi

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[1] Respectively Project Leader, International Development Group, Silsoe Research Institute, Wrest Park, UK; Senior Technician, and Research Assistants (Mzileni, Mapeyi and Njekwa), Animal Traction Centre, Department of Agronomy, University of Fort Hare, South Africa; PhD Student, Centre for Tropical Veterinary Medicine (CTVM), University of Edinburgh, UK. The authors are grateful to Dr RA Pearson, CTVM, for assistance in the preparation of the article, to the Agricultural and Rural Development Research Institute (Ardri), Fort Hare, for providing introductions to some of the farmers interviewed, and to the British Department for International Development (DFID) for financial support provided through their RNRRS Livestock Production Programme (Grant No R6609). The information and views expressed are entirely the responsibility of the authors and are not attributable to any of the organisations involved.

cated that the use of animal power is widespread on smallholder farms and is even increasing in some areas of the country (Starkey, 1995). This increase is occurring despite the fact that many of the agricultural institutions in the country perceive animal power to be an outdated and impractical technology for agricultural production.

In other parts of southern Africa (eg Zimbabwe and Zambia) animal power plays a significant role in crop production in small-scale agriculture, and farmers value the contribution that draught animals make on their farms. Major production problems reported in these areas include a shortage of animal power, owing mainly to a shortage of large cattle and the feed resources to maintain them (Barrett et al, 1992). Another constraint is considered to be the lack of suitable implements to use with the smaller animals (cows and donkeys) that are now being worked to supplement the power provided by oxen (Barrett et al, 1992).

There is little detailed information on smallholder farming systems in South Africa, particularly that appropriate for draught animal inputs. The present study was undertaken to ascertain the attitudes to draught animal ownership and the way in which local smallholder farmers typically use and manage their draught animals, and to gain some insight into their socio-economic circumstances. A survey of farmers and households was undertaken in 19 districts in the Eastern Cape Province of South Africa, with varying levels of animal and draught animal ownership (Ardri, 1996).

## 2. MATERIAL AND METHODS

The survey was conducted in areas of the former Ciskei (districts of Melani, Ngwenya, Debe Marela, Koloni, Peuleni, Upper Ncera, Chamama and Dishi) and Transkei (districts of Lady Frere, Upper Ndonga, Ngqweleni, Maxelegweni, Butterworth, Gwegwe, Xwili, Centuli, Nqunge, Thuthura and Qamata) where smallholder farming using draught animal power predominates. Local extension officers identified households in the 19 districts for participation, but not specifically on the basis of ownership of draught animals.

A survey team, consisting of two to four people, visited the households over a period of four months from August to November 1996 where they conducted semi-structured interviews. At least two of the team members spoke fluent Xhosa, including the team leader who led the discussion. The interview was wide-ranging and based on a questionnaire covering four main areas: demography, socio-economics, animal factors and crop factors. The survey was designed to yield both factual information and matters of opinion. The questionnaire consisted of 104 questions, with which the team leader was totally familiar, and the other team members present recorded the information elicited from the farmers on the questionnaire as the interview progressed.

The information ranged from binary (eg yes/no) to simple numeric (eg how many oxen?) to open-ended (eg why is it profitable/not profitable to own draught animals?), and was coded before analysis. During coding the information was incorporated into 181 response boxes, each of which was coded into as many categories (represented by integers) as were needed to cover the responses. For example, Box 2 contained the response to Question 2 'area or district' and was coded 1 to 19 to cover each of the districts surveyed. After coding, the data were collated on a spreadsheet and analysed using standard data reduction techniques and statistical analyses, such as chi-squared and t-tests, where appropriate.

## 3. RESULTS

### 3.1 Use of draught animal power

Of the 94 farmers interviewed, 79 per cent were currently using draught animals. Some 74 per cent of farmers had at some time made use of tractors for land preparation, although 3 per cent had only used a tractor for the purpose of breaking new ground. Seven per cent did not respond. Of the 17 per cent of farmers not using draught animals, all but one (hand labour) made use of a tractor in crop production. However, none of the farmers interviewed owned a tractor and they tended to hire or borrow when land had to be prepared.

### 3.2 Landholding and cropping area

It was not possible to obtain the sizes of the farmers' individual landholdings, as much of the grazing land was communally owned within each community. Most farmers considered their landholding to be the total grazing area owned by the immediate community plus the individually owned cropping areas. The size of these total areas ranged from 345 to 15 000 ha, with 40 per cent of farmers reporting total community landholdings of 1 000 ha and only 25 per cent reporting smaller landholdings. On 71 per cent of the farms, farmers classified a quarter of the available land as crop land. Other farmers generally cropped up to 50 per cent of the available land. There was no significant difference in landholdings or proportion cropped by farmers owning or not owning draught animals.

The majority of farmers (62 per cent) believed that they had enough land, while only 22 per cent felt they did not have enough. Most of the latter were from the districts of Upper Ndonga and Qamata. Of the remaining farmers (15 per cent) who responded that they did not have quite enough land, most were from the Melani, Peuleni and Maxelegweni districts.

### 3.3 Demographic and economic circumstances

Eight of the households interviewed were headed by females. All heads of household lived permanently with their families. Their ages ranged from 20 to 94 years, with more than half being over 60 years of age. The sizes of the households ranged from two to 18 people, with the majority being seven or more (Table 1). Many of the households comprised members working away from home. No significant differences in these characteristics were seen between those households using animal power and those that relied on tractor power.

**Table 1: Composition of the 94 households surveyed in the former Ciskei and Transkei[1]**

| Variable | Min | Max | Mean | Median | Mode |
|---|---|---|---|---|---|
| Age of head of household | 20 (1) | 94 (1) | 61.7 | 63 (2) | 68 (7) |
| Household size | 2 (1) | 18 (1) | 8.0 | 7 (14) | 6 (16) |
| Household members working away from home | 0 (24) | 9 (1) | 2.2 | 2 (15) | 0 (24) |
| Household children at school | 0 (1) | 13 (1) | 4.0 | 4 (20) | 5 (20) |

*Note:* [1]The number of observations of each value is given in parenthesis.

In most households (84 per cent), women helped with the management, use of the animals and caring for crops (86 per cent). The commonest response to the role played by women was 'housewife' (48 per cent), although what this entailed seemed open to interpretation, for example, helping to grow food for the family could be part of a housewife's duty. A further 41 per cent of the responses indicated that the women undertook general farming activities in addition to their roles as housewives. Only 3 per cent of the responses, however, indicated that women did ploughing. The predominant agricultural activities of women which were associated with fieldwork were a combination of planting, weeding and leading animals.

The use of children to help with draught animals was even more widespread, although they were not necessarily the only helpers. Only 5 per cent of respondents indicated that children did not help and assistance was provided by hired hands or neighbours, or that there was no help at all.

Examination of the eight homes headed by females as a subgroup did not reveal any differences from the above pattern for the group as a whole. In one of the female-headed households children did not help with the draught animals, only hired hands, and women did not become involved in crop care.

### 3.4 Crops and cropping practices

The main crop grown by all farmers was maize. For the 57 farmers for whom the information is available, 22 per cent did not sell any of their crop, whilst 50 per cent sold about a quarter. Additional crops grown were beans and/or peas (86 farmers), squashes (79 farmers), potatoes (64 farmers) and vegetables (3 farmers). Two farmers in Maxelegweni grew millet and three farmers in Qamata grew stock feed (one farmer grew rain-fed barley and two grew lucerne under irrigation). The majority of farmers (79 per cent of those interviewed) used only manure to fertilise their crops (40 per cent) or used it in conjunction with inorganic fertiliser (39 per cent). Only 3 per cent of those interviewed used inorganic fertiliser alone; and 14 per cent of farmers interviewed did not respond. Some 82 per cent of the farmers reported that their yields were satisfactory and a further 5 per cent, in the Qamata district, reported that their yields were satisfactory because of irrigation. Only 2 per cent reported unsatisfactory yields. There were no differences between farmers currently using draught animal power and those who did not.

All the farmers for whom the relevant responses are available reported that they weeded their crops. Most of the weeding was done with hand hoes and cultivators (83 per cent), with only a further 1 per cent and 6 per cent respectively being done with cultivators and hand hoes alone. Draught animals therefore clearly play a major role in establishing and caring for crops. None of the farmers reported the use of herbicides. Farmers used the residues from their crops in various ways (Table 2).

**Table 2: The different uses of crop residues and the percentage of farmers carrying out each activity (n = 84)**

| | Leave on field | Collect | Feed to animals | Use as fertiliser | Sell |
|---|---|---|---|---|---|
| Number of farmers | 42 | 36 | 79 | 3 | 1 |
| Percentage of farmers | 50 | 43 | 94 | 4 | 1 |

### 3.5 Ownership and use of ruminants and equids

All farmers interviewed owned some ruminants or equids. Eighteen farmers owned more than 100 ruminants – mainly sheep and sometimes goats – in addition to cattle. Two of the farmers with over 100 ruminants had more than 50 cattle. At the other end of the scale, two farmers interviewed owned no cattle or horses, only small ruminants. One farmer kept two horses, which he used for draught, but no cattle, and one farmer kept only oxen with his sheep and goats. All other farmers interviewed (90, ie 96 per cent) kept at least one cow (Table 3). Oxen were kept by 86 per cent of the farmers interviewed and bulls by 29 per cent (22 farmers kept one bull each and four kept two bulls). All except eight farmers, located in the Dishi and Upper Ndonga districts, kept some small ruminants. Farms on which draught animal power was used had significantly more cattle than those farms not using animal power. One of the farmers not keeping cattle used a tractor for land preparation and the other relied on manual labour.

The use of oxen and bulls for draught was reported by 67 per cent of the farmers. Some 22 per cent of farmers used their own cows for draught, although 52 per cent said they would be happy to use cows for draught and this willingness to use cows was similar over all the districts surveyed. Of the farmers using cows, 18 spanned them with oxen to make up the spans, two farmers borrowing oxen from neighbours for this purpose. Three farmers used only cows without spanning them with oxen, one using them to complement the work done by his horse.

**Table 3: A comparison of ownership of oxen, cows, bulls and horses in households using draught animal power (+DAP, n = 75) and those that do not (–DAP, n = 17)**

| | Oxen (508) | | Cows (779) | | Bulls (30) | | Horses (96) | |
|---|---|---|---|---|---|---|---|---|
| | +DAP | –DAP | +DAP | –DAP | +DAP | –DAP | +DAP | –DAP |
| Average number per household[1] | 6,19 | 2,44** | 9,09 | 5,39* | 0,36 | 0,17 | 1,15 | 0,56 |
| Median | 5 | 1 | 6 | 3 | 0 | 0 | 0 | 0 |
| Mode | 3 | 0 | 6 | 2 | 0 | 0 | 0 | 0 |
| Maximum per household | 50 | 14 | 98 | 15 | 2 | 1 | 13 | 3 |
| Minimum per household | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

*Note*: [1]Difference within each animal type between +DAP and –DAP farmers significant at $*p < 0,05$ and $**p < 0,01$.

Mixed breeds of cattle (crossbreeds) were kept by 97 per cent of the farmers who kept cattle and six farmers kept purely indigenous animals (Nguni cattle). Farmers using cattle for work used mainly the mixed breeds (91 per cent), whereas three farmers used the western breeds and five used indigenous breeds.

Thirty-four farmers (36 per cent) kept horses (see Table 3), eleven of them keeping only one horse and nine keeping two horses. Horses were used mainly for riding and cultural activities but ten of the farmers with horses (11 per cent of all farmers interviewed) used them for draught work. Two farmers in the Qamata district owned five donkeys and two donkeys respectively, and three farmers in the Melani district owned two, five and two donkeys respectively. Four of the five farmers used the donkeys mainly for carting firewood, water and feed while the other did not use his pair for work. The farmer owning five donkeys in Melani used four of them for all cropping practices, including ploughing, as well as for transport. He did not use the three oxen he had for work. Only two farmers surveyed kept mules, one of these being one of the donkey-owning farmers in Qamata, who kept three horses and a mule. He used these for carting but not for fieldwork, preferring a tractor. The other mule owner in the Ngqweleni district kept two mules but no cattle. He used the mules for both fieldwork and transport together with a cart. It appeared that farmers not using draught animal power were either farmers with some of the larger animal holdings or those who kept few large ruminants (usually cows) and few oxen, and rarely kept equids.

### 3.6 Ownership of implements

Four farmers currently using draught animal power did not own any implements; two others owned only a sledge each. Ten farmers not currently using draught animal power provided information on implements. Of these, two did not own any implements but the other eight owned one or more ploughs, with a harrow and/or cultivator. Two seeders and a cart were also owned in this group. Results from all farmers who responded were pooled and are given in Table 4.

**Table 4: Ownership of implements – percentages of farmers owning none, one or more implements**

| | None | 1 | 2 | 3 | 4 | 5 | Unspecified |
|---|---|---|---|---|---|---|---|
| Plough | 13 | 24 | 8 | 5 | 0 | 0 | 51 |
| Harrow | 71 | 17 | 5 | 0 | 0 | 0 | 7 |
| Seeder | 52 | 17 | 3 | 2 | 0 | 0 | 24 |
| Cultivator | 23 | 19 | 7 | 5 | 2 | 3 | 41 |
| Cart | 71 | 18 | 5 | 0 | 0 | 0 | 6 |
| Sledge | 37 | 60 | 0 | 1 | 0 | 0 | 1 |

The most commonly owned implement, not surprisingly, was the plough, which was sometimes also used as a cultivator between maize rows. Few farmers owned seeders or harrows, and sledges were more commonly used for transport than carts, although sledges were usually used for transport around the farm. None of the farmers owned a tractor, although most (74 per cent) had used them occasionally. Some 41 per cent of farmers currently using draught animals said implements were available locally, but the other 59 per cent said implements were difficult to obtain and were not available locally. Of the current draught animal users, 78 per cent (59 farmers) hired or borrowed animal-drawn equipment when needed. Although almost half of the farmers (44 per cent) who were not using draught animal power did not respond, those who did hire or borrow equipment when needed were in the same proportion. Of the 67 farmers who did hire or borrow equipment, 16 (24 per cent) hired or borrowed ploughs, 41 (61 per cent) harrows, 43 (64 per cent) seeders, 23 (34 per cent) cultivators and four (6 per cent) carts. Several farmers also reported hiring or borrowing some or all of the animals needed for work, usually from relatives.

The commonest uses of draught animals were for ploughing and harrowing (76 per cent). The use of animals for transport (excluding riding) was rather limited, with 46 per cent of the farmers not using their animals for this purpose. Only 36 per cent of the farmers owned a cart and, of the remaining 64 per cent, 24 per cent did not own a sledge. The most commonly reported uses for a cart were for the collection of firewood alone (67 per cent), or water and firewood (29 per cent). Transport of people (1 per cent), goods for pay (1 per cent) and a general combination of all (2 per cent) were given as the other uses.

### 3.7 Working practices

The majority of farmers responded that they preferred to use animals rather than tractors for their cropping operations (Table 5).

**Figure 1: Span sizes for ploughing**

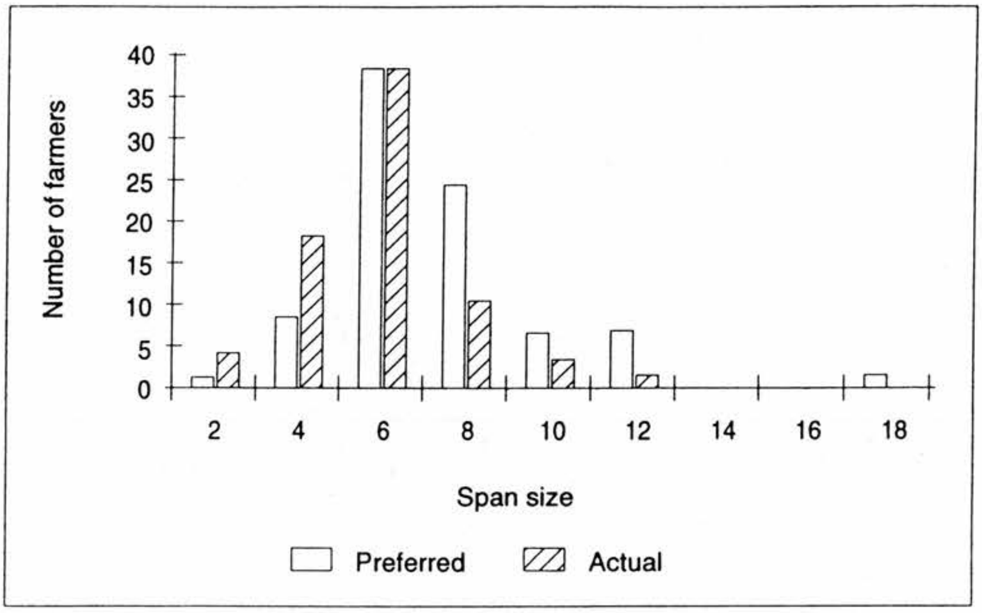


**Figure 2: Farmers with inadequate oxen for ploughing**

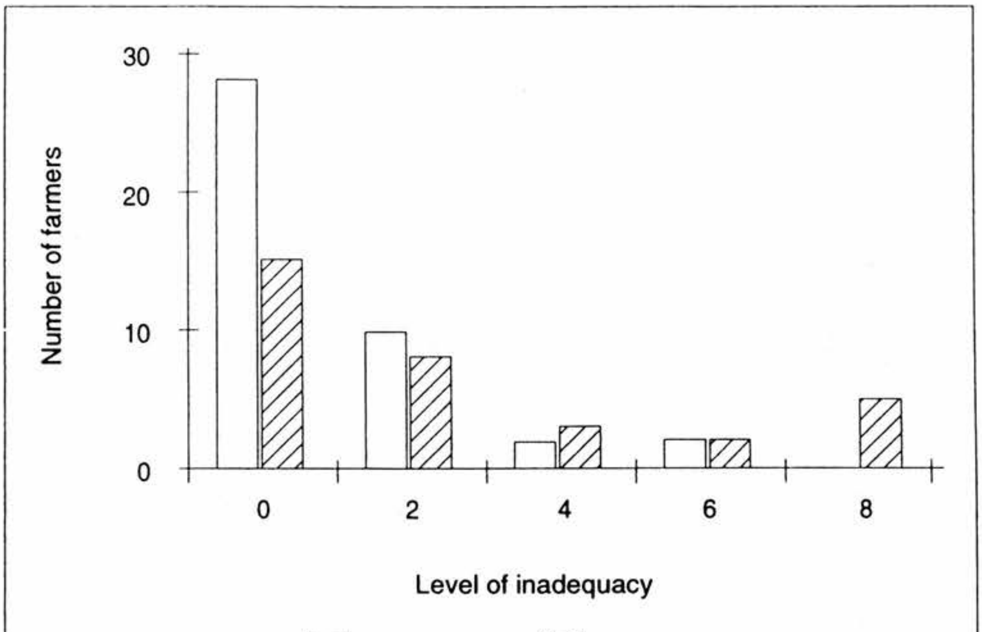

**Table 5: Preferences of farmers (number and percentage) for tractor or animal power in cropping practices**

| | Ploughing | | Harrowing | | Seeding | | Cultivation | | Transport | |
|---|---|---|---|---|---|---|---|---|---|---|
| | n | % | n | % | n | % | n | % | n | % |
| Animals | 81 | 86 | 81 | 86 | 85 | 91 | 85 | 91 | 57 | 60 |
| Tractors | 9 | 10 | 8 | 9 | 6 | 6 | 6 | 6 | 7 | 8 |
| Neither | 4 | 4 | 5 | 5 | 3 | 3 | 3 | 3 | 30 | 32 |

There was a difference between preferred and actual use of span size for ploughing with cattle, as shown in Figure 1. Most farmers preferred to span six animals and actually did so. Farmers in the districts of the former Ciskei were generally more satisfied with the number of animals they were using for draught than the farmers interviewed in the former Transkei, as shown in Figure 2 ($0,05 < p < 0,01$) – chi-squared on the difference between mean shortages, with negative binomial distributions fitted to Ciskei and Transkei data (Ross, 1987). The farmers interviewed in Ngqweleni and Maxelegweni were least satisfied with the number of animals they had available for work. Most of them wanted more oxen, and here the need for eight more oxen predominated, although the numbers of cattle owned in these districts did not appear to differ from districts elsewhere.

Farmers used the same span sizes for harrowing as for ploughing. However, only one pair of animals was used for cultivation and seeding by all farmers currently using draught animals. For carting, all farmers also used one pair of animals, except for three farmers using four animals and two using eight animals. One farmer who had a four-wheeled wagon used a span of 12 animals to pull it. Animals were worked both in the mornings and the afternoons as required. The ten farmers using horses for work generally used them for harrowing, seeding, cultivation and carting. Ploughing was done either by oxen or tractor. The horses worked in pairs or singly.

A total of 81 farmers responded to the question on training. Animals were trained either by the head of the household alone (22 per cent), or with assistance from children, spouse and/or brothers (74 per cent). On only three farms were the animals trained by hired hands (4 per cent). Some 93 per cent of the farmers started training their oxen at between 2 to 3 years of age.

All farmers except one said they worked their animals until they were fully grown, the exception being one farmer who said that when he had a group of young oxen fit to be worked, he would sell the older ones. Animals too old for work were used in local customs by 80 per cent of the farmers before being sold or eaten (100 per cent) or just eaten (3 per cent).

### 3.8 Feeding and management practices for livestock

All except two of the farmers interviewed grazed their animals on communal grazing land. One of those did not pay for grazing on neighbouring farms and the other had leased a government farm and so did not graze his animals on the communal land. All grazing land was natural pasture. When asked to assess the quality of their grazing land, 22 per cent of farmers said it was very good, 19 per cent said good, 16 per cent said fair, 13 per cent said poor and 30 per cent said very poor. A score from 1 (very poor) to 5 (very good) was given to these assessments of quality. Comparing these ratings for the districts in Ciskei and Transkei showed that the grazing was considered better in the former Ciskei than Transkei ($0{,}05 > p > 0{,}01$) – Pearson chi-squared on a $2 \times 3$ contingency table. For example, of the 28 farmers who assessed the grazing as very poor, 20 were in the former Transkei and eight were in Ciskei.

Half the farmers interviewed supplemented the grazing with other feedstuff. Irrespective of whether or not farmers gave additional feed, 51 per cent responded that their priority for feeding would be cows with calves. Only 4 per cent responded that their priority would be for working animals, whilst 26 per cent indicated that any animals in poor condition, usually because of drought, would be a priority for extra feed. The reasons for these priorities were given as milk production (44 per cent), better prices at the market (14 per cent), work output (5 per cent) and survival (2 per cent). Supplementary feeding was provided 'when necessary' (75 per cent) and 'in drought periods' (21 per cent). Stover was the most commonly fed supplement, usually in combination with lucerne (Table 6). Because of the stated priorities, this supplement would be fed mainly to milking animals rather than those used for work.

**Table 6: Number and percentage of farmers giving the different types of feed to livestock to supplement grazing (n = 47)**

| Type of feed | Stover | Lucerne (purchased) | Lucerne (home-grown) | Dairy concentrate |
|---|---|---|---|---|
| Number of farmers | 41 | 35 | 4 | 5 |
| Percentage of farmers | 87 | 74 | 9 | 11 |

That 43 per cent of respondents collect stover to feed to animals (see Table 2) supports the finding in Table 6 that nearly all the farmers (87 per cent) who give their livestock supplementary feeding (n = 47) use their home-grown stover for this purpose.

Access to water for livestock was generally close, with 34 per cent of farmers having a supply available to the animals on farm and 27 per cent having water within 1 km. Some 27 per cent of farmers regarded their access to water for livestock as distant.

All farmers reported the use of vaccination for disease prevention, with two farmers also using traditional methods. All respondents used spraying and dipping to cope with ticks and external parasites. Although farmers reported the presence of worms in their livestock, none of them acknowledged the use of dewormers. Most farmers (98 per cent) used antibiotics to treat their livestock for diseases, with some (81 per cent) reporting the use of vaccines. Few farmers (3 per cent) reported the use of home remedies to treat livestock diseases.

### 3.9 Farmers' opinions on draught animals

Most of the farmers interviewed (91 per cent) believed that it is profitable to own draught animals. Of the remainder, only one said that it is not (this farmer had inadequate oxen and spanned his cows), three said that they did not know, and no response was recorded for six farmers. The main reasons for profitability were the low outlay (67 per cent) associated with the use of draught animals, low running costs, inexpensive operation (14 per cent) and income generation (11 per cent).

When farmers were asked which fetched higher prices – draught or other animals – 57 per cent responded that draught animals are less valuable and 32 per cent responded that they are more valuable. The latter opinion seemed to be prevalent in the Peuleni, Dishi and Xwili districts.

Most farmers believe that draught animals should have relatively small frames (86 per cent), typical of the local, indigenous mixed breeds. Among the few farmers who specified a breed, the Nguni was the clear favourite. The main reason (91 per cent) for the farmers' choices was given as 'hardiness'.

In comparing the use of tractors and draught animals, the farmers gave wide-ranging responses. The most commonly held views were related to the comparative speed and cost of each power source. Some 85 per cent of farmers interviewed suggested 'tractors are fast but are costly' and 'oxen are slow but save money'. Additional comments made by six farmers were 'tractors can plough deeper'. Two farmers said 'communal grazing is free', two more farmers said 'tractors can work in all conditions', while a further two said 'animals are readily available, in contrast to a hired tractor' and 'tractors can cause compaction', respectively.

In addition to draught work, animals may provide four useful outputs: milk, meat, skin/wool and manure. A large majority of farmers (88 per cent) reported that they utilised all four, while 10 per cent of farmers reported that manure was not a useful output to them.

The survey also tried to elicit what farmers like about farming and what the major risks to their success as farmers are. The reported benefits of being a farmer were satisfaction, prestige and status, and showed very clearly the importance of job satisfaction. The risks were categorised into controllable and uncontrollable threats. Of the controllable threats, the greatest were theft and disease at 92 and 88 per cent respectively. Drought constituted the greatest uncontrollable threat and was reported by 97 per cent of the farmers.

## 4. DISCUSSION AND CONCLUSIONS

The smallholder farmers interviewed used and, for the most part, relied on draught animal power for their farming activities. Whilst this sample of farmers interviewed may not represent the poorest resourced members of the community in the districts surveyed, it was apparent that amongst livestock farmers it was representative of the smallholder farmers present in the area. Starkey (1995), in a rapid rural appraisal of draught animal power in South Africa, observed that in Transkei 40–80 per cent of farmers used draught animal power for weeding and planting, and at least 30 per cent used animal power for ploughing. He found that cattle were the animals most commonly used for work.

In the present study, cattle were the most important source of animal power, with a considerable number of farmers (over 50 per cent of those interviewed) willing to use cows for crop production. Although there are virtually no statistics on this, the number of cows used for work is probably increasing in sub-Saharan Africa (cf Jabbar, 1993; Starkey, 1993). In Zimbabwe, for example, Chawatama & Ndlovu (1995) report an increase in the use of cows for draught as a result of drought. Moreover, Ndlovu & Francis (1997) comment that the use of cows for traction could be considered as a barometer of draught animal power shortage. The acceptance of draught cows found in the present survey seems higher than might be expected from the situation elsewhere, but this may well be due to differences in the sizes of the breeds and crosses used for work by smallholder farmers in the respective countries. The breeds and crosses used for work in the districts surveyed were generally large compared to the size of those used in Zimbabwe, where the Zebu is prevalent, for example (Ndlovu & Francis, 1997). Hence, the generally smaller female animal would be more acceptable in areas such as the Eastern Cape than in areas where working breeds are smaller. The use of cows may also be a reflection of the farmers' perceived shortage of draught power. Horses mentioned in the survey were generally kept for riding and ceremonial purposes. Some farmers also used them for work but not in the numbers found for working cattle.

The circumstances which may predispose farmers in the Eastern Cape to use draught animal power can be described in three categories:

### 4.1 Resources

The survey has confirmed that the semi-arid zone livestock-crop production systems typical of the Eastern Cape are generally livestock oriented. There was a wide availability of animals, especially cattle, potentially suitable for draught work. Most farmers expressed a preference for animal power over tractor power, although the majority of farmers had used tractor power when they considered it necessary, usually for opening up fallow ground. Farmers seem to be well resourced, relative to smallholders in neighbouring countries, since tractor power was available and span sizes were generally larger (4–8 animals) than those typically found elsewhere in sub-Saharan Africa (Dibbits, 1993; Chawatama &

Ndlovu, 1995). Also, most farmers used vaccines and antibiotics to maintain animal health. Implements were not obviously in short supply although some farmers felt that access could be improved. Grazing supplied most of the nutritional needs of livestock for most of the year, supplemented by crop residues. Few farmers seemed prepared to purchase supplementary feeds for their draught animals, preferring to supplement cows first. This may be because the value of the working animal is less readily converted to cash.

### 4.2 Economic factors

The majority of farmers interviewed, most of them current users of draught animal power, believed it was profitable to own or use draught animals, the main reason (67 per cent) being the low capital outlay. Thus, among those farmers owning livestock in the smallholder farming community, draught animal power is more economically attractive at present than tractor power. It was noticeable that one farmer with limited numbers of livestock used manual labour to work his land. Many farmers, including those not currently using draught animal power, stated that tractors were fast but costly, whereas animals were a slow but inexpensive form of power. Many appreciated that animals provide other benefits in the form of milk, meat, manure and skins, whereas tractors are associated with expensive overheads, such as fuel, parts and servicing. None of the farmers raised the issue of the cost of caring for animals. Either this was considered insignificant or farmers did not regard the care of their animals as warranting any expenditure.

For supplementary feeding, the preference was to give extra feed to cows in milk rather than to working animals (only 4 per cent), as this was economically more advantageous. The opinion on whether draught animals were more or less valuable than other animals was more evenly divided, with 32 per cent believing that they were and 57 per cent that they were not. This suggests that at least some farmers would be prepared to consider management intervention that might improve work performance or the health and longevity of their working animals.

### 4.3 Social factors

Animals are associated with many traditions and customs, particularly *lobolo* – the Xhosa custom whereby a bridegroom hands over cattle for his bride/wife – and so are fully integrated into the farming culture in the Eastern Cape (Elliot, 1995; Panin & Ellis-Jones, 1994). Hence, the farming practices in the Eastern Cape are unlikely to become separated from the use of livestock and its interaction with crop production. The farmers have a long history and a sound understanding of using animals and this has been reflected by their general preference for using draught animal power rather than tractor power, for which there seems to be less affinity. Almost every farmer (94 per cent) reported enjoying the satisfaction of farming (and hence by definition their association with livestock) but perceived drought (97 per cent) and the risks of theft and disease (also 97 per cent) to be the greatest threats to their success.

The current management and use of draught animals in the areas surveyed in the Eastern Cape province indicate that for those smallholder livestock farmers wishing to maintain or increase their crop production, draught animal power is an appropriate technology to use at present. It therefore merits promotion in the region.

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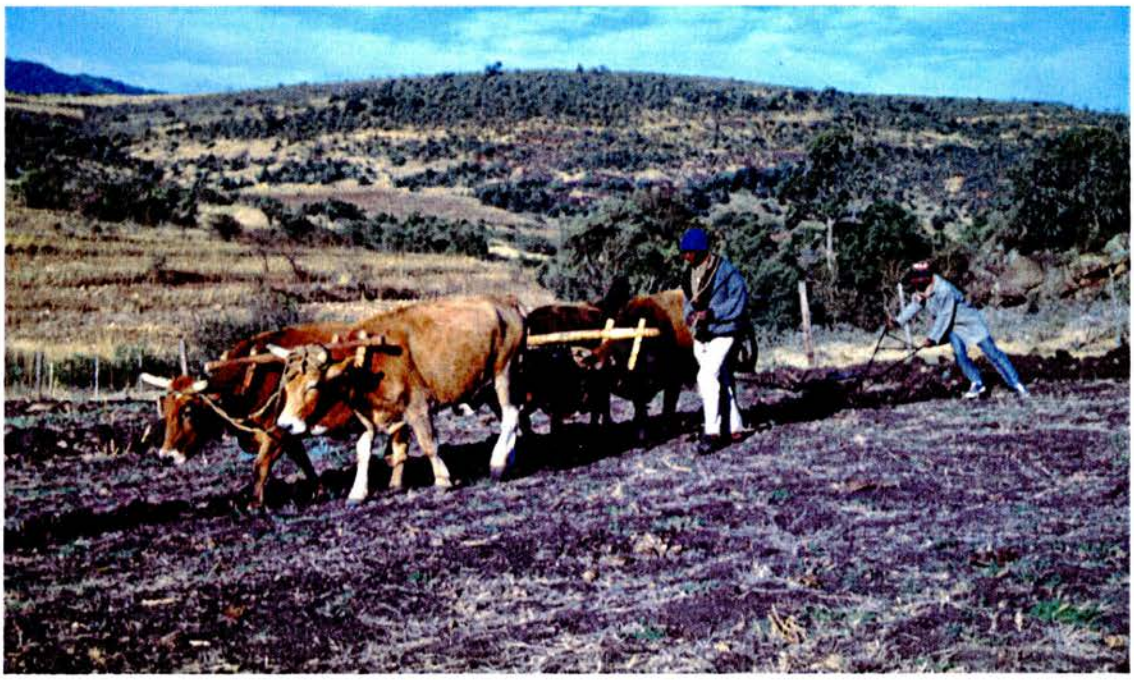
University of Fort Hare

# Seasonal contributions of draught animals to activities in small-scale "emerging" farming in the Eastern Cape of South Africa



Stanley H. Israel, Nkosi T. Mzileni, R. Anne Pearson and David H. O'Neill

*Centre for Tropical Veterinary Medicine, University of Edinburgh, Animal Traction Centre, University of Fort Hare and Silsoe Research Institute, Bedfordshire, UK*

**1999**

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Stanley H. Israel[1], Nkosi T. Mzileni[2], R. Anne Pearson[1] and David H. O'Neill[3]

*[1]Centre for Tropical Veterinary Medicine, University of Edinburgh, Easter Bush, Roslin, Midlothian, EH25 9RG, UK.*

*[2]Animal Traction Centre, Department of Agronomy, University of Fort Hare, P.B. X1314, Alice 5700, South Africa*

*[3]Silsoe Research Institute, Wrest Park Silsoe, Bedfordshire, MK45 4HS, UK*

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The information and views expressed are entirely the responsibility of the authors and are not attributable to any of the organisations involved.

**Front cover:**

The photograph on the front cover is of Mr Hamilton Gobodo working with his draught cattle on his farm in Chamama, Eastern Cape Province.

The photograph was taken by Paul Starkey, 64 Northcourt Avenue, Reading, RG2 7HQ, UK. We are grateful to him for permission to reproduce it here.

**SUMMARY**

Tractor hire schemes in the Eastern Cape have not been widely adopted by small-scale farmers, who have found them expensive and unreliable. Animal power is seen by many of the "emerging" farmers as an economic and available source of power with which to complement manual labour and some tractor power on their farms. Three farmers from Chamama, in Amatole Basin and three farmers in Esixekweni, Debe Nek kept diaries recording the activities they undertook with their draught animals and the management of these animals on their farms, from July 1997 to October 1998.

The main crop grown was maize, with some vegetables grown as supplementary crops. The animals were busiest between August and November in Esixekweni and later in the year, from November to January, in Chamama. Teams of four to six animals were generally used for ploughing, with teams of two usual for cultivation, planting, harvesting and transport. More animals were used for transport if the load was heavy. Cows were spanned together with oxen when the need arose. No extra management of working animals was undertaken, they were kept and fed as the other cattle on the farms, with any preferential feeding usually given to the cows in milk. Peak times of use were influenced by the rainfall and coincided with land preparation and planting. Transport - of water (all year), manure (July to October), firewood (October to February), branches for kraals (as necessary) and building materials (intermittently) - was a regular use of draught cattle, using sledges at Chamama and carts at Esixekweni. Men and women worked together in carrying out farm activities, but men usually did most of the work, particularly with the draught cattle, as women were involved in the domestic chores.

Livestock, particularly cattle were the farmers' main resource, with farmers generally selling cattle for slaughter, not to other farmers as draught animals. Replacements were produced on-farm. Tick borne diseases were the main health problem in both areas. Dipping occurred only in Chamama (November to May). Most diseases were treated using local remedies due to the cost and difficulty of reaching veterinary advice and drugs. Implements were handed down through the families and spare parts were purchased when necessary during the year from Middledrift.

Apart from inaccessible veterinary services, the main concerns of farmers over the period were shortages of labour (necessitating farmers having to wait until boys returned from school to help with working the draught cattle), encroachment of cattle on to crop land through inadequate fencing or supervision, and local lawlessness, where crops may be stolen or vandalised, sometimes by neighbours allowing their animals into crops that had yet to be harvested. Farmers used their pensions to finance their agricultural activities, contributing to the fairly widely held belief that farming needs outside cash support. This is something which farmers felt may be deterring young people from taking up agriculture, although they themselves were pleased with the produce and income they obtained from farming.

# 1. INTRODUCTION

In the past extensive use was made of draught animal power on smallholder farms in Eastern Cape. Oxen provided the main source of power for ploughing, cultivation and transport. Historically horses have tended to be regarded as status symbols and have been kept largely for riding, but some donkeys and mules are used mainly in transport. In more recent times the use of animal power has tended to be discouraged by programmes that have promoted the use of tractor power. In the 1970s and early 1980s the Department of Agriculture started its mechanisation programme with the promotion of subsidised tractor services to all small-scale farmers. This scheme was largely privatised in the late 1980s and early 1990s and tractor hire schemes continue to operate today. The "betterment schemes" of the Government followed. These involved land-use planning and consolidation of cropping and grazing areas. They have tended to help make tractor use more efficient and also discouraged the maintenance of animals for work (Starkey, 1995). Although a lack of power may be a limiting factor to food production (Kotsokoane, 1997), small-scale farmers have to rely on power sources they can afford. A comparison of draught animal and tractor costs by Fowler (1996) showed that although tractors could work almost 10 times faster than animals, their costs are at least 10 times as much. This observation is supported by the opinions of farmers in Eastern Cape (see O'Neill *et al.,* 1999), who commented that tractors are fast but costly, whereas oxen are slow but save money. Use of draught animal power can also alleviate the drudgery associated with manual cultivation especially for women, and increase productivity where tractors are not a viable alternative to manual cultivation of crops.

The tractor hire schemes led to a decline in the number of draught cattle being used in land preparation and a decrease in the promotion of animal power by extension services from the 1970s to the early 1990s. Use of oxen did not stop altogether, particularly in the remote rural areas, as the government tractor schemes were generally regarded as unreliable, except near the tractor centres. Since privatisation, the tractor hire schemes have become too expensive for many of the smallholder farmers. This has resulted in an increase in the number of farmers using animal power in crop production in Eastern Cape (Starkey, 1995) and a belief by farmers interviewed in the former Ciskei and Transkei that animal power is a viable option to engine power for those who cannot afford tractors, and can complement engine power for those that use tractors for primary tillage (Jaiyesimi-Njobe, 1995). According to Kotsokoane (1997), poverty can be eliminated by providing an "enabling climate" for farmers to produce efficiently and profitably within the limitations of the environment. It is suggested that this "enabling climate" must include draught animals.

A more recent survey found that 91% of farmers believed that it was profitable to own draught cattle (O'Neill *et al.,* 1999), but virtually all were concerned about the risks of drought, theft and disease. Kotsokoane (1997) believes that it is through intensification and diversification that farmers can be successful and will be able to create employment opportunities and bring prosperity to their communities.

In view of the increasing belief in the use of animal power in small-scale farming in Eastern Cape, a study was undertaken to investigate, in detail, the seasonal patterns of management and use of animal power on co-operating farms in Amatole Basin and Debe Nek, Eastern Cape. The focus of the study was on "emerging farmers", those farmers who are developing their commercial activities and are generating cash flow through mixed farming. It is farmers such as these who have a major part to play in agricultural production in the "New South Africa". The aim of the study was to obtain a picture of the contribution that animal power makes on "emerging" farms in Eastern Cape throughout the year, rather than to gather statistical or detailed numerical information.

## 2. METHODOLOGY

Two study areas were selected on the bases of their known use of draught animals for agriculture and their distance from Fort Hare University to ensure access throughout the year. The areas were Esixekweni in Debe Nek and Chamama in Amatole Basin, both of which are within Middledrift district in the Eastern Cape Province. Three farmers who keep and use working cattle were picked from each area to participate in the monitoring. Each farmer was given a diary and agreed to record in it all activities pertaining to farming, as well as draught animal use and management. Regular farm visits by one or two members of the research team were arranged every two weeks in order to support the farmers in their record keeping, transfer the information from the diaries and collect any additional information through personal observations around the households or farms. On these visits additional information was also collected through discussions with the farmers or other members of their families. The monitoring lasted sixteen months (July 1997 - October 1998, inclusive). Information obtained was summarised in chronological order and collated under specific topics. Many topics are inter-linked and, as far as possible, information is cross-referenced. Where relevant, information is included in more than one section to aid understanding of that topic.

## 3. PARTICIPATING FARMERS

The six farmers participated in the survey with varying levels of commitment as the survey progressed. Three farmers - Mr Hamilton Gobodo, Mr Sipo Mapitiza and Mr Simon Salusalu - were from Chamama, and the other three - Mr Kwedana Dyantyi, Mr Benjamin Kedama and Mr Pitwell Ndarala were from Esixekweni. Before participating in the seasonal monitoring study, the farmers took part in informal interviews, similar to those in a wider survey of draught animal power owners in Eastern Cape (O'Neill *et al.,* 1999). During the individual interviews they each described their farming systems. The results of these informal interviews, together with those from a final brief interview in January 1999, are given in this section.

### *3.1 Chamama farmers*

All three farmers own at least four oxen and two cows (according to interview in January 1999) and use them for draught purposes (Table One). None of them owns donkeys or horses, but they all own small livestock. They all use their animals for harrowing, planting, cultivation and transport (for which they use a sledge). Two of them who do not have all the implements they need are able to borrow. Two of the farmers use six cattle for ploughing and two farmers use six cattle for harrowing. The other farmer uses a tractor for ploughing and four oxen for harrowing. This farmer does not span his two cows. Except for ploughing and harrowing, two cattle are used. They are all satisfied with these span sizes and all say they can afford to purchase the equipment they need for farming. The two farmers who plough with animals occasionally hire a tractor for primary cultivation but, in general, all three prefer to use animals for their agricultural tasks. The agricultural tasks are undertaken as family activities except that women do not plough, although they may lead the animals. The priorities for women are to attend to domestic tasks. The commonest agricultural task for women is weeding with the hoe.

The main crops grown are maize, beans, peas, pumpkins and potatoes, on cultivated areas of about 2 to 5 ha. The proportions grown for home consumption vary from between 10% to 75%, with the remainder being available for sale. All three farmers fertilise their crop lands with manure, although not every year, and use both cultivators and hand hoes to weed their crops. They are happy with their yields and all their marketing is local. All three farmers leave stover in the fields for communal grazing. None of the farmers said that he provides extra feed for his working animals; two of them said preference would be given to milk cows, the third did not give any indication. The most prevalent animal pests are ticks and worms and the commonest diseases are Heart-water (Cowdriosis) and Red-water (Babesiosis). All three farmers believe it is profitable to own draught animals.

**Table One: Number of cattle and oxen kept from June 1997 to October 1998 by three farmers in Chamama and three in Esixekweni, Eastern Cape Province, South Africa**

| Location and farmer | Total no. cattle | Work oxen owned | Cows used for work | Average weight of work oxen (kg) |
|---|---|---|---|---|
| **Esixekweni:** Farmer 1 | 17 - 18 | 4 | 7 | 504.5 |
| 2 | 5 - 6 | 2 | 2 | 480.0 |
| 3 | 7 | 2 | 0 | 495.0 |
| **Chamama:** Farmer 1 | 8 - 12 | 6 | 0 | 453.3 |
| 2 | 10 - 12 | 5 | 1 | 396.8 |
| 3 | 10 - 17 | 6 | 3 | not available |

### *3.2 Esixekweni farmers*

All three farmers own at least four head of mature cattle and use them for draught work, but one farmer (farmer 3) does not span his cows (Table One). None of them owns donkeys but one owns a horse which is not used for work; all own small livestock. They all use their animals for ploughing, harrowing, planting, cultivation and transport. All the farmers own ploughs and harrows and at least two of them who do not have all the implements they need are able to borrow (it is not clear in the case of the other farmer). They all say they can afford to purchase the equipment they need for farming. The number of animals used varies from two to eight, depending on the task, the number of animals and people available and, in the case of carting, the weight of the load. The farmers are able to borrow animals to make their preferred spanning arrangement and all say that they are satisfied with the spans used. All three occasionally hire a tractor for primary cultivation but, in general, all three prefer to use animals for their agricultural tasks. As in Chamama, the agricultural tasks are undertaken mainly by all members of the family, except that women do not use a plough, but can lead the animals. The priorities are for women to undertake the household tasks, so at least one farmer hires labour to help with his agricultural activities.

The main crops grown are maize, beans, potatoes, peas and pumpkins, on cultivated areas from around 4 to 6 ha. About 30% to 80% of the produce is for home consumption, with the remainder being available for sale. The produce that is sold is marketed locally, but one of the farmers had traders coming to him to purchase. The farmers are happy with their yields, but use manure only when they believe it is necessary. They are prepared to give away manure that is surplus to their requirements. Stover may be left in the fields or carried to the homestead for use as fodder, depending on the individual farmer's needs or wishes. All three farmers provide extra feed for their animals, with both home-grown and purchased supplements; the preferences regarding milk or working animals vary, with one farmer feeding cows in bad condition, another feeding oxen and the third not stating a preference. The most prevalent animal pests are ticks and worms and the commonest disease is Red-water (Babesiosis). It is generally considered profitable to own draught animals.

### *3.3 Comparison of situations at Chamama and Esixekweni*

From the farmers' questionnaires, the situations at Chamama and Esixekweni are very similar. The biggest contrasts, particularly regarding the management of draught animals, are (a) the difference in feeding strategies, with the Chamama farmers leaving stover in the field and not mentioning extra rations for the draught animals, (b) the generally smaller (and more variable) span sizes at Esixekweni and (c) the absence of carts for transport at Chamama. Following on from the questionnaire analysis, further differences will be seen from the seasonal monitoring programme reported below.

## 4. OBSERVATIONS

### *4.1 Crops grown during the year and products transported using animal power*

Two out of the six farmers, one in each location started their primary cultivation in May and June (Table Two), immediately after the maize harvest. This, they claimed, simplified the work because at that time the soil was still moist and therefore easy to work. They also noted that early ploughing of the soil reduced runoff, preserved more

**Table Two: Cropping calendar and related activities based on the period June 1997 to October 1998 on three farms in Chamama and three in Esixekweni, Eastern Cape Province, South Africa**

| | January | February | March | April | May | June | July | August | September | October | November | December |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Plough & Harrow** | | | | | Primary Cult. | Primary Cult. | Primary Cult. Harrow | Primary Cult. Harrow | Primary[2] & Secondary Cult. Harrow | Secondary Cult. Harrow | Secondary Cult.[2] Harrow | Secondary Cult. & Harrow |
| **Planting & Weeding** | Peas Potatoes | Maize Potatoes | Oats[3] | | | Potatoes Peas | Pumpkins | Pumpkins | Pumpkins Maize Beans | Maize Beans Peas | Maize Beans Potatoes | Maize Beans Potatoes |
| **Harvest** | | Pumpkins Potatoes | Maize | Maize beans | Maize | Maize Peas | | Potatoes | Peas Potatoes | | | Potatoes |
| **Transport** | Wood Water Branches Bricks | Wood Water | Wood Water Poles | Wood Water Sand | Water Poles | Water | Manure Water Wood[1] Branches | Manure Water Wood[1] Branches | Manure Water Branches | Manure Water Stone | Water | Water |
| **Other Activity** | | | | | | | | | Spread manure | Spread manure | | |

[1] firewood for ceremony; [2] One farmer used a tractor as well as oxen; [3] Oats grown for winter grazing (Chamama).

moisture within the soil and reduced soil erosion. It also helped to reduce weeds, since the latter were removed before their seeds had fully matured. Having done primary tillage early, secondary cultivation and harrowing became easier. The other farmers ploughed later in the year, influenced by rainfall pattern (see Section 4.2).

One farmer in Chamama had sown oats in March 1997 before the start of the monitoring period, for winter feed (see Section 4.4). He said he turned his livestock on to the oats for supplementary grazing in the winter months (May, June and July).

Table Two shows that cattle were used for transport activities throughout the year. Water was the only commodity that required transport throughout the year. Transport of firewood occurred mainly between January and April (summer time) whereby enough was accumulated to supply the farm over the winter and early spring months. There was however an exception to this general trend whereby one farmer in 1997 and 1998 transported firewood in late winter for use in a ceremony. Manure was transported during late winter and spring (July - October), this preceded and to some extent overlapped with the main planting season for maize, pumpkins and beans. Transport of stover for animal feeding was not practised at Chamama. Crop residues were transported by two farmers at Esixekweni in April. While maize was planted in spring when enough rain had fallen, the planting of vegetables, particularly potatoes and peas was sometimes staggered, particularly when it was for home consumption. Harvesting depended on when the crop was sown. Maize was harvested green or dry depending on the farmers' preferences.

### *4.2 Draught animal use*

Table Three shows the amount of time spent (according to the diary records) for each activity in each area over a whole year (July 1997 - June 1998) and the average time spent working per day each month from information available. The data are likely to represent the minimum use that was made of the animals, since not all farmers were diligent in recording each activity. A tractor was used for ploughing by some farmers. For example farmer 1 in Chamama used one on three days:- in September and November 1997 and in September 1998 (see Appendix 1). Figures from the Fort Hare Animal Traction Centre suggest that if draught power alone was used, the time taken for ploughing would exceed the values given in Table Three (A..B.D. Joubert, personal communication). Therefore it is likely that other farmers may also have made use of a tractor for ploughing, but did not record it. Given these suppositions, Table Three does however show the peak season of use of the animals. Draught cattle on the farms in the two areas were recorded as being used for a total of at least 33 days in Esixekweni and 70 days in Chamama in the year July 1997 to June 1998 (Table Three). The three farmers in Esixekweni cropped a total of 11 ha whilst those in Chamama cropped a total of about 13 ha. The animals did some work almost every month, but were busiest (based on hours worked) between August and November in Esixekweni and later in November to January in Chamama. The difference in seasonal use for the two areas was due to the differences in the rainfall pattern during the year in the two areas. Due to the erratic rain showers in Chamama, the farmers had to replant maize up to three times within the same season in Chamama and so continued to work their cattle in cropping activities until March 1998, long after farmers in Esixekweni had ceased using their cattle on the land (November 1997).

**Table Three: Amount of time (h) recorded as spent by draught cattle each month on all farms for activities over a year from July 1997 to June 1998**

(a) Chamama (3 farmers)

| | July | Aug | Sept | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | June |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Plough** | | 9 | | | | 8.5 | 31 | | | | | |
| **Harrow** | | | 4.5 | | 7.5 | | | | | | | |
| **Plant** | | | | 6 | 21 | 7.5 | | | | | | |
| **Cultivate** | | | | | | 2 | | 9 | 6 | | | |
| **Transport** | | 1 | 8 | 11 | | | 4.5 | | 6.5 | | 3 | |
| **Total (h)** | | 10 | 12.5 | 17 | 28.5 | 18 | 35.5 | 9 | 12.5 | | 3 | |
| **Total (d)** | | 2 | 3 | 3 | 5 | 6 | 8 | 2 | 3 | | 1 | |
| **Time/d** | | 5 | 4.2 | 6.3 | 5.7 | 3 | 4.4 | 4.5 | 4.2 | | 3 | |

(b) Esixekweni (3 farmers)

| | July | Aug | Sept | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | June |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Plough** | | 35 | | | 11.3 | | | | | | | 16.8 |
| **Harrow** | | | 1.5 | | 6 | | | | | | | |
| **Plant** | | | | | 3 | | | | | | | |
| **Cultivate** | | | 2 | | 1 | | | | | | | |
| **Transport** | | 5 | 33 | | | | | | | | | |
| **Total (h)** | | 40 | 36.5 | | 21.3 | | | | | | | 16.8 |
| **Total (d)** | | 11 | 9 | 9 | 8 | 6 | 2 | 6 | 0 | 6 | 8 | 5 |
| **Time/d** | | 3.6 | 4.1 | | 2.7 | | | | | | | 3.4 |

In Chamama, all farmers used six animals for ploughing, adding in cows to make up the number if necessary (two farmers) or borrowing from another (one farmer). In Esixekweni farmer 3 (see Table One), who only had two oxen, used them for all activities including ploughing and did not attempt to hire in others from outside. The other farmers in Esixekweni used 4-6 animals for ploughing, borrowing one span where necessary for ploughing. In Chamama farmer 1 would span eight of his animals when transporting materials or water long distances with his sledge. Harrowing by all farmers was usually done with only 2-4 cattle, although in the informal interview some had reported six were always used. Only a pair of cattle were used when planting and weeding, except when planting was done on the same day as ploughing, when the team was usually kept unchanged. During the monitoring period, the farmers were offered the use of a ripper tine which some of the farmers used with two oxen to open a furrow for planting maize, pumpkins and potatoes. This implement was not very widely used because there was only one at each location.

Field work started about 0700-0900 h in the morning and lasted until it was finished or until about 1400-1500 h. Where there was a labour shortage, the farmer delayed his start to wait for assistance from boys after school (see Section 4.3).

### *4.3 Distribution of farm labour*

The majority of farm or household activities that involved use of draught animals on the farms were done by males. This meant that most farming activities were almost exclusively done by males. Inadequacies in supply of labour for working the animals were rectified by making arrangements with those members of the community who did not have their own oxen so that they could assist in return for having their plots worked. Another arrangement was to schedule farm operations so that they took place in the afternoon with assistance from boys after they had returned from school. Girls returning from school did not help with the animals. At peak periods of farm activity, some farmers were forced to hire labour for activities that needed to be accomplished promptly. Examples include weeding following some rain after a prolonged dry period (November/December, Chamama) and when the plants were too tall for working animals to pass through without causing damage (February). Further strategies to overcome the problem of labour inadequacy entailed the use of working animals in pairs for ease of working, so that one operator only was needed at a time. An added advantage of this arrangement which farmers spoke about was that if only two animals are worked at a time, all the oxen have time for grazing. One pair work while the others are grazing and then once the working pair show signs of getting tired, the others are spanned in their place while the worked pair then have time to graze. Females members of the household were allowed to work with animals, but in practice were engaged mostly in domestic chores. Sometimes they assisted in doing farm work which did not involve working with animals, such as weeding between the rows and planting by hand.

### *4.4 Resource management*

Farmers in the two study areas obtained income mainly from the sale of livestock and any farm products that were produced in excess of those they required for their home consumption. This income added to the money they received from their monthly pensions. The main inputs that went into farming included costs for tractor hiring, purchase of seed, repair of animal traction equipment, costs for animal health care and in a few cases hiring of labour. Some of the farmers said that they had been able to build a reasonable standard of housing for the family and send their children to school by making use of income generated from crop production. For some of the farmers income from crop production seemed very little compared to the inputs, but more than three-quarters of the food produced on the farms was consumed by the household, and farmers all said that they met most of their domestic needs for food from farm production.

Maize stover is the only by-product from crops that is available in substantial quantities in Chamama and Esixekweni. After threshing, bean and pea crop residues were fed to livestock in the kraals in the evenings and were not stored. Two farmers in Esixekweni harvested the maize stover and stored it near their homesteads for winter feeding. These two farmers had crop land close to their homesteads. The other farmers left the stover standing on the field and grazed all their animals when the need arose, letting their oxen graze during the working period. In the latter arrangement, oxen that were not inspanned were left to graze on the area that was yet to be ploughed, until their turn to work came. The farmers in Esixekweni who did transport stover did so on their carts. Farmers at Chamama even if they wanted to collect stover

In-spanning a pair of oxen at the start of a working day

Transporting manure using a cart in Esixekweni for animal feed said they could not because it was difficult on a sledge. One farmer in Chamama used oats that he has sown in March as a supplementary winter livestock feed. The animals were turned onto the crop periodically over the winter season, according to crop growth.

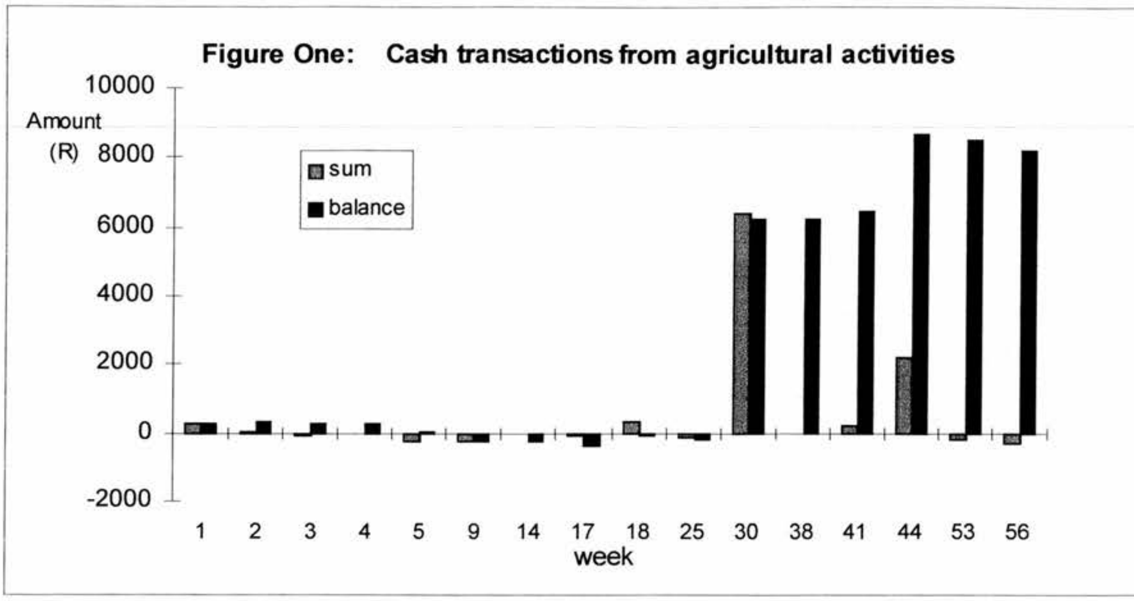
All livestock in Esixekweni were always confined in kraals at night, but at Chamama only the goats were confined at night. Manure was transported by two farmers in the study period, farmer 1 at Esixekweni (using his cart) and farmer 2 at Chamama (using bags and his sledge). The manure was turned out in heaps at several points in the fields. Depending on the crop that was going to be established, manure was either spread manually all over the field from the piles before ploughing, or it was applied on specific points together with the seeds during planting (for example when planting pumpkins). Two reasons for not applying manure to the fields were the distance from the household to the field and because the farmer believed the land being cropped did not need it that year. The farmers believe that the soils were sufficiently fertile not to need an application of manure every year. It was general practice to manure once in three years, the main indicator of need being the performance of the previous crop. Farmer 3 from Esixekweni, for example, who had crop land near his household, did not use manure this year because he believed the soil did not need it.

Farmers invested considerable effort in protecting their resources and assets. Kraal building and repairing was a regular activity and, before and after the cropping season, repairs to maintain the fences and gates around the plots. These activities involved significant use of animal power for the transport of branches and poles (Table Two).

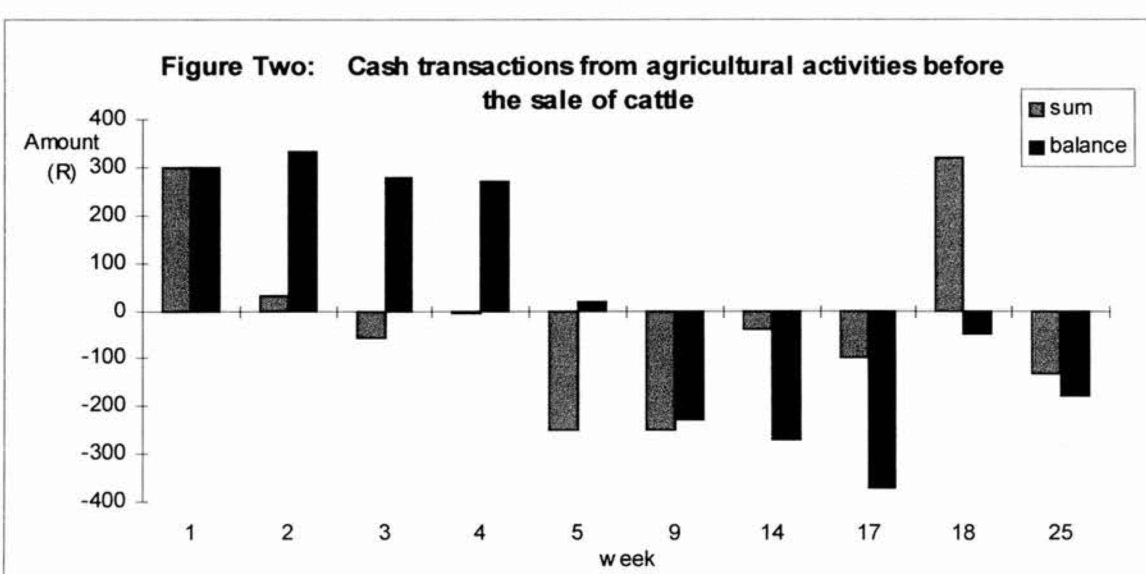
Livestock, particularly cattle, are the farmers' most significant resource and they exist as a reasonably liquid asset. Farmers selling cattle generally sold then for slaughter, not to other farmers for use as draught animals. Amongst these farmers over the monitoring period, replenishment of cattle was by the birth of calves. Farmer 1 at Chamama who sold three of his cattle and slaughtered two for ceremonial purposes was provided with three male calves by his cows. He also lost a 3-month old heifer which died, but no reasons were given. There is very little information on cattle rearing from the other participating farmers, with no details of buying or selling. However, births and deaths were noted and over the period of study six births and two deaths were recorded, as well as the two slaughtered, mentioned above. Overall, therefore, the cattle ownership of these farmers increased by two. Of the six births, two were female and four were male. Breeding is a natural, uncontrolled process with bulls serving the cows whilst they are grazing.

### *4.5 Cash flow*

An indication of the size and range of cash transactions typical of small-scale farmers can be obtained by examining the records of one of the farmers. The greatest detail was available from one of the farmers at Chamama, and transactions arising from his agricultural activities for a period of just over a year, from September 1997 to October 1998, are shown in Figure One. It is doubtful that every transaction is represented but this figure does illustrate the very large influence that livestock, especially cattle, has on the household economy. Dealings in cattle are of the order of ten times that of other transactions, except, presumably, the purchase of major items of equipment.




The relatively small transactions during the earlier weeks cover items such as the purchase of seed (from 40 to 180 R), equipment repair (7 R), hire of tractor (250 R twice, then 300 R) and hire of labour (130 R). On the cash input side, prices of sales of produce varied from 32 R for skins and hides to 228 R for mealie cobs to 300 R for potatoes. These and the farmer's negative cash flow situation are illustrated more clearly in Figure Two, which shows the transactions in the first half of the year before the sale of two oxen (for 6400 R). Here, it can be seen that from the 9th to the 25th week the farmer was in negative cash flow as a result of purchasing his crop inputs. However, it would be reasonable to assume that, had the farmer needed cash, he could have sold some livestock. It is felt that these two figures emphasise the importance of livestock in the farming system because they can be traded for so many other inputs. However, what an analysis such as this does not show is how the loss of livestock, particularly cattle, deplete a farmer's assets and influence his purchasing power. Conversely, the successful birth of a calf adds to a farmer's assets with virtually no outlay - as bulls' services are not usually paid for.



### *4.6 Animal diseases*

Farmers at Esixekweni showed no interest in recording details of animal diseases or health care, but two of the farmers reported unspecified sickness in their animals in February. Farmers at Chamama were willing to report details of diseases and treatments given. Tick borne diseases presented the biggest health threat with the majority of reported incidences of sickness being locally diagnosed as Red-water (Babesiosis). Cases were reported by the farmers throughout the summer months (November to May). A few cases of Heart-water (Cowdriosis) were also reported in April and May. These observations supported the information provided by the farmers during interview at the start of the monitoring period (see Section 3).

### *4.7 Health care for working oxen*

There was no special attention given to health status of working cattle. Apart from excluding them from work when sick, cattle received the same care and remedies as any other sick animal in the farmstead. Treatment of animals with sickness was mostly accomplished with local remedies (see Table Four). Expert advice was sought only when the local remedies seemed to fail. The main reason for this almost total reliance on local remedies was the costs involved in seeking expert advice. Money was needed to cover taxi fares for going back and forth from Chamama to Fort Cox College of Agriculture to obtain veterinary advice after reporting the case, and to purchase the medicine at Middledrift, as well as the payment required for the treatment. All these trips also take time. Another problem farmers' reported was that the veterinarian may not arrive for several days after an animal is reported sick. Traditional remedies for several of the animal diseases that are endemic in the two areas were recorded by one farmer in Chamama. The farmers claimed that these remedies are effective in treating their animals and they usually learn them from their parents, relatives or local people (Table Four).

Internal parasites were also controlled with local concoctions (Table Four) that were given whenever the farmer felt the need to do so after observing his animals (one farmer in Chamama treated his animals in September and November). In Chamama dipping for the control of ticks was done on a monthly basis sometimes twice a month during the summer months from November to May. Farmers were prepared to contribute to the cost of buying acaricide because there was a heavy tick challenge. Despite dipping farmers reported tick borne diseases in their oxen, cows and in young animals ("isifo somqeku" - ephemeral fever) during these months, although they admitted that they did not always take all animals to the dip. In Esixekweni dipping was not recorded by the farmers, but one of the farmers attended two meetings in March 1997 to discuss repairs to the dip tank in his area. Other reasons given for not dipping were: a lower prevalence of ticks, the distance from the dip (about 6 km), a lack of water at times and an unwillingness of farmers to purchase acaricide. In the past it had been provided free by the Government.

One farmer in Chamama gave a twice yearly dose of a mixture of vinegar, sugar and water to prevent/control bovine TB (Table Four). In May the cattle were vaccinated with help from the Department of Agriculture for "unomkhonwana" (Black-quarter, *Clostridium chauvoei*) in combination with a vaccine against anthrax.

## Table Four: Local remedies for common diseases as reported by one farmer in Chamama in the Amatole Basin, Eastern Cape Province in 1997/98

***1. Treatment of tick borne diseases***

(i). Ingredients: *Aloe ferox,* especially the dry parts at the base of the plant
Table salt
"Bloustan" (Copper sulphate)

Preparation: Cook the aloe leaves to boiling point, add salt and "bloustan" (about a knife point).

(ii). Ingredients: "Umdubu" leaves
"Imbethe" roots
"Bloustan" (Copper sulphate)

Preparation

The "umdubu" leaves are cooked together with "imbethe" roots and then "bloustan" is added

***2. Treatment of Red water (Babesiosis)***

Ingredients:

| | |
|---|---|
| 1 part | "umbomuane" bark (*Elaeo dendron croceum*, saffron tree) |
| 2 parts | "umngwenya" bark (*Ekebergia capensis*) |
| 3 parts | "umgxam" bark (*Schotia afra*) |
| 4 parts | "umfinca-fincane" leaves (*Leonotis leonoris*, red dagga) |

Preparation: Take and mix each of the ingredients above and pound them thoroughly on a stone to crush the bark. Transfer the mixture into a cooking pot, add 1 litre of water and bring to boiling point, boil for half an hour. When cool, separate the juice from the rest of the mixture and this is ready for use. Adult cattle are given one bottle (1 litre) of the mixture while younger animals are given half this dosage.

***3. Treatment for* "Amathumba" *(lumpy skin disease)***

Ingredients: Luke warm water and "uzifozonke" (potassium permanganate) and an injection of antibiotic

***4. Treatment of injuries***

Take "umadolwana womlambo" (*Chloris compressa* grass), crush it on a stone, squeeze the juice into the injury with a cloth. The residue can also be bandaged onto the wound and after a short time the injury heals.

***5. Use of Vinegar sugar and water mix:***

The farmer was unwilling to divulge the proportion of water to vinegar as he sold the mixtures locally:

*(i). Treatment of worms* "diarrhoea"

A mixture of water and vinegar with 500 ml of vinegar mixed with one and a half cups of sugar

*(ii). Treatment for liverfluke (Fasciolosis)*

350 ml of vinegar mixed with one and a half cups of sugar, the bottle was dosed to one large ox or cow and half a bottle was given to the calves.

*(iii). Treatment for "umbolane" (Bovine tuberculosis)*

Preparation: Pour 2 tea cups full of sugar into 750 ml of vinegar (one bottle) and mix them thoroughly. The whole mixture is sufficient for one adult ox (above 300 kg), use half of the mixture for younger animals.

One farmer from Chamama was concerned about poor veterinary services in his area as these were now restricted by the Government. He therefore had meetings in April 1998 with other local farmers to discuss the formation of a farmers union. He reported some local farmer interest. The main aim was to organise a plan to take some young men to the training centres to learn how to treat animal diseases so that they could assist the whole community.

### *4.8 Training of draught animals*

Farmer 3 from Chamama trained his two young oxen in June. He first worked them in a pair for one day, pulling a log in the field, then the next day spanned them with his four older experienced oxen to collect firewood using a sledge. Boys (usually his children) help the farmer train his animals. By the end of the month he was using them with the other oxen for ploughing. The farmers said they preferred to train their young animals alongside their older ones, when possible, even to the extent of borrowing oxen from others. But, if there were no experienced oxen available then they would train them on their own, usually using them for transport activities first (branches or firewood), before using them for land preparation and cultivation. The farmers breed their replacement oxen themselves. If they lose an animal, they said they would use a cow as a replacement in the span or borrow from others until their young animals are old enough to work. These farmers who were already using animal power never considered buying draught oxen from others, however they said that they would consider selling working oxen to farmers new to animal traction if the price was good.

### *4.9 Acquisition and care of equipment*

All farmers owned a plough, but not all owned a harrow and very few a planter. These had been handed down through the families. No farmers purchased new equipment in the 16 months study period. Repairs were carried out to a plough owned by farmer 2 at Chamama for 100 R in May and a planter owned by farmer 1 in Esixekweni for 250 R in November. The repairs were carried out at the Animal Traction Centre at Fort Hare. At Esixekweni a replacement ploughshare and heel were brought by farmer 1 in December and a ploughshare, heel and wheel were brought by farmer 3. They purchased these materials from N. N. Fettings and Sons Trading Store, Middledrift.

At each location, one ripper tine was provided by the Animal Traction Centre for the farmers to use and evaluate. The farmers reported some success with planting in the furrows opened by the tine, but this necessitated a further harrowing operation. Full evaluation of the ripper tine is part of another project and will be reported separately (A. B. D. Joubert, personal communication).

The three farmers in Chamama, which was hilly terrain, owned sledges, whereas the farmers in Esixekweni, in a less undulating area with better road access owned carts that they had made themselves. No records were made of any repairs to these during the study period.

Threshing the bean harvest at the homestead in Esixekweni

The products of a successful maize crop produced using animal power at Esixekweni

Only one farmer in Chamama basin made yokes and skeis for use on his own oxen. All the other farmers relied on local craftsmen who specialised in making the equipment for sale. It was possible for some farmers in Chamama to fabricate their own equipment because they have a forest nearby making it easy for them to find a suitable wood for that purpose. The one farmer in Chamama who made his own equipment pointed out that the tree species he used for making yokes was "umbaba" (*Caledondrum capensis*). The main reason given for this was that when dry the wood is light but strong. "Umkhaza" (*Euclea natalensis* - Gwarri) is another tree that was occasionally used by the same farmer, however this one, although strong, tends to be relatively heavy when dry. It was also possible to make yokes and skeis from "umdakana" (*Apodytes dimiata* - white pear).

Riems and strops used by the farmers had been made by the farmers themselves, but they did not record making any during the study period.

### *4.10 Cultural considerations*

The farmers' diaries provided very little information on cultural matters, but some insights into how social factors interact with agricultural production can be drawn.

Regarding agricultural work, some farmers delayed their work in the fields, particularly the tasks that needed more people, until their children, especially boys, came home from school. These tasks usually involved the use and control of their draught animals. Other arrangements to overcome labour shortages could involve payment "in kind", whereby a farmer would use labour provided by neighbours or other members of the family in return for him taking his animals to plough their fields.

There were also communal activities involving animals, such as dipping to protect the animals against disease, or farmers using their animals to help with a community project, such as building a church. Other community activities which would take precedence over agricultural activities were funerals and ceremonies in honour of the family's ancestors or for religious festivals (e.g. Easter). The latter can involve the slaughter of oxen.

A number of farmers, particularly the older ones, used their pensions to finance (at least in part) their agricultural activities. Thus, it is difficult to assess the financial success, or sustainability of their farming enterprises. This contributes to the fairly widely held impression that farming is not a viable activity, thereby possibly deterring younger people to take it up as a profession. Another possible deterrent was evident from the diary of one farmer who was becoming increasingly concerned about the growing lawlessness in society, particularly in his own neighbourhood, where his crops may be stolen or vandalised, sometimes by his neighbours allowing their animals into crops that had yet to be harvested. This is a serious sociological problem that needs to be addressed. Nevertheless, one farmer, who may have been more motivated than most, rented and cropped land that was superior to his own for growing crops. However, it is not clear how widespread this practice is.

## 5. DISCUSSION AND CONCLUSIONS

The crops grown, activities undertaken with draught animals and the management of the animals on the farms, as reported in the monthly record-keeping, agreed fairly well with the information obtained in the informal interviews conducted at the start of the project. The advantage of the monthly diary keeping by the farmers was that it enabled information to be obtained on the time of different activities on each farm and their frequency throughout the year. It also revealed the role that draught animals play in infrequent activities such as community repairs and building activities, which is not always apparent at informal interviews. The disadvantage of the monthly monitoring was that it relied on the farmers themselves to record the information, and therefore was influenced by when and what each farmer decided was worth recording. One farmer for example reported his animal health and treatments for disease in great detail, whereas another was more concerned with cropping activities, rather than the health of his animals. Nevertheless the farmers' efforts in keeping their diaries are to be commended.

Some anomalies between the diaries and the interviews were apparent. Farmers frequently harrowed with fewer oxen than they had said; this was probably because harrowing could be done satisfactorily with fewer animals, without compromising work output. Clearly, the numbers of animals owned by a farmer can change at any time due to a death or a birth, so the head counts will vary, as may span sizes or the number of cows used for draught purposes. Some activities that farmers said they carried out were not recorded in the diaries nor observed by the research staff during the 16-month monitoring period. These activities centred on management of animal feed resources and may not have been thought by the farmers to be relevant to the management and use of their working animals, confirming, indirectly, the farmers' priorities for other livestock products rather than those associated with crop production. For example collection and transport of stover for animal feeding was reported only by two farmers and no mention was made of purchase of supplementary feeds by farmers at Esixekweni although they said that they regularly did this. Similarly one farmer at Chamama, who had sowed oats for winter grazing for his livestock before the start of the monitoring period, did not mention its use specifically for working animals. The use of cows was far more common than had been apparent when the farmers were initially interviewed. Farmers often spanned cows, even when oxen were available (in one case "the ones which were easiest to catch in the camps") and thought nothing of doing so. This practice is less common, although on the increase, in smallholder farming communities in other semi arid areas of Africa (Starkey and Mutagubya, 1992; Mwenya, Mwenya and Dibbits, 1994; Ellis-Jones, Pearson, O'Neill and Ndlovu, 1977). The ready acceptance of draught cows and their use by the farmers in Esixekweni and Chamama may be due to the availability of generally larger cattle for work in Eastern Cape than in the other countries.

The division of labour was not so rigidly defined as it appeared in informal interview. The priorities for men were the agricultural tasks just as the priorities for women were the domestic tasks. People worked according to these priorities without men being precluded from the domestic tasks (e.g. they may fetch water), nor women from the agricultural tasks. The one exception was that women did not use the plough.

Labour shortages occurred from time to time, especially during periods of the greatest agricultural activity. This seems to be exacerbated by the high proportion of older people (more than 60 years old) engaged in agriculture. These shortages were overcome by neighbours working for each other, usually offering their services "in kind", but sometimes for a share of the harvest or occasionally cash. The most serious shortage seemed to occur during land preparation, which is a male-dominated activity, and farmers delayed their work until boys (often their grandchildren) arrived home from school.

There was a reluctance for farmers to use veterinary services and most use local remedies for prevention and treatment of the common diseases. In the past, there was considerable support from the Government (for example dipping) but now that this has been withdrawn, the farmers feel that they can not afford the significant expense of summoning a veterinarian, paying for a consultation and paying for any necessary medicines. One farmer was so concerned that he tried to instigate action to improve local veterinary knowledge. Farmers also expressed concern over the reduction in other Government services such as agricultural inputs (particularly seeds) and health care but had not taken any action.

The importance to farmers of livestock rather than crops is evident at both locations. The most significant indications are provided by (a) the sums of money involved (see Section 4.5), (b) the preference to supplement the feed (where this is practised) to milk cows and to cows in calf, rather than working cattle which facilitate crop production and (c) the use of horses for riding or as status symbols rather than for draught work. A possible explanation may be that the toil and drudgery of crop production in often difficult soils and erratic rainfall for little economic gain is relatively unattractive compared to the extensive rearing of livestock, particularly cattle, with the associated cultural implications of dowries and ancestral ceremonies.

At the community level, there are differences between the levels of cattle ownership, the willingness to offer supplementary feed, the incidence of disease (and how to deal with it) and use of draught animals. Within the scope of the survey, lasting just over a year, it is difficult to determine whether all these differences are substantive or brought about by differences in local meteorology over the period concerned and, therefore, ephemeral. The extended period of use of draught animals in Chamama is likely to be explained by the latter, but the differences in levels of ownership, span sizes and feeding policies are likely to be deeper-rooted. It seems likely that these factors interact, as lower levels of ownership will inevitably influence span sizes and farmer attitude towards growing, storing and feeding supplements.

Returning to the communities surveyed, a number of inferences can be drawn about their constraints and, hence, possible interventions to alleviate them. Despite the superficial differences in veterinary needs, both groups of farmers suffer from a lack of veterinary services, which could be met at an elementary level with modest local training inputs. It appears that some crop production activities are held back, particularly around primary tillage, with farmers waiting for boys to come home from school to start ploughing. Whilst it is gratifying that boys are not kept out of school, a re-appraisal of land preparation techniques might facilitate crop production. The hilly terrain around Chamama prevented the use of carts, which influenced the farmers in the way they used their crop residues (mainly maize stover), and caused one farmer to grow oats as a supplementary livestock feed. Carts, in use in Esixekweni enabled farmers to collect the stover more easily for storage and feeding in the dry periods. The encroachment on to crops by cattle and crop theft are difficult to overcome when not all farmers in the area consider crop production as important as that of livestock and not all members of the community see farming as an occupation worthy of undertaking. The erection of fences would help overcome this problem, but it is not unknown for the fences themselves to be stolen. That farmers use their pensions to finance their agricultural activities, contributes to the fairly widely held belief that farming in the area needs outside cash support. This is something which farmers felt may deter young people from taking up farming. If the numbers of "emerging farmers" are to increase then the challenge is to find ways of attracting the younger members of the community into agricultural production.

This monitoring exercise has confirmed the importance of cattle to smallholder farmers in the Eastern Cape. Crop production relies heavily on livestock outputs, particularly draught power. The more successful emerging farmers are now complementing their animal power with tractor power for primary tillage operations. Although this initiative has been taken by the more elderly farmers, the selection of appropriate power sources for crop production tasks is a significant step forward, and may increase the incentives for younger people to take up farming. There seem to be bright prospects for younger, energetic people to run small-scale agricultural enterprises commercially, based on livestock and the judicious use of draught animal power.

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**Appendix 1: Monthly summary of diary kept by one farmer in Chamama, Amatole Basin, Middledrift, Eastern Cape Province, of activities undertaken from August 1997 to October 1998**

| | |
|---|---|
| August 1997 | 10: Ploughing 0.125 ha with 6 oxen, 0900-1200 h. |
| | 25: Ploughing 0.5 ha with 6 oxen, 0800-1500 h |
| | Transport of firewood for ceremony, 1100-1200 |
| | 30: Sick oxen, treated with local remedy and an "Injection" |
| September 1997 | 04: All cattle dosed against internal parasites (mixture of sugar + vinegar + water) |
| | 10: Storage of 9.5 bags of maize in bins |
| | Harvesting and sale of potatoes at R300 |
| | Sale of cattle and sheep skins at R32 |
| | 12: Transport of tree branches for repairs of kraal with 4 oxen, over 2 miles, 1400-1600 |
| | 15: Cutting wood for making 2m yoke |
| | 26: Purchase of potato seed R55 |
| | Repair of share (replaced nuts at R7) |
| | Transport of branches for repairs of kraal, 6 oxen 2 trips @ 2.5 miles, 1100-1700 |
| | 29: Tractor hire for ploughing 0900-1630 h at R250 |
| | 30: Harrowing, 2 oxen 1000-1430 h |
| October 1997 | 03: Planting maize, 2 oxen (137 x 30 m), 0930-1530 h |
| | 04: Transport of water for church building, 8 oxen, 2 drums on sledge, 4 trips, 0800-1300 |
| | 07: Transport of stone for church building, 12 oxen per sledge for 6 h |
| November 1997 | 01: Tractor hire for Ploughing 0930-1700 h at R250 |
| | 03: Harrowing, 2 oxen (137 x 20 m), 1000-1730 h |
| | Planting maize and potatoes, 2 oxen 1200-1630 h |
| | 04: Dipping all animals |
| | 05: Planting maize, 2 oxen (137 x 20 m), 0930-1430 h |
| | 06: Planting maize, 2 oxen (142 x 22 m), 0830-1430 h |
| | 10: Planting maize, 2 oxen, 0830-1500 h |
| | 11: Sick ox, Red water, Local remedy |
| | 13: All animals dosed for internal parasites, local mixture |
| | 19: Dipping all animals |
| December 1997 | 01: Ploughing, 2 oxen 0830-1200 h |
| | 03: Planting maize, 2 oxen 0830-1200 h |
| | 05: Planting maize, 2 oxen 0900-1100 h |
| | 06: Planing maize, 2 oxen 0830-1200 h |
| | 07: Purchase of maize seed R40 |
| | 08: Ploughing and Planting maize, 6 oxen 1330-1800 h |
| | Planting potatoes by hand |
| | 10: Cultivation on maize 0930-1130 h |
| | 24: Start sale of potatoes up to 31/12/1997 at R320 (total) |
| January 1998 | 01: Sick ox, Red water, Local remedy |
| | 19: Ploughing and planting maize, 6 oxen (142 x 22 m), 0930-1500 h |
| | 20: Ploughing and planting maize, 6 oxen (137 x 20 m), 1600-1730 h |
| | 21: Ploughing and planting maize, 6 oxen (136 x 18 m), 1100-1600 h |
| | 22: Ploughing and planting maize, 6 oxen (134 x 9 m), 0800-1300 h |
| | Transport of branches to mend fence, 2 oxen |
| | 23: Ploughing and planting maize, 4 oxen (120 x 12 m), 0730-1300 h |

| | |
|---|---|
| | 24: Ploughing and planting maize, 6 oxen (121 x 12 m), 0700-1300 h |
| | 26: Ploughing and planting peas and potatoes (110 x 10 m), 1500-1730 h |
| | 31: Transport of bricks for church building, 12 oxen pulling sledge loaded with 30 bricks over 2 km, 1000-1430 h |
| February 1998 | 03: Harrowing for weed control in maize, 2 oxen 0730-1200 h |
| | 04: Harrowing for weed control in maize, 2 oxen 0730-1200 h |
| | 06: Dipping of all animals |
| | 13: Slaughter of 1 ox for ancestral rituals<br>Hand weeding |
| March 1998 | 04: Cultivation of weeds in maize, 2 oxen (136 x 18 m), 0830-1200 h |
| | 05: Cultivation of weeds in maize, 2 oxen (136 x18 m), 0830-1200 h |
| | 20: Dipping of all animals |
| | 25: Sale of 2 oxen at R6400 |
| | 30: Transport of fencing poles, 8 oxen over 2.5 miles, 1030-1700 h |
| April 1998 | 01: Sick ox, local remedy |
| | 14: Dipping all animals |
| | 24: Dipping all animals |
| | 28: Sick ox, Red water, local remedy |
| May 1998 | 11: Sick ox, Red water, local remedy |
| | 19: Dipping all animals |
| | 21: Sale of green maize @ R1 |
| | 27: Mass treatment of all livestock against Heart-water |
| | 29: Mass treatment of all livestock against Heart-water |
| | 30: Transport of fencing poles, 6 oxen over 2.5 miles, 1030-1330 |
| June 1998 | 11: Sale of green maize, R228 |
| | 15: Harvest peas |
| July 1998 | 01: Sale of 1 ox at R2200 |
| | 02: Transport of firewood for ceremony, 2 trips @ 2.5 miles, 0830-1430 |
| | 03: Transport of branches for kraal repair, 2 trips @ 1.5 miles, 0830-1430 |
| | 04: Slaughter of 1 ox for ceremony |
| August 1998 | 01: Primary tillage of garden with 6 oxen (9 x 12 m), 1930-1230 h<br>Transport of fencing poles, 1300-1700 |
| | 05: Harrowing garden (9 x 12 m), 0930-1530 h |
| | 28: 1 heifer died from an unknown cause |
| September 1998 | 02: 1 Cow calving male calf |
| | 04: Purchase of 3 bags of potato seed for R180 total |
| | 10: Dipping all cattle, 0700-1230 h |
| | 30: Primary tillage with hired tractor at R300 from 0700-1700 h<br>Harrowing, 2 oxen from 1400-1700 h |
| October 1998 | 01: Harrowing, 2 oxen 0830-1230 h<br>Planting potatoes, 4 oxen (112 x 10 m), 1300-1730 h |
| | 02: Planting maize, 2 oxen (142 x 22m), 1430-1730 h |
| | 03: Planting maize, 2 oxen (142 x 22 m) |