THE DONKEY (*EQUUS ASINUS*) AS A DRAUGHT ANIMAL IN SMALLHOLDER FARMING AREAS OF THE SEMI-ARID REGIONS OF ZIMBABWE

EDWARD MUSIWA NENGOMASHA

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UNIVERSITY OF EDINBURGH

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Dedicated to my late father, Edward Paradzai Nengomasha

ABSTRACT

Donkeys are becoming increasingly important for draught animal power (DAP) in Zimbabwe and the sub-Saharan region. This is mainly because cattle, the traditional DAP source, have suffered high mortalities in recent droughts. However, there is limited information on the extent of use and potential of donkeys for DAP in Zimbabwe. In an attempt to rectify this deficiency, a rapid rural appraisal (RRA) and a series of studies were undertaken. The RRA was conducted first to assess the status, role and current management practices of DAP in smallholder farming areas in the semi-arid regions of Zimbabwe. Studies were carried out to assess; the morphological characteristics of 335 working donkeys in south-western Zimbabwe, the relations between live weight and body measurements and the seasonal fluctuations of live weight and body condition of selected donkeys in semi-arid areas. The other studies evaluated the draught performance of teams of donkeys and cattle ploughing at different sites. Finally, the effects of drinking water and work on dry matter intake (DMI) as well as apparent dry matter digestibility (DMD) and mean retention time (MRT) of donkeys were investigated.

The results of the RRA showed that large numbers of cattle died (up to 75 per cent in some areas) during the 1991-92 drought and that this had increased the farmers' dependency on donkeys for DAP. However, the management of donkeys was generally inadequate. For example, there was widespread use of the inappropriate neck yokes and improper harnesses on donkeys in some of the areas.

The study on morphological characteristics indicated that the typical "Zimbabwean" donkey weighed 142 ± 1.4 kg, had a heart girth of 115 cm (range 93 -

140), a height at withers of 105 cm (range 91 - 120) and was normally light grey in colour. Male and female donkeys were of similar weight and body dimensions. The single best predictor of live weight was heart girth ($r^2 = 0.864$) followed by umbilical girth ($r^2 = 0.753$). There were seasonal fluctuations in the live weights and body condition of 38 monitored donkeys with weight losses more apparent late in the dry season (October/November).

When used for ploughing in the wet season, a team of 4 donkeys considered "optimal" for ploughing and 2 oxen of similar total team weights exerted similar draught forces, 867 N and 900 N ($P>0.05$); generated similar power outputs, 689 W and 920 W ($P>0.05$); worked at similar speeds, 0.87 m/s and 1.03 m/s ($P>0.05$) and had similar effective field capacities, 14.2 hours/ha and 14.5 hours/ha ($P>0.05$), respectively. Lighter donkey teams generated less power output than heavier teams.

Over a 35-day period, individually penned donkeys that had access to water every 48 hours ($n = 6$) and every 72 hours ($n = 6$) consumed less water (by 42 per cent, $P<0.001$), 4.9 ± 0.30 litres/d and 5.1 ± 0.29 litres/d, respectively, compared with 8.5 ± 0.61 litres/d for donkeys with *ad libitum* access to water ($n = 6$). This was accompanied by a reduction in DMI of 13 per cent ($P<0.05$). Donkeys with restricted access to water lost less water through the faeces (by 9 per cent, $P<0.05$) than those with *ad libitum* access. Donkey teams subjected to work (carting) had similar DMI to those teams not working. The work did not have an effect on DMI, 3.3 kg DM/d for working and non-working donkeys and neither did the time of access to feed ($P>0.05$). DMD and the MRT of digesta were not affected ($P>0.05$) by work.

It was concluded that the shortage of cattle had increased the use of donkeys for DAP in the semi-arid areas of Zimbabwe. Extension information on good management practices and general welfare of draught animals, particularly donkeys, was clearly lacking. The morphological characteristics of male and female donkeys showed few differences and potentially the draught performances of the two sexes could be similar. Donkeys in Zimbabwe were morphologically similar to their counterparts in other parts of Africa implying that these donkey types are related. Heart girth, the best single predictor should be included in predictive equations for estimating live weight using body measurements. Weighbands and nomograms which are important management tools for smallholder farmers should be produced from these predictive equations. Although there were seasonal fluctuations in live weight and body condition of donkeys, these were less than those reported in cattle. Thus, donkeys are more likely to be in better condition at the start of the ploughing season than cattle. Donkey teams were capable of ploughing for up to four hours per day provided they had a sufficient combined team weight to pull the plough. Training and experience are very important factors affecting the performance of working animals. Donkeys were able to continue eating despite the limited access to water and this is an important mechanism for survival during droughts. Working donkeys could not increase DM intake of hay and this was attributed to the poor quality and physical form of the hay. Supplementation of working donkeys might be necessary.

The importance of donkeys is likely to increase in the semi-arid areas where the susceptibility of cattle to the recurrent droughts has been exposed.

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LIST OF ABBREVIATIONS

ADF:	Acid Detergent Fibre
AEW:	Agricultural Extension Worker
AFC:	Agricultural Finance Corporation
AGRITEX:	Department of Agricultural, Technical and Extension Services
ANOVA:	Analysis of Variance
BCS:	Body condition score
°C:	Degree Celsius
cm:	Centimetre
CP:	Crude Protein
Cr:	Chromium
Cr_2O_3:	Chromic Oxide
Cr-hay:	Chromium mordanted hay
CSO:	Central Statistics Office
CTVM:	Centre for Tropical Veterinary Medicine
d:	Day
DADF:	Distance Averaged Draught Force
DAEO:	District Agricultural Extension Officer
DAP:	Draught Animal Power
DDF:	District Development Fund
DE:	Digestible Energy
DF:	Draught Force
DIN:	Deutsche Industrie Norm

DM:	Dry Matter
DMD:	Dry Matter Digestibility
DMI:	Dry Matter Intake
DNA:	Deoxyribonucleic Acid
DRSS:	Department of Research and Specialist Services
DVS:	Department of Veterinary Services
EFC:	Effective field capacity
EWT:	Elapsed working time
FAO:	Food and Agriculture Organization
FLW:	Final live weight
FRD:	Farmer Recommendation Domain
g:	Gramme
GDP:	Gross Domestic Product
GIT:	Gastro-intestinal tract
GLM:	General Linear Model
GTZ:	Deutsche Geselleschaft für Technische Zusammenarbeit
h:	Hour
ha:	Hectare
HG:	Heart girth
IDU:	Integrate and display unit
ILCA:	International Livestock Centre for Africa
ILW:	Initial live weight
kg:	Kilogramme

kJ:	Kilojoule
l:	Litre
log:	Logarithm
log_{10}:	Logarithm to the base 10
LW:	Live weight
$LW^{0.75}$:	Metabolic live weight
LWG:	Live weight gain
m:	Metre
Mcal:	Megacalorie
ME:	Metabolisable Energy
mm:	Millimetre
MRS:	Matopos Research Station
MRT:	Mean retention time
m/s:	metres per second
n:	Number
N:	Newton
NDF:	Neutral Detergent Fibre
NGO:	Non-Governmental Organization
nm:	nanometre
NR:	Natural Region
NRC:	National Research Council (USA)
Pow:	Power
r^2:	Coefficient of Determination

RRA: Rapid Rural Appraisal

s: Second

s^2: Variance

sem: Standard error of the mean

SRI: Silsoe Research Institute

SSA: Sub-Saharan Africa

TADF: Time Averaged Draught Force

TLW: Total live weight

$TLW^{0.75}$: Total metabolic live weight

TWT: Total working time

UG: Umbilical girth

UK: United Kingdom

USA: United States of America

VIDCO: Village Development Committee

W: Watt

WADCO: Ward Development Committee

ZFU: Zimbabwe Farmers Union

ZIMDAP: Zimbabwe Draught Animal Power Project

Z$: Zimbabwe Dollar (exchange rate: Z$17.5 = £ stlg 1, February 1997)

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CHAPTER ONE

1. INTRODUCTION

1.1. BACKGROUND AND LITERATURE REVIEW

Agriculture plays a vital role in most of the developing economies of countries in Sub-Saharan Africa (SSA). Crop and livestock production are both important and interrelated. Increasing emphasis is being placed on cash-based agricultural production systems for smallholder farmers, sometimes referred to as communal farmers, who have traditionally practised subsistence farming. Mixed crop-livestock farming systems can help smallholder farmers spread the risks associated with agriculture especially when important resources such as land and water are limited. The advantages of mixed crop-livestock farming systems include the synergistic relationship between crops and livestock, the latter providing important inputs to cropping, in the form of traction and manure with crops providing feed for the animals (ILCA, 1992).

In Southern Africa, animal draught power has traditionally provided a solution to the reduction of the drudgery of using human draught power in agriculture. The failure of numerous, poorly-implemented tractorisation programmes in Africa has also prompted increased use of draught animal power (DAP) in the crop-livestock farming system. Cattle and donkeys are the main sources of DAP in the region. Cattle are considered more capable than donkeys and therefore are the preferred source of DAP (Bwakura, 1994). Donkeys are largely regarded as single-purpose animals in Zimbabwe and, therefore, are conceived to be of lower status (Munn, 1991; Bwakura, 1994) than cattle. The provision of DAP is the main economic role of cattle in the smallholder farming sector (Barrett, 1992). Other important roles include provision of meat, milk for household consumption, traditional rites, social status and as storage of capital (Barrett, 1992). Oxen are the preferred type for DAP (Tembo, 1989). Cows and bulls are also used for DAP (Prasad, Marovanidze and Nyathi, 1991), but to a lesser extent than oxen. These oxen have been selected for their size and are thus typically used for performing arduous tasks such as ploughing and heavy transport (Morriss, 1995).

The recurrence of droughts in the sub-region since 1981 and the war of liberation from 1966 to 1980 in Zimbabwe, have both largely contributed to reductions in livestock numbers in the country. The losses have particularly affected the cattle population in the drought-prone semi-arid areas. The reduction in the cattle population, which is expected to continue into the next century (FAO, 1984), has consequently led to a steady decline in DAP availability in the smallholder farming areas. During the 1991-92 drought alone, 1.4 million head of cattle perished of which over a million were from the smallholder farming sector (Mitchell, 1993; Hagmann and Prasad, 1995). This has aggravated the DAP shortages of the smallholder farmer, who before this drought, had access to an estimated 700 000 to 800 000 head of draught cattle. Rusike (1988) and Tembo (1989) estimated that draught power availability, expressed as the number of cattle per cultivated hectare, has diminished from 1.7 to 1.4 between 1977 and 1985. Tembo (1989) suggested that this decline could be attributed to the reduction of cattle numbers and the increase in the number of people cultivating the land (cultivators). The higher number of cultivators increased the area of arable lands resulting in an increased requirement for DAP and at the same time, reduced the size of the grazing areas. The shortage of DAP adversely affects the timeliness of cropping operations such as land tillage. Both a reduction in the area cultivated by the farmers and late planting of crops, due to DAP shortages, results in lower crop yields. The work of Barrett, O'Neill and Pearson (1992) showed that ownership or access to draught animals strongly correlates with the amount of crop produced by the household. The effects of droughts are more adverse in the short term, on crop than livestock production. However, the drought-induced depletions in livestock numbers can have more severe long-term effects on crop production.

Another cause of concern in the smallholder farming sector is the apparent reduction in the frame size of cattle (Barrett *et al.,* 1992). Before the droughts, smallholder farmers had access to large-framed cattle for DAP. Since selection of cattle for draught is generally based on the animals' size, it is considered that those cattle currently at the farmers' disposal are not appropriate for heavy draught tasks. According to Tembo (1989), the absence of breeding programmes and overgrazing in the smallholder farming sector have contributed to the animals in this sector getting progressively smaller. This has apparently led to the need to span more animals together, consequently compounding the DAP shortages currently being experienced by smallholder farmers. The other reason for this reduction in size is likely to be that during droughts, when there is a shortage of food, nutritional deficiencies prevail, larger animals such as oxen whose nutritional requirements are higher, cannot cope with these deficiencies and are more likely to die of malnutrition than smaller animals. Thus, smaller animals tend to survive droughts better, hence the observed predominance of small-framed animals in the smallholder farming sector. Poor conception during and after droughts will also contribute to the shortage of animals for DAP. This has emphasised the need to find alternative or supplementary sources of DAP. Equids could provide a sustainable alternative to the chronic DAP crisis currently being experienced in the smallholder farming sector, particularly in the semi-arid regions.

In Zimbabwe, equids are generally used for DAP to a lesser extent than bovids. Of the equids, the donkey (*Equus asinus*) is the most widely used. Horses (*Equus cabalus*) are largely owned by large scale commercial farmers whose farm operations are highly mechanised. Mules are not common in Zimbabwe and are therefore not widely used for DAP. The use of donkeys is more prevalent in the semi-arid regions of the country. Zimbabwe's donkey population is estimated at between 300 000 and 400 000 (Prasad *et al.*, 1991), most of which are in the semi-arid regions. The donkey has long been neglected by both farmers and researchers (Munn, 1991). Farmers have generally considered donkeys as inferior, probably because this species is not used for any other purpose in Zimbabwe, except for draught power. The use of donkeys by smallholder farmers has been traditionally restricted to performing lighter tasks such as carting, cultivating (weeding) and carrying. Consumption and use of donkey products such as meat, milk and hide is uncommon in Zimbabwe. Research in livestock production has until recently largely ignored donkeys as they were considered to be of little or no economic value (Bwakura, 1994). However, donkeys are increasingly being used for ploughing in smallholder farming (Prasad *et al.,* 1991; Starkey, 1994) although farmers still prefer to use cattle for DAP.

There is evidence that donkeys have managed to survive the series of droughts in the semi-arid regions better than cattle, with fewer drought-related donkey losses being reported (Munn, 1991; Hagmann and Prasad, 1995). Hagmann and Prasad (1995) carried out a survey in two districts in the semi-arid regions of Zimbabwe and reported that drought-related donkey deaths were 15 per cent compared with 56 per cent and 44 per cent, for oxen and cows, respectively. In other semi-arid regions, the deaths were estimated at about 10 per cent in donkeys compared with up to 75 per cent in cattle (Ellis-Jones, Muvirimi, Nengomasha and Msara 1994). The ability of the donkey to survive harsh conditions has been attributed to its evolution as a desert-adapted species and its apparent capacity to utilise poor quality feeds efficiently and to withstand long periods without water. This makes donkeys more suited to the semi-arid regions than cattle (Mpande, 1994). MacDonald and Low (1985) described the donkey as one of the most efficient and economical power units in agriculture. These positive attributes of the donkey and the unavailability of cattle for DAP have contributed to the increased interest among farmers and researchers in this species. The advent of the recurrent droughts and other adverse effects on the cattle population indicated a real need to investigate the potential of the donkey as an alternative source of DAP in the smallholder farming sector. The increasing significance of the donkey as a source of DAP is demonstrated by the recent increases in price which has increased 40-fold, from Z$20 per donkey before the 1991-92 drought to over Z$800 in 1996 (prices of Z$2 000 for a donkey are now not uncommon). During the same period, the annual rate of inflation was 23.3 per cent and 21.7 per cent for 1991 and 1996, respectively (CSO, 1997).

There is however scant information in Zimbabwe on the potential of the donkey as an alternative source of DAP to cattle, particularly for ploughing. There is also lack of research and extension information in Zimbabwe on the type of donkey available to the farmer or the nutritional requirements and the optimum management practices of this species. From the little information available on donkeys in Zimbabwe they have been shown to contribute significantly to the success of smallholder farming system (Munn, 1991). This is particularly true in areas where cattle have been withdrawn due to the threat from *Trypanosomiasis* and smallholder farmers have adapted to using donkeys. However, in areas where cattle are the predominant source of DAP, the use of donkeys is restricted to light draught tasks, such as carting and as pack animals. Donkeys have largely been under-utilised for the heavier tillage operations such as ploughing. Some work has also been carried out to determine the role and potential of the donkey as a DAP resource in smallholder farming sector (Munn, 1991; Prasad *et al.,* 1991; Barrett *et al.,* 1992; Mpande, 1994; Hagmann and Prasad, 1995; Morriss, 1995). The work of Prasad *et al.* (1991) showed that donkeys are potentially capable of ploughing. These workers suggested that on a weight for weight basis, donkeys are more efficient and can produce more work than cattle. Nengomasha *et al.* (unpublished data) also showed that properly managed donkeys were capable of ploughing. Little work has been carried out on the nutritional requirements of the donkey apart from attempts by O. Randi, C. Nyama and R. Pluke (pers. comm.) at Matopos Research Station (MRS), who investigated the grazing behaviour of donkeys and digestibility of hay (see also Nengomasha, Nyama and Mpofu, 1993). Despite these encouraging efforts, there is still a general lack of information in Zimbabwe about the potential of the donkey as a DAP resource. This makes it difficult for researchers and extension workers to make recommendations to farmers on optimum management practises and utilisation of this species.

The factors highlighted above led to the initiation of the research described in this thesis, whose broad objectives were to:

- determine the current status of DAP in the smallholder farming sector in semi arid areas
- evaluate the donkey resource available to the smallholder Zimbabwean farmer as indicated by morphological characteristics of this species
- evaluate the potential of the donkey as an alternative or supplementary source of DAP for ploughing and compare with the available cattle
- evaluate some of the nutritional requirements of the donkey and how these are affected by the work and other conditions to which the donkey is exposed.

A brief introduction to Zimbabwe, its agriculture and farming systems is also given in the following chapter.

CHAPTER TWO

2. DESCRIPTION OF ZIMBABWE

2.1. GENERAL

Zimbabwe is a landlocked country in the Southern African region, lying between 16^0S and 23^0S latitudes and 25^0E and 33^0E longitudes (Map 2.1). It is situated within the tropical savannah region. It borders Zambia in the North, Mozambique in the East, South Africa in the South and Botswana in the West. The total land area is 390 759 km^2. The population for 1997 was projected to be 12.3 million people (CSO, 1994). The economy which has been centrally planned since attainment of independence in 1980, has been liberalised from 1990 and is becoming more market-oriented. Zimbabwe is largely dependent on agriculture and mining with manufacturing and tourism becoming increasingly important sectors of the economy. The climate is subtropical with four overlapping seasons; summer, autumn, winter and spring. Typically summers are wet and hot while winters are dry and cool.

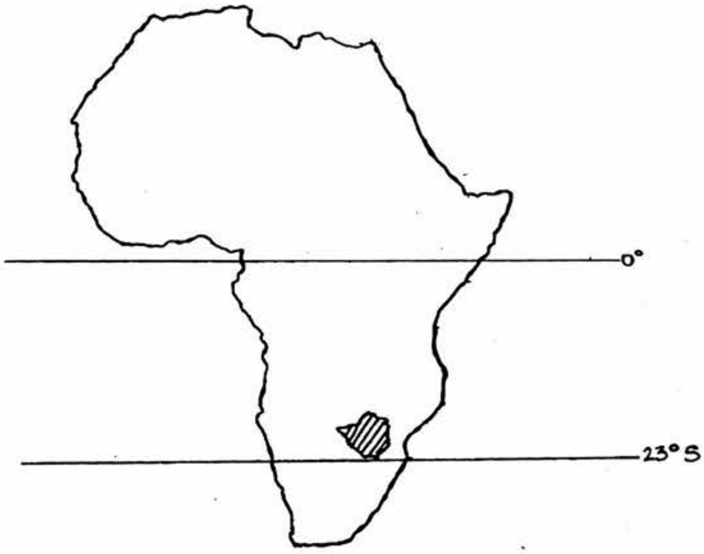
2.2. NATURAL REGIONS AND LAND DISTRIBUTION

The country is divided into five agro-ecological Natural Regions (NR). These are classified by the soil type and amount of average rainfall in the region. The soil and rainfall determine the type of agricultural activity recommended for the NR (Table 2.1).

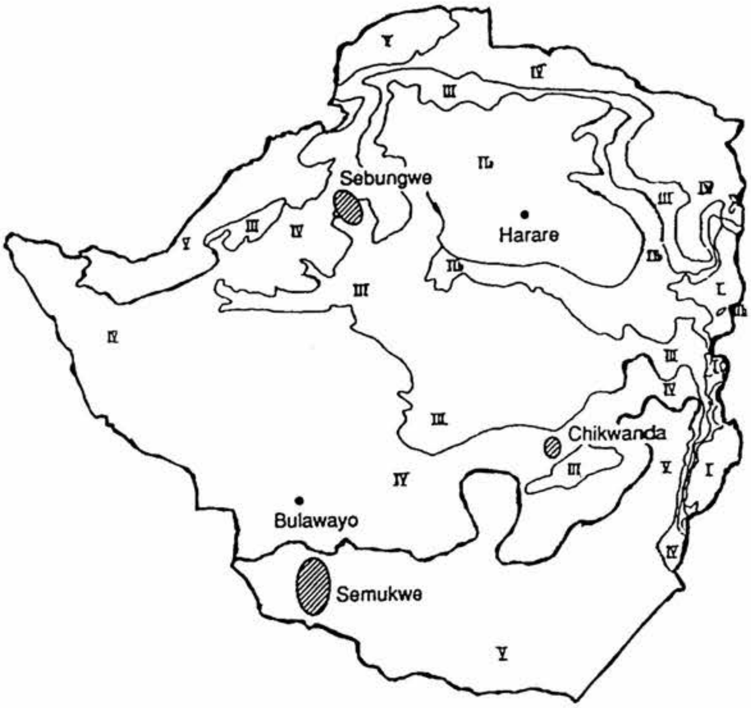
Table 2.1: Classification of Natural Regions and Farming systems in Zimbabwe.

NATURAL REGION	TYPE OF SUITABLE FARMING	% LAND AREA	MEAN ANNUAL RAINFALL (mm)	RAINFALL RELIABILITY	DOMINANT FARMING SYSTEMS
I	Specialised and diversified farming	1.8	>1000	Rain all-year round	Forestry, plantations and intensive livestock production
II	Intensive farming	15.0	750 - 1000	Reliable summer rain	Cropping (tobacco, wheat) and intensive livestock production
III	Semi-intensive farming	18.7	650 - 750	Erratic with seasonal droughts	Cropping (can be risky) and livestock production
IV	Semi-extensive farming	37.8	450 - 650	Frequent seasonal droughts	Drought resistant cropping and semi-extensive livestock production
V	Extensive farming	26.7	<450	Low, prone to droughts	Extensive livestock production

(Adapted and modified from Ellis-Jones et al., 1994 and Morriss, 1995)



Map 2.1: Location of Zimbabwe in Africa.



Map 2.2: Map of Zimbabwe showing the Natural Regions and areas visited during the Rapid Rural Appraisal (RRA, Chapter 3) (after Ellis-Jones *et al.,* 1994).

Historically land distribution has been based on these NRs, with the higher potential regions (I, II and parts of III) being mainly occupied by a few commercial farmers and the majority of the population communally occupying the lower potential regions (IV and V).

Over 80 per cent of the agricultural land falls within NRs III, IV and V and is suitable only for semi-extensive and extensive farming. The current land distribution presented in Table 2.2. was adapted from the land policies of the colonial regimes pre-independence in 1980 which prevented the majority of the population from access to larger portions of land.

2.3. FARMING SECTORS

There are two predominant farming sectors, the commercial and the communal. The commercial farming sector is characterised by high levels of agricultural production for commercial purposes, while communal farming is primarily for subsistence. Since independence, two other farming sectors have evolved namely the small scale commercial and resettlement sectors. The small scale commercial sector is mainly comprised of farmers who have commercialised their operations but using fewer resources than those in the large scale commercial sector. The resettlement sector is comprised of former "landless" people who are being allocated blocks of land communally as a measure to redress the imbalances in land ownership of the past. Resettlement schemes tend to be more organised and better funded than the communal farming sector.

Table 2.2: Land distribution (%) in the different farming sectors by Natural Regions.

NATURAL REGION	I	II	III	IV	V	TOTAL
Large scale commercial	3.0	29.7	15.8	23.6	27.9	100
Small scale commercial	0.4	17.7	38.1	36.7	7.1	100
Communal farming areas	0.9	7.8	17.3	44.7	29.3	100
Resettlement areas	2.1	21.3	38.0	34.7	3.9	100

(Source: adapted from Mitchell (1993) from World Bank: Zimbabwe, Land subsector study. Report No. 3271 - Zimbabwe. January 1986).

2.4. AGRICULTURE AND FARMING SYSTEMS

Agricultural production is the mainstay of Zimbabwe's economy with more than 70 per cent of the country's population depending on it (Tembo, 1989). Agriculture provides most of the commodities for the manufacturing sector and therefore plays a pivotal role in Zimbabwe's economy contributing 11 to 13 per cent of GDP (Mpande, 1994). The main crops grown are maize, tobacco and cotton. Livestock production is dominated by cattle production for draught power, beef and milk.

The commercial farming sector achieves high levels of agricultural production through the use of sophisticated mechanisation, access to large tracts of land and high input costs. Commercial farmers also have greater access to finance than smallholder farmers to sustain the high levels of production. In the communal farming sector, agricultural production is much lower and farmers have less access to land than commercial farmers. These smallholder farmers still depend heavily on the use of human and animal draught power. When communal area farmers have access to finance, few can afford the repayment interest rates on the loans (Ellis-Jones *et al.*, 1994). Thus, communal area farmers will continue to rely heavily on meagre resources and their dependency on human and animal draught power will remain high.

The majority of farmers in the smallholder farming sector practise mixed crop-livestock farming systems (Ellis-Jones *et al.*, 1994). The interdependency of crop and livestock production provides the smallholder farmers with both opportunities and problems. With inadequate DAP, land preparation is delayed resulting in reduced crop yields due to delayed crop establishment (Shumba, 1985). Thus, timely availability of DAP at the start of the wet season is vital for crop production.

CHAPTER THREE

3. STATUS OF DRAUGHT ANIMAL POWER IN ZIMBABWE

3.1. INTRODUCTION

This chapter describes the results of a rapid rural appraisal (hereafter referred to as the RRA) which was undertaken to identify and confirm researchable issues which are discussed later in the thesis. Some results of a formal survey (Muvirimi, 1997) are also discussed. A rapid rural appraisal can be described as a way by outsiders (interested parties, for instance researchers) to gain information and insight from rural people about rural conditions (Chambers, 1992). A brief background to the RRA is provided below.

Barrett *et al.* (1992) carried out a detailed investigation on the DAP status in selected areas of Zimbabwe. Their diagnostic study sought to identify and formulate possible areas of research with regards to the DAP status within the crop-livestock farming systems common in smallholder farming in Zimbabwe. The team investigated the DAP status in Zimbabwe, consulting with local research, veterinary, tertiary and extension institutions, local administrators, farmers, interested non-governmental and international organisations. In a wide-ranging report, their diagnostic study identified some of the following areas of research:

- Identification and characterization of farmer recommendation domains regarding DAP.
- Improved crop production by better use of donkeys and locally available cattle.

- Assessment of draught characteristics of various implements and possible modifications of some existing ones to reduce draught requirements.

The investigation described in this Chapter was based on the above-mentioned diagnostic study by Barrett *et al.* (1992) and a review of the available literature (Munn, 1991; Prasad *et al.,* 1991). A multi-disciplinary programme of research comprising the following three studies was initiated:

- Management, nutrition and health of draught animals
- Socio-economic issues of farmers using DAP
- Implements used with draught animals.

The author, currently working for the Department of Research and Specialist Services (DRSS) and two fellow research workers in the Department of Agricultural, Technical and Extension Services (AGRITEX) were tasked with investigating these issues. An expatriate scientist from Silsoe Research Institute (SRI) in the United Kingdom, led and co-ordinated the multi-disciplinary team investigating these DAP issues in the RRA. The team comprised the following members (including their disciplines and involvement in the research programme):

1. James Ellis-Jones (Socio-economist and Team leader, SRI - Socio-economic issues of farmers using DAP)
2. Forbes Muvirimi (Agricultural economist, Zimbabwe Farmers Union (ZFU), formerly AGRITEX - Socio-economic issues of farmers using DAP)
3. Philip Msara (Agricultural engineer, AGTRITEX - Implements used by draught animals)

4. Edward Nengomasha (Animal scientist, DRSS - Management, nutrition and health of draught animals).

3.2. PURPOSES OF THE RAPID RURAL APPRAISAL

The RRA was carried out to investigate the prevailing issues with regard to DAP in selected smallholder farming areas of Zimbabwe. The general information sought included the following:

- DAP farming systems and resource use
- constraints and issues relating to DAP use
- livestock numbers and prevalence of disease
- welfare of farmers with regard to DAP availability.

3.3. MATERIALS AND METHODS

3.3.1. LOCATION OF THE RRA

Three areas in the semi-arid region, Semukwe (NR V, Matabeleland South Province), Chikwanda (NR IV, Masvingo Province) and Sebungwe (NR III and IV, Midlands Province), were selected and visited for the RRA (Map 2.2). These areas lie in the west and south-western parts of Zimbabwe. They were selected according to the predominance of DAP species and level of use in the areas as follows:

1. Semukwe - Donkeys
2. Chikwanda - Cattle
3. Sebungwe - Cattle and donkey mix.

3.3.2. INFORMANTS

The RRA team interviewed people using or involved with DAP in the smallholder farming areas of the selected areas. These included local traditional leaders (chiefs, headmen), local and political leaders (Party Chairpersons, Village Development Committee (VIDCO) and Ward Development Committee (WADCO) councillors), farmer groups (members and non-members of the Zimbabwe Farmers Union (ZFU)) and individual farmers and support institutions such as AGRITEX, the Department of Veterinary Services (DVS), the Agricultural Finance Corporation (AFC) and non-governmental organisations (NGOs). The farmers interviewed were selected as randomly as possible to reflect the different social classes of the societies in which they lived. This ensured that the information collected was as representative of the areas under study as possible.

With the assistance of local AGRITEX officials, meetings were arranged with the farmer groups and discussions with the RRA team were informal (participatory approaches). Wherever possible, meetings were held with farmer groups first, to establish the general perceptions of the farmers in the area. Farmers were encouraged to discuss and share their own understanding of issues and constraints relating to the use of DAP. Although the discussions were general and wide-ranging, individual RRA team members would probe for information on preconceived questions and topics relating to their respective disciplines. The RRA team would then visit selected individual farmers' homesteads for more formal interviews and for observations of available resources (socio-economic domains, draught animals, draught implements). This was done to corroborate some of the information collected from the farmer group meetings. Every effort was made to visit individual farmers with different levels of available resources, that is the resource-rich, average and resource-poor.

3.3.3. INFORMATION SOUGHT

Information for the multi-disciplinary research programme was sought on the following:

3.3.3.1. GENERAL TOPICS:

- rainfall amounts, dominant vegetation, soil types
- farming systems and livestock numbers
- draught animal management and use (see Section 3.3.3.2.)
- socio-economic status of farmers using DAP (partially discussed in this thesis)
- draught implements (partially discussed in this thesis)
- support services available to farmers utilising DAP (partially discussed in this thesis)

The technique most commonly used to obtain information was that of semi-structured interviews, which entailed having a mental checklist, but being alert and following up on the unexpected (Chambers, 1992). The following questions on animal management were put to the farmers during these semi-structured interviews:

3.3.3.2. DRAUGHT ANIMALS:

- **Draught animal use:** what animals are used; preference; and for what purposes?
- **Other draught tasks:** apart from ploughing, what other draught tasks are animals expected to perform?

- **Harnessing and draught implements:** what harnessing techniques and implements are used?
- **Working regimes:** how often are animals worked, particularly during ploughing; is ploughing finished in time for planting?
- **Contract hiring of DAP:** is it practised; how?
- **Live weight, body condition and feeding strategies:** body condition of draught animals, particularly when ploughing starts; what do animals eat; are they given supplementary feed during work?
- **Health aspects:** what are the health problems with draught animals?
- **Constraints associated with DAP:** what are the constraints and possible interventions/solutions regarding the use of DAP?

3.3.4. DURATION OF RRA

The RRA was carried out over a period of 10 days (Appendix I)

3.3.5. DATA INTERPRETATION

Data on the RRA were not subjected to complete statistical analyses and where appropriate the results are presented as averages and proportions.

3.4. RESULTS

3.4.1. RAINFALL, SOIL TYPE AND DOMINANT GRASS SPECIES

The results are presented in Table 3.1.

Table 3.1: Natural region, mean rainfall (mm), altitude (m), soil types and dominant grass and tree species in Semukwe, Chikwanda and Sebungwe communal farming areas.

COMMUNAL AREA	SEMUKWE	CHIKWANDA	SEBUNGWE
Natural Region	V	IV	III/IV
Mean annual rainfall[1]	395	616	648
Altitude (above sea level)	960	1020	850
Soil types	Sandy, clays, sandy clay loams	sandy and sandy clay loams	sandy, sandy clay loams, clays, heavy clays
Dominant grass species	*Eragrostis curvula, Heteropogon contortus, Aristida spp.*	*Eragrostis spp, Andropogon spp, Aristida spp, Tristachyia spp, Digitaria pensii, Hyparrhenia spp*	grass cover very poor, mainly annuals, some perennials
Dominant tree species	*Acacia spp, Terminalia spp, Colophospermum mopane*	*Brachystegia spp, Julbernardia globiflora, Terminalia spp, Burkea spp*	*Combretum spp, Colophospermum spp, Adansonia digitata*

(adapted and modified from Ellis-Jones et al., 1994).

[1] Rainfall figures presented are from the nearest rainfall station to the areas of the RRA and are averages from 1977 to 1993.

Of the areas visited by the RRA team, Semukwe had the lowest rainfall. The mean annual rainfall for Sebungwe was 648 mm. However, some regions of Sebungwe lie in NR III with an average rainfall of 650 to 800 mm while others are in NR IV (450-650 mm). The soil type, tree and grass species data were obtained from local AGRITEX officials, literature and personal observations. The common feature among the three areas was the predominance of sandy soils. In Sebungwe it was noted that there was very little grass cover and the area was dominated by *Combretum spp* and *Colophospermum mopane* (Jesse bush and Mopane trees, respectively) and there was an abundance of *Adansonia digitata* (Baobab).

3.4.2. FARMING SYSTEMS AND LIVESTOCK NUMBERS

The farming system in these three areas was predominantly a mixed crop-livestock system with crop production playing a major role and cattle and donkeys providing the necessary support (draught power, income and manure). Cattle and donkey ownership data are presented in Table 3.2.

Table 3.2: Cattle and donkey ownership, DAP availability and drought-related deaths in Semukwe, Chikwanda and Sebungwe communal farming areas.

	SEMUKWE			CHIKWANDA			SEBUNGWE		
	Total	Average per household	Range	Total	Average per household	Range	Total	Average per household	Range
Cattle	8962[1]	1.9[1]	0-25[1]	30 771	3.3	0-6	59 383	10.2	0-100
Donkeys	15 808	3.4	0-15	1519	0.2	0-6	8724	1.5	0-6
Cattle:donkey ratio	0.57			20.26			6.81		
Households with inadequate draught animals (%)[2]	75			60			50		
Drought-related livestock deaths (%)	75			28			10		

(Adapted and modified from Ellis-Jones et al. 1994).

[1] estimates based data from AGRITEX and the RRA

[2] inadequate was considered as less than two working cattle or 4 donkeys for a 3 ha plot, see Muvirimi (1997).

The highest number of cattle per household was in Sebungwe (10.2 head) and lowest in Semukwe (1.9 head). However, farmers in Semukwe owned the highest number of donkeys per household (3.4 donkeys), compared with Chikwanda (0.2 donkeys). The cattle to donkey ratio, an indicator of ownership and extent of use of the species, was lowest in Semukwe and highest in Chikwanda. In relative terms, cattle were more widespread in Chikwanda (cattle:donkey ratio of 20.26) than in Semukwe (cattle:donkey ratio of 0.57). However, in Sebungwe there was a tendency towards increasing cattle and decreasing donkey numbers. The farmers attributed this to the eradication of *Trypanosomiasis* in the area which led to the reintroduction of cattle (Appendix I, Table 1). There were reports of a considerable increase in thefts of donkeys from the area. Farmers stated that they were no longer keen to keep donkeys because of these thefts. Livestock losses due to the drought of 1991-92 in these areas were reported by farmers to be high. The highest losses were in Semukwe and the lowest in Sebungwe, 75 per cent and 10 per cent, respectively (Table 3.2). In all areas, there had been more drought-related deaths in cattle than in donkeys.

3.4.3. DRAUGHT ANIMAL POWER USE AND MANAGEMENT

The farmers responses to questions and topics posed on DAP use and management, yielded the following general responses. The author's own observations derived from the questions posed to the farmers, are also included.

3.4.3.1. Draught animal use

There was widespread use of DAP in the crop-livestock farming systems of the three areas surveyed. Cattle were the preferred source of DAP although donkeys were becoming increasingly important. In all areas, ploughing for wet season cropping was the most important draught task for which DAP was employed. For this task, over 90 per cent of the farmers interviewed said that they preferred using cattle. The main reason given for the preference of cattle to donkeys, was that cattle worked faster than donkeys. The preferred animal for ploughing was the ox. Cows and bulls were also used when farmers did not have enough oxen, especially in Chikwanda. In Semukwe and to a lesser extent in Chikwanda, farmers indicated that they were increasingly using donkeys for ploughing. In Semukwe most farmers stated that the use of donkeys for ploughing had a long tradition because of the shortage of cattle in the area. In Chikwanda while most farmers were still using cattle for ploughing, there was widespread use of combinations of cattle and donkeys in mixed species spans or donkeys alone for ploughing. In Sebungwe there was a tendency to increase the use of cattle for ploughing since the reintroduction, from 1975 of this species in the area after the eradication of *Trypanosomiasis* (DVS, 1984). The use of donkeys in this area appeared to be decreasing. When donkeys were used for ploughing or any other task, the sex of the animals was not considered important by the farmers.

3.4.3.2. Other draught tasks

Although the benefits of winter ploughing were appreciated by smallholder farmers, it was not widely practised by most farmers. Most farmers indicated that they could not winter plough because of lack of DAP. However, those with adequate DAP were more likely to winter plough. The main reason for winter ploughing was given by farmers as a weed control measure rather than breaking up the soil crust for easier ploughing during the wet season, and for moisture conservation. The other important tasks for which DAP was used were transport (carting and to a lesser extent packing) and weeding. Donkeys were the preferred species and were used extensively for these tasks. For weeding some farmers said they used two donkeys or in some cases single animals. Donkeys were reportedly better than cattle for weeding because of their ability to move easily between plant rows. It was also reported that for weeding, donkeys were strong enough to pull the lighter cultivators or ploughs which were stripped to leave the beam and share only. Hand weeding with hoes was practised extensively in all areas. This was reportedly due to the unavailability of cultivators and, or, DAP. Other draught tasks such as harrowing, ridging and ripping were not widely practised, although harrows were used more often by farmers in Sebungwe than in Semukwe and Chikwanda.

3.4.3.3. Harnessing techniques and draught implements

Depending on the number of draught cattle available to farmers, they would use either two or four animals in a span for ploughing. When donkeys were used for ploughing, usually four or more animals were spanned. Farmers also indicated that when they did not have an adequate number of donkeys to form a suitable span, they would combine their own animals with those of their relatives or neighbours and plough each others' fields in turns.

In all areas traditional neck yokes were used for cattle. Farmers in Semukwe used breastband harnesses for donkeys. Those in Sebungwe used either breastband harnesses or yokes when harnessing donkeys. In Chikwanda farmers extensively used yokes for donkeys. The reasons given by farmers for use of yokes on donkeys were that yokes were more efficient or that collar or breastband harnesses were not readily available in the area or were too expensive.

Whether cattle or donkeys were used for ploughing, the ox-drawn plough was used in all areas. Farmers in general complained that the available ploughs were too heavy, particularly for donkeys to pull. Almost all the farmers, including those without any draught animals, had ploughs. The age of the ploughs ranged from new to over 20 years old. Most farmers did not have cultivators, harrows or planters. However, more farmers in Sebungwe owned these implements than those in Semukwe and Chikwanda.

3.4.3.4. Working regimes

Draught animals were used to provide draught power for the greater part of the year, the peak period being ploughing at the start of the wet season (November/December). When asked for how long animals were worked during the peak ploughing season, most farmers stated that the animals would be worked for three to six hours a day. Ploughing was carried out early in the morning (05:00/06:00 h) and later in the afternoon (from about 16:00 h), when ambient temperatures would have subsided. Farmers indicated that the animals would be worked daily (depending on the weather and soil moisture content) until they finished ploughing the fields in readiness for wet season planting. This would take from two weeks to two months, depending on the availability of DAP and the size of the fields to be ploughed. The size of fields ranged from 1.5 ha to 6 ha per household. Most farmers however, stated that because of the DAP shortages, they were unlikely to finish tilling the land before the onset of the planting season.

3.4.3.5. Contract hiring of DAP

There was limited use of contract hiring of DAP. Farmers with adequate DAP would plough their own fields first before hiring out their draught animals to those with inadequate or no DAP. The charge for contract hiring of DAP depended on the relationship between the households concerned. Normally, between relations no fee was charged. When fees were charged, these would be either in the form of money or in barter arrangements, for example provision of labour for other tasks or subletting of plots of land to DAP providers for cropping. In general, farmers with inadequate or no DAP, were usually late in planting and realised lower crop yields than those with DAP.

3.4.3.6. Live weight, body condition and feeding strategies

According to farmers, the body condition of the draught animals at the start of the ploughing season was generally poor. Donkeys were reportedly always in better body condition than the cattle. The RRA team observed that at the time of the appraisal (August, mid-dry season) although both species were in fair to good condition, donkeys were in better condition than cattle. It was however, noted that grazing was generally poor. There was extensive and strategic use of crop residues, mainly stovers for supplementing the animals. Farmers said that they would supplement their animals when grazing became limiting or in some cases, when the animals were working. In all the areas there was very limited use of commercial feed supplements. Farmers stated that the costs of these supplements were prohibitive and therefore, not used.

3.4.3.7. Health aspects

When the RRA team inquired about the major health issues related to draught animals, workers of the DVS stated that while there were regular dipping and monitoring programmes for cattle, there were none for donkeys. However, no major problems were cited on the general health of donkeys apart from harness sores and warts. The DVS workers reported no evidence of tick-borne diseases or internal parasites in donkeys. The RRA team could not establish the existence of these diseases during the visit or what effect they had on the performance of the draught animals.

3.4.3.8. General constraints associated with DAP

The major constraint in the three areas was the shortage of DAP. Farmers with access to DAP were more likely to get higher crop yields than those with inadequate access. Farmers, mainly those in Chikwanda, implied that the frame size of their cattle in general had been decreasing and this was further worsening the animals' draught power capabilities. This aspect could not however, be validated by the RRA team. Nonetheless, from the RRA team's observations, cattle in Chikwanda area appeared to be smaller-framed than those in the two other study areas, Semukwe and Sebungwe. The use of cows for DAP to overcome shortages, was also believed to be contributing to low fertility rates. Farmers also indicated that having to resort to using donkeys for ploughing due to the shortage of cattle, was a constraint.

Farmers also emphasised that the unavailability of appropriate implements for use with the small-framed cattle and donkeys, was a constraint which limited the success of their cropping operations. Most farmers suggested that the use of the heavy ox-drawn plough with donkeys was leading to shallow ploughing depths, which consequently reduced crop yields.

According to farmers in Semukwe, existing harnesses for donkeys needed modification. In Chikwanda, harnesses were not readily available. In Sebungwe, while harnesses were available, some farmers chose to use yokes on donkeys.

Lack of financial support for DAP-related problems, was also cited as another major constraint to sustainable crop production. Financial institutions did not readily give financial support for DAP problems as most farmers could not afford the interest rates charged on repayments. According to the financial institutions, most farmers were defaulting and some had equipment such as carts repossessed by the institutions. This was corroborated by the farmers.

3.5. DISCUSSION

The use of donkeys in crop production was increasing in Semukwe and Chikwanda as cattle, the traditional DAP source, were becoming unreliable. It had earlier been shown in the survey work of Munn (1991) that in Kanyati communal area, a semi-arid area of low *Trypanosomiasis* challenge where cattle were not easily available, farmers had readily adapted to using donkeys for DAP. Munn (1991) reported that donkeys in Kanyati contributed extensively to the income of smallholder farmers using donkeys only. These farmers earned as much as those using cattle only. The main challenge therefore, appears to be the need to optimise and maximise the use of the existing donkey population in the semi-arid regions. The ability of donkeys to survive harsh conditions better than cattle, makes it an appropriate alternative for DAP in these areas. Whether donkeys are used as supplementary or alternative sources of DAP to cattle, depends on the prevailing DAP availability in the affected areas. In a survey carried out before the 1991-92 drought in the Semukwe area, it was reported that the average number of donkeys per household was 3.4 head while that of cattle was 9.5 head (Sibanda, 1996). The present RRA revealed that donkey numbers per household were virtually unchanged in 1994 compared with pre-drought figures while cattle numbers were reduced to 1.9 head per household, a drought-related mortality rate of 80 per cent. This further illustrates that donkeys are a more reliable and sustainable source of DAP in the drought-prone semi-arid regions. In Semukwe the emphasis should therefore be on the improved use of donkeys, particularly for ploughing as donkeys were more important for this purpose than cattle. Sibanda (1996) from his survey in this area, estimated that the land area ploughed by donkeys and cattle per household in the 1990-91 season was 1.73 ha and 0.77 ha, respectively, indicating the fundamental role donkeys have in Semukwe. Despite the lack of resources (especially finance), farmers in Semukwe showed commitment and initiative to ensuring better management and welfare of the donkeys. However, no extension information on proper working regimes or potential of the donkey was available to these farmers. Therefore, there is need for research on donkeys to provide information which is applicable to the farmers' conditions to optimise the use of this species. The indications from the RRA and other surveys (Munn, 1991; Prasad *et al.,* 1991; Hagmann and Prasad, 1995) were that the donkey was becoming an increasingly popular DAP resource in smallholder farming in the semi-arid regions.

The present RRA confirmed what had been largely assumed before the RRA, that the distribution (prevalence) of species in the three areas studied was: donkeys in Semukwe, cattle in Chikwanda and cattle:donkey mix in Sebungwe. However, the general increase in the use of donkeys in areas such as Chikwanda where cattle had long been the predominant source for DAP, was evident. Kondor (1991) reported that some farmers in Chivi district, in the same province (Masvingo) as Chikwanda, actually favoured using donkeys for domestic chores rather than cattle. This indicated that smallholder farmers in Masvingo province were increasingly adopting and relying on donkeys as an alternative source of DAP as their livelihood was threatened by the recurrence of droughts in the region. This was a direct response to the prevailing shortage of cattle. However, in Sebungwe, with the eradication of *Trypanosomiasis* from the area, farmers who have always preferred cattle, were keen to own and use cattle again. This illustrates the general preference by smallholder farmers in

Zimbabwe, of owning cattle to donkeys, often disregarding the risks associated with cattle in the semi-arid regions. Barrett (1992) suggested this was an indication of the value attached to cattle which are multipurpose (draught power, meat, milk, social and ritual, hides) and offer a better storage of capital than donkeys.

It would appear that attempts to promote the use of donkeys in Sebungwe, could be ineffectual because farmers in this area have solutions for their draught power options. Sebungwe lies in the cotton-growing region of the country, where soils and rainfall are better suited to cotton production than in most semi-arid regions. Therefore, farmers in Sebungwe have more disposable income than those in Semukwe and Chikwanda. Most farmers in Sebungwe could afford to either purchase cattle to replace donkeys for DAP, engage in contract ploughing or even use tractors. There was more scope for contract hiring of DAP in Sebungwe than in the other two areas. Indeed, farmers in Sebungwe had the highest number of tractors, or access to them, when compared with Semukwe and Chikwanda. The reported widespread thefts of donkeys in Sebungwe, were understandably increasing the reluctance by farmers to keep donkeys. However, despite the decreasing popularity of the donkey in Sebungwe, a few farmers were still retaining some donkeys for carting and other lighter draught tasks.

In Chikwanda the situation regarding the donkey as a DAP resource showed a lack of information on proper management and appreciation of even basic husbandry practices of the donkey. The farmers in Chikwanda lacked experience in using donkeys, as demonstrated by their continued use of yokes on donkeys. It has been shown that equines in general have strong shoulders and breasts (Devnani, 1987) and use the chest for pulling. Therefore, donkeys cannot pull the implements as efficiently as when using the recommended collar or breastband harnesses (Jones, 1991). When the farmers were challenged on their use of yokes on donkeys, they claimed that this was due to either the lack of extension information on the proper harnessing procedures for donkeys or the cost of harnesses, if available. This was confirmed by the extension personnel who stated that breastband harnesses were not readily available in the Chikwanda area, although some local artisans elsewhere in the province were reportedly manufacturing donkey harnesses. It could not be verified whether these artisans were manufacturing the recommended collar or breastband harnesses. The widespread use of mixed cattle:donkey spans the farmers were resorting to, was due to the acute shortage of cattle for DAP. The survey of Prasad *et al.* (1991), revealed that 75 per cent of farmers in the Gutu district (the same district in which Chikwanda is located), were using donkeys in mixed spans with cattle. There is no scientific evidence available to validate the efficiency of using donkeys in mixed spans with cattle or on the appropriate spanning formations.

Before the 1991-92 drought communal grazing areas were reportedly over-stocked, due to the high numbers of animals and the increased conversion of these areas into arable land (Tembo, 1989; Barrett, 1992). The significant reduction in livestock numbers, due to the high mortalities during the drought, could have reduced stocking rates resulting in fewer animals competing for the available grazing than during the pre-drought period. The fair to good body condition of the animals during the present RRA in August 1994 was probably due to this reduction in stocking rates. However, this theory of lower stocking rate could not be validated as no grazing assessment was carried out before the 1991-92 drought or during the RRA. The use of crop residues probably also contributed to the observed fair to good body condition of the animals during the RRA. Animals in Sebungwe could also have benefited from browsing the high quality Jesse Bush and Mopane trees, which dominate the Sebungwe vegetation (Table 3.1).

Although health was not considered a major problem for donkeys, work by Pandey and Eysker (1991) has shown that donkeys in Zimbabwe do have a heavy worm burden, although the effects of this on animal performance has not been investigated. During the present RRA, there appeared to be no prevalence of tick-borne diseases in donkeys in the three areas although they can be affected by mange and ringworm (see Fielding, 1988). There is need for studies to be carried out on the effects of internal parasites, tick-borne and other diseases on the overall performance of donkeys.

The results of the RRA revealed that the recurrent droughts had severely affected crop yields in the smallholder farming sector in the semi-arid regions of Zimbabwe. This was evident from the discussions with farmers. Despite the above-average rainfall during the 1992-93 season, farmers did not achieve increased crop yields when compared to the pre-drought 1990-91 season. Considering that smallholder farmers were given free seed and fertilisers by the government as part of the drought recovery programme, the reduction in crop production from this sector was due to the shortage of DAP which resulted in reduced arable land being planted. Muvirimi (1997) reported that 40 per cent of the farmers in Semukwe left land fallow due to the shortage of DAP. Although in some areas there was provision of tractors through government organisations such as local District Development Funds (DDF) as well as NGOs, this did not have a marked impact on land tillage and subsequent crop production as there were not enough tractors to service all the farmers in need of draught power. Frequent break-downs of these tractors further worsened the situation. This resulted in widespread delays in planting at the start of the rainy season. These problems highlight the adverse effects of inadequate DAP on crop yields in the crop-livestock farming systems of the majority of smallholder farmers. Smallholder farmers in these semi-arid regions have to resort to mixed crop-livestock farming systems as the only viable option to guarantee their livelihood, albeit of meagre proportions. The role of DAP in the farming systems of these regions remains a very vital one. The present RRA showed that although the short-term effects of drought were most evident in crop production, the farmers were beginning to experience the long-term effects on DAP availability. This has compelled farmers, extension and research workers to appreciate the need for alternative sources of DAP to the traditional, but unreliable, cattle resource.

As a follow-up to the RRA, a detailed formal survey in the three areas studied by the RRA, was carried out between 1994 and 1996 by one of the collaborators in the ZIMDAP project. This formal survey (Muvirimi, 1997) formed a major component of the socio-economic study within the collaborative ZIMDAP project. Questions on draught implements and draught animal management (the other two components of the ZIMDAP project), were included in a structured questionnaire used during Muvirimi's formal survey (hereafter referred to as the formal survey). The formal survey was used to verify and expand on the findings of the RRA in Semukwe, Chikwanda and Sebungwe. This socio-economic study grouped farmers with different levels of ownership of DAP into eight recommendation domains. A recommendation domain is defined as a group of farmers with similar DAP resources and constraints and requiring similar solutions (Muvirimi, 1997). They were classified as follows in Table 3.3.

<u>Table 3.3:</u> Classification of recommendation domains of rural households in Semukwe, Chikwanda and Sebungwe.

<table>
<tr><td colspan="8">RURAL HOUSEHOLDS IN SEMUKWE, CHIKWANDA AND SEBUNGWE</td></tr>
<tr><td colspan="2">NO ANIMALS OWNED</td><td colspan="6">ANIMAL OWNERS</td></tr>
<tr><td colspan="2"></td><td colspan="3">INADEQUATE ANIMALS FOR DAP</td><td colspan="3">ADEQUATE ANIMALS FOR DAP</td></tr>
<tr><td>No access to DAP</td><td>Some access to DAP</td><td>Donkeys only</td><td>Donkeys and cattle</td><td>Cattle only</td><td>Donkeys only</td><td>Donkeys and cattle</td><td>Cattle only</td></tr>
</table>

adapted from Muvirimi (1997).

The results of the formal survey of 249 farmers showed that Semukwe had the highest number (81 per cent) of households without adequate DAP, while Chikwanda and Sebungwe had 50 per cent and 29 per cent, respectively. While these figures differed in magnitude from those of the RRA (75, 60 and 50 per cent, for Semukwe, Chikwanda and Sebungwe, respectively), they showed a similar trend and illustrated the shortages of DAP. According to the formal survey the highest number of donkeys per household was in Semukwe (5.2), followed by Chikwanda (3.2) and Sebungwe (2.6). This suggests that the RRA underestimated the numbers of donkeys in all areas, especially Chikwanda. However, these results of the formal survey confirmed the higher prevalence of donkeys in the drier regions of Zimbabwe such as Semukwe (NR V) and Chikwanda (NR IV), compared with Sebungwe (NR III/IV). These results confirmed earlier findings of Prasad *et al.* (1991) which showed a similar trend of decreasing draught cattle and increasing donkey use from NR III through to NR V.

The aspects on current DAP status and use highlighted by the RRA (Ellis-Jones *et al.* 1994) and the formal survey (Muvirimi, 1997) reveal the lack of basic information on many aspects of donkey management in Zimbabwe. Hagmann and Prasad (1995) showed from the results of their survey in two districts (Chivi in Masvingo Province and Gokwe in Midlands Province) that 93 per cent of respondents had never been advised on donkey use and management by extension workers. The present RRA also revealed similar trends, especially in Chikwanda where farmers exposed their lack of information, particularly on harnessing and donkey management in general. This further reinforces the need to increase availability of local information on aspects of donkey management and this can be aided by increased understanding of the potential output and inputs required to optimise the performance of this class of livestock (Munn, 1991; Hagmann and Prasad, 1995). This can be achieved through exploratory and adaptive research to establish the potential of this species in Zimbabwean smallholder farming systems.

The following Chapters examine some of the issues highlighted above. It is important to have knowledge of the type of donkey the farmers have available when determining its potential capabilities. Characterization of the type of donkey in the semi-arid regions of Zimbabwe is the subject of the next Chapter.

CHAPTER FOUR

4. CHARACTERIZATION OF THE DONKEY IN ZIMBABWE

4.1. INTRODUCTION AND LITERATURE REVIEW

4.1.1. MORPHOLOGICAL CHARACTERISTICS OF WORKING DONKEYS

There is a wealth of information on the types of cattle available to the smallholder farmer for DAP and other purposes. The types of cattle are predominantly Sanga, local types believed to originate from crosses between humpless and Zebu *Bos indicus* cattle, which are better adapted to Zimbabwe's environmental conditions than the exotic *Bos taurus* breeds (Oliver, 1983; Hatendi, Nengomasha, Mguni and Mushawatu, 1993). Due to the haphazard mating and lack of breeding programmes in the smallholder farming sector, these cattle types consist mainly of nondescript crossbreds of the local breeds: the Mashona, Nkone, Tuli; and the Afrikaner. Crossbreds between the indigenous cattle and exotic breeds, mainly the Hereford, Aberdeen Angus, Simmental and Jersey are also common. The draught performance of the cattle types in Zimbabwe have been evaluated (Mupeta, Ndlovu, and Prasad, 1990; Francis and Ndlovu, 1995; Hagmann and Prasad, 1995).

Although "breeds" or "types" of donkey may exist in Zimbabwe, there is little information recorded on the description of those used by smallholder farmers. Therefore, it is largely assumed that all donkeys in Zimbabwe are similar. Attempts to identify donkey "breeds", although of interest, would be costly and require the advanced laboratory techniques of DNA analysis and genetic finger-printing.

In Zimbabwe this would not be financially or technologically feasible, given the present unavailability of these resources. At present it is easier and more practical to characterise the "type" of donkey available to the farmer using morphological attributes of the species. These can help identify the type(s) of donkey available and assist in establishing whether it is capable of performing assigned draught tasks. Comparisons could then be made with other donkey types or breeds in the region. This would be useful to establish whether information (management, feeding, breeding regimes etc.) on other donkey types is directly applicable to the type of donkey found in Zimbabwe.

Donkeys in Africa originate from the Somali wild donkey (*Equus asinus somaliensis)* and the Nubian wild donkey (*Equus asinus africanus*) (Camac, 1989; Wilson, 1990). The Nubian, which is the smaller of the two, has a marked "cross" on the shoulder while the Somali has leg stripes like the zebra (Wilson, 1990; Varshney and Gupta, 1994). These are the main features which differentiate the two wild donkey species. The morphological characteristics which are unique to the donkey, include the large ears and head, which Wilson (1990) described as the most well-known features. The predominant coat colour of the donkey in the tropics is grey (Mason and Maule, 1960; Wilson, 1990). The donkey has been described as a small hardy animal, rarely exceeding 110 cm at the withers and weighing no more than 150 kg (Wilson, 1990). A review of some of the morphological characteristics of donkey types in Africa and Asia was given by Varshney and Gupta (1994) and is presented below (1 hand = 10.16 cm).

<u>African wild asses:</u>

a). Nubian type: 12 hands (122 cm) height at shoulder and thin shoulder cross b). Somali type: bigger than the Nubian, 14 hands (142 cm) height at shoulder and prominent leg stripes

Asiatic wild asses: found over a much larger area stretching from the Red Sea to North India and Tibet

a). Syrian type: height under 10 hands (102 cm)

b). Onager type: height 12 hands (122 cm), light coloured and swift-footed

c). Kulan type: height 12.5 hands (127 cm), dark coloured with a broad stripe along the back, no shoulder stripe

d). Kiang type: height 14 hands (142 cm), short ears and round feet, certain features more like the horse

e). Indian asses: i) small grey with zebra markings on limbs, neck and quarters, average height under 8 hands (81 cm), have long ears

ii) large white, average height under 9 hands (91 cm), never mix or interbreed with domestic donkeys

Other types: White Egyptian, Persian, Arabian and Poitou

The donkeys in the tropics are generally smaller than their counterparts in the temperate regions of the world e.g. Europe and the USA. The Poitou donkey in France, measures 14-15 hands (142 cm - 152 cm) at the withers (Camac, 1989) and is considered to be the largest of the donkey breeds (Varshney and Gupta, 1994). Others include the Spanish donkey, a large breed used for mule breeding in Europe and the USA. (Schmidt-Nielsen, 1964).

Most donkeys in Zimbabwe have the characteristic cross on the back and rarely have leg stripes. From these descriptions, it is likely that the "Zimbabwean" donkey is a descendant of the Nubian wild donkey. Although it is not clear where donkeys in Zimbabwe originated from, it has been suggested that they came from North Africa (Jones, 1991) or from the Horn of Africa (L. R. Ndlovu, pers. comm.). They were reportedly introduced into the country in the last century during the period of pioneering in the late 1890s when, along with oxen, horses and mules, they supplied motive-power to the colonists (Kondor, 1991; Starkey, 1994). It can be concluded therefore, that donkeys in Zimbabwe and indeed those in the sub-region, are morphologically and genetically similar to their ascendants in North and East Africa. Mason and Maule (1960) described the donkeys found in Zimbabwe as feral and of all colours; black, brown, grey and light grey shades, all having pale bellies. This is a fairly accurate description of some of the morphological attributes of the present-day Zimbabwean donkey. However, apart from the attempts of Mason and Maule (1960), there is no other descriptive literature available. The visual observations made on the Zimbabwean donkey could be further substantiated by information on body dimensions.

4.1.2. THE RELATIONS BETWEEN BODY MEASUREMENTS AND LIVE WEIGHT

Routine monitoring of live weight provides the farmer with a management tool when assessing the draught capability of donkeys. Apart from determination of the donkeys' potential for work, knowledge of live weight is important for veterinary interventions, for instance administration of anthelmintics (Eley and French, 1993) and assessment of nutritional adequacy and interventions. However, accurate measurement of the animals' live weight requires the use of weighing equipment. The majority of smallholder farmers in Zimbabwe have no access to weighing equipment. Most farmers rely on visual assessment of the frame-size of the donkeys without the use of weighing scales. Therefore, there is a need to establish simple and practical methods of estimating the live weight of donkeys without using weighing equipment. Frame-size, which can be easily assessed through body dimensions, provides a useful indicator of the live weight of the donkeys. Work has been carried out elsewhere to determine whether there are relations between different body dimensions and live weight. Eley and French (1993) measured body dimensions of 243 donkeys at the Donkey Sanctuary in Britain and reported strong relations between live weight and height as well as heart girth. In Morocco, Pearson and Ouassat (1996) measured 516 donkeys used mainly for transport and likewise reported that some body dimensions could be accurately used to predict the live weight of donkeys. Body measurements similarly have been measured on donkeys in Botswana (Aganga and Maphorisa, 1994), Cameroon (Ebangi, Vall and Mbah, 1995) and in South Africa (Wells, 1996). Assuming that Zimbabwean donkeys are morphologically similar to their counterparts in other countries, body measurements could be used in the estimation of live weight. These body dimensions are easily measurable and require little equipment. The practical implications are that smallholder farmers in Zimbabwe or anywhere else in the region, would have a simple and useful management tool to assist them in efforts to optimise the use of donkeys.

4.1.3. SEASONAL FLUCTUATIONS IN LIVE WEIGHT AND BODY CONDITION OF DONKEYS

It is important for smallholder farmers to monitor any changes in their donkeys' draught capacity as affected by environmental factors. The climatic conditions experienced in Zimbabwe result in wide fluctuations in availability of feed for livestock. The quantity and quality of natural grazing, which constitutes the main feed resource for livestock in the smallholder farming areas, is influenced by seasonal climatic changes. The growth characteristics of the natural grasses from the wet to the dry season lead to a rapid decline in crude protein (CP) content accompanied by an increase in lignification, resulting in a decline in overall nutrient content. The CP content of grasses can decrease from about 8 per cent in the wet (mid-growing) season around January to as low as 2 per cent at the middle of the dry season, around July (Plowes, 1957; Topps and Oliver, 1978). It has been observed that the live weight and body condition of grazing cattle follow these fluctuations, animals gaining weight when the quality and quantity of grasses is high and losing weight and body condition during the dry season. However, unlike the situation in cattle, there is little or no information available on the fluctuations in live weight and body condition of donkeys due to the seasonal climatic changes. Tembo (1989) illustrated that draught cattle are in poor body condition at the end of the dry season mainly due to the poor grazing at that time of the year. The DAP requirements of smallholder farmers increase considerably at the onset of the ploughing season in October/November (Ellis-Jones *et al.*, 1994). Tembo (1989) concluded that the live weight and body condition of draught cattle were out of phase with the farmers' draught power requirements at the start of the wet season (see Appendix II, Figure 2.1). The seasonal fluctuations of live weight and body condition of donkeys have not been monitored.

Three studies were carried out to identify the characteristics of working donkeys in south-western Zimbabwe.

The objectives were to determine;

- The morphological characteristics as indicated by body dimensions
- The relation between some body measurements and live weight
- The seasonal changes in live weight and body condition of donkeys.

4.2. MATERIALS AND METHODS

4.2.1. THE MORPHOLOGICAL CHARACTERISTICS

4.2.1.1. ANIMALS AND ORIGINS:

Three hundred and thirty five donkeys from the smallholder farming areas of Matabeleland North and South Provinces, were measured. The donkeys were from Matopos Research Station (n = 41), donkey farms in Bulawayo (Donkey Sanctuary and Esigodini) (n = 101), Matobo District of Matabeleland South (n = 101) and Nkayi District of Matabeleland North (n = 92). Only donkeys which were being or had been used for work, were included in this study. When a group was large, indelible paint was used to mark donkeys whose body measurements had been taken to avoid measuring the same animals twice.

Matabeleland North and South Provinces were selected because these provinces have the highest prevalence and level of use of donkeys when compared with other areas of Zimbabwe. In 1994 out of an estimated total donkey population in Zimbabwe of 303 000 head, over 51 per cent were in Matabeleland North and South Provinces (DVS, unpublished data). Therefore, it was considered that donkeys in these areas were likely to be representative of the donkey population in Zimbabwe.

The easier access afforded by the proximity of Matabeleland North and South Provinces to the main experimental site (Matopos Research Station) was also taken into account when selection of these areas was made. Donkey owners in these provinces were identified and visited after consultation with the local leadership and AGRITEX officials. The donkeys were measured, usually at the farmers' homesteads or fields, and with the owners' full cooperation. Wherever appropriate, measuring of donkeys was performed *ad hoc* when the research team came across donkey owners willing to have their donkeys measured. The donkeys' names or other forms of identification and any distinguishing marks were recorded to ensure that the same donkeys were not measured again. The owners' names and villages or wards from where they came, were also noted.

4.2.1.2. BODY MEASUREMENTS, LIVE WEIGHT, SEX AND AGE:

The following body measurements of donkeys were taken (adapted from Pearson and Ouassat, 1996) (Plate 4.1a, b, c, d, e):

1. Heart girth

This measurement represented the circumference of the heart or chest girth on the caudal edge of the withers and behind the elbow. This measurement was taken by tape measure (nearest cm) (Plate 4.1a).

2. Umbilical girth

The girth circumference was measured by tape measure approximately over the umbilicus (in the present study regarded as the widest part of the abdomen) (nearest cm) (Plate 4.1b). The physiological status of pregnancy was recorded for female donkeys which were confirmed or appeared to be pregnant.

3. Body length

This was measured from the olecranal process of the elbow to the *tuber ischii* (diagonally) using a measuring stick. Other studies (e.g. Jones *et al.*, 1989; Pearson and Ouassat, 1996) have shown that this method of measurement was easier, repeatable and therefore, more accurate. It also made it possible to compare the body lengths of donkeys in Zimbabwe with those taken elsewhere by the same method. Body length was taken while the donkeys were standing upright on level ground or a wooden platform with fore and hind legs in a straight line. The length was measured in centimetres (cm) to the nearest cm (Plate 4.1c).

4. Height at withers

Height at withers was measured from level ground to the highest point on the withers using a measuring stick (nearest cm). Animals were standing upright as during the body length measurement.

5. Cannon bone

This measurement represented the circumference at the narrowest part of the cannon bone of the foreleg (nearest cm). A tape measure was used (Plate 4.1d).

6. Live weight

The live weight of the donkeys was measured using a portable livestock electronic weighing system, Ruddweigh KM-2 (Ruddweigh Australasia Pty. Ltd., NSW, Australia). The weighing system comprised of two beams, each fitted with an electronic load cell, and a digital display unit. The scale was powered by a 12 volt car battery. A wooden platform was placed in balance over the two beams for the donkeys to stand on while being weighed. The scale was zeroed with the wooden platform and then the donkeys were weighed while standing as still as was possible on the platform. This was to ensure stability and hence accuracy of the scale when weighing the donkeys. Live weight was measured to the nearest kilogramme.

7. Sex

The sex of the donkeys was visually appraised. Whenever possible, the male donkeys were described as castrates or entires/intacts.

8. Age

The estimation of the ages of the donkeys was based on information supplied by the farmers and, or, by dentition using the method of Tutt (1987) (Appendix II, Figure 2.2). Before this study was carried out the author and the research team practised Tutt's (1987) method to ensure accuracy and repeatability of estimation of age.

However, it must be stated that the dentition method of Tutt (1987) was based on horses and the scale could only accurately estimate the age up to 14 years. Beyond 14 years, the estimation was speculative. For purposes of data analysis, the ages of all donkeys deemed to be over 14 years were coded as 15 years. Therefore, some of the donkeys determined by dentition to be 15 years old could in fact have been older. Nonetheless, this method of estimating the ages of donkeys has been shown to be fairly accurate (R.A. Pearson pers. comm.). Dyce, Sack and Wensing (1996) in their rough guide for ageing horses by dentition, stated that the age could be accurately estimated up to about 8 years, beyond which estimation was speculative (see Plate 4.1e).

Plate 4.1a: Measuring heart girth of a donkey.

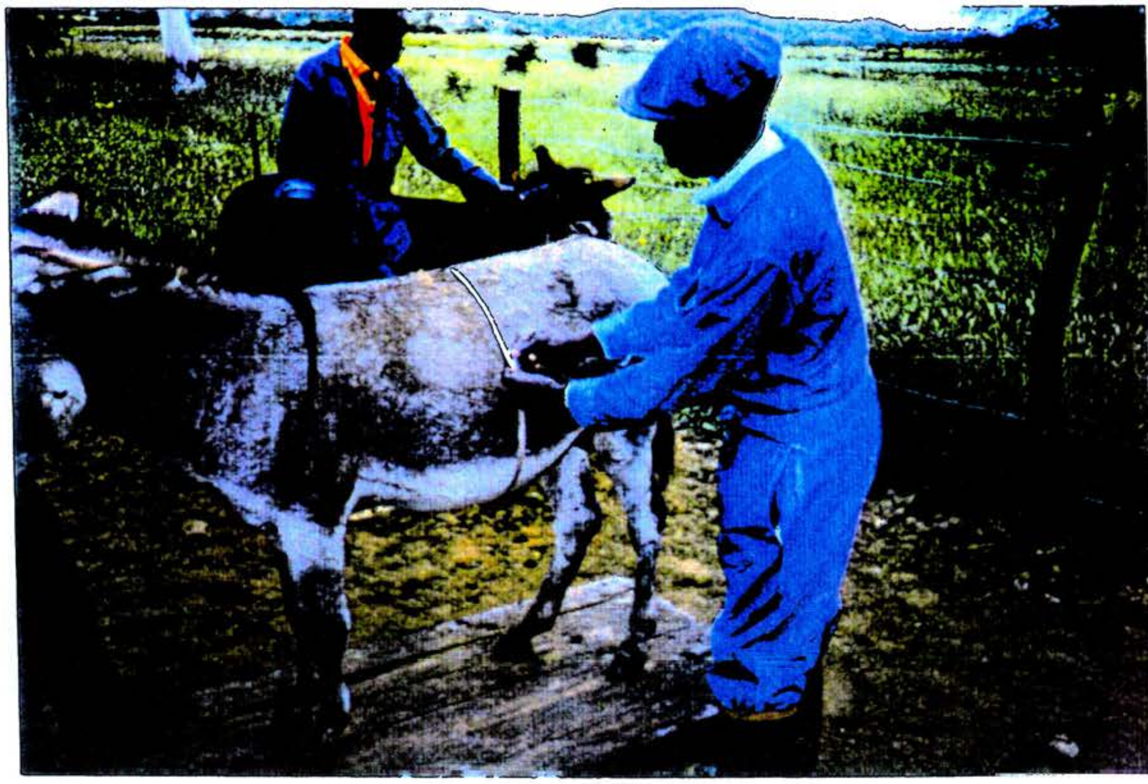


Plate 4.1b: Measuring umbilical girth of a donkey.

Plate 4.1c: Measuring body length of a donkey.

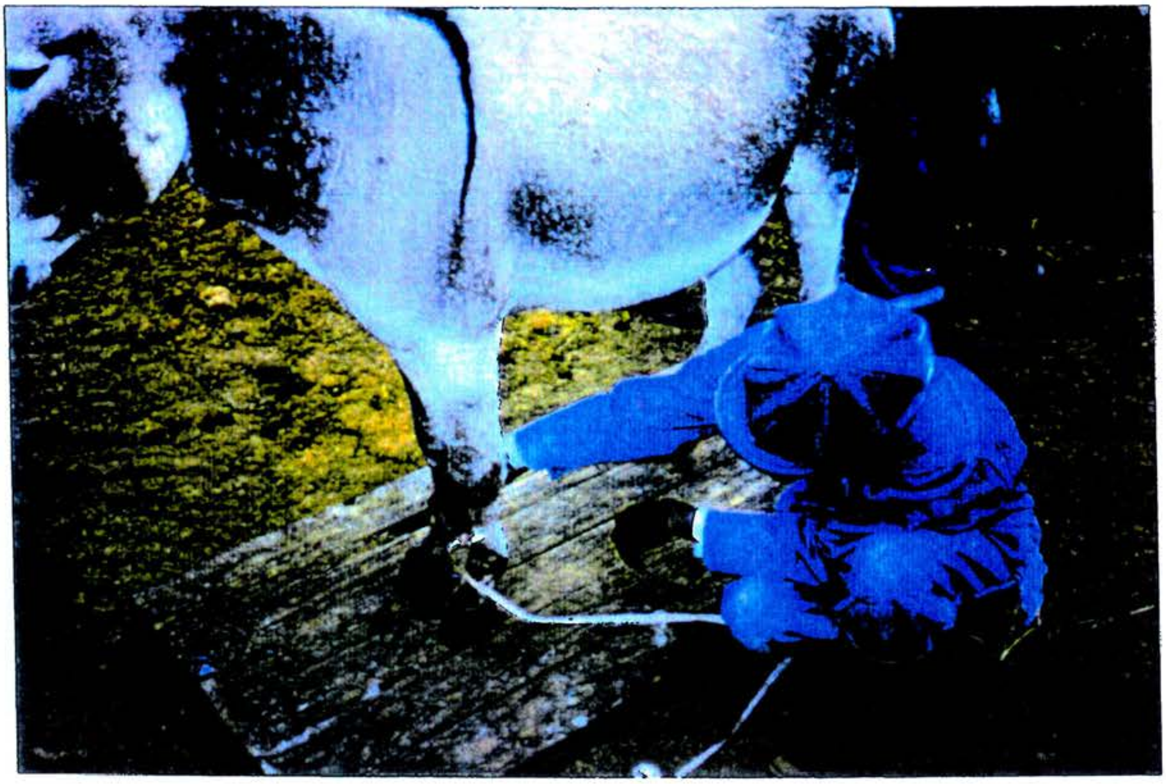


Plate 4.1d: Measuring foreleg cannon bone circumference of a donkey.

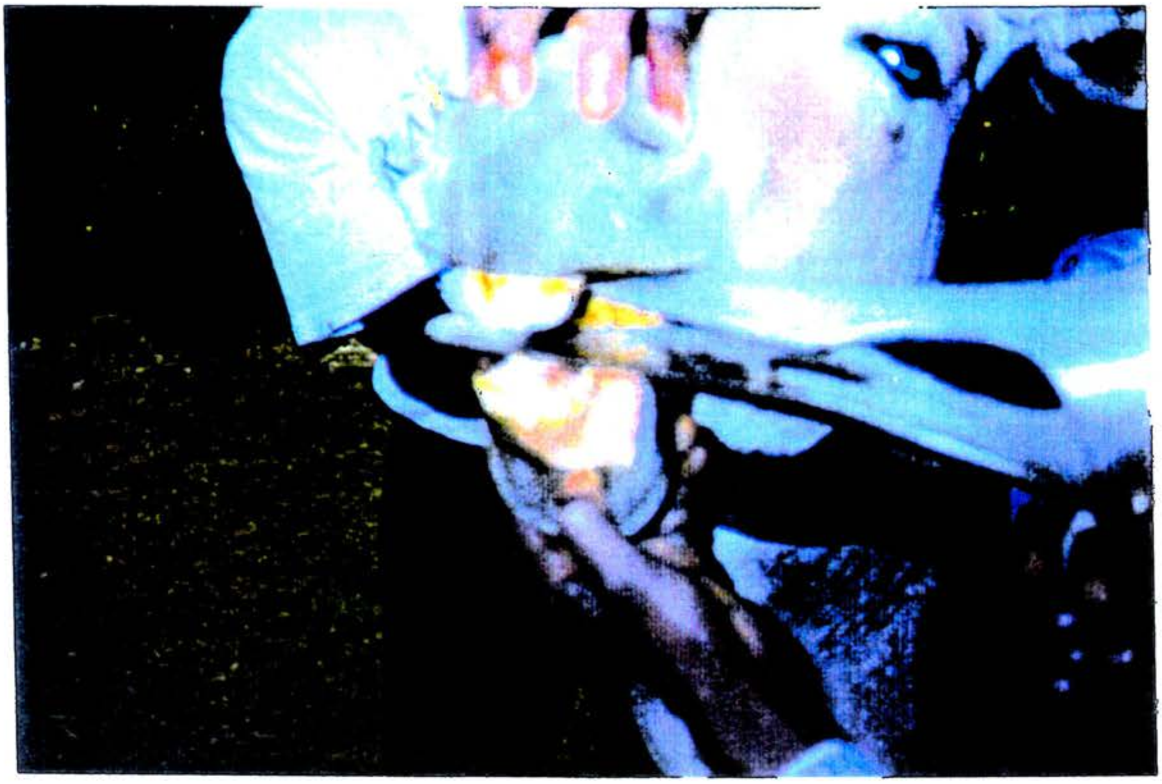


Plate 4.1e: Opening the mouth to estimate age of a donkey by dentition.

4.2.1.3. STATISTICAL ANALYSIS:

Pooled data on the body measurements of the 191 male and 144 female donkeys were initially subjected to the Anderson-Darling Normality Test to test for normality. Thereafter, data for male and female donkeys were separated and again tested for normality. For variables where the data were not normally distributed, the results were subjected to non-parametric tests (MINITAB Inc., 1994) to test for the differences between male and female donkeys. For variables which fulfilled the conditions for parametric tests, the pooled data were subjected to ANOVA using the GLM procedure (MINITAB Inc., 1994) statistical programme, with sex as one of the sources of variation.

4.2.2. THE RELATIONS BETWEEN BODY MEASUREMENTS AND LIVE WEIGHT

4.2.2.1. ANIMALS:

Data from donkeys reported in Section 4.2.1. (n = 335) were used to compute the relations between body measurements and live weight.

4.2.2.2. MEASUREMENTS AND DETERMINATION OF RELATIONS BETWEEN LIVE WEIGHT AND BODY MEASUREMENTS:

The body measurements used for estimation of live weight were heart and umbilical girths, body length and height at withers. Earlier studies have shown that the relation between live weight and body measurements is non-linear in horses (Jones, Lawrence, Veevers, Cleave and Hall, 1989) and in donkeys (Pearson and Ouassat, 1996). Similarly in the present study, variance (s^2) of live weight increased with increasing values of the body measurements. Therefore, in the present study the measured values for all donkeys were transformed to $\log_{10}$ before regression analysis to determine the relation between live weight and body measurements. Live weight, as the dependent variable, was regressed against the individual body measurements (independent variables). The relations were represented by the following general equation for linear regression (1):

$$\textbf{(1)}\ \log LW = \log a + b \log X$$

where log LW = $\log_{10}$ of live weight (dependent variable)

log a = constant

b = intercept/slope

log X = $\log_{10}$ of measured values of body dimensions X e.g. heart girth (independent variable).

When more than one independent variable was used, the regression analysis was represented by the following equation (2):

$$\textbf{(2)}\ \log LW = \log a + (b_1 \log X_1 + b_2 \log X_2)$$

where $b_{1,2}$ = intercepts for independent variables $X_{1,2}$

log $X_{1,2}$ = $\log_{10}$ of independent variables $X_{1,2}$

4.2.2.3. STATISTICAL ANALYSIS:

Statistical analyses were performed on all the measured values of the live weight and body dimensions after transformation to their logarithmic values ($\log_{10}$) (Section 4.2.2.2.) and the data were subjected to linear regression analysis (MINITAB Inc., 1994). Histograms of the residuals of the actual and the predicted values were also computed. The coefficient of determination (r^2) values are also presented and where there are more than one variable, adjusted r^2 values are used. Data for 55 growing donkeys (3 years and under, live weight range 78 kg to 146 kg) were then analysed separately in the same way after data transformation.

4.2.3. SEASONAL FLUCTUATIONS IN LIVE WEIGHT AND BODY CONDITION OF SELECTED DONKEYS

4.2.3.1. ANIMALS:

Sixty two donkeys from Semukwe in Matobo District were originally selected for monitoring. The animals belonged to farmers who had volunteered to take part in the study. These donkeys were some of the 335 donkeys used in the other two studies reported in Sections 4.2.1. and 4.2.2. However, the monitoring of 24 of the 62 donkeys was discontinued for various reasons, including withdrawal of cooperation by the farmers, animals being sold or relocated to other villages or animals being continuously absent when required for monitoring. Therefore, data from a total of 38 working donkeys (19 males and 19 females) are presented in this section. During the periods of monitoring, the donkeys were managed and worked according to the practices normally carried out by the farmers.

4.2.3.2. MONITORING OF LIVE WEIGHT AND BODY CONDITION:

The donkeys' live weight and body condition were monitored for 18 months from January 1995 to August 1996. The monitoring of the donkeys was carried out four times a year in the months of January/February, April/May, July/August and October/November. These months were selected to establish whether there were any seasonal fluctuations of live weight and body condition of donkeys as have been observed in cattle. The periods were selected to reflect climatic changes due to effects of seasons:

January/February - mid-wet season

April/May - late-wet season

July/August - early to mid-dry season

October/November - late-dry season.

Recording of the donkeys' live weight and body condition was carried out in the morning before the donkeys were released for grazing or subjected to work. Live weight measurements were carried out as previously described. Body condition scoring of the donkeys was based on the Pearson and Ouassat, (1996) scoring system developed with donkeys in Morocco. In this scoring system, a body condition score ranging from 1 to 9 is used (Table 4.1).

Table 4.1: Guide to the body condition scoring of donkeys (adapted from Pearson and Ouassat, 1996).

Body Condition Score	Description
1 Very thin (emaciated)	Animal markedly emaciated; bone structure easily seen over body; little muscle present; animal weak; lethargic
2 Thin	Animal emaciated; individual spinous processes, ribs, tubers coxae and ischii and scapular spine all prominent; some muscle development; neck thin; prominent withers; shoulders sharply angular
3 Less thin	Vertebral column prominent and individual spinous processes can be felt (palpated); little fat, but superspinous musculature apparent over spinous, ribs tubers coxae and ischii prominent; loin area and rump concave; little muscle or fat covering over withers and shoulders
4 Less than moderate	Vertebral column visible; tuber ischii palpable but not visible, tuber coxae rounded but visible; rump flat rather than concave; ribs palpable but not obvious; withers, shoulders, neck with some muscle and fat cover; scapular less clearly defined
5 Moderate	Superspinous muscles developed and readily apparent; can palpate vertebral column; tuber coxae rounded; rump rounded, convex; tuber ischii not visible; some fat palpable in pectoral region and at base of neck; can palpate ribs, but not visible
6 More than moderate	Cannot palpate spinous processes easily; back becoming flat, well covered; rump convex and well muscled; some fat palpable on neck, base of neck and pectoral region; neck filled into shoulder, tuber coxae just visible
7 Less fat	Back flat, cannot palpate spinous processes; tuber coxae just visible; fat on neck and pectoral region beginning to expand over ribs; flank filling, neck thickening
8 Fat	Animal appears well covered with body rounded with fat and bones not discernible; flanks filled; broad back
9 Very fat (obese)	Bones buried in fat; back broad or flat. in some cases crease down back; large accumulations of fat on neck, over pectoral area and ribs; flank filled with fat

The assessment of body condition score was carried out independently by at least two people (the author always included) and mean scores were used. In total, the donkeys were monitored seven times from January 1995 to August 1996.

4.2.3.3. STATISTICAL ANALYSIS:

The data from this study were subjected to the Anderson-Darling Normality Test (MINITAB Inc., 1994) to test for normality in the distribution of the data. Data for live weight changes were shown to be normally distributed, while those for body condition scores were not. Therefore, parametric tests (paired *t-tests*) were carried out on the live weight by comparing the data between monitoring periods. For example, the live weights from the first monitoring period were compared to those of the second period, while those of the second period were compared with those of the third period and so forth. Paired *t-tests* were also carried out between the highest and lowest live weight for the seven monitoring periods. Comparisons were also made between the live weights in the two seasons (January to October 1995 and January to August 1996) (Appendix II, Table 2.1). Since data for body condition scores were not normally distributed, non-parametric tests (Mann-Whitney Test) were carried out on the body condition scores. Seasonal effects on body condition scores were also tested as with the live weights of the donkeys (Appendix II, Table 2.2).

4.3. RESULTS

4.3.1. THE MORPHOLOGICAL CHARACTERISTICS OF WORKING DONKEYS

There were no serious problems experienced while taking the body measurements of the donkeys. The donkeys measured were generally placid, co-operative and easy to handle. When the results were tested for normality of the distribution (Anderson-Darling Normality Test), only the data for live weight and umbilical girth were normally distributed. Appendix II, Figures 2.3a, b, c, d, e, f, g and h show histograms of the distribution and the results of the Anderson-Darling Normality Test for the 335 working donkeys used in this study. These data (live weight and umbilical girth) were subjected to parametric tests (ANOVA) using the GLM procedures (MINITAB Inc., 1994). The mean live weight (kg ± sem) for all the donkeys was 142 ± 1.4 kg. There was no significant difference ($P>0.05$) between the live weights of the male and female donkeys. The mean umbilical girth for the 335 donkeys was 140 ± 0.6 cm with the female donkeys having larger ($P<0.001$) girths than their male counterparts, 142 ± 1.0 cm compared with 138 ± 0.8 cm, respectively. The data for the rest of the variables, age, heart girth, body length, height at withers, cannon bone circumference and body condition score, were not normally distributed. The results (presented as the medians) of the sample of 191 working male and 144 female donkeys in south-western Zimbabwe are presented in Table 4.2. Male donkeys were older ($P<0.05$) than their female counterparts, 9 and 7 years, respectively. However, it must be noted that these data on age are approximate estimates as 32 out of the 335 donkeys, were recorded as being 15 years when they could have been much older. There were similarities between male and female donkeys in heart girth circumference (115 cm), height at withers (105 cm), body length (89 cm) and body condition score (5). However, the foreleg cannon bone circumference was larger ($P<0.001$) for male donkeys than for female donkeys. Visual and subjective assessment showed that light grey was the most predominant coat colour of the donkeys measured in this study. There were no apparent differences in colour patterns between male and female donkeys. Coat colours ranged from white to black with various other colours such as tan, coffee and even roan. Although the colour tended to be even all over the body, most of the donkeys had bellies which were of a paler shade than the upper body colour. Some of the donkeys also had lighter muzzles than the rest of the body and light-coloured rings around the eyes. All donkeys had a "cross" on the back which was more prominent in lighter than darker coloured donkeys.

Table 4.2: Medians of age, heart girth, body length, height at withers, cannon bone circumference and body condition scores of 335 working donkeys (191 males and 144 females) in south-western Zimbabwe.

	n	Age (years)	Heart girth (cm)	Body length (cm)	Height at withers (cm)	Cannon bone circumference (cm)	Body condition score[1]
Males	191	9	115	89	105	14	5
Females	144	7	115	90	105	13	5
Significance of difference		P<0.005	P>0.976	P>0.747	P>0.170	P<0.001	P>0.119
Median	335	8	115	89	105	14	5
Range	335	1 - 25	93 - 140	67 - 103	91 - 120	11 - 17	2 - 7

[1] based on the Pearson and Ouassat (1996) scoring system

4.3.2. THE RELATIONS BETWEEN BODY MEASUREMENTS AND LIVE WEIGHT

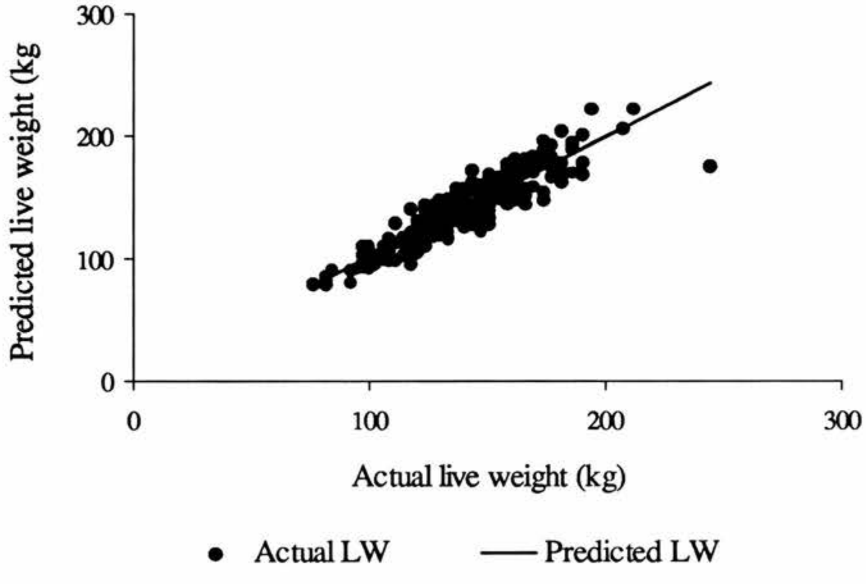
This study was carried out to examine the relations between the various body dimensions and live weight of the donkeys by use of linear regression techniques. The body dimensions as the predictors were regressed against the live weight of the donkeys representing the dependent (predicted) variable. To minimise the variance (described in Section 4.2.2.2.) the measured data were transformed to their corresponding logarithms ($\log_{10}$). The regression analyses of the $\log_{10}$ resulted in less scatter of the residuals (the difference between the predicted or fitted and actual or observed values). The predictive equations presented in Table 4.3 were therefore based on the back-transformed data of the $\log_{10}$ values of the body dimensions of the 335 donkeys.

Table 4.3: Predictive equations of the $\log_{10}$ transformations of heart and umbilical girths, body length, height at withers, foreleg cannon bone circumference and body condition in the estimation of live weight of 335 working male and female donkeys.

Body dimension	Predictive equation	r^2	Significance[1]
Heart girth	Live weight (kg) = Heart girth (cm)$^{2.83}$/4786	0.864	$P<0.001$
Umbilical girth	Live weight (kg) = Umbilical girth (cm)$^{2.07}$/195	0.753	$P<0.001$
Body length	Live weight (kg) = Body length (cm)$^{2.06}$/72	0.624	$P<0.001$
Height at withers	Live weight (kg) = Height at withers(cm)$^{3.09}$/12589	0.547	$P<0.001$
Cannon bone circumference	Live weight (kg) = Cannon bone circumference (cm)$^{0.67}$/0.04	0.153	$P<0.001$
Body condition score (BCS)	Live weight (kg) = Body condition score$^{0.34}$/0.012	0.150	$P<0.001$

[1] significance of the regression equations

Figure 4.1: Predicted and actual live weights (LW) (kg) derived from the heart girth (cm) of 335 working donkeys in south-western Zimbabwe.



The heart girth (HG) was the best single predictor of live weight with an r^2 value of 0.864 (Table 4.3 and Figure 4.1). The second best single predictor of live weight was umbilical girth (UG) ($r^2 = 0.753$) (Figure 4.2). Body length (Figure 4.3) and height were less accurate in predicting live weight than heart and umbilical girths ($r^2 = 0.624$ and 0.547, for length and height, respectively). Body condition score had the lowest accuracy of predicting live weight ($r^2 = 0.150$). When more than one variable was used in the regression analyses there was a general improvement in estimating the live weight of the donkeys as judged by the adjusted r^2 values. The best predictive equation was derived from heart and umbilical girths as shown below in equation 3:

$$\text{(3) Live weight (kg)} = \text{Heart girth (cm)}^{2.00} + \text{umbilical girth (cm)}^{0.8}/5012$$

$$\text{(adjusted } r^2 = 0.902)$$

The second best regression equation was derived from using heart girth and body length, presented in equation 4:

(4) Live weight (kg) = Heart girth $(cm)^{2.32}$ + body length $(cm)^{0.6}/6026$

(adjusted $r^2 = 0.887$)

Various combinations of the other variables resulted in lower adjusted r^2 values than when heart and umbilical girths and body length were used in the predictive equations. The inclusion of more than two variables further improved the adjusted r^2 value, for example when heart and umbilical girths and body length and height at withers were included, the following equations (5 and 6) were obtained;

(5) Live weight (kg) = Heart girth $(cm)^{1.51}$ + umbilical girth $(cm)^{0.79}$ + body length $(cm)^{0.58}/6310$

(adjusted $r^2 = 0.925$)

(6) Live weight (kg) = Heart girth $(cm)^{1.84}$ + umbilical girth $(cm)^{0.8}$ + height at withers $(cm)^{0.31}/9333$

(adjusted $r^2 = 0.904$)

When data for the male (n = 191) and female donkeys (n = 144) were subjected to separate regression analyses the regression equations based on the two sexes were similar to those of the group (n = 335). For example, when heart girth was used as a predictor, the following equations (7 and 8) were obtained:

(7) males: Live weight (kg) = Heart girth $(cm)^{2.84}/5129$

($r^2 = 0.861$)

(8) females: Live weight (kg) = Heart girth $(cm)^{2.81}/4467$

($r^2 = 0.868$)

The predictive equations suggest that there were similarities between male and female donkey populations in this sample of 335 donkeys.

Figure 4.2: Predicted and actual live weights (LW) (kg) derived from umbilical girths (cm) of 335 working donkeys in south-western Zimbabwe.

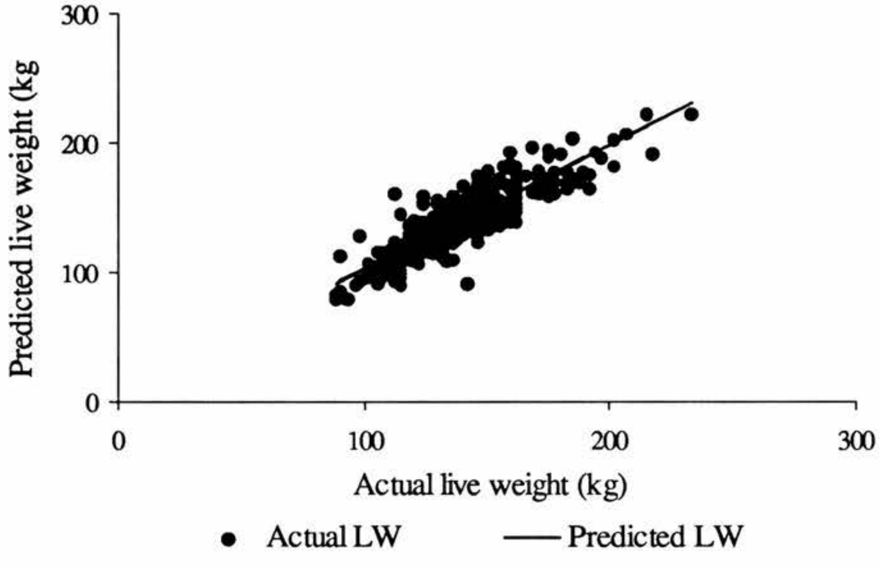
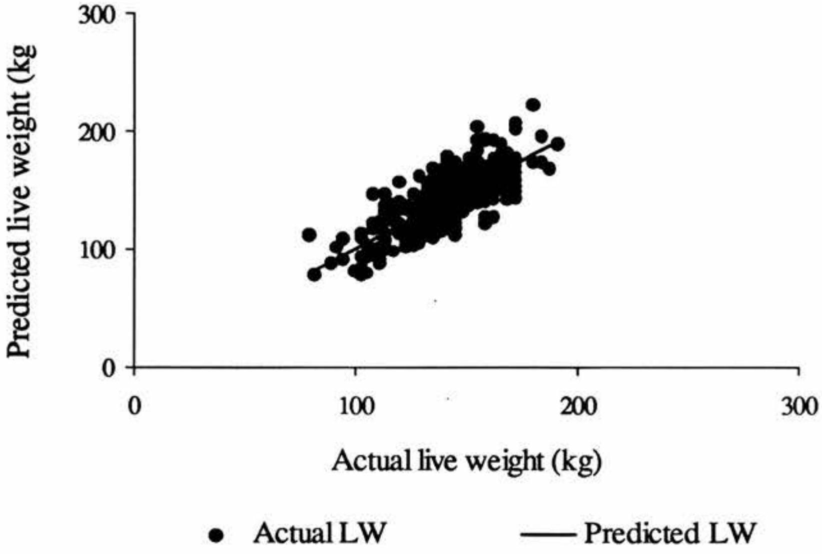


Figure 4.3: Predicted and actual live weights (LW) (kg) derived from body length (cm) of 335 working donkeys in south-western Zimbabwe.



In growing donkeys (3 years and below), the best single predictor of live weight was again heart girth as represented by the following equation (9):

$$(9)\ \text{Live weight (kg)} = \text{Heart girth (cm)}^{2.8}/4266$$

$$(r^2 = 0.880)$$

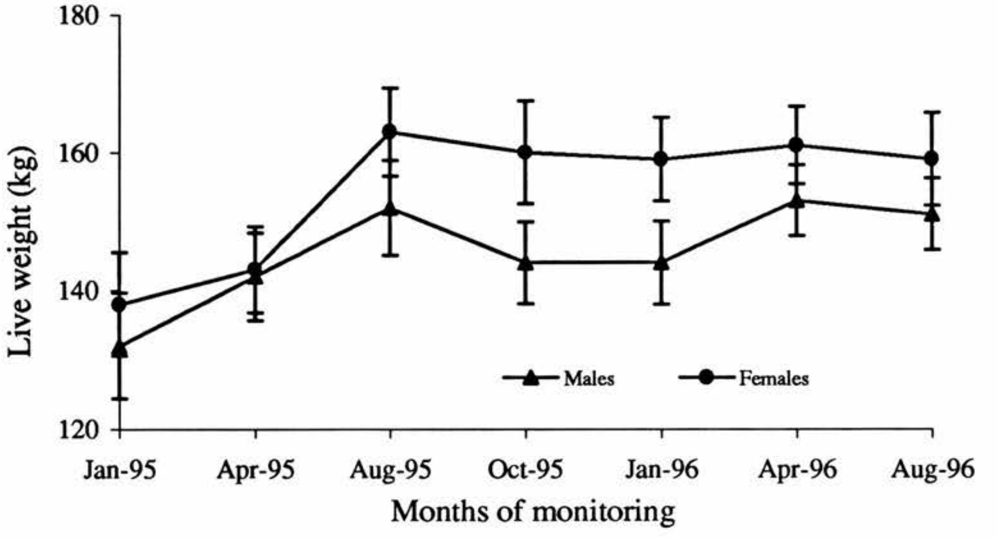
Unlike adult donkeys, umbilical girth was not the second best single predictor of live weight ($r^2 = 0.622$). Height at withers was a better predictor ($r^2 = 0.656$) of live weight than umbilical girth. The other body dimensions were less accurate (body length $r^2 = 0.569$; cannon bone circumference $r^2 = 0.335$; body condition score $r^2 = 0.037$)

4.3.3. SEASONAL FLUCTUATIONS IN LIVE WEIGHT AND BODY CONDITION

During the monitoring of the 38 donkeys, on certain occasions, some were not present for weighing and body condition scoring. The main reason for absence was that they were being used for work far from the homestead. However, at no time were there more than seven donkeys missing during each monitoring.

The live weight and body condition score data are in Appendices II, Tables 2.3 and 2.4. The results indicate that although there were no significant differences between the live weight of male and female donkeys throughout the 7 periods of monitoring, the female donkeys tended to be heavier than their male counterparts. Figure 4.4 gives a graphical presentation of the seasonal fluctuations of live weight of the 19 male and 19 female donkeys monitored in this study.

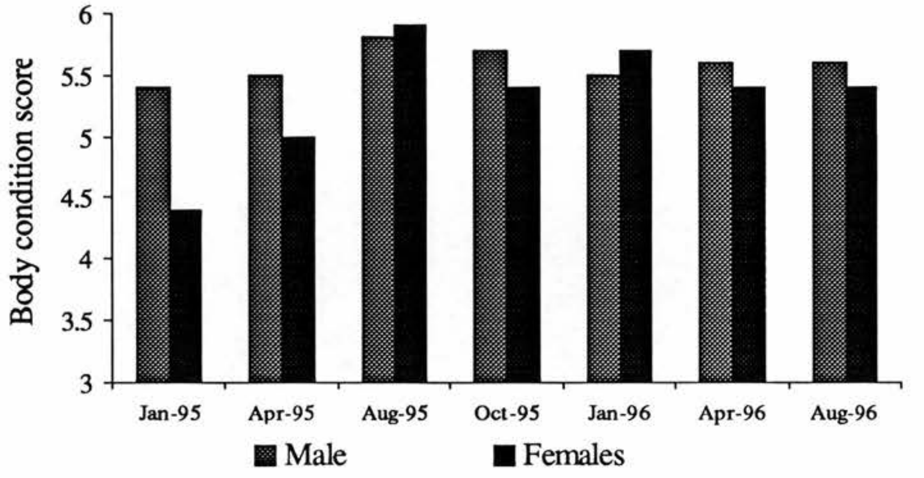
Figure 4.4: Seasonal changes in live weight (kg ± sem) of 19 male and 19 female donkeys in Matobo District monitored from January 1995 to August 1996.



The live weight of the donkeys increased progressively from the wet season of January 1995 to reach a peak in July/August 1995 (Figure 4.4 and Appendix II, Table 2.3). Thereafter, donkeys tended to lose weight particularly at the end of the dry season (October/November 1995). They then maintained or gained weight until the end of the second dry season (August 1996), when there were indications that they were beginning to lose weight again. At this point, the monitoring was terminated.

At the start of the monitoring (January and April 1995 monitoring periods), female donkeys tended to be in poorer ($P<0.05$) body condition (median of 4.5) than their male counterparts (median 5.5, Figure 4.5). Thereafter, body condition scores were similar between males and females ($P>0.05$) (Appendix II Table 2.4).

Figure 4.5: Seasonal changes in body condition score (Pearson and Ouassat, 1996 scoring system of 1 to 9) of 19 male and 19 female donkeys in Matobo District monitored from January 1995 to August 1996 (medians).



Although no veld (pasture) assessments were carried out, observations indicated that grazing was abundant during the wet season when compared with the other monitoring periods (Plates 4.2a, b, c and d, taken from the same site) reflecting the seasonal fluctuations in herbage availability. It was not possible in this study to accurately assess the work regimes the donkeys were being subjected to as this would have required closer monitoring of all the donkeys in the study. Most farmers had finished ploughing by the time of the first monitoring resulting in the donkeys working less than during the peak ploughing seasons in November and December. The overall fluctuations in live weight and body condition from the start of the monitoring in January 1995 to the end in August 1996, are shown in Figure 4.6. Although there were significant differences in the live weights between some of the monitoring periods, for example January 1995 (135 ± 5.4 kg) and January 1996 (152 ± 4.4 kg), there were no apparent seasonal effects on live weight and body condition. The rainfall in the 1994-95 season was above-average. The rainfall patterns for Kezi (recording station) for January 1995 to December 1996 are shown in Figure 4.7. The total rainfall amounts were 603 mm and 701 mm, for 1995 and 1996, respectively.

Figure 4.6: The mean live weight (kg ± sem) and body condition score (median) (Pearson and Ouassat, 1996 scoring system of 1 to 9) changes of 38 donkeys in Matobo District monitored from January 1995 to August 1996.

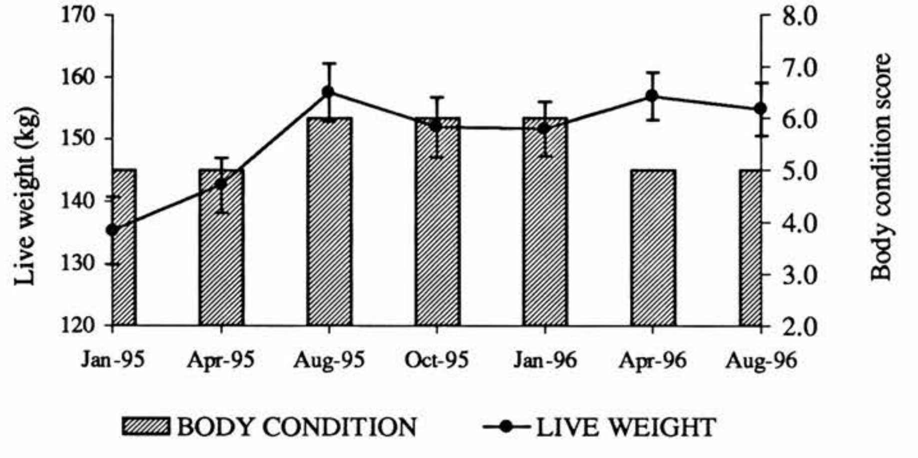
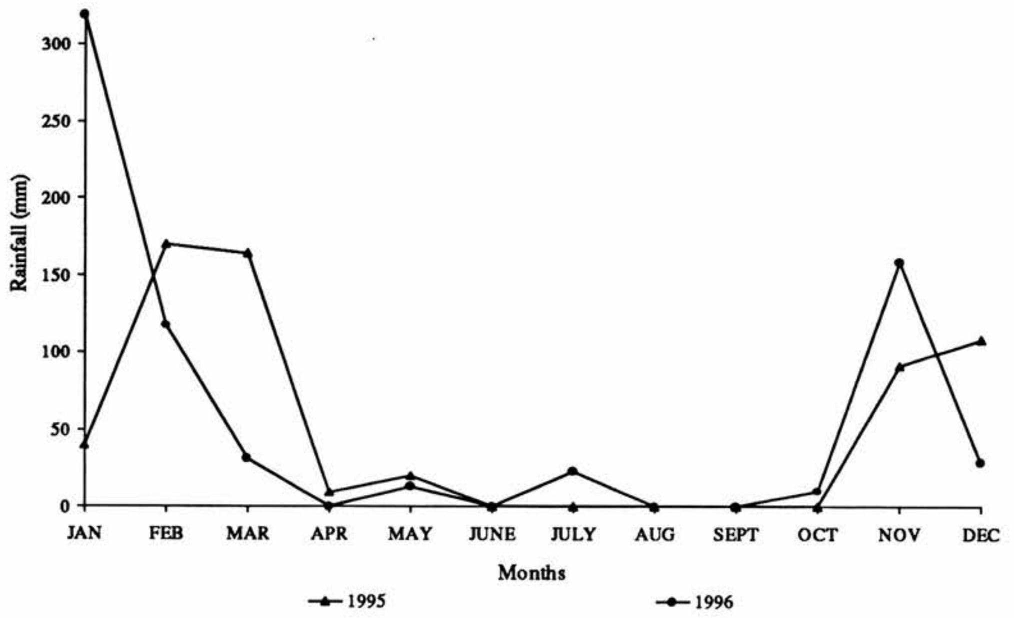


Figure 4.7: Rainfall pattern in Kezi (recording station) for the period January 1995 to December 1996.



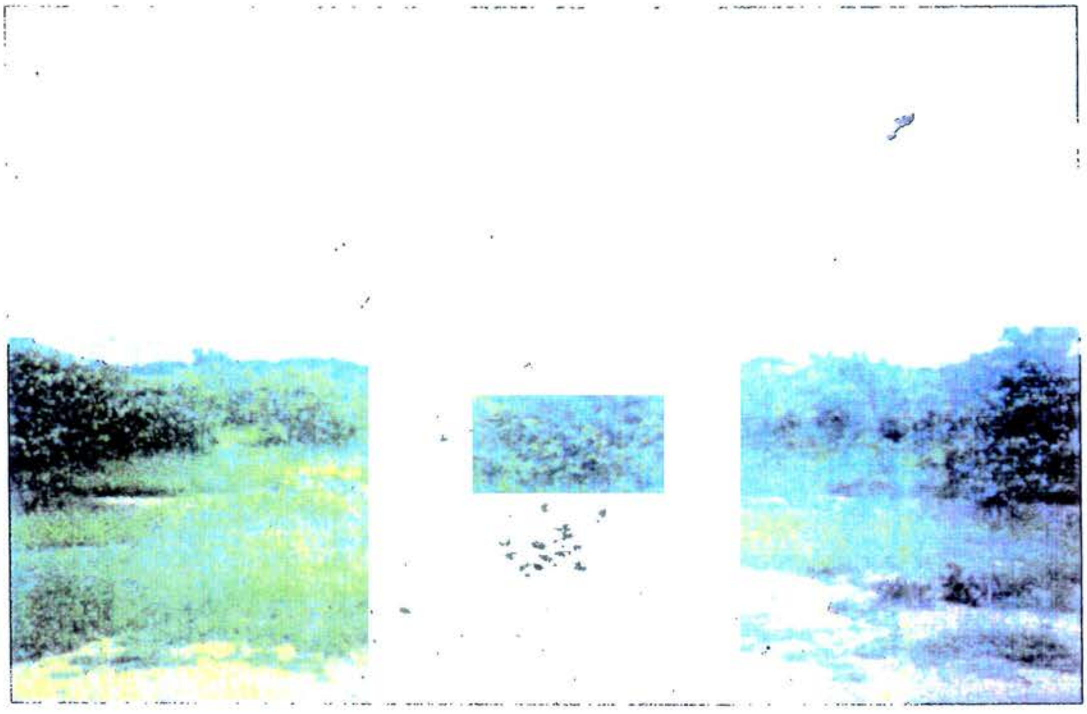


Plate 4.2a: Example of available grazing and browsing during the January/February monitoring period (1995).

Plate 4.2b: Example of available grazing and browsing during the April/May monitoring period (1995).

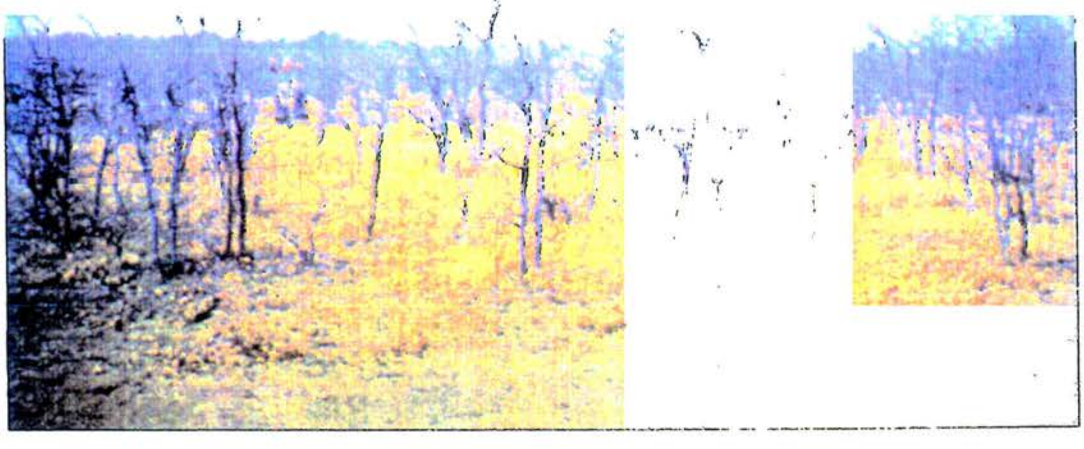


Plate 4.2c: Example of available grazing and browsing during July/August monitoring period (1995).

Plate 4.2d: Example of available grazing and browsing during the October/November monitoring period (1995).

4.4. DISCUSSION

4.4.1. THE MORPHOLOGICAL CHARACTERISTICS OF WORKING DONKEYS

The study reported here was carried out to establish what type of donkey, with particular emphasis on the size, the local smallholder farmers have available for their draught requirements. The results of this study suggested that there were little or no differences in live weight and body dimensions between male and female donkeys in south-western Zimbabwe. For example, live weight was similar (142 kg, range 78 kg to 222 kg) although mean live weight tended to be higher in female donkeys because between 15 and 20 per cent of them were showing signs of pregnancy. No pregnancy diagnosis tests were conducted. Pregnancy, which includes an increase in live weight due to the weight of the foetus and increased anabolism, would have resulted in a higher mean live weight for the 144 females.

The effects of pregnancy also influenced the observed difference ($P<0.01$) in the median of umbilical girths between male and female donkeys (142 cm vs 138 cm, for female and male donkeys, respectively). The distension of the umbilicus due to pregnancy resulted in an exaggeration of this body dimension in female donkeys.

Heart girth, height at withers and body length were similar ($P>0.05$) for both sexes, 115 cm, 105 cm and 89 cm, respectively.

Thus, in terms of the similarities in body dimensions between male and female donkeys, it could be expected that the potential draught resource from both sexes would be similar.

The predominant coat colour of the donkeys in this study was light grey with paler shades on the bellies when compared to the upper body. This observed predominance of light grey coat colour confirms the earlier reports of Mason and Maule (1960) on the colour patterns of donkeys in Zimbabwe.

The age distribution of the donkey population is another important factor in the overall evaluation of draught potential. The donkeys in the present study were about 8 years old (median). Approximately 10 per cent (25 male and seven female) of the total number of donkeys in this study were older than 14 years. In only four cases were farmers able to state the actual ages of donkeys older than 14 years and these were 16 years (n = 2), 20 years and 25 years old.

There is no known recorded information on the average age of working donkeys in Zimbabwe which could be used for comparison with the donkeys in the present study. Pearson and Ouassat (1996) reported that the age of donkeys in Morocco was rarely above 12 years. This suggests that they have a shorter life span than their counterparts in Zimbabwe. Although this could not be verified, personal observations suggest that donkeys in Morocco are subjected to harsher working regimes and more sparse grazing in the desert environments which prevail in greater parts of Morocco. Environmental and management factors such as nutrition play a significant role in the average longevity. It has reported that donkeys in Britain can live beyond 37 years (Bliss, 1989). Probably the ideal situation for draught power availability in Zimbabwe, would be that the majority of the donkey population are in the group of approximately 4 to 8 years of age. This represents the ages when donkeys are typically introduced to work and are also at the start of their reproductive life. This would ensure continuity and growth of the donkey population and provide the farmer with animals suitable for draught purposes.

The results reported in this study are similar to those obtained elsewhere. Bwakura (1994) measured 151 donkeys (97 males and 54 females) in Masvingo Province and Sanyati (Midlands Province) between October and April, 1994 and reported a similar mean heart girth of 115 cm for mature male and female donkeys (range 103 cm to 125 cm). The mean live weight of mature donkeys in that study was slightly higher than for those in the present study, 154 ± 15.9 kg for 63 male and 149 ±17.0 kg for 62 female donkeys. However, these differences are most probably due to environmental differences. Sanyati lies in Natural Region III where the quality and quantity of grazing is normally better than in Natural Regions IV and V. Thus, given these environmental differences, the mean live weight of donkeys in Zimbabwe could be between 142 kg and 152 kg. The differences between the body length measurements of donkeys in the present study and those of Bwakura (1994), 89 cm compared with 92 cm, respectively, could be accounted for by the different measuring techniques. In the present study, body length was measured diagonally from the olecranon to the tuber ischii (pin bone) while in Bwakura's study, this measurement was taken from the withers (7th thoracic vertebrae) to the point where the tail begins (4th coccygeal vertebrae). It has been demonstrated in studies with horses (Carroll and Huntington, 1988; Jones, Lawrence, Veevers, Cleave and Hall, 1989) and donkeys (Pearson and Ouassat, 1996) that body length measured diagonally from the olecranon to the tuber ischii was more repeatable and easier to take than from the withers and is therefore recommended.

There are indications of similarities between the "Zimbabwean" donkey and those in the sub-region. For example, Aganga and Maphorisa (1994) reported an average live weight of about 140 kg for 120 mature male and female donkeys in Botswana. The mean heart girth for these donkeys was also reported to be 115 cm. The major difference between donkeys in the present study and those in the study of Aganga and Maphorisa (1994) was in body length which was recorded as 97 cm for male and 100 cm for female donkeys, compared with a mean of 89 cm for donkeys in the present study. However, in the report by Aganga and Maphorisa (1994), it was not specified how body length was measured, making it impossible for comparisons to be made. Wilson (1981) suggested that there were few physical differences in donkeys in Africa and reported a mean height at withers of those in Sudan of 105 cm, similar to the median reported in the present study. The height at withers (105 cm) of donkeys in the present study falls within the range for donkeys in the UK of between 96.5 cm and 111.8 cm at the withers (Camac, 1989). However, Ebangi *et al.* (1995) using live weight and height at withers of 449 donkeys (aged between 1 and 13 years) in Cameroon, reported measurements of between 64 kg and 138 kg and 83 cm and 100 cm, for the two parameters, respectively. These results suggest differences, particularly in the height at withers between donkeys in Zimbabwe (present study) and Cameroon. Ebangi *et al.* (1995) stated that the donkeys in the zone where their study was carried out were noted for their small body size. Other body dimensions could not be compared across the two studies since there were no descriptions of how some of the parameters were measured. In the study of Pearson and Ouassat (1996), the live weights of the 516 donkeys measured ranged from 74 kg to 252 kg, while height at withers and body length ranged from 82 cm to 129 cm and 64 to 106 cm, respectively. The mean live weight, height at withers and body length of Moroccan donkeys were calculated as 135 kg, 105 cm and 84 cm, respectively (R.A. Pearson, pers. comm.) indicating similarities between donkeys in Morocco and their counterparts in the present study.

Knowledge of the average size of the Zimbabwean donkey is essential in the assessment of their draught potential. Tembo (1989) emphasised that draught capability is directly proportional to weight of the draught animals. In China, larger sized donkeys are expected to carry out heavier draught tasks, for example hauling 400 kg cart loads. Smaller donkeys in India are only capable of hauling 100-150 kg cart loads (Varshney and Gupta, 1994). Reh (1982) gives the average size of donkeys in Africa as 70 - 100 cm at the shoulders and weighing 80 - 100 kg and suggested that ploughing is too heavy a task for donkeys. The average size of the "Zimbabwean" donkey as indicated in the present study, are bigger and heavier than that defined by Reh (1982) and, if managed properly, would be capable of performing tasks like ploughing (Chapter 5). Apart from defining the type of donkey available in Zimbabwe, body measurements and other morphological characteristics are important in that they could also serve as an inception point in "breed" improvement strategies, should such breed characterization be carried out on Zimbabwean donkeys in the future.

4.4.2. THE RELATIONS BETWEEN BODY MEASUREMENTS AND LIVE WEIGHT

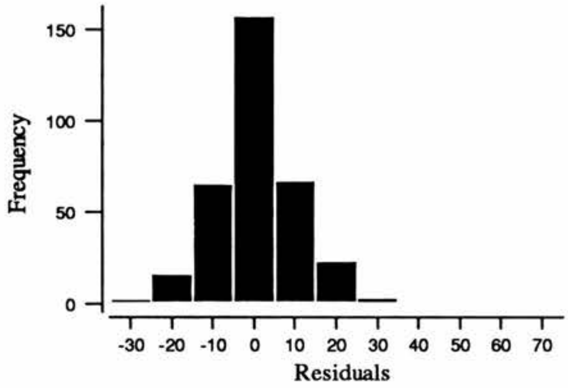
It has been reported that the live weight of an animal is important in determining the potential to carry out prescribed draught tasks (Upadhyay, 1992;

Bartholomew *et al.,* 1993). Live weight could be used to estimate the amount of work the animal can potentially perform (Pearson and Ouassat, 1996). Appropriate management of working donkeys requires the ability to match the animals' live weight to the prescribed tasks. Some body dimensions of donkeys can be used to estimate the live weight of working donkeys. The ability to estimate the live weight of draught animals is therefore an important management tool.

The predictive equations derived in the present study showed that certain body dimensions can be used to accurately estimate the live weight of adult donkeys, confirming similar findings in adult cattle (Johansson and Hildeman, 1954), horses (Carroll and Huntingdon, 1988; Jones *et al.,* 1989) and donkeys (Eley and French, 1993; Pearson and Ouassat, 1996). The transformations to logarithmic values improved relations between live weight and the body dimensions enabling linear regression analysis to be carried out. In agreement with other studies on donkeys (Bwakura, 1994; Pearson and Ouassat, 1996), heart girth was the single most accurate predictor of live weight. Similarly, in mules (Miltenberger, Bray, Wickler, Anderson, Lewis, Greene and Cogger, 1997) heart girth was also the best single predictor of live weight. The relation between live weight and heart girth is between a linearly increasing variable (heart girth) and a cubically increasing one (live weight) (Brody, 1945; Johansson and Hildeman, 1954). Thus, it has been shown that in such relations, it is "biologically correct" to raise the linear measurements to the power of nearly 3 if this functional relation is used (Johansson and Hildeman, 1954). In the present study, the predictive equation between live weight and heart girth showed such a relation.

The histogram of residuals using the predictive equation based on heart girth (Table 4.3) in the present study is shown below.

Figure 4.8: Histogram of residuals using the predictive equation (based on heart girth) in the present study.



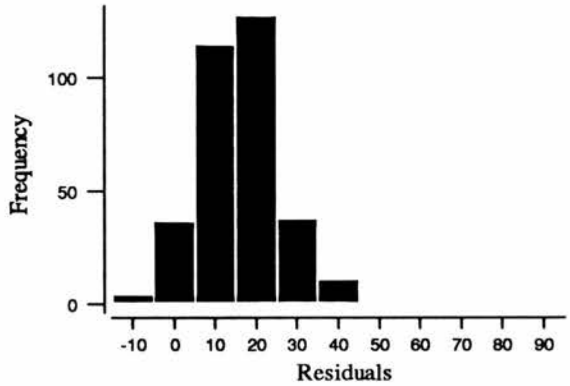
Eley and French (1993) concluded that a combination of height at withers and heart girth gave a reasonable estimate of the live weight as shown by the following equation:

$$\text{(11) Live weight (kg)} = \text{height}^{0.24} \times \text{heart girth}^{2.576} \times 0.000252$$

$$(\text{adjusted } r^2 = 0.923)$$

When the predictive equation of Eley and French (1993) was applied to the data collected in the present study, the predicted live weights were greater than the actual (Figure 4.9).

Figure 4.9: Histogram of residuals using the equation of Eley and French (1993) on donkeys in the present study.



This overestimation was probably because the regression equation of Eley and French (1993) was derived from data of a group of non-working donkeys selected systematically rather than randomly. Although the origin of these donkeys was not stated, they were most probably those in Britain where they are generally kept as pets, being seldom used for work, apart from leisure riding (Camac, 1989). Thus, these donkeys are more likely to be overfed and overweight than those in the tropics. The generally better grazing and management practices in Britain when compared with the developing world, would contribute to this.

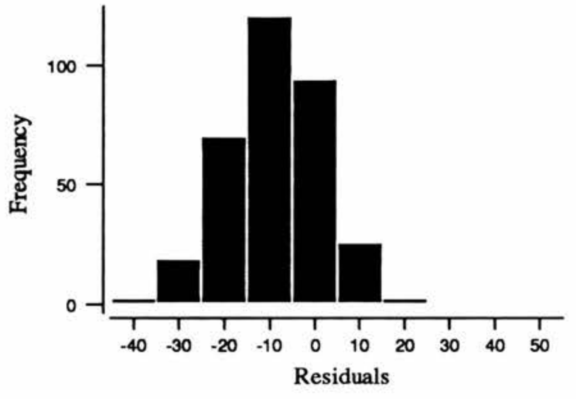
Pearson and Ouassat (1996) produced the following equation (12) using heart girth:

$$\text{(12) Live weight (kg)} = \text{Heart girth (cm)}^{2.65}/2188$$

$$(\text{adjusted } r^2 = 0.81)$$

Although this equation tended to underestimate the actual live weights of donkeys in the present study (Figure 4.10), it was more accurate than the equation of Eley and French (1993).

Figure 4.10: Histogram of residuals using the equation of Pearson and Ouassat (1996) on the donkeys in the present study.



Assuming that the donkeys used in the present study are representative of the "Zimbabwean" donkey, given the similarities in morphological characteristics between donkeys in the study of Pearson and Ouassat (1996), the above equation (12) could be applicable to the donkeys in Zimbabwe. Equally, the present equation (Table 4.3) could be used on donkeys in Morocco. In South Africa, Wells (1996) measured body dimensions of 56 working donkeys and derived the following regression equation (13) for predicting live weight:

(13) Live weight (kg) = 4 x body condition score + 3 x heart girth + length - 308

$(r^2 = 0.85)$

This equation was more accurate than those of Eley and French (1993) and Pearson and Ouassat (1996) when used on donkeys in the present study. However, the main apparent deficiency of this equation is its use of body condition score, a subjective assessment and therefore, more prone to "operator" error. The use of body condition score would require that farmers had some training in scoring techniques and even then, it is unlikely that uniformity of assessment would be achieved. The sample size of 56 donkeys used by Wells (1996) may not be large enough to make conclusions on the prediction of live weight of donkeys.

Although in theory the use of more variables increases the accuracy of prediction, in practical terms, this would also increase the chances of error due to the number of body dimensions involved. Moreover, the ultimate objective of using these predictive equations is to produce simple management tools such as weighbands (using one predictor) and nomograms (using at most two predictors) which can be used to estimate the live weights. A nomogram is a set of parallel scales stacking for example, live weight against corresponding predictors e.g. heart girth and umbilical girth, as described by Smith (1966). Production of a nomogram using more than two predictors is complicated and thus not recommended (R.A. Pearson, per. comm.).

When the body dimensions of growing donkeys (here regarded as 3 years and under) were subjected to linear regression analyses after data transformation, heart girth again was the single most accurate predictor of live weight. This differs from the finding of Pearson and Ouassat (1996) where umbilical girth was shown as a better predictor of live weight than heart girth in growing donkeys. Furthermore, height at withers as a single predictor of live weight of growing donkeys in the present study was more accurate than in the work of Pearson and Ouassat (1996) where it did not improve any of the predictive equations. However, in the study of Pearson and Ouassat (1996), only 16 young donkeys (under 3 years, live weight range 52 kg to 128 kg) were measured. In agreement with the present study, Bwakura (1994) also reported height at withers as an accurate predictor of live weight of growing donkeys.

4.4.3. SEASONAL FLUCTUATIONS IN LIVE WEIGHT AND BODY CONDITION

This study was carried out to assess the seasonal fluctuations in the live weight and body condition of donkeys and to relate these to seasonal changes, in the availability of grazing. Other factors which could affect the live weight and body conditions of the donkeys are the working regimes and disease manifestations. However, these factors could not be accurately monitored on-farm due to the logistical constraints of labour and finance, as well as lack of technical support of veterinary personnel. It was, therefore, assumed that the working regimes would follow typical patterns reported by Ellis-Jones *et al.* (1994) during the RRA in Semukwe, Chikwanda and Sebungwe.

The monitoring of the donkeys commenced in the middle of the wet season (January, 1995) at a time when donkeys were likely to be gaining weight and improving in body condition, assuming donkeys respond to increased availability of grazing, as do other species. The weight gains and improvement in body condition of the donkeys, were probably in response to the quantity and the quality of grazing available from the start of the year (January/February) through the late wet season (April/May 1995), culminating in peak weights and body condition in the middle of the dry season (July/August 1995). The mid-season rains which fell in February and March 1995 (170 mm and 164 mm, see Figure 4.7) were probably responsible for the grass growth which could have produced the observed increases in live weight and body condition in April to August in the 1995 season. Plowes (1957) observed at MRS that late showers in February were responsible for a flush of green leaf in the pasture usually accompanied by a slight increase in the CP content of the herbage. The above-average rainfall in the 1994-95 season resulted in an abundance of crop residues (April/May 1995) which also contributed to the increase in live weight and body condition of the donkeys. Despite the increased work load during the April/May period due to the extensive use of donkeys for transportation of produce (Ellis-Jones *et al.*, 1994; Bwakura, 1994), the donkeys were able to maintain their weight gains. However, transportation by carts is a relatively easy task and unlikely to adversely affect the live weight and body condition of the donkeys. However, the time the donkeys would have had no access to feed while carting (6 h to 7 h/d) might be expected to affect feed intake and consequently live weight and body condition. This topic is discussed in Chapter 6.

There was evidence of a decline in the available grazing (Plate 4.2d) during the July/August monitoring period compared with the April/May period (Plate 4.2c). The quality and quantity of grazing tends to decline from the late wet/early dry season. Plowes (1957) reported that in May the level of CP in grasses at MRS reached 5 per cent at which point young Afrikaner steers (2.5 years old) started losing weight. It was thought that the threshold CP content for maintenance was around 6 per cent for young cattle. Most other studies with cattle (Moyo, 1997) have also shown that cattle not receiving supplements during the dry season respond to the inadequate grazing (depending on the previous wet season) in early dry season by losing weight and condition. Ndlovu, Francis and Hove (1996) reported weight losses in cattle in Chinhamhora communal area (NR II) as high as 30 per cent from July to October, while at the Grasslands Research Station (NR II) losses of between 12 and 20 per cent were observed (T. Smith, pers. comm.). However, the donkeys monitored in the present study continued to gain weight and improve in body condition until

July/August 1995. While it is accepted that in this group there were some young donkeys which would have been growing, the influence of their growth was unlikely to have marked effect on the observed live weight changes of the group since the young animals were similarly subjected to work which for their age could have reduced their rate of growth. The weight losses of up to 4 per cent in the October/November monitoring period when compared with the July/August weights ($P>0.05$) and decline in body condition in these donkeys, were probably incurred from September 1995. This suggests that the monitored donkeys were capable of maintaining live weight and body condition. It is unlikely that cattle in the same environment would have responded similarly. During the RRA reported by Ellis-Jones *et al.* (1994) in August 1994, donkeys were in better body condition than cattle exposed to similar nutritional deficits. This further enhances the reputation of the donkey as a survivor in conditions of limited resources, such as those experienced in the semi-arid regions.

Although health factors were not monitored in this study, they could potentially affect the live weight and body condition of donkeys and are discussed here briefly. It has been stated that although donkeys are exposed to some equine diseases, they appear capable of tolerating most of them (Kneale, 1996; Pearson, Nengomasha and Krecek, 1997). Fielding (1988) suggested that this apparent tolerance and resistance to disease could be due to the aridity and the relatively low stocking rates in environments where donkeys are likely to be found.

Some studies have, however, suggested that endoparasites in donkeys in parts of Africa (Bliss, 1989), in Zimbabwe (Munn, 1991; Pandey and Eysker, 1991) and in Uganda (Saul, Siefert and Opuda-Asibo 1997) could be a major health problem.

Pandey and Eysker (1991) in studies with 14 donkeys in Zimbabwe showed that some of the parasite infections, for example *Strongylus vulgaris* occur during the wet season leading to a heavy immature worm burden by July but thought that adult animals are tolerant. Equids are also reportedly resistant to parasites such as *Fasciola gigantica* which is known to affect cattle (Pandey and Eysker, 1991). In the present study some of the donkeys exhibited signs often associated with the presence of infectious or parasitic disease including distended abdomens, unthriftiness and pale membranes (which can be caused by anaemia) (R.C. Krecek, pers. comm.).

The vulnerability of equids to tick-borne diseases is also considered to be lower than in other domestic livestock (Kneale, 1996). In Uganda Saul *et al.* (1997) reported that it was difficult to observe tick infestation in donkeys. The effects of endo and ectoparasites on the overall draught performance of donkeys is not clearly understood and requires further research.

Donkeys are thus more likely to be in relatively better body condition than cattle throughout the year and particularly at the start of the ploughing season when DAP requirements are highest. It has been shown that even in "normal" rainfall years, when the quality and quantity of grazing starts improving (increasing CP content) around September/October, cattle only responded by gaining weight from mid-November (Plowes, 1957; Tembo, 1989). With the decreasing availability of cattle due to high mortalities (Chapter 3), smallholder farmers in the semi-arid regions would benefit from the increased use of donkeys for the all important task of ploughing at the start of the wet season, timeliness of which has been adequately emphasised (Shumba, 1985; Tembo, 1989). Despite these advantages of the donkey, little is known in Zimbabwe about its capacity for heavy tasks like ploughing. The inherent limitations such as its small size, have restricted the use of the donkey to light tasks such as carting. It is, therefore, imperative that the capacity of donkeys to plough be investigated to optimise the use of this species. This is the subject of the next chapter.

CHAPTER FIVE

5. THE DRAUGHT POTENTIAL OF THE DONKEY

5.1. INTRODUCTION AND LITERATURE REVIEW

The traditional source of DAP for land cultivation in most parts of the developing world has been cattle or buffaloes, with equids being comparatively unimportant (Smith, 1991). Indeed research, for example in Africa, has largely concentrated on the use of cattle for draught power (Goe, 1983; ILCA, 1992). The ploughing potential of cattle has been studied and is fairly well understood in Zimbabwe (Howard, 1980; Mupeta *et al.,* 1990; Francis, Ndlovu and Nkuuhe, 1994). Other workers have evaluated the draught performance of cattle in different parts of the world for example in Ethiopia (ILCA, 1992) and Nepal (Pearson, 1991a).

Despite the large number of donkeys on the African continent estimated at about 12 million head (Wilson, 1990) and the apparent advantages of using donkeys which include:

- a lower purchase price when compared with cattle (for example Z$800 compared with Z$3 000 for an ox)
- an ability to survive on poor quality foods and little water (Schmidt-Nielsen, 1964; Maloiy, 1970)
- easier to handle when compared with cattle (Jones, 1991)
- a lower susceptibility to diseases affecting livestock (Pandey and Eysker, 1991),

there have been few investigations undertaken on this species by researchers. In the developing world donkeys are used extensively. For example, in Mexico donkeys perform various tasks such as carrying, carting, cultivating and ploughing (Aluja and Lopez, 1991). In India and in many other parts of the world the potential of the donkey has been highlighted by the numerous tasks undertaken (Varshney and Gupta, 1994). In a review by these workers, the various tasks undertaken by donkeys include ploughing, supply of static power, transport (carting and packing) and riding. They were also regarded as a source of meat, milk and manure (Varshney and Gupta, 1994). In the Southern African region the importance of the donkey as a DAP resource has been increasing in the last two decades (Starkey, 1994). In Botswana donkeys have been widely used for ploughing (Varshney and Gupta, 1994; Mrema, 1995) while in South Africa (Starkey, 1994; Kneale, 1996) donkeys are increasingly being used. The increased use of donkeys in southern Africa has been primarily attributed to the vulnerability of cattle, the traditional source of DAP in the region, to the adversities of drought as has been described in the previous chapters (Ellis-Jones *et al.,* 1994).

In Zimbabwe the donkey has established itself as an essential component in the crop-livestock farming systems in land tillage operations, especially ploughing. A RRA (Ellis-Jones *et al.,* 1994) showed clearly that donkeys were an important alternative source of DAP to cattle, particularly in the semi-arid areas. Farmers in these marginalised areas were increasingly depending on the use of donkeys, particularly for ploughing during the wet season. The work of Prasad, *et al.* (1991) and Hagmann and Prasad (1995) represents probably the most comprehensive attempt at assessing the draught potential of donkeys in Zimbabwe. These workers evaluated the draught potential of donkeys in the smallholder farming areas of Masvingo

Province and reported that donkeys were capable of ploughing, although not with the same efficiency as cattle. However, this work has not been repeated in other areas including the Matabeleland Provinces where donkeys predominate.

Some preliminary studies in 1993 (Nengomasha, unpublished data) have shown that donkeys (n = 4) total team live weight 750 kg with a body condition score of 7 were capable of ploughing for 2 hours without showing signs of fatigue. In that preliminary trial, the ploughing potential of teams of 2 and 4 donkeys was evaluated. Although the team of 2 donkeys with a total team live weight of 320 kg managed to plough for two hours, it was apparent that this team could not sustain longer working durations because of fatigue and refusal to work. It was concluded that teams of 4 donkeys were more appropriate for ploughing. When the donkeys are weak or small farmers generally use more animals per team. In Botswana, it is common practice for farmers to use teams of 6 to 10 animals with a mean live weight of 140 kg (Mrema, 1995), notwithstanding the reported loss of efficiency of 7 to 10 per cent per animal, for every additional animal in a team (Barwell and Ayre, 1982; Viebig, 1982).

Farmers short of draught animals resort to using teams of mixed species (cattle and donkeys) as was observed during the RRA in Chikwanda (Ellis-Jones *et al.,* 1994). The two species use different parts of their anatomy to exert force when pulling draught implements; donkeys have a strong chest and shoulders and work best with collar or breastband harnesses while cattle have strong shoulders and work best with neck-yokes (Littauer and Crouwel, 1979; Barwell and Ayre, 1982; Dibbits, 1991; Krause, 1993). The differences in the live weight and draught forces exerted by cattle and donkeys might also affect their performance when used in mixed spans.

The draught performance, efficiency and co-ordination of using donkeys and cattle in the same team therefore, requires investigation.

The DAP shortages in the smallholder farming sector have increased the need to investigate the potential of single animals for some land preparation activities, particularly minimum tillage operations (Dube, 1996). The use of single animals is also appropriate in operations such as weeding (Betker and Kutzbach, 1991), where manoeuvrability of the animals between plant rows is essential to minimise damage to the crops. However, information on the use of single animals for draught work in Zimbabwe is scant. Of the information available, research into light-weight implements, some of them designed for use by single animals, has been carried out in Zimbabwe by various manufacturers and institutions. The Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) developed a light-weight single-donkey toolframe for use in various draught tasks including weeding, ridging, ripping and opening of planting furrows (Hagmann, 1994) and it appeared to work well (Dube, 1996).

All the factors reported above indicate that donkeys are likely to be a sustainable and viable alternative DAP resource to cattle. However, it is necessary to evaluate and understand the capabilities and limitations of the donkey with the objective of optimising its use by smallholder farmers.

In this Chapter the results of two studies will be discussed:

1. To evaluate and compare the draught performance of donkey and cattle teams ploughing at Matopos Research Station and Nkayi District and donkeys-only teams ploughing in Matobo District

2. To evaluate and compare the draught performance of donkey-only, cattle-only and mixed cattle:donkey teams ploughing at Matopos Research Station

5.2. MATERIALS AND METHODS

5.2.1 PLOUGHING WITH DONKEY AND CATTLE TEAMS ON DIFFERENT SOIL TYPES AND SITES

5.2.1.1 ANIMALS AND TRAINING:

1. Matopos Research Station:

The study was carried out in the wet season of 1994-95. Seven male donkeys with a mean age of 8 years, four female donkeys with a mean age of 5 years and two Jersey crossbred oxen aged 3 years, were used. From these animals, 4 teams were formed (Table 5.1). The total team live weights at the start of the study were 680 kg, 460 kg, 646 kg and 500 kg, for Teams 1, 2, 3 and 4, respectively. The mean body condition scores for the donkey teams were 7, 5 and 4, on a scale of 1 to 9 (Pearson and Ouassat, 1996) for Teams 1, 2 and 4. The body condition scores of the oxen were estimated at between 5 and 7 on the ILCA scale (Nicholson and Butterworth, 1986). The oxen were crossbred progeny from the MRS's Dairy project where indigenous Nkone and Tuli cows were mated to a Jersey bull. Teams 1, 2 and 3 were used for ploughing on all soil types (Section 5.2.1.5.), while Team 4 was introduced only on sandy clay soils.

Table 5.1: Animals (species, sex, live weight (kg) and identification) used for ploughing at Matopos Research Station (at the start of the study).

Team	Species and sex	Number per team	Total live weight	Animal identification[1]
1	heavy male donkeys	4	680	1[2], 4, 6, 8
2	light female donkeys	4	460	2, 5, 6, 11
3	cattle, oxen	2	646	Khaki, Russia
4[3]	light male donkeys	4	500	1[2], 2, 5, 11

[1] ear-tag numbers and names [2] same animal used in both teams [3] not used in statistical analysis, although subjective comparisons were made with other teams on sandy clay soils (see text).

All male donkeys in Team 4 and three in Team 1 were entire.

Temperament of animals was monitored and subjectively rated as: *docile or submissive* when animals were obedient and easy to handle; *temperamental or unstable* when animals were stubborn or restless and difficult to handle. The ability of the animals to obey voice commands and move in straight lines following furrows or being led (where necessary) and level of co-operation, were factors taken into account in the final assessment of the suitability of the animals for draught work. The subjective scores were rated as: *docile or submissive* = 1; *temperamental or unstable* = 2. The same subjective assessment of temperament and level of training of animals was made during the studies in Nkayi and Matobo Districts.

All donkeys used at MRS were originally from the smallholder farming sector and had been previously trained and used for draught tasks. However, the donkeys were re-trained on-station three weeks prior to the commencement of the ploughing study. Preliminary training consisted of adaptation of the donkey teams to breastband harnesses and pulling an old truck tyre for 3 km on a farm road. When it was deemed that the donkeys had adapted well to pulling the tyre, they were hitched to a mouldboard plough and worked on fallow land. During the retraining period, depending on the level of co-ordination and co-operation of the animals in the teams, the positions of individual animals were altered in the spanning formation to ensure the best possible positions for each animal in the team. The donkey teams generally adapted well to handling and training and did not require any leading except when marking and opening the first furrow.

The two oxen used in this study had been trained to pull a cart prior to the start of the study. However, the oxen had no previous ploughing experience. The oxen were trained to plough on virgin as well as fallow land for a week. Unlike the donkey teams, the oxen required continuous leading as they did not follow the furrow when not led probably due to their inexperience.

2. Nkayi District:

This study was carried out in May, 1995 at Fanisoni Irrigation Scheme in Nkayi District. The study involved smallholder farmers who were members of the irrigation scheme. It must be stated that the original objective of this study was to assess the draught performance of donkeys belonging to these farmers. However, shortly before the start of the study most of the farmers unexpectedly decided to use cattle instead of donkeys. Therefore, this study involved only one team of donkeys and more cattle teams than had been originally planned.

A total of 34 cattle and donkeys belonging to the smallholder farmers were used. These comprised 28 cattle (oxen, bulls and cows) and 6 donkeys consisting of males (castrates and entire) and females. Ten teams were formed from these animals. The formation and composition of the teams was the responsibility of the farmers taking part in the study. According to the farmers all animals used in this study had been trained and previously used for ploughing. However, the resultant teams varied in live weight, age, sex, species and level of training and experience (Table 5.2).

Table 5.2: Animals (species, sex and live weight (kg)) used for ploughing at Fanisoni Irrigation Scheme (Nkayi District).

Team	Species and sex	Number per team	Total live weight[1]
1	oxen	4	1709
2	oxen	4	1609
3	3 cows, 1 bull	4	1387
4	3 cows, 1 bull	4	1102
5	2 bulls, 2 oxen	4	974
6[2]	2 cows, 2 donkeys	4	898
7	bulls	2	893
8	oxen	2	879
9	donkeys	4	658
10	cows	2	558

[1] teams ranked according to total live weight. [2] donkeys in front, cows behind

3. Matobo District:

This study was carried out in the 1995-96 wet season in Semukwe (Matobo District). As in Nkayi the animals used in this study belonged to the farmers. A total of 37 donkeys were used. They included castrated and entire males and female donkeys. Ten teams were formed ranging from 3 to 7 animals in a span (Table 5.3).

Table 5.3: Donkeys (sex and live weight (kg)) used for ploughing in Matobo district.

Team	Sex	Number per team	Total live weight
1[1]	4 males, 3 females	7	1007
2[1]	3 males, 3 females	6	854
3	4 males, 2 females	6	796
4[2]	2 males, 4 females	6	773
5[2]	2 males, 4 females	6	772
6	3 males, 1 female	4	614
7	4 males	4	492
8	2 males, 1 female	3	428
9	1 male, 2 females	3	340
10	2 males, 1 female	3	319

[1] teams composed of the same animals, plus one more in Team 1, see text for details
[2] teams composed of the same animals, except one replaced by another, see text for details

The formation of the working teams was the responsibility of the farmers involved in the study. Some farmers pooled their animals to form spans. This resulted in some animals being used in more than one team. For example, the animals used in Teams 1 and 2 were the same except that there was an extra animal added in Team 1. Teams 4 and 5 were composed of the same animals with the exception of one animal in Team 4 which was replaced by another in Team 5.

5.2.1.2. THE ERGOMETER AND PLOUGHING PROCEDURES:

5.2.1.2.1. THE ERGOMETER

Measurements of some draught parameters were carried out using an ergometer as described by Lawrence and Pearson (1985). It consisted of three components; the load cell, the odometer and the integrate and display unit (IDU).

LOAD CELL

A Novatech F241 load cell (Novatech Ltd., Hastings, England) with 8 mm rod ends, dust seals and mechanical overload protection, was used. The load cell was capable of measuring a range of draught forces, from 0 to 3 000 N (300 kg, 10 N = 1 kg). The output from the load cell was processed by the IDU (see below) which also provided a stable input voltage of approximately 10 V to the load cell. One end of the load cell was attached to the animals via the "evener" (Figure 5.1b) and the other end to the plough. Thus, the draught forces exerted by the animals to pull the implement passed through the load cell in a straight line.

ODOMETER

This component of the ergometer was used to measure the distance travelled by the animals. The odometer consisted of the following;

1. A shaft coupled to a cross-piece via a universal joint (this shaft was attached to the plough using rubber bands)

2. Two forks were used to attach the shaft to a wheel (see below) and these could be rotated in relation to the shaft such that the odometer could be attached horizontally or vertically on the plough
3. A rear 26 - inch bicycle wheel fitted with a 60-tooth timing pulley which replaced the back sprocket (gear block of the wheel)
4. A sealed aluminium disc containing a wheel with 60 slots round the perimeter which pass through an infra-red detector. The gearing system of the 60-tooth timing pulley (see 3) was such that 360 slots passed through the infra-red detector per revolution of the bicycle wheel (see 3). One pulse was produced from the detector for every 5.8 mm of forward movement of the plough. The outputs (pulses) from the odometer were integrated and displayed as metres on the IDU (see below)

An aluminium mudguard was used to cover the 60-tooth timing pulley.

When the odometer was attached to the plough (Plate 5.1), forward motion of the wheel represented movement of the plough, hence work was being done. When animals were turning at the end of the furrows, the bicycle wheel was lifted and turned. This temporarily stopped the ergometer from recording.

INTEGRATE AND DISPLAY UNIT

The IDU provided and regulated power for the load cell and odometer and integrated and displayed data collected from them. The IDU had three digital displays, Displays 1, 2 and 3, reading from left to right. Electrical cables with 5-pin DIN (Deutsche Industrie Norm) 180° (for the odometer) and 240° (for the load cell) plugs together with interchangeable extension cables, were used to connect the load cell and the odometer to the IDU.

The ergometer operated in four modes:

Mode 1: This was the normal operating mode. In this mode, the ergometer displayed as follows: Display 1 = work done (kilojoules); Display 2 = distance travelled (metres) and Display 3 = elapsed working time (seconds).

Mode 2: As in mode 1 but Display 1 displayed data in joules. This mode was suitable for very light loads and short distances (<1 km). It was not used in the present study.

Mode 3: Used only for calibration of the ergometer.

Mode 4: Produced distance-based repeat measurements on Displays 1 and 2 only. Measurements would be taken every 4 m. In this mode, Display 1 = draught force (N); and Display 2 = reciprocal speed (msec/m). This Mode was not used in this study.

5.2.1.2.2. PLOUGHING PROCEDURES:

Matopos Research Station:

In all the ploughing studies (MRS, Nkayi and Matobo), the ploughing method used was the casting procedure whereby ploughing in the furrow started on the outside periphery of the plot and continued either clockwise or anticlockwise from the periphery to the centre of the plot. At MRS minimal or no coercion was applied on the working animals. When minimal coercion was necessary, a light leather whip was used. A typical working programme at MRS is shown in Table 5.4.

Table 5.4: Typical working programme during each ploughing and recording session at Matopos Research Station.

Time	Activity	Remarks
05:30 h	Walk team to ploughing site; hitch plough A or B[1]; attach ergometer	Donkeys walked to ploughing site then harnessed; oxen yoked while restrained in crush then walked to site
06:00 h	Start ploughing with, for example, plough A	Stop and take readings from ergometer every 15 minutes[2]; tare after every reading and continue ploughing; take measurements of ploughing depth and width; collect soil for determination of moisture content
08:00 h	Stop ploughing; unhitch plough A and hitch team to plough B; attach ergometer	Animals resting during change-over; ergometer checked and any minor faults repaired; measure area ploughed with plough A
08:30 h	Start ploughing with plough B	Stop and take readings from ergometer every 15 minutes; tare after every reading and continue ploughing; take measurements of ploughing depth and width; collect soil for determination of moisture content
10:30 h	Stop ploughing, unhitch plough and detach ergometer	Team released for the day; measure area ploughed with plough B

[1] See text below (Section 5.2.1.3.) for details of plough types; the order of using plough A and B was reversed on the same team during the next ploughing session.
[2] stop-watch was used.

Plate 5.1: The ergometer comprises the odometer (on the bicycle wheel), load cell (covered for protection) and the IDU (in bag).

Nkayi and Matobo Districts

The ploughing procedures in Nkayi and Matobo were similar to those at MRS. Ploughing started at about 06:00 h. The duration of each ploughing and recording session varied between teams and the two sites. At Nkayi the duration of each ploughing and recording session was limited by the size of the plots allocated to the individual households which was 0.1 ha each. Ploughing was carried out with each team continuously until the plot had been completely tilled. Nevertheless, each ploughing and recording session lasted for about 2 hours. Two sets of ergometers were used to measure the draught parameters. This allowed simultaneous measurement of draught parameters of any two teams to minimise differences in weather effects. At Matobo, however, the duration of each ploughing session tended to depend on the farmers' ploughing schedules. Other factors which also influenced the duration of ploughing sessions included timely availability of donkeys and labour, target land areas to be tilled during each ploughing session and the weather conditions. Duration of ploughing ranged from less than one hour to 2 hours. Only one ergometer was used at Matobo.

During the ploughing sessions in Nkayi and Matobo districts farmers were required to handle the animal teams at all times while the research team was responsible for the ergometers. The farmers were encouraged to comply with their normal ploughing and handling practises. The use of the whip or other forms of coercion on the working animals was monitored. The level of coercion was subjectively assessed and rated as *minimal* when considered unlikely to cause injury to the animals or *excessive* when it was considered likely to cause injury. Subjectively, *minimal* coercion was rated as 1 and *excessive* coercion as 2.

5.2.1.3. PLOUGHS:

At Matopos Research Station a conventional ox-drawn single mouldboard plough (Master Farmer, Bulawayo Steel Products, Zimbabwe) with a weight (gravitational force) of 40 kg (plough A in Table 5.4) and a lighter single mouldboard plough (Walco Manufacturing Pvt. Ltd., Zimbabwe) with a weight (gravitational force) of 32 kg (plough B in Table 5.4) were used. The main difference between the two ploughs was that the lighter plough, hereafter referred to as the Walco plough, had a longer but thinner beam than the ox-drawn plough (Plates 5.2 and 5.3).

At Fanisoni Irrigation Scheme in Nkayi district, two ox-drawn single mouldboard Master Farmer ploughs from MRS were used. This was to minimise the possible differences in team performances due to the effect of different plough types. In Matobo district, single mouldboard ox-drawn ploughs (Master Farmer) belonging to the farmers were used. The ploughs were similar in condition (age and gravitational weight) to those used at MRS and in Nkayi district.

5.2.1.4. HARNESSING:

At Matopos Research Station, breastband harnesses made from rubberised canvas straps were used to hitch the donkeys to the ploughs (Figure 5.1a). The breastband harnesses used in all on-station studies were modified from those manufactured by local artisans, which had fixed backstraps.

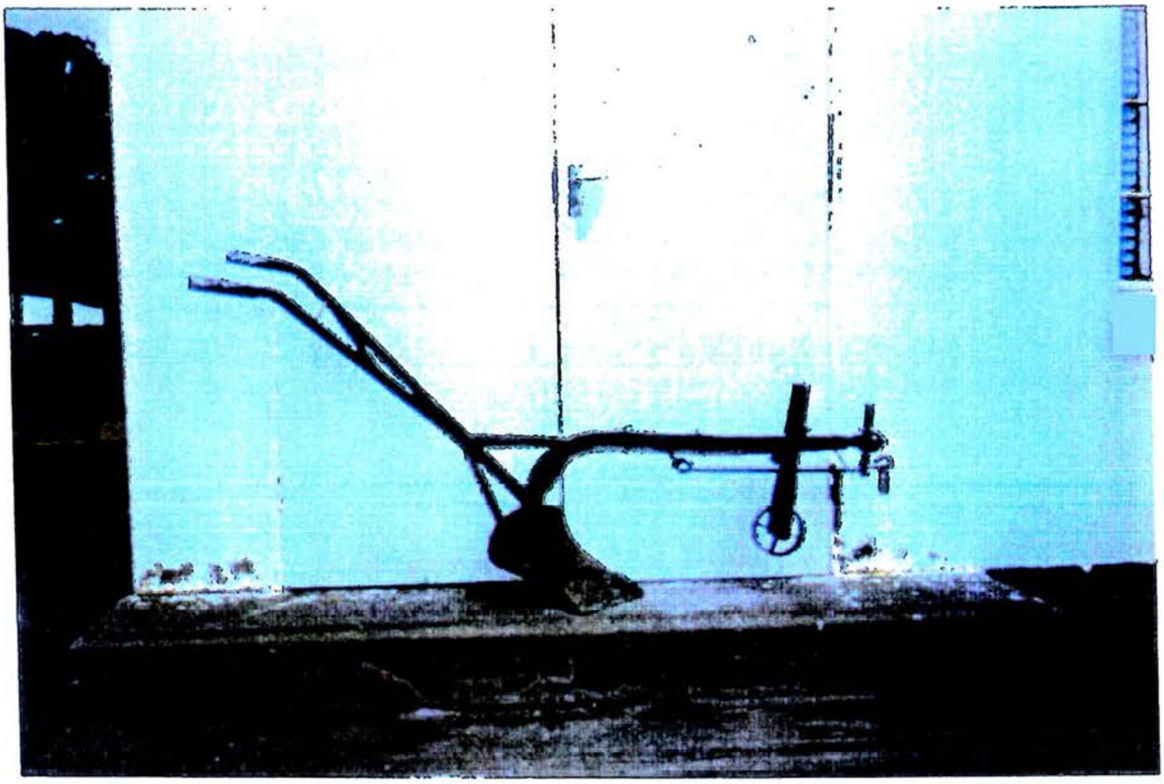


Plate 5.2: The conventional ox-drawn single mouldboard plough (Master Farmer) (40 kg).

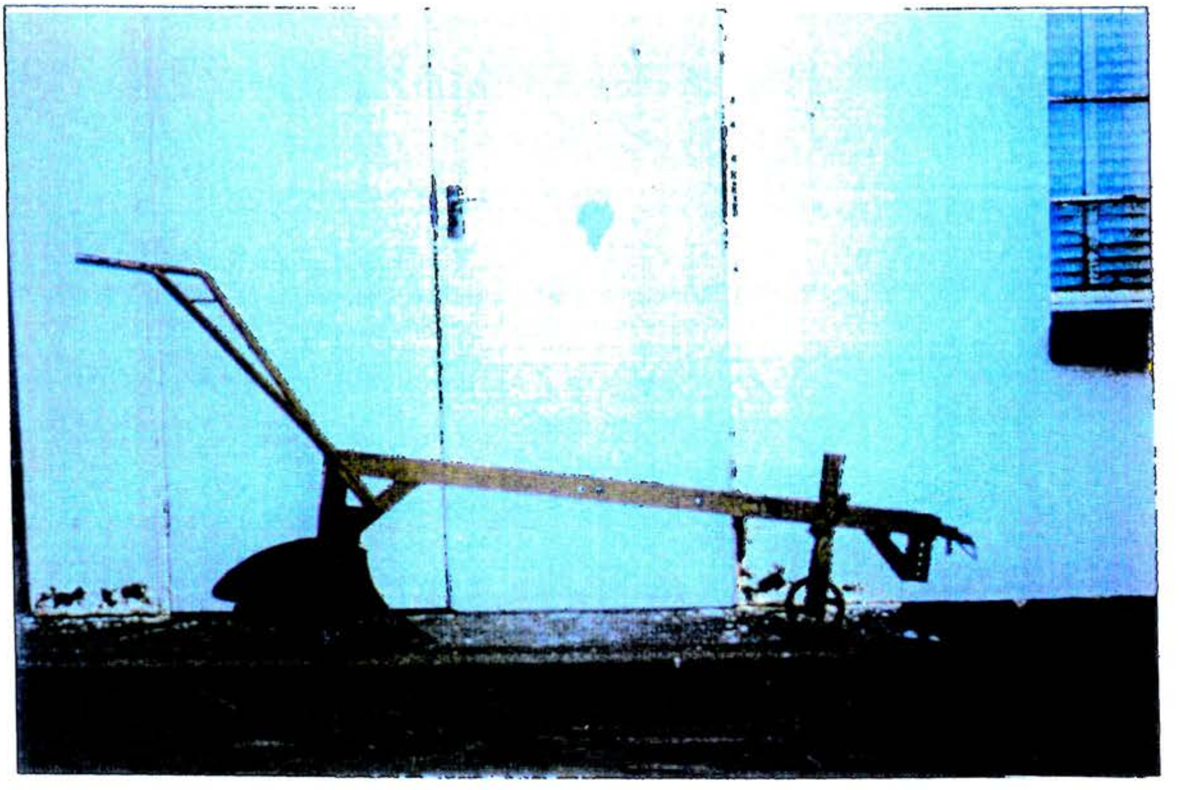


Plate 5.3: The Walco "donkey-adapted" single mouldboard plough (32 kg)

In the modified harnesses, the fixed backstraps were replaced with adjustable canvas straps made from car seat belt material. This enabled the harnesses to be used on different sizes of donkeys. A detailed description of these harnesses was given by Barwell and Ayre (1982). The width of the chest and back straps measured 8 cm and 5 cm, respectively. The chest strap was 120 cm long and 1 cm thick. All edges of the chest straps of the harnesses were smoothed to minimise injury and discomfort to the donkeys. Chain traces were used to attach the harnesses on each donkey to a wooden swingle tree. Rod metal rings fastened the swingles to an "evener" for each pair of donkeys. Figures 5.1a and 5.1b show the breastband harness and the swingle trees.

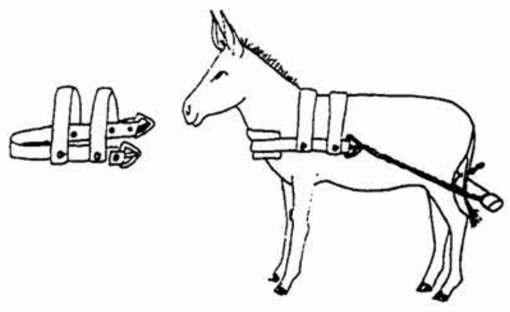


Figure 5.1a: Breastband harness with fixed backstrap (after Jones, 1991) (those used in the present study had adjustable backstraps).

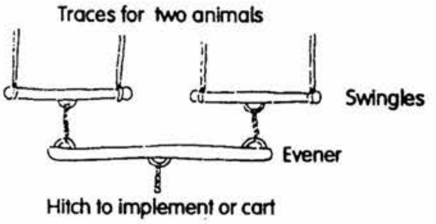


Figure 5.1b: Diagram of swingles and eveners (after Jones, 1991).

A description of swingle trees and eveners is presented in Appendix III (after Krause, 1993).

Donkeys were spanned in pairs abreast, two in front and two at the rear. A trek chain 80 cm long (from the evener on the rear pair of donkeys) was used to hitch the donkeys to the plough. For the oxen, a double-neck yoke as described by Howard (1980) was used. This type of yoke has been referred to as a "withers yoke" by Viebig (1982), whose definition of a "neck yoke" describes that which is attached to the cattle's horns. The yoke measured 156 cm in length and a standard trek chain 250 cm long, from the centre of the yoke was used to attach the oxen to the plough.

In both Nkayi and Matobo districts, breastband harnesses were used whenever donkey teams were studied. However, donkeys in Nkayi were spanned four and two abreast in teams 9 and 6 (Table 5.2), respectively. Cattle teams in Nkayi were hitched using double-neck yokes with a standard trek chain as described above.

5.2.1.5. SOILS:

At Matopos Research Station, ploughing was carried out on four soil types described below (after Thompson, 1960):

1. Clay (vertisols): These are soils in valley bottoms, where soil drainage is poor. They are black colluvial soils derived from epidiorite, with a high clay content (36 per cent clay, 26 per cent silt and 38 per cent sand) and a high nutrient content. They are moderately shallow (50 to 100 cm), self-mulching and susceptible to waterlogging.

2. Redsoil: This is underlain by basement schists giving rise to deep (> 150 cm) reddish-brown clay soils (36 per cent clay, 29 per cent silt and 35 per cent sand) of moderate nutrient status on the low slopes (Ward *et al.*, 1979).

3. Sandy: Soils are sandy, moderately deep (100 to 150 cm) with low silt and clay content (6 per cent clay, 7 per cent silt and 87 per cent sand). The nutrient content of the topsoil is low but soil physical conditions are ideal for plant growth (Ward *et al.*, 1979).

4. Sandy clay: More clay content than in sandy soils, but retains main sandy characteristics.

At Nkayi the predominant soil type in the Fanisoni Irrigation Scheme was redsoil as described above. In Matobo district the soil types were not as homogeneous as in the irrigation scheme in the Nkayi study. Ploughing was carried out on the same soil types as at MRS, that is sandy, sandy clay, redsoil and clay.

5.2.1.6. WEATHER CONDITIONS:

The weather conditions in the three experimental sites were monitored and wherever possible, ambient temperatures were recorded during ploughing. When thermometers were not available, as at some of the sites at MRS and all of the fields in Nkayi and Matobo districts, ambient temperatures were subjectively appraised and described as cool (below 20°C), warm (21 - 25°C) and hot (above 25°C). Other weather conditions such as relative humidity and wind speed could not be measured due to lack of appropriate instrumentation.

5.2.1.7. MEASUREMENTS AND CALCULATIONS:

Direct measurements and calculations from ergometer:

1. Draught force in Newtons (N) - force exerted to pull plough
2. Distance in metres (m) - distance covered while working
3. Elapsed working time in seconds (s) - actual time the animals spent moving, assumed to be working
4. Work output in kilojoules (kJ) - product of force and distance
5. Power output in Watts (W) - rate at which work is done or product of force and speed
6. Working speed in metres per second (m/s) - time taken to cover a given distance

Other measurements and calculations:

7. Total working time (hours) - time from the start to the finish including stoppages during work (stop-watch)
8. Ploughing depth in centimetres (cm) - depth of cut of ploughshare
9. Ploughing width in centimetres (cm) - width of cut from landside to furrow
10. Total area ploughed in hectares (ha) - product of length and width of ploughed plot
11. Effective field capacity in hectares per hour (ha/h) - average work output per hour (total area/elapsed time worked). The reciprocal, time taken to plough a hectare (h/ha) was also calculated
12. Soil moisture content (%) - water content of soil as a percentage of the weight of soil dried in an oven at 60° C for 48 hours

5.2.1.8. STATISTICAL ANALYSIS:

The data from the ploughing sessions with the three teams at MRS (Teams 1, 2 and 3; Table 5.1) were tested for normality using the Anderson-Darling Normality test and then subjected to the Kruskal-Wallis non-parametric test (MINITAB Inc., 1994). The data on the ploughing performance of the three teams (two donkey teams; Teams 1 and 2 and the oxen team; Team 3) with each plough type were analysed separately. On sandy clay soils the fourth team of light male donkeys (Team 4) was included and only subjective comparisons were possible with Teams 1, 2 and 3. The differences between the two ploughs were subsequently analysed. Because only one measurement per team was possible on-farm, subjective comparisons were made between the draught performance of these teams with those on-station. Likewise, subjective comparisons were made between the donkeys-only, cattle-only and mixed cattle:donkey teams ploughing on sandy clay soils on-station. See also Tables in Appendix III.

5.2.2. PLOUGHING ON-STATION WITH MIXED CATTLE:DONKEY TEAMS

5.2.2.1. ANIMALS AND TRAINING PROCEDURES:

This trial was carried out at MRS in May 1996. The draught performance of four male donkeys with a total team live weight 622 kg and used in the study reported above (Section 5.2.1.) and five 2-year old oxen with a mean live weight of 293 kg from the MRS herd was studied. The oxen were crossbred animals of mixed genotypes comprising of progeny mainly from the Jersey, Brahman, Simmental and Tuli breeds. They had no previous experience with draught work. The oxen were initially trained to the yoke, achieved by putting single neck yokes on and letting the oxen become accustomed to wearing them. After this initial training the oxen were spanned in teams of two or four and trained to work as a team (using double neck-yokes) pulling an old tyre over distances of up to four kilometres on rough hilly terrain. Whenever possible, the oxen were trained for five consecutive days a week (four to five hours a day). When the best possible working combinations were determined, appropriate working spans of two or four were formed. The teams were then trained to pull the plough. The training procedures lasted for a total of 10 weeks when it was considered that the oxen had received an acceptable level of training and working experience to introduce them to the study.

5.2.2.2. TEAMS, SPANNING AND PLOUGHING PROCEDURES:

From the groups of four donkeys and five oxen, six teams were formed (Table 5.5).

Table 5.5: Animals used in mixed species ploughing study.

Team	Species
1	cattle (n = 4)
2	cattle (n = 2)
3	donkeys (n = 4)
4	donkeys, cattle (n = 4)
5	donkeys, cattle (n = 4)
6	donkeys, cattle (n = 4)

Animals were spanned in pairs abreast in all teams. In the mixed oxen:donkey teams, the two donkeys were always in front and the oxen at the rear. This was to simulate the spanning arrangements commonly practised by smallholder farmers. The rationale for this spanning arrangement was that the stronger oxen were hitched at the rear where more tractive effort was required to pull the plough.

All teams ploughed on sandy clay soils. An ox-drawn single mouldboard plough (Master Farmer) was used for ploughing by all teams. The ergometer was used to monitor the draught performances of these teams. Measurements and procedures were as described above. Each team worked for 2 hours in one ploughing session. Every effort was made to work the teams in similar weather conditions.

5.3. RESULTS

5.3.1. PLOUGHING WITH DONKEY AND CATTLE TEAMS ON DIFFERENT SOIL TYPES AND SITES

Matopos Research Station

5.3.1.1. ANIMALS AND WEATHER CONDITIONS

The animals used in this study, were generally well-trained and of manageable temperament. However, it was apparent that the donkey teams were more docile, easier to handle and work with than the team of Jersey crossbred oxen. Of the donkey teams, Team 1 (4 male donkeys, Table 5.1) was the easiest to work with requiring little or no stoppages during work. The two other donkey teams, although requiring no leading apart from when marking and opening up the first furrow, tended to be involved in more work stoppages: animals refusing to move but not necessarily due to fatigue; lack of proper co-ordination between animals in team; animals not always following the furrow. The team of oxen was less docile than the donkeys and required constant leading when working. For both species, minimal coercion (Section 5.2.1.2.2.) was used on the animals to minimise any "operator" influence on the draught performance.

Generally, all teams worked under similar weather conditions and with soil of a similar moisture content. The median soil moisture content was 3.1 per cent. The median temperature during this study was 24°C. Although relative humidity was not measured, this was subjectively considered to be within the range typical in smallholder farming areas during ploughing at the onset of the wet season. However, ploughing was always stopped whenever there was incessant and heavy precipitation. The wind speed during ploughing was considered low (characteristic of normal conditions in the wet season) and unlikely to affect the performance of the animals.

5.3.1.2. PLOUGHING AND DRAUGHT PARAMETERS

5.3.1.2.1. DRAUGHT PERFORMANCE OF DONKEYS AND OXEN PLOUGHING WITH THE OX-DRAWN SINGLE MOULDBOARD PLOUGH:

Table 5.6 shows the results (medians) of the draught parameters measured and calculated while ploughing with Teams 1, 2 and 3 (Table 5.1) on the 4 soil types with the conventional ox-drawn single mouldboard plough. There were no significant differences ($P>0.05$) in the distances covered (medians): 3608 m, 2311 m and 3532 m; for Teams 1, 2 and 3, respectively. There were also no significant differences between teams in the draught forces exerted on all soil types, although distance and draught force tended to be higher for the oxen than the donkey teams. However, the team of oxen (Team 3) generated more power output (920 W vs 461 W; $P<0.05$) and their working speed was faster (1.03 m/s vs 0.59 m/s; $P<0.05$) than the team of female donkeys (Team 2).

Table 5.6: Pooled data from four soil types for draught force, speed, power output, area ploughed, elapsed working time (EWT), ploughing depth, ploughing width and effective field capacity (EFC) of two donkey teams and one oxen team ploughing on clay, redsoil, sandy and sandy clay soils with a conventional ox-drawn plough at Matopos Research Station (medians).

	n	Team 1 "heavy" male donkeys (n = 4)	Team 2 "light" female donkeys (n = 4)	Team 3 Jersey crossbred oxen (n = 2)	Significance of difference
Draught force (N)	4	867	778	900	P>0.584
Speed (m/s)	4	0.87[a]	0.59[b]	1.03[a]	P<0.019
Power output (W)	4	689[a]	461[b]	920[a]	P<0.019
Area ploughed (m^2)	4	770	452	597	P>0.276
EWT (sec)	4	4118	3639	3261	P>0.926
Ploughing depth (cm)	4	13.5	13.0	15.0	P>0.476
Ploughing width (cm)	4	26.5	24.5	28.0	P>0.351
EFC (h/ha)	4	14.2	22.1	14.5	P>0.069
Temperament[1]		1	1	2	

[1] see Section 5.2.1.1.; medians in the same rows with different superscripts differ at P<0.05.

Power output and working speed of the oxen and male donkey teams were similar ($P>0.05$). The heavier team of donkeys (Team 1) worked faster (0.86 m/s vs 0.59 m/s; $P<0.05$) than the female donkey team (Team 2). There were no significant differences ($P>0.05$) between Teams 1 and 2 in draught force and work and power output.

The total area ploughed (m^2), elapsed working time (EWT in seconds), ploughing depth and width (cm) and effective field capacity (EFC, h/ha) of Teams 1, 2 and 3, were similar ($P>0.05$). However, ploughing depth tended to be greater for the oxen (Team 3) compared with the donkey teams (Teams 1 and 2).

Subjective comparisons were made of the ploughing data on sandy clay soils of Teams 1, 2 and 3 with those of the lighter team of male donkeys (Team 4) on the same soil type. The data for Team 4 suggested that there were little apparent differences between the work done (2699 kJ) and distance covered (3415 m) by this team. However, the values for Team 4 for draught force (782 N), speed (0.63 m/s) and power output (497 W), were lower than for Teams 1 and 3, respectively, but similar to that of the lighter female donkey team (Team 2). Other parameters for Team 4 (area ploughed, elapsed and total working time and ploughing width and depth) on sandy clay soils were similar to those of Teams 1, 2 and 3. The EFC for Team 4 (23.8 h/ha) was comparatively worse than for Teams 1 (12.8 h/ha) and 3 (15.9 h/ha), but similar to that for Team 2 (25.6 h/ha).

The pattern of working for the three teams ploughing with the conventional plough (work output, draught force, working speed and power output) is shown in Figures 5.2a, b, c, and d.

Figure 5.2a: The work output (kJ) of teams of donkeys (Teams 1 and 2) and oxen (Team 3) while ploughing with a conventional single mouldboard plough on clay, redsoil, sandy and sandy clay soils for 2 hours a day.

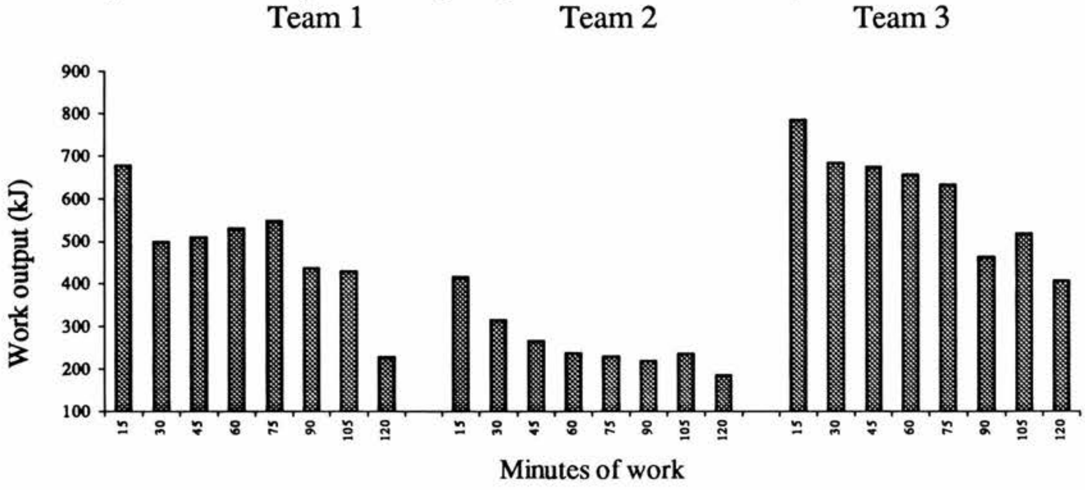


Figure 5.2b: The draught force (N) of teams of donkeys (Teams 1 and 2) and oxen (Team 3) while ploughing with a conventional single mouldboard plough on clay, redsoil, sandy and sandy clay soils for 2 hours a day.

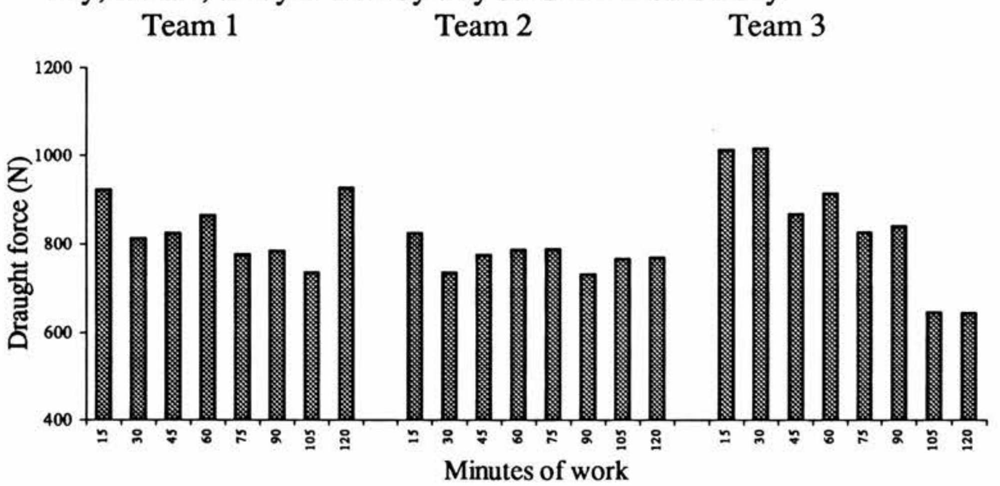


Figure 5.2c: The working speed (m/s) of teams of donkeys (Teams 1 and 2) and oxen (Team 3) while ploughing with a conventional single mouldboard plough on clay, redsoil, sandy and sandy clay soils for 2 hours a day.

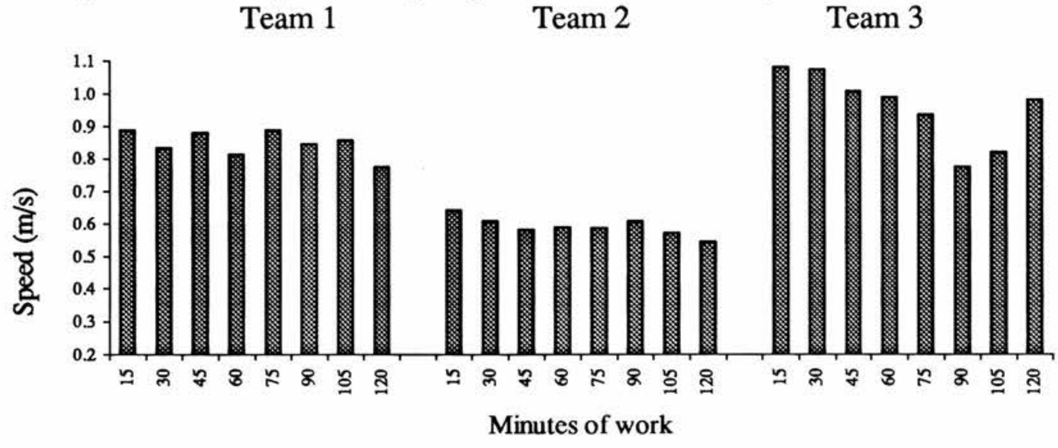


Figure 5.2d: The power output (W) of teams of donkeys (Teams 1 and 2) and oxen (Team 3) while ploughing with a conventional single mouldboard plough on clay, redsoil, sandy and sandy clay soils for 2 hours a day.

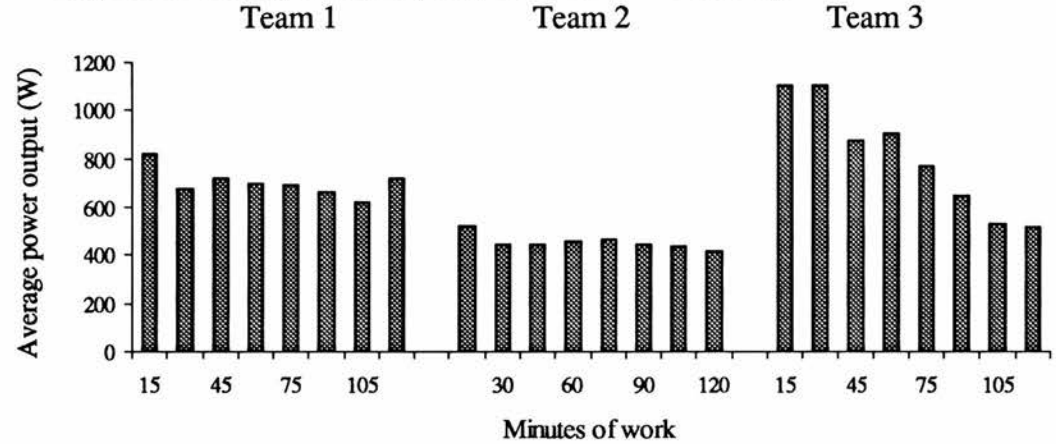


Figure 5.2a, b, c and d indicate that values for the parameters (work output, draught force, speed of working and power output) tended to be highest in the first 30 minutes, followed by a decline, then remained constant and would increase or decrease towards the end of the measurements. For the team of oxen, the tendency was for a gradual decline in the performance from the start to the end while donkey teams particularly Team 1, appeared to start at a high level and then maintain a

constant level of output. Similar trends were observed when teams ploughed with the lighter Walco plough (Section 5.3.1.2.2.). An example of donkeys ploughing on-station is shown in Plate 5.4.

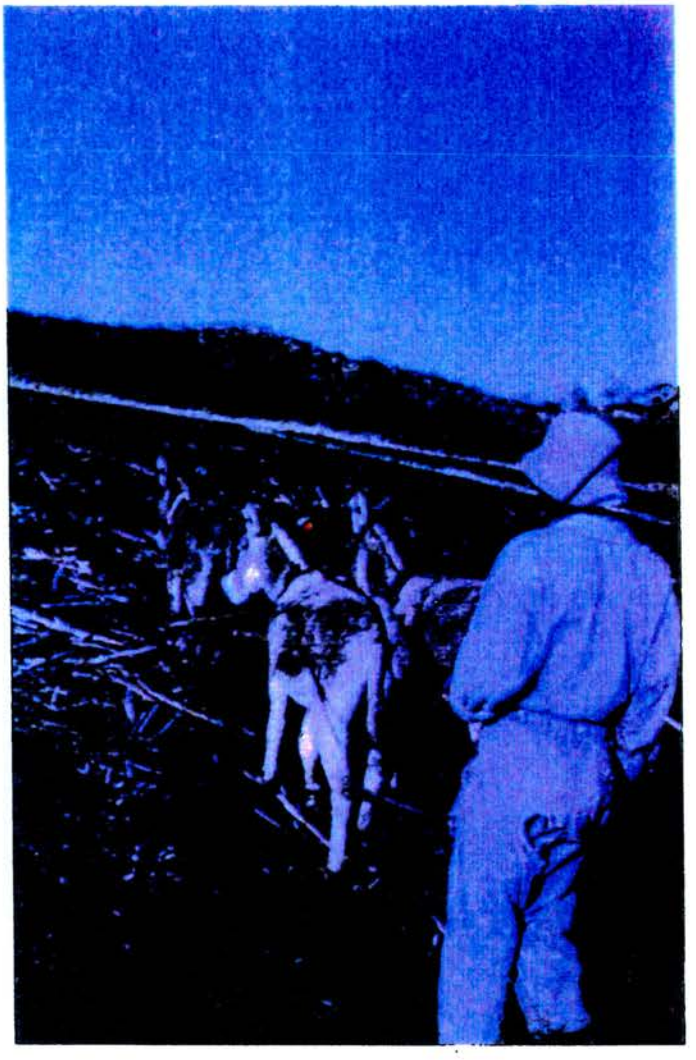


Plate 5.4: Team of donkeys ploughing on-station.

5.3.1.2.2. DRAUGHT PERFORMANCE OF DONKEYS AND OXEN PLOUGHING WITH THE WALCO SINGLE MOULDBOARD PLOUGH:

On the clay soils the data for oxen (Team 3) are not available due to a breakdown of the ergometer and it was not possible to carry out a repeat evaluation. Therefore, the results presented in this section are for 4 measurements for the donkey and 3 for the oxen teams ploughing on clay, redsoil, sandy and sandy clay soils working with the lighter Walco plough (Table 5.7). The distances covered by the teams were 3575 m, 2304 m and 2546 m for Teams 1, 2 and 3, respectively ($P>0.05$).

Table 5.7: Pooled data from four soil types for draught force, speed, power output, area ploughed, elapsed working time (EWT), ploughing depth, ploughing width and effective field capacity (EFC) of two donkey teams and one oxen team ploughing on clay, redsoil, sandy and sandy clay soils with the Walco plough at Matopos Research Station (medians).

	n[1]	Team 1 "heavy" male donkeys (n = 4)	Team 2 "light" female donkeys (n = 4)	Team 3 Jersey crossbred oxen (n = 2)	Significance of difference.
Draught force (N)	4	747	685	749	P>0.310
Speed (m/s)	4	0.87^{a}	0.64^{b}	0.99^{a}	P<0.012
Power output (W)	4	649^{a}	445^{b}	745^{a}	P<0.012
Area ploughed (m^2)	4	787	455	517	P>0.449
EWT (sec)	4	4209	3725	2580	P>0.268
Ploughing depth (cm)	4	12.5	12.0	13.0	P>0.524
Ploughing width (cm)	4	26.0	24.5	26.0	P>0.832
EFC (h/ha)	4	$17.3^{a,b}$	23.4^{b}	13.9^{a}	P<0.023
Temperament[2]		1	1	2	

[1] for Team 3 n = 3; [2] see Section 5.2.1.1.; medians in the same rows with different superscripts differ at $P<0.05$.

When using the lighter Walco plough all teams covered similar distances ($P>0.05$) (only 3 measurements were taken with Team 3). Teams exerted similar draught forces to pull the Walco plough. However, the team of oxen worked faster ($P<0.05$) and produced more power ($P<0.05$) than donkey Team 2. Plough depth and width were similar ($P>0.05$) for all teams. The oxen team required less time to plough a hectare than the donkey Team 2 ($P<0.05$), but similar to donkey Team 1.

When comparisons were made using the Mann-Whitney test (MINITAB, Inc., 1994) between the two plough types used by the teams on all soil types, there were no significant differences ($P>0.05$) in any of the parameters except the draught force required to pull the ploughs (Table 5.8). The teams required more force ($P<0.05$) to pull the heavier ox-drawn single mouldboard plough, 811 N than the lighter Walco plough 745 N.

Table 5.8: A comparison between the performance (ploughing depth, ploughing width, draught force, speed, power and effective field capacity (EFC)) of two types of plough used on clay, redsoil, sandy and sandy clay soils at Matopos Research Station (medians).

	Conventional single mouldboard plough (n = 13)[1]	Lighter single mouldboard plough (n = 12)	Significance of difference
Ploughing depth (cm)	13	12	P>0.198
Ploughing width (cm)	26	26	P>0.425
Draught force (N)	811[a]	746[b]	P<0.019
Speed (m/s)	0.85	0.81	P>1.000
Power output (W)	663	631	P>0.399
EFC (h/ha)	15.6	18.5	P>0.462

[1] number of measurements; medians in the same rows with different superscripts differ at P<0.05.

5.3.1.2.3. PLOUGHING WITH DONKEYS, CATTLE AND MIXED TEAMS ON DIFFERENT SOIL TYPES AND SITES

Nkayi and Matobo Districts

Because only one measurement was taken on each team on-farm (Nkayi, Table 5.9; Matobo District, Table 5.10), only the results of selected teams with an elapsed working time (EWT) of approximately one hour, are presented here (see also Appendix III, Table 3.2a and b). This was done to enable more equitable subjective comparisons between these teams and those on-station and also to provide information on the differences in teams used by farmers. However, no statistical analyses were possible with the on-farm data. In both Matobo and Nkayi, in only one case was the use of force considered *excessive*. The comparisons of the on-station and the on-farm results suggest that there were similarities in the performances of the teams in both situations. In agreement with the results on station, the draught performance of the teams appeared to depend on the combined weight of the teams, with the heavier teams having higher values than the lighter teams. However, in Nkayi it was observed that a lighter team (Team 8, Table 5.2) performed better than heavier teams (higher power output, faster speed of working and greater effective field capacity). When compared with cattle, the donkey teams in Matobo and Nkayi Districts were slower at working, produced less power output and required more time to plough a hectare of land. Plates 5.5 and 5.6 show farmers' animals ploughing in Nkayi and Matobo Districts, respectively.

Table 5.9: Draught force (DF), speed, power output and effective field capacity (EFC) of cattle and donkey teams ploughing on redsoils in Nkayi District.

Team[1]	TLW[2, 3] (kg)	DF (N)	Speed (m/s)	Power (W)	EFC[4] (h/ha)	Temperament[5]	Coercion[6]
1. 4 cattle	1709	1451	0.78	1136	11.1	1	1
2. 4 cattle	1609	908	0.76	692	14.3	2	1
3. 4 cattle	1387	1009	1.08	1087	10.0	1	1
4. 4 cattle	1102	1149	0.81	929	11.1	1	1
5. 4 cattle	974	1233	0.82	1007	12.5	1	1
6. 2 cattle + 2 donkeys	898	1119	0.75	842	14.3		1
7. 2 cattle	893	1143	0.77	898	12.5	1	1
8. 2 cattle	879	756	1.02	775	9.1	1	1
9. 4 donkeys	658	823	0.62	510	14.3	1	1
10. 2 cattle	558	832	0.63	527	11.1	2	1

[1] cattle teams were oxen, cows or bulls, in various combinations, [2]TLW = total live weight, [3]ranked according to live weight, [4]effective field capacity, here expressed as the time taken to plough one hectare. [5, 6] see Section 5.2.1.1.

Table 5.10: Draught force (DF), speed, power output and effective field capacity of selected donkey teams ploughing on varying soil types in Matobo District.

Team[1]	TLW[2] (kg)	DF (N)	Speed (m/s)	Power (W)	EFC[3] (h/ha)	Temperament	Coercion
1. 7 donkeys	1007	812	0.74	601	9.1	1	1
2. 6 donkeys	854	794	0.60	475	12.5	1	1
4. 6 donkeys	773	605	0.78	469	16.7	2	1
9. 3 donkeys	340	609	0.65	395	25.0	1	1

[1]see Table 5.3; [2]TLW = total live weight; [3]effective field capacity, here expressed as the time taken to plough one hectare.

Plate 5.5: Team of cattle ploughing in Nkayi District (on-farm).

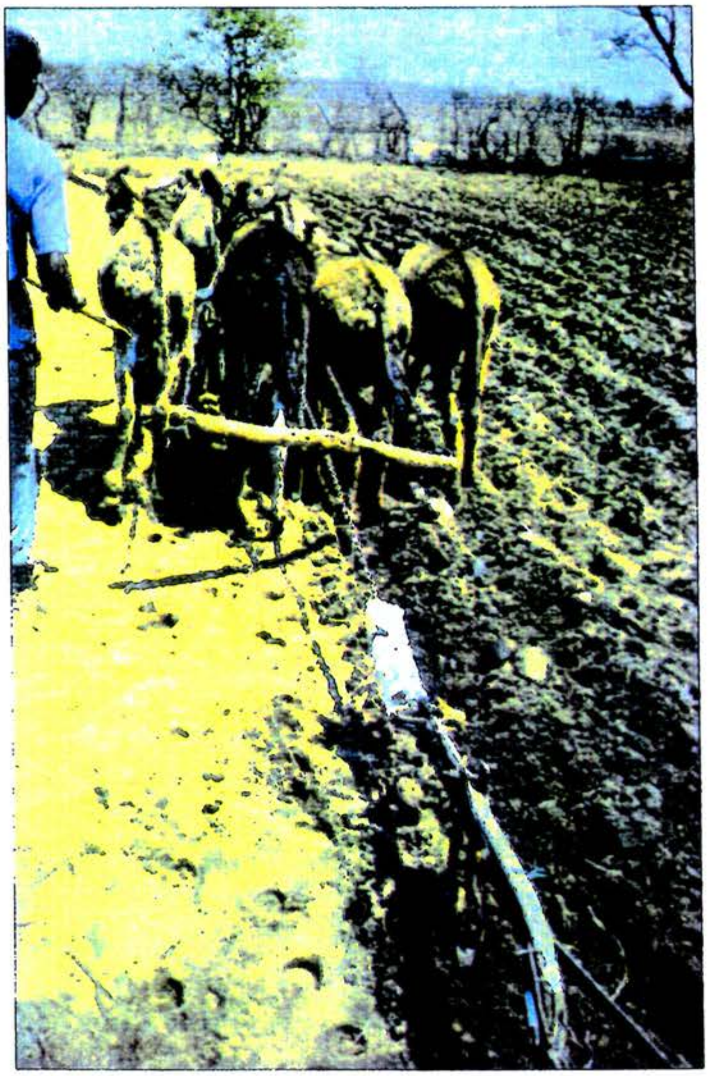


Plate 5.6: Team of donkeys ploughing in Matobo District (on-farm).

5.3.2. PLOUGHING ON-STATION WITH MIXED CATTLE:DONKEY TEAMS

Because of a shortage of land for ploughing, only one measurement, for 2 hours, was possible with each team (see Appendix III, Table 3.3). Therefore, informal comparisons were made between the different teams. The results of the single species and mixed teams ploughing on sandy clay soils are shown in Table 5.11 and Figures 5.3a, b, and c.

Table 5.11: Draught force (DF), speed, power and effective field capacity (EFC) of cattle, donkey and mixed cattle:donkey teams ploughing on sandy clay soils.

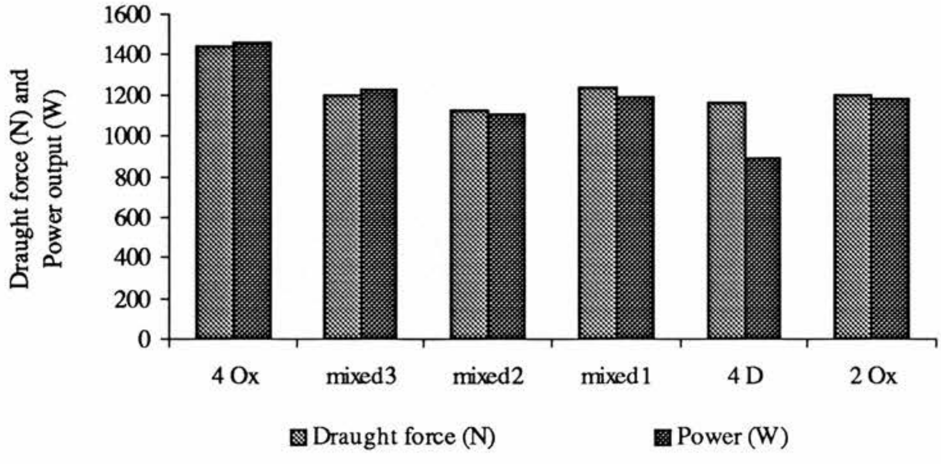
Team[1]	TLW[2] (kg)	DF (N)	Speed (m/s)	Power (W)	EFC[3] (h/ha)	Temperament
1. 4 oxen	1178	1437	1.01	1459	10.4	2
2. 2 oxen	559	1200	0.98	1180	13.9	1
3. 4 donkeys	622	1162	0.76	885	15.9	1
4. mixed	920	1196	1.02	1224	12.0	1
5. mixed	879	1122	0.98	1103	19.2	2
6. mixed	875	1232	0.96	1184	11.9	1

[1] see text above for details of teams [2]TLW = total live weight ranked in descending order
[3]effective field capacity, here expressed as the time taken to plough one hectare.

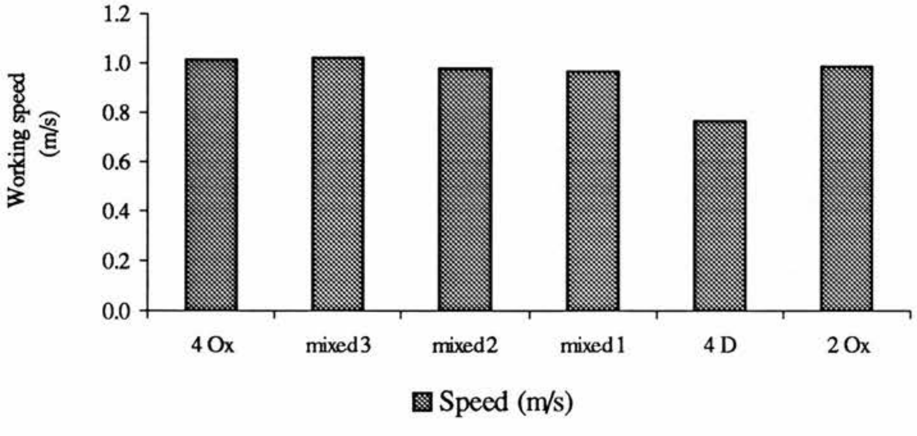
The team of 4 oxen (Team 1, Table 5.2), which was also the heaviest team, exerted the highest draught force of 1437 N (359 N per animal), produced the highest power output per team (1459 W) and was the most efficient, requiring 10.4 hours to plough a ha. This team was, however, temperamental and occasionally difficult to work with. The team of two oxen (Team 2) exerted the highest draught force per animal (600 N) or 21 per cent of their live weight. The team of 4 donkeys (Team 3) was the slowest at ploughing (0.76 m/s or 2.7 km/h), produced the least power, 885 W and required 15.9 hours to plough a ha. Apart from Team 5 (Table 5.5), the performance of the mixed teams was better than that of the donkeys alone but worse than that of the oxen-only teams. An example of a mixed team of donkeys and oxen is shown in Plate 5.7.

Figure 5.3: The draught force (N) and power output (W) (**a**), working speed (m/s) (**b**) and effective field capacity (h/ha) (**c**) of donkey (D), oxen (Ox) and mixed donkey:cattle (mixed) teams ploughing on sandy clay soils with a conventional ox-drawn plough at Matopos Research Station (ranked from heaviest team on the left to lightest on the right of the figure).

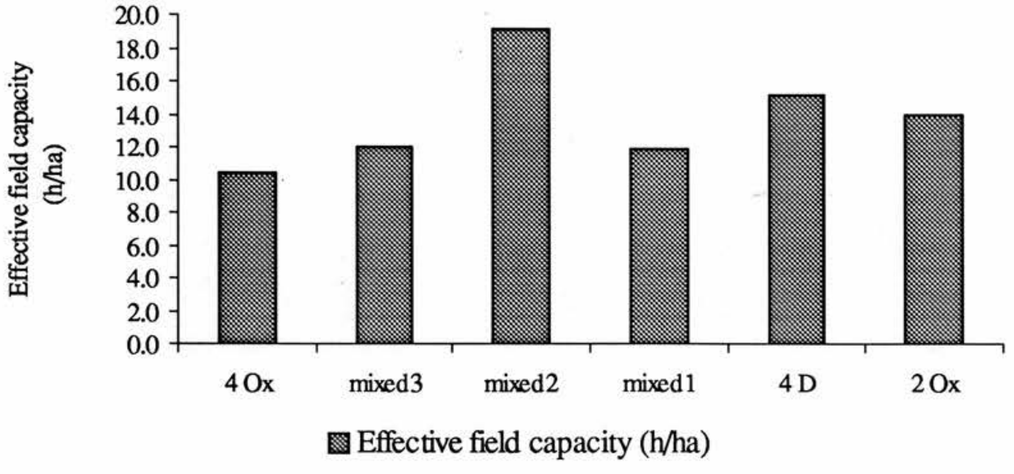
(a)



(b)



(c)



Effective field capacity (h/ha)
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
4 Ox
mixed3
mixed2
mixed1
4 D
2 Ox
Effective field capacity (h/ha)

Plate 5.7: Donkeys and oxen ploughing on-station.

5.4. DISCUSSION

The potential of donkeys to plough was investigated and compared with the performance of oxen ploughing with the conventional ox-drawn single mouldboard and a lighter "donkey-adapted" Walco plough. The conventional ox-drawn single mouldboard plough was used because until recently this plough (designed for use by cattle) was the only type available. The lighter Walco plough used in this study was a prototype (Walco Manufacturing Company Ltd., Zimbabwe) designed for use by donkeys or light-weight cattle. The testing of the Walco plough in this study was in response to one of the farmers' apparent constraints that the implements available, particularly ploughs, were too "heavy" for their draught cattle, which were getting smaller, and for donkeys. Therefore, the use of these ploughs enabled testing a traditional practice and a proposed innovation.

The results showed that regardless of the plough type, the team of oxen (Team 3, Table 5.1) was better at ploughing than the donkey teams (Teams 1 and 2). However, significant differences ($P<0.05$) were only observed when the draught performance of the oxen team was compared with the lighter donkey team (Team 2, Table 5.1). The main differences were in working speed (1.03 m/s vs 0.59 m/s and 0.99 m/s vs 0.64 m/s) and power output (920 W vs 461 W and 745 W vs 445 W), using the conventional and Walco ploughs, respectively. When comparisons of these results were made based on the calculated metabolic body weight ($LW^{0.75}$) of the animals to enable more equitable comparisons, there were similarities in some parameters of both the oxen and donkey teams (Tables 5.6 and 5.7). The draught forces exerted and the power outputs generated by the two species showed no differences suggesting similar performances of the oxen and donkey teams. It was earlier suggested by Prasad *et al.* (1991) that on a weight to weight basis, the work output of donkey teams was 120 per cent higher than that of cattle teams although donkeys could not work beyond 2.5 hours. Power output of donkey teams was almost double that of cattle in the first two hours of work (Prasad *et al.,* 1991).

The results of the present study did not show any advantage of the donkeys over the oxen when ploughing for 2 hours with a conventional plough on all soil types (Table 5.12). For example, when comparisons were made between the team of 4 male donkeys (Team 1) and that of 2 oxen (Team 3), the oxen generated a power output of 461 W per animal compared with 173 W per animal for the donkeys ($P<0.01$) but when calculated per kg LW, the oxen generated 1.3 W/kg compared with 1.1 W/kg for the donkeys ($P>0.05$). Similarly, power outputs per kg $LW^{0.75}$ were 5.6 W/kg $LW^{0.75}$ and 4.0 W/kg $LW^{0.75}$ for the oxen and donkeys, respectively ($P>0.05$). However, if it is considered that output per team tends to decline with more animals in the team, then the power output per kg LW and kg $LW^{0.75}$ for the donkeys could have been higher than reported here.

All teams exerted less draught force ($P<0.05$), worked at similar speed, had lower power outputs and ploughed shallower with the lighter donkey-adapted Walco plough than with the conventional ox-drawn plough ($P>0.05$; Table 5.8). These results show a similar trend with those of Mbanje (1997) who recorded draught forces of 1160 N and 920 N for the conventional ox-drawn (Master Farmer) and the Walco ploughs, respectively, while ploughing on redsoils with a moisture content of 6.5 per cent. Draught force from the same plough types on redsoils (moisture content of 3 per cent) in the present study were lower than in the study of Mbanje (1997), 748 N and 695 N for the conventional and Walco ploughs, respectively. The differences in the draught forces were possibly due to the equipment and measuring techniques and also the soil moisture content. In Mbanje's (1997) study, a dynamometer was used to measure the draught parameters while an ergometer was used in the present study. Lawrence and Pearson (1985) reported that the ergometer was more accurate than the dynamometer as it measured distance averaged draught force (DADF) while the dynamometer measured time averaged draught force (TADF). In typical working conditions, draught force and speed of the draught animals vary continuously and at any given time are affected by factors including soil conditions and the presence of obstacles. Nonetheless, in both studies the draught requirement was higher with the conventional ox-drawn plough than the lighter Walco plough.

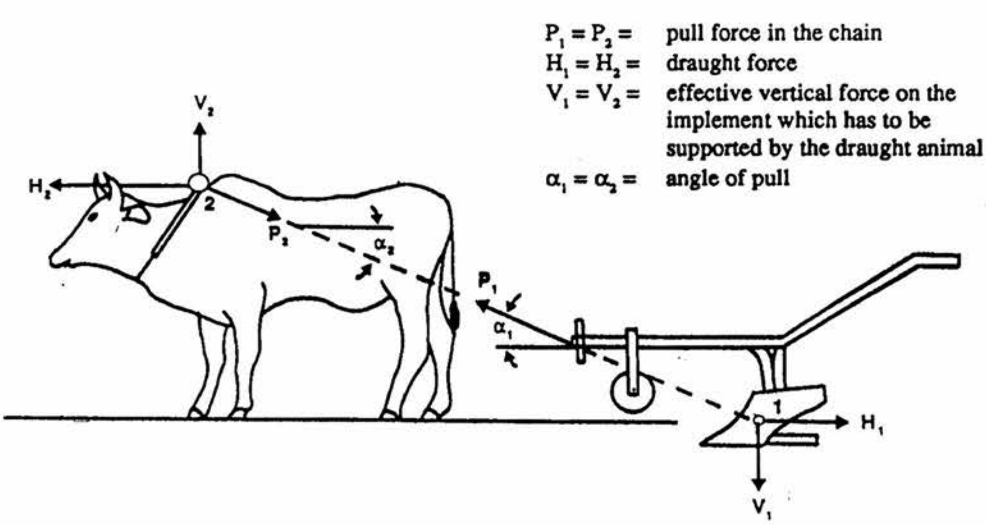
Table 5.12: Comparisons of draught forces (DF, N)and power output (Pow, W) based on total live weight (TLW, kg) and total metabolic live weight ($TLW^{0.75}$, kg) of teams of donkeys and oxen ploughing with a conventional ox-drawn plough on clay, redsoil, sandy and sandy clay soils at Matopos Research Station.

Team	TLW	$TLW^{0.75}$	DF/anim.[1]	Pow/anim.[2]	DF/kgLW	Pow/kgLW	$DF/kgLW^{0.75}$	$Pow/\ kgLW^{0.75}$
1. "heavy" male donkeys	611^{a}	174^{a}	217^{a}	173^{a}	1.4	$1.1^{a,b}$	5.0	$4.0^{a,b}$
2. "light" female donkeys	470^{b}	143^{b}	195^{a}	116^{b}	1.7	1.0^{a}	5.5	3.2^{a}
3. Jersey crossbred oxen	661^{a}	155^{a}	450^{b}	461^{c}	1.3	1.3^{b}	5.5	5.6^{b}
Significance of difference	$P<0.016$	$P<0.016$	$P<0.019$	$P<0.007$	$P>0.168$	$P<0.05$	$P>0.491$	$P<0.018$

[1] DF/anim. = draught force per animal in team [2] Pow/anim = power output per animal in team; medians in the same column with different superscripts differ at $P<0.05$.

The comparisons between the two ploughs (Table 5.8) show that the performance of the teams with the two ploughs were similar, apart from the draught force which was higher ($P<0.05$) with the conventional than the Walco plough. Whether the differences in draught forces can be attributed to the differences in the weights of the ploughs alone, is not likely. It has been noted that implement manufacturers regard the weight of the plough as irrelevant to the draught requirement (Inns, 1991). In his attempt to clarify the complexities of forces acting on implements, Inns (1991) showed that the factors affecting the draught requirement are the pull force which is the force applied to the implement through the trek chain, the vertical force which comprises the weight of the implement, the forces from the soil and from the operator and the implement draught which is the sum of all horizontal forces acting on the implement which are the soil and the operator (Figure 5.4).

Figure 5.4: The forces acting on the draught implement (after Inns, 1991).



The angle of pull which is the angle between the draught line (pull force from the hitch point on the plough and point of attachment to yoke or harness through which the animals pull the plough), the ploughing depth and resistance of the soil, have also been reported to influence the draught requirement of implements (Matthews, 1987; Inns, 1991). Viebig (1982) recommended that the angle of pull should be between 15° and 25°. However, these parameters were not measured in this study. Therefore, the results of draught force refer to the horizontal forces applied by the animals to pull the plough. Although the differences were not significant ($P>0.05$), ploughing depth tended to be greater with the conventional plough than the Walco (13 cm vs 12 cm, respectively). As the main differences in the ploughs were the weights and the length of the beam, this implies that these factors could have had some effect on the working depth. Inns (1991) suggested that the downward force (V) of the implement would cause an increase in working depth until an equilibrium is reached with the other forces (pull force, P and horizontal forces, H). The longer beam on the Walco plough could have altered the line of pull with respect to the mouldboard and share (D.H. O'Neill, pers. comm.) and the animals could then have tended to pull upwards thus reducing the ploughing depth and probably the draught requirement as well.

The donkeys in Team 1, considered the "optimal team", produced draught forces which were calculated to be equivalent to about 216 N per animal, representing 13 per cent of live weight. Exerting forces at this rate, the donkeys were able to work continuously for 4 hours without exhibiting observable signs of fatigue, such as excessive sweating and leg uncoordination. The working speed of 0.86 m/s (3.1

km/h) for Team 1 in the present study, was faster than the 2.5 km/h (0.69 m/s) for donkeys weighing between 120 kg and 300 kg (Goe and McDowell, 1980). These workers reported that donkeys with a live weight of 120 kg and working with drawn implements, are capable of a tractive effort (draught force) of 186 N per donkey at a speed of 2.5 km/h (0.69 m/s), considered to be a low speed. Although the values in the present study are lower than the potential draught force of 250 N per donkey if the reduction in the tractive effort of 22 per cent for 4 animals (Goe, 1983) is accounted for, then the potential tractive effort of the donkeys in the present study would have been about 260 N per animal. The value of 250 N per donkey is probably higher than the forces exerted by donkeys in typical working conditions. The duration of work can often exceed 4 hours, making it improbable for the donkeys to sustain such high draught forces.

Indeed Betker and Kutzbach (1991) suggested that the optimal draught forces of single donkeys were about 190 N. In the study of Prasad *et al.* (1991), 4 donkeys (mean live weight 120 kg) pulling sledges with a draught force requirement of 950 N (about 238 N/donkey), could only work for 2 hours before signs of fatigue were observed and animals refused to work. The difference between the results of the present study with that of Prasad *et al.* (1991) was that in the present study the donkeys had slower average working speeds over the duration of the working session. In the study of Prasad *et al.* (1991), the donkeys started working at an average speed of 1.5 m/s (5.4 km/h) in the first half hour and maintained an average speed of at least 1.0 m/s (3.6 km/h) for the next hour. For donkeys pulling at 950 N, this rate of exertion was likely to result in fatigue. It is known that working at greater speeds and pulling heavy loads such as 950 N in the study of Prasad *et al.* (1991), is likely to result in anaerobic metabolism when intramuscular glycogen reserves are utilised for provision of energy, with resultant production of lactate which is known to induce fatigue (Erickson, 1993). Thus, the intensity of the work in the study of Prasad *et al.* (1991), might be considered high leading to the observed fatigue symptoms.

In another study by Hagmann and Prasad (1995), when donkeys (mean live weight 144 kg) were subjected to ploughing in teams of four and exerting draught forces of 730 N/team, they could not work beyond 2.5 hours per day. Although the draught forces were lower than in the study of Prasad *et al.* (1991), the failure of the donkeys to work beyond 2.5 hours could be attributed to the speed of working, which was almost 1.1 m/s (4 km/h) in the first one and half hours of work. It was also likely that a certain degree of coercion could have been used for the donkeys to maintain these relatively high speeds of working. In the present study, especially because ploughing was considered a heavy task, the minimal use of coercion enabled the donkeys to work at speeds (2.1 km/h to 3.1 km/h) which could have been optimal for them to maintain. However, the lighter team of donkeys (Team 2) exerted a draught force of 797 N which although lower than for the other two teams, was higher as a proportion of the live weight (equivalent to 16 per cent or 199 N per animal). Thus, by exerting a higher proportion of their live weight, the lighter donkeys were likely to be more fatigued by the task of ploughing than Teams 1 and 3. Their slower speed of working (0.59 m/s or 2.1 km/h) was probably a reflection of the intensity of the work relative to their weight. According to FAO (1972), donkeys are capable of producing a continuous effort of between 17 per cent and 20 per cent of their weight at an average speed of 2.5 km/h (0.69 m/s) to 2.8 km/h (0.77 m/s) for up to 3 to 3.5 hours per day. The donkeys and oxen in the present study (on-station) worked for a total of 4 hours a day, with only a short break (up to 30 minutes) when ploughs were changed over.

Pearson (1991a) working with Jersey and local crossbred cattle in Nepal observed that the lighter teams tended to suffer more from the exertion of the work (ploughing) than the heavier animals. This was attributed to the greater effort by lighter animals when carrying out the same task. Endurance has been shown to be positively related to body weight in camels (Roy, Rai and Khanna, 1992) and in cattle (Bartholomew *et al.,* 1993). The same could explain the poorer performance of the lighter donkeys in the present study. In an earlier study at MRS (Nengomasha, unpublished data), a team of two donkeys exerted draught forces of 22 per cent of their live weight, compared with 16 per cent for the team of 4 animals of similar weight per animal, suggesting that the total weight of the team is important and that lighter teams will exert a greater proportion of their weight and thus tire quicker than heavier teams. Considering that donkeys in the smallholder farming sector weigh approximately 142 kg (Chapter 4) and donkeys exerting draught forces proportional to approximately 13 per cent to 16 per cent of their live weight, 4 donkeys would be able to exert draught forces of between 185 N and 227 N each, which straddles the figure of 190 N per donkey proposed by Betker and Kutzbach (1991) which is suggested as optimal for this species.

If the working speed for donkeys during ploughing with a conventional ox-drawn plough is maintained at between 0.58 m/s (2.1 km/h) and 0.86 m/s (3.1 km/h), as was achieved in the present study without use of excessive force, then donkeys should be able to work continuously for 4 hours. At this rate, it would require between 11 and 18 days for a team of 4 donkeys to complete ploughing a 3 ha plot, the average plot size in the smallholder farming areas, assuming an effective field capacity of between 14.9 and 23.8 h/ha as was achieved in the present study. The importance of timeliness of ploughing during the wet season was adequately emphasised by Tembo and Elliot (1987) who reported a 5 per cent loss per week in yield of some high yielding varieties of maize after the optimum planting date. Kunze and Loos (1991) reported that donkeys in Botswana, ploughing with a VS-10 single furrow plough (recommended for donkeys) in spans of 6 and 8 animals required between 14 hours and 30 hours to plough a hectare. These workers also reported that there were no significant differences in the time required to plough a hectare between teams of 4 and 6 donkeys, highlighting the "inefficiencies" of using large numbers of animals per team.

Although the results in this study show little differences between the two plough types, potentially if donkeys ploughed with a lighter plough, such as the Walco plough, then they would be expected to finish the same task in a relatively shorter time but probably at the expense of shallower ploughing depth. Therefore, assuming the average weight of a donkey is at least 142 kg, farmers with access to 4 donkeys or more can potentially finish ploughing in time for wet season planting.

The effects of body condition on the draught performance of donkeys were not exclusively investigated during this study. Studies on cattle have shown that body condition had less of an effect on draught performance than live weight (Pearson, 1991a; Bartholomew *et al.*, 1993; Fall, 1995). In the present study, the differences in the draught performance of the donkey teams were attributed to the differences in the combined live weights of the donkeys in the teams. However, body condition is important when animals have to draw from their body reserves due to the increased energy demands for work. The sex of the donkeys did not appear to have any effect on the draught performance. When the draught performance of the light team of female donkeys (Team 2, Table 5.1) on sandy clay soils at MRS was compared with that of a similar (live weight and body condition) light team of male donkeys (Team 4, Table 5.1), there were no significant differences in the results. This probably reflects the similarities in morphological attributes between male and female donkeys as reported in Chapter 4. The on-farm studies in Matobo District also showed that the farmers use both male and female donkeys, as most of the teams were made up of both sexes depending on availability.

It has been suggested that the donkey is the most efficient power unit in agriculture and is extremely strong despite its size (MacDonald and Low, 1985). Vall (1996) working with horses, cattle and donkeys calculated that net efficiency (traction work/energy expenditure) was highest with donkeys at 26 to 29 per cent followed by horses at 24 to 27 per cent and then cattle at 16 to 20 per cent. Calculations made of the performance per kg live weight (kg LW) and metabolic body weight ($LW^{0.75}$) of the donkeys and cattle in the present study indicate that the two species can perform similarly.

The soil moisture content is important in determining the draught forces required. In the work by Bakrie and Komarudin-Ma'sum (1992) it was reported that an increase in soil moisture content from 9.1 to 11.7 per cent reduced the draught force required in fine sandy loam soils by 15 to 35 per cent and that moisture content above 35 and below 23 per cent, increased the draught of the plough (see Bakrie and Komarudin-Ma'sum, 1992). Soil moisture content in the present study was below 23 per cent and no apparent effects of low soil moisture on draught power were observed.

Subjective observations during ploughing on-station indicated that the team of male donkeys (Team 1) showed a greater willingness to work when compared with the other three teams. The lighter team of donkeys tended to show signs of fatigue earlier than the other two teams. This was attributed to the lower combined weight of this team compared with the other two teams rather than the sex of the donkeys. This point was demonstrated when the fourth team of donkeys (Team 4) was introduced on the sandy clay soils and showed no apparent advantages in draught performance over the team of female donkeys of similar combined weight. The performance of the team of oxen was more variable as the animals were unpredictable and prone to sudden changes of temperament and were easily excited. Overall, it was easier to work with the donkey teams than the oxen team. In Nkayi District although farmers had been encouraged to handle animals according to their normal practices, it was suspected that most farmers deliberately avoided the use of *excessive* force, probably in fear of any possible "repercussions" from the MRS staff. It could therefore, be assumed that the coercion used during the study did not reflect that typically used by the farmers. Observations showed that the level of experience and training differed between the various teams used, particularly in Nkayi. The results of the draught performance of these teams supported these observations. For instance, the lighter Team 8 (Table 5.2) which obeyed commands and displayed co-ordination between the two animals in the team was the most efficient with the capacity to plough a hectare in 9.1 hours. This was better than the heavier but less experienced teams (e.g. Team 2, Table 5.2, 14.3 h/ha). In their work with buffaloes Martin and Teleni (1989) observed that when subjected to a heavy work load (20% of the animals' live weight), untrained buffaloes had higher plasma lactate concentrations than trained buffaloes subjected to similar work loads indicating that the animals had reached or exceeded their anaerobic threshold. High plasma lactate levels are closely associated with fatigue symptoms. This could be because untrained animals probably exert a lot more effort when attempting to resist the work and are therefore, less efficient in their use of energy for draught.

It is important that animals are properly trained and experienced for optimal draught performance. However, training and experience are not quantitative parameters and therefore, difficult to evaluate. Some information is however available on training procedures for draught animals. Cannon (1985) in his handbook on drovers suggested some guidelines on training procedures for oxen including the use of voice commands. Conroy (1997) stated that cattle, unlike other domestic animals, are content to avoid work. This is probably illustrated by the experiences with cattle in the present study. However, the onus will always be on the farmers to improvise training procedures for draught animals to suit their particular circumstances. This is a topic requiring further investigation.

This study on the draught performance of donkeys illustrates that donkeys can potentially be used for heavy draught tasks such as ploughing. However, this is largely assuming that proper management (nutrition, working regimes, health) practices are followed to ensure that the donkeys subjected to ploughing are capable of carrying out the prescribed tasks. Some aspects of the nutrition of the donkey are discussed in the next chapter.

CHAPTER SIX

6. SOME ASPECTS OF THE NUTRITION OF THE DONKEY

6.1. INTRODUCTION AND LITERATURE REVIEW

6.1.1. WATER AVAILABILITY AND VOLUNTARY FEED INTAKE

Donkeys seem to be well-suited to arid and semi-arid environments (Maloiy, 1973; Wilson, 1990; Varshney and Gupta, 1994) and with a few exceptions, such as camels and goats, generally thrive better than most other domestic livestock. Wilson (1981) reported that the donkey's water conservation mechanism was second only to the camel. In several studies, the hardiness of the donkey has been reported. Izraely, Choshniak, Stevens, Demment and Shkolnik (1989) observed that donkeys appear capable of coping with adverse nutritional conditions as efficiently as Bedouin goats (desert ruminants) and better than other domestic equines. This capacity to tolerate adverse conditions could be attributed the donkey's evolution or adaptation as a desert animal. According to Janis (1976), the evolution of the *Equidae* has produced an animal capable of living in areas with sparse, low quality vegetation as observed in wild asses, for example the Onager of Central Asia and Przewalski horses. The water and energy economies are much more frugal in desert-adapted species and breeds in comparison to close relatives from more moderate climates (see Salinkove, 1989). Schmidt-Nielsen (1964) noted that desert mammals have not developed unique adaptations to cope with the environment but have specialised their ordinary thermal and water regulatory mechanisms to make them more efficient for desert survival.

Whatever the mechanism adopted by the donkey, it is apparent that this species is capable of withstanding the adverse conditions prevalent in arid and semi-arid regions.

Factors such as the apparent lower energy requirements for maintenance and lower energy costs of walking when compared with cattle (Dijkman, 1992) also contribute to the donkey's ability to survive in adverse conditions. Donkeys are able to tolerate a water loss of 30 per cent from the body (Schmidt-Nielsen, 1964; Maloiy, 1970). Water is necessary for thermoregulation and the amount required by the donkey when expressed as a percentage of body weight, is about 50 per cent less than that of man (Dill, Yousef, Cox and Barton, 1980). These workers attributed the lower water requirement of the donkey to the lower surface area to weight ratio compared with man. This confirmed the earlier work of Yousef, Dill and Mayes (1970) which suggested that the small body size of the donkey could be a major advantage in difficult environmental conditions. Therefore, donkeys are highly versatile in surviving adverse conditions which are clearly becoming more pronounced especially with the increasing population pressure and land degradation (Tembo, 1989). These factors are predicted to reduce the availability of food and water for humans and livestock alike.

In cattle, a direct relationship has been established between the amount of feed and the amount of drinking water consumed, the latter increasing in direct proportion to an increase in the former (Forbes, 1995). Shortage of water would result in a corresponding reduction in feed intake and in extreme cases, to complete anorexia (Forbes, 1995). Donkeys have been reported to have an ability to continue feeding during times of water scarcity (Dill *et al.,* 1980). This could contribute to the donkey's survival during droughts when water is a major limiting factor. The lower energy requirements (per $LW^{0.75}$) of donkeys when compared with cattle (Dijkman, 1992), could also contribute to their resilience to the conditions of limited nutrient availability experienced during droughts. Given this predicament, the option available to smallholder farmers whose livestock production is prone to these natural adversities is to make optimal use of the available donkey resource. This entails proper management of the working donkey taking into account the advantages and limitations of this species.

6.1.2. WORK AND FEEDING MANAGEMENT

Smallholder farmers commonly use their donkeys for 3 to 6 hours a day (Chapter 3). The demand for provision of DAP is particularly high in the ploughing season when farmers endeavour to finish ploughing at the optimum time for crop planting. When donkeys are subjected to long periods of work, the time available for feeding is correspondingly reduced. In theory this would result in working animals losing weight due to the reduced feeding time and increased energy expenditure. In the tropics and sub-tropics where both the quality and quantity of natural grazing are highly variable but generally poor, the effects of work and feeding time are likely to reduce feed intake of draught animals. Thus, draught animals might not be able to meet the energy demands of work. Several studies have been carried out on the effect of work on voluntary feed intake. Most of these studies have been conducted on cattle, buffaloes (Mupeta *et al.,* 1990; Bakrie, Murray, Hogan, Teleni and Kartiarso, 1989) and horses (Orton, Hume and Leng, 1985). Information is sparse on the effect of work on feed intake in donkeys (Pearson and Merritt, 1991). In all the experiments it appears that the results were dependent on the severity of the draught tasks and the feed quality the experimental animals were subjected to.

Some workers reported increased feed intake due to work (Orton *et al.,* 1985; Bakrie *et al.,* 1989) while others found no increases (Mupeta *et al.,* 1990; Pearson and Merritt, 1991). The quality of the feeds used may have affected the results. When the quality of the feed offered was of low quality, draught animals were unable to increase their intake in response to work. The quality of feed available to draught animals in the tropics and sub-tropics is generally of lower CP and higher fibre content, especially in the dry season when compared with temperate regions. If draught animals, particularly cattle, are deprived of grazing time (as they are when working) then they are unlikely to meet their energy requirements by increasing intake of the poor quality grasses available (Janis, 1976).

The digestibility of roughages is important. Although it is generally recognised that ruminants are better at digesting high fibre diets than equines, the latter have an advantage in that they can increase their intake of poor quality roughages through a relatively faster rate of passage through the gastro-intestinal tract (Janis, 1976; Butterworth, Mosi and Nuwanyakpa, 1987; Cuddeford, Pearson, Archibald and Muirhead, 1995). Studies have also shown that donkeys are better at digesting fibre than ponies and horses (Izraely *et al.,* 1989; Pearson and Merritt, 1991; Tisserand, Faurie and Toure, 1991; Cuddeford *et al.,* 1995). It has been suggested that work or light exercise could increase the digestibility of roughages (Pearson and Merritt, 1991), although the mechanisms for this are not clear.

Although the ability of donkeys to withstand long periods of dehydration and to continue feeding has been investigated elsewhere, this has not been confirmed in the local Zimbabwean donkey whose capabilities have not been investigated. Assuming that donkeys in Zimbabwe are similar to donkeys elsewhere, their response in feed intake to the effects of work and water restriction would be expected to be comparable to those reported above. However, their response would depend on the conditions (type of feed, work regimes) prevailing in the smallholder farming sector in Zimbabwe. It is therefore, essential to have some knowledge and understanding of the donkeys' ability to survive in these conditions. This would enable researchers and extension workers to inform and advise smallholder farmers on the options available for proper management of donkeys with the objective of optimising the use of this species.

Two studies were carried out at Matopos Research Station to assess the response of donkeys to water and work stress. The objectives were:

- to assess the effect of water restriction on voluntary feed intake and faecal water content of penned donkeys
- to determine whether the voluntary feed intake and apparent digestibility of hay in working donkeys is affected by work *per se* and or, time of access.

6.2. MATERIALS AND METHODS

6.2.1. WATER AVAILABILITY AND VOLUNTARY FEED INTAKE

6.2.1.1. ANIMALS AND TREATMENT GROUPS:

Eighteen donkeys (nine males and nine females) were used in this study. The mean live weights and ages of the males and females were 150 ± 3.6 kg and 142 ± 8.7 kg, and 8 ± 0.8 years and 6 ± 1.2 years. None of the females was pregnant or lactating. Within sex donkeys were ranked according to live weight and then allocated into three blocks of three (from heaviest to lightest). In each block animals were randomly allocated to three treatments. Animals allocated to the same treatment groups (within and between sex) formed three corresponding treatment groups. Therefore, each treatment group comprised six donkeys (three males and three females) and all groups were of a similar mean initial live weight. The treatments and initial live weights of the treatment groups are presented in Table 6.1 All donkeys were weighed at the start and at the end of the study. The study lasted for 35 days.

Table 6.1: Treatment groups and mean initial live weights (kg ± sem) of donkeys used in the water study.

Treatment group	Treatment	Initial live weight (kg)
1 (n = 6)	water offered *ad libitum*	147 ± 10.7
2 (n = 6)	water offered every 48 h	145 ± 9.8
3 (n = 6)	water offered every 72 h	146 ± 3.6

6.2.1.2. HOUSING, WATERING AND FEEDING MANAGEMENT:

The donkeys were acclimatised to penning and individual feeding for one week prior to the start of the study. The animals were individually penned in partially roofed stalls, to provide shade and with earthen floors. Each pen measured 3 m in length and 3 m in width. Mesh fencing 1.75 m high, was used to partition the pens and allow the animals to see each other. Each animal had individual access to a water and feed trough. Animals in each treatment group were in adjacent pens and a vacant pen was left between the treatment groups. Animals in treatment 1 (water *ad libitum*) were at one end of the stalls (Appendix IV, Figure 4.1). This partitioning was necessary to remove temptation from animals, in treatments 2 and 3 (restricted water) to break out in search of water. A thermometer placed in the middle of the stalls, was used to monitor fluctuations in ambient temperatures in the stalls.

Animals in treatment 1 were offered clean water every morning (08:00 h) after removal and recording of refusals from the previous day. Thereafter, known amounts of water were added whenever necessary according to consumption of individual animals. For animals in treatments 2 and 3 water was offered *ad lib* for one hour during the appropriate watering times, every 48 h and 72 h, respectively. Water was withdrawn after the hour had passed and consumption recorded. A marked cylinder was used to measure water intake. In the first two weeks of the study animals in treatments 2 and 3 were weighed (portable electronic weighing system) before and after watering. This was to assess whether changes in live weight corresponded to the recorded water intake. However, due to a temporary breakdown of the electronic weighing equipment this was stopped after Week 2. The general behaviour of the donkeys in treatments 2 and 3 towards the availability of water was monitored (the donkeys' attitude to the presence of water and when they started drinking, how long they drank in the one hour). The watering programme is presented in Appendix IV, Table 4.1.

All donkeys were fed a low quality veld hay (Spring Farm, Hay Distributors Ltd., Zimbabwe) *ad lib* (see Table 6.5). The hay was fed straight from the bales without chopping. The donkeys were fed twice a day at 08:00 h and 14:00 h in portions of up to 2 kg. However, it was ensured that donkeys had access to feed at all other times by adding more hay whenever it was deemed necessary.

6.2.1.3. SAMPLING PROCEDURES AND ANALYSIS:

Samples of the hay as fed, were taken at the start, middle and end of the study for chemical analysis (CP, Neutral Detergent Fibre (NDF), Acid Detergent Fibre (ADF) and Ash). Samples of the hay were bulked and sub-sampled at the end of the study for chemical analysis. Samples of the hay were milled in a laboratory hammermill (1 mm screen). The milled hay was dried at 60°C for 24 h to determine the DM content. Grab samples of the faeces of all donkeys were taken in the morning before water was offered, for analysis of water content. The faecal samples were taken at the start, middle and end of the study. Faecal samples were weighed and oven-dried at 60°C for 48 h and water content of the faeces was calculated from the weight lost during drying. The mean faecal DM for each animal over the 35 days of the study, was calculated. Crude protein was analysed by the Kjeldahl method recommended by the AOAC (1965) while NDF and ADF were analysed by the methods of Goering and Van Soest (1970).

6.2.1.4. STATISTICAL ANALYSIS:

Data were analysed using the MINITAB Inc. (1994) statistical software package. Analyses of variance were performed on the data using the GLM procedure with sex, treatments and random error as the sources of variation according to the following model:

$$\mathbf{Y_{ijk} = \mu + T_i + B_j + e_{ijk}}.$$

where Y_{ijk} = the kth observation in the ith treatment and the jth block

μ = the population mean for the variable considered

T_i = the effect of the ith treatment

B_j = the effect of the jth block

e_{ijk} = the random variation (residual) of that observation

When the F-test in the ANOVA table of results indicated significant differences in the variables under investigation due to the treatments, least significant difference (LSD) tests were carried out to determine the differences between treatment groups.

6.2.2. WORKING AND FEEDING MANAGEMENT (WORK, TIME OF ACCESS TO FEED, VOLUNTARY FEED INTAKE, DIGESTIBILITY AND GASTRO-INTESTINAL TRANSIT TIME IN DONKEYS)

6.2.2.1. ANIMALS, TREATMENT GROUPS AND EXPERIMENTAL DESIGN:

Twelve male donkeys with a mean live weight 154 kg, were used in this study. The donkeys were divided into three groups of four animals. The three groups were of similar total team live weight. The three groups were randomly allocated to three treatments. The three treatments were:

Treatment 1 = Working, not feeding

Treatment 2 = Not working, not feeding

Treatment 3 = Not working, feeding

In a 3 x 3 Latin square change-over design (3 treatments, 3 periods and 3 teams), animals in each team were subjected to the three treatments. The treatment allocation is shown below (Table 6.2).

Table 6.2: Treatment allocation and design.

	TEAM AND TREATMENTS		
PERIOD[1]	Team 1[2]	Team 2	Team 3
I	1[3]	2	3
II	3	1	2
III	2	3	1

[1] each period lasted for 21 days [2] each team comprised 4 donkeys (see Appendices for teams)
[3] see text above for details

Each period lasted for 21 days with the first 14 days for acclimatisation to the working regime (for the team subjected to work during that period) and final 7 days for working, marker dosing, faecal collection and measurements of feed intake. However, faecal collection for Cr_2O_3 and apparent digestibility determination continued for two more days (see Section 6.2.2.4 and Table 6.3) after the 7-day period. Donkeys were weighed at the start and end of each period.

6.2.2.2. HOUSING AND FEEDING:

Donkeys were acclimatised to the pens and feed for one week prior to the start of the study. The donkeys were individually penned indoors. These pens were originally designed for cattle and measured 3 m by 2.1 m. The floors were of concrete with a 2 per cent slant towards a canal for urine drainage (urine was not collected in this study). Each animal had access to an individual feed and water trough. Animals in each treatment group were in adjacent pens for the duration of the study. All donkeys were fed a poor quality hay (g/kg DM: CP = 60; NDF = 780; ADF = 460; Ash = 40) *ad libitum* according to the following feeding regime:

- Treatment 1 (working): no food during work
- Treatment 2 (not working): no food during the time when animals in Treatment 1 were working
- Treatment 3 (not working): fed *ad lib.*

Because of the bulkiness of the hay which was fed long and the size of the feed troughs, every effort was made to minimise wastage and ensure accurate recording of intake. This was achieved by offering the daily feed in 2 kg portions as required. It was observed during the acclimatisation period that the donkeys rarely exceeded a daily intake of 4 kg of the hay. The feeding troughs used in this study were half-200 l metal drums which were sufficiently deep to prevent excessive spillage. Wastage through spillage was minimised by returning the feed into the troughs before it could be trampled or soiled.

Throughout the study feed was offered in two portions at 08:00 h after removal of orts from the previous feed and at 14:00 h. Feed troughs were removed from the donkeys in Treatment 2 when donkeys in Treatment 1 were working and only returned when the working donkeys had been returned to their respective pens and feed. Daily feed intake of all the donkeys was recorded during the three weeks of each period but only data from the 7-day collection week of each period were used in the estimation of DM intake, apparent digestibility and the gastro-intestinal tract (GIT) transit time of the hay.

6.2.2.3. WORKING REGIME:

The work consisted of carting over a 11.3 km route (4.8 km dirt and 6.5 km tarmac) twice a day for 5 days during the appropriate collection period. The terrain of the route was generally flat with occasional gentle slopes. A two-wheeled cart with a differential and pneumatic tyres, designed for cattle but also suitable for donkeys (Biddak Engineering Pvt. Ltd., Zimbabwe) was used. The net gravitational weight of the cart was 280 kg. A load of 350 kg (mineral and vitamin blocks) was placed in the cart (Plate 6.1). For the working team (Treatment 1), work commenced at 08:00 h with the first carting session. After the first carting session donkeys remained hitched to the cart and were rested for one hour during which they had access to water but not feed. The second carting session was the same as the first. Thus, total distance covered was 22.6 km a day and donkeys (Treatments 1 and 2) had no access to feed for approximately 5 hours per day (Section 6.3.2.2.). The average speed of carting for each team was calculated.

The four working donkeys were spanned two abreast. Breastband harnesses were used to hitch the team to the cart. The donkeys in front were harnessed, as described in the ploughing study (Chapter 5, Section 5.2.1.4), and then hitched to a wooden bar at the front end of the shaft. The donkeys at the rear were hitched to the same bar and then attached to the cart through an evener.

6.2.2.4. MARKER DOSING AND SAMPLE COLLECTION PROCEDURES:

Feed was removed from the troughs at least 12 hours before dosing with an inert marker and donkeys had access to water only. On Day 1 of each collection period (at 06:00 h) (Table 6.3), all animals were dosed with 50 g of chromium-mordanted hay, prepared according to the method of Udén, Colucci and Van Soest (1980) with Cr_2O_3 as an inert marker to estimate the transit time of the solid phase of the digesta through the gastro-intestinal tract of the donkeys. The chromium-mordanted hay (hereafter referred to as Cr-hay) was mixed with sugar-cane molasses (Triangle Animal Feeds Ltd., Zimbabwe) to improve palatability. The animals were offered the molassed Cr-hay in open pans. It was ensured that donkeys consumed the whole amount of the Cr- hay and when necessary were force-fed by hand until all of it had been consumed.

Table 6.3: Marker dosing and faecal collection times for working and non-working donkeys.

Activity	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9
Dose[1]	06:00								
Faecal collection[2]	14:00	02:00							
	16:00	08:00	08:00	08:00	08:00	08:00	08:00	08:00[3]	08:00[4]
	18:00	10:00							
	20:00	12:00	12:00	12:00	12:00				
	22:00	14:00							
	24:00	16:00	16:00	16:00	16:00	16:00	16:00		
		21:00	21:00	21:00	21:00				

[1] see text for details of dosing; [2] see text for sampling procedures; [3] final sample for Cr_2O_3 determination; [4] final sample for DM content and apparent digestibility determination.

There was an improvement in rate of intake of the Cr-hay by the donkeys when mint powder was added to the molassed Cr-hay. Feed was made available soon after dosing. Faeces voided up to 10:00 h on Day 1 (4 hours after dosing), were removed and not used in subsequent analyses. The first collection of faeces for analysis of Cr_2O_3 was 8 hours after dosing. For that first faecal collection, the faeces voided between 10:00 h and 14:00 h were collected. Thereafter, for all other collection times, faecal collection was carried out by removing all faeces voided between collection times. For example, faeces collected at 16:00 h on Day 1 were faeces voided between 14:00 h and 16:00 h on that day and so forth. For the working animals, faeces voided during work were collected in labelled buckets for each animal. For each collection time faeces were collected and bulked separately for each animal (Table 6.3). The bulked samples were sealed in plastic sample bags and frozen at -20°C whilst awaiting drying and analysis. Samples were dried at 60°C for 48 h. For faecal DM content determination and calculation of apparent digestibility, the samples collected from Day 2 (08:00 h) up to 08:00 h Day 9 were used while for analysis of Cr_2O_3 samples collected from 14:00 h (Day 1) to 08:00 h (Day 8) were used. Because the same samples were used for both analyses, DM was calculated before the analysis of Cr_2O_3. After drying and calculation of DM, bulk samples for each animal were thoroughly mixed and sub-sampled for analysis of Cr_2O_3, NDF, and ADF.

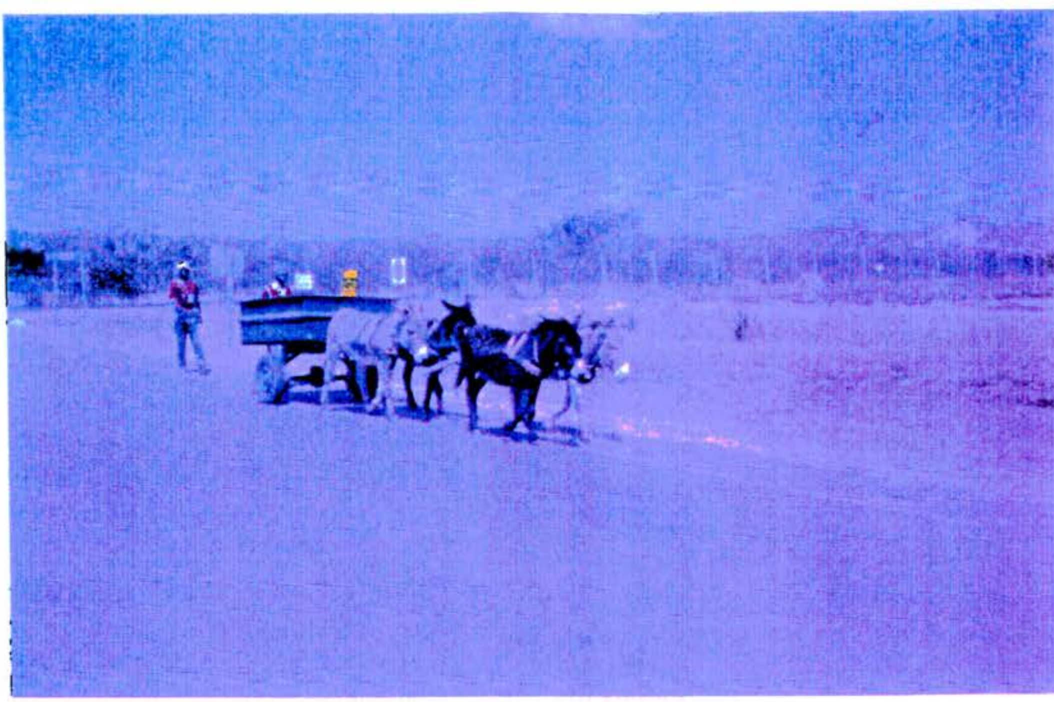


Plate 6.1: Team of donkeys (Treatment 1, working and not feeding) pulling a cart on tarmac.

6.2.2.5. CHEMICAL ANALYSES, CALCULATIONS AND STATISTICAL ANALYSES:

Faecal samples were ground in a coffee blender to pass through a 1 mm screen and after thorough mixing, a 0.4 g sample was taken for Cr_2O_3 analysis. The analysis was carried out as described by Mathers, Baber and Archibald (1989). Samples were digested to bring the Cr_2O_3 into liquid, in a Microwave Digestion System (MDS 2000, CEM Innovators in Microwave Technology, UK) after addition of 10 ml of concentrated HNO_3 with temperature rising to 120°C. They were digested for one hour, cooled and filtered (Whatman filter paper, 110 mm ∅). The filtrate was made up to 50 ml with distilled water. The samples were then analysed in an Atomic Absorption Spectrophotometer 357 (Instrumentation Laboratory, UK) with five Cr standards, selected from 0.5, 1, 2, 3, 4 and 5 ppm, depending on the Cr concentration in the samples (absorbance of the samples was read at 358 nm to determine the concentration of Cr in the samples).

Faecal water content of the bulk samples was determined by calculating the weight of the water lost during drying. Apparent digestibility of the hay was calculated from DM intake and faecal DM output during each collection period according to the equation:

$$\text{Apparent digestibility} = \frac{\text{DM intake - faecal DM output}}{\text{DM intake}} \times 100$$

The transit time of the Cr-hay (marking the solid digesta), was determined by calculation as the reciprocal of the mean retention time (MRT) given in the equation:

$$\mathbf{MRT\ (h)} = \frac{\Sigma\, \mathbf{m_1\, t_1}}{\Sigma\, \mathbf{m_1}}$$

where m_l is the amount of Cr_2O_3 excreted in faeces at time t_l after dosing with the marker (Blaxter, Graham and Wainman, 1956). Analysis of variance was performed on the data to determine the effects of the different treatments. Sources of variation included treatment, period , team (individual animals) and random error. Two analyses (MINITAB Inc., 1994) by the GLM procedure were performed on the data according to the models;

$$\mathbf{Y_{ijk} = \mu + T_i + C_j + R_k + e_{ijk}}$$

where Y_{ijk} = the lth observation in the treatment i, row j and column k

μ = the population mean for the variable considered

T_i = the effect of the ith treatment

C_j = the effect of the jth column

R_k = the effect of the kth row

e_{ijk} = the random variation (residual) of that observation

In the first GLM analysis, the sources of variation were treatment, period, team (span) and random error. This was considered the true analysis and gave the following degrees of freedom (df):

Treatment = 2 df	Period = 2 df	Team = 2 df
Error = 2 df	Total = 8 df.	

Although the parameters investigated in this study included the individual performances of each animal (DM intake and digestibility and transit time), the team performances were used in the analysis. The second GLM analysis considered each animal within each team individually, resulting in the following df:

Animal = 11 df Treatment = 2 df Period = 2 df

Error = 20 df Total = 35 df.

However, only the results of the ANOVA using the GLM based on the teams (df = 8) are presented (see also Appendices IV, Tables 4.5 and 4.6).

6.3. RESULTS

6.3.1. WATER AVAILABILITY AND VOLUNTARY FEED INTAKE

6.3.1.1. ANIMALS AND HOUSING:

There were no significant differences (P>0.05) in the mean initial live weights (kg ± sem) of the three treatment groups. These were 147 ± 10.7 kg 145 ± 9.8 kg and 146 ± 3.6 kg, for treatment groups 1, 2 and 3, respectively. The average ages of the donkeys in the three treatment groups were similar (P>0.05), 6.5 ± 1.7 years 7.3 ± 1.5 years and 7.2 ± 0.5 years, for treatment groups 1, 2 and 3.

The donkeys appeared to adapt well to individual penning and there were no obvious signs of stress or discomfort. The donkeys also did not appear to have any problems with the hay offered. The earthen floors ensured that while lying down or rolling, donkeys did not injure themselves. The mesh wire partitioning of the pens enabled the donkeys to "communicate" with their counterparts in adjacent pens and not to feel isolated. This study was carried out during the winter months and ambient temperatures in the stalls ranged from -5° C to 26° C.

6.3.1.2. WATER AND FEED INTAKE, FEEDING

Visual observations of the behaviour of donkeys in treatments groups 2 and 3 when water was offered for one hour, showed that the donkeys would start drinking as soon as the water was made available. They consumed at least 14 litres within the first 10 to 15 minutes of the water being available. However, on two occasions some donkeys did not drink at all when water was made available. On the first occasion, two male donkeys, numbers 15 and 22 in treatment group 2 did not drink while on the second, female donkey number 1 in treatment group 3 did not. Although it was ensured that the donkeys were aware of the presence of the water, no effort was made to entice or coerce them to drink. After the water was withdrawn, the three donkeys were monitored closely to detect any signs of possible adverse effects of the prolonged water restriction (a total of 96 hours of restriction for male donkeys 15 and 22 and 144 hours for female donkey 1). No visible signs of distress or ill-effects were observed (DM intake of donkeys 15 and 22 during the next 48 hours remained unchanged and animals showed no apparent signs of distress). However, there was a decrease in DM intake for female donkey 1 a day after the initial 72 hours of water restriction (from 2.2 kg DM/d to 1.2 kg DM/d). This was then followed by an increase to normal DM intake for this donkey after drinking.

In the first two weeks of the study when donkeys in treatment groups 2 and 3 were weighed immediately before and after drinking, their water intake was similar to the corresponding live weight gain. The water intake and corresponding gains in live weight were 11.4 ± 0.63 l and 10.1 ± 0.61 kg and 16.6 ± 1.09 l and 14.2 ± 0.87 kg, for donkeys in treatment groups 2 and 3, respectively. It was calculated that the donkeys in treatment groups 2 and 3 drank an equivalent of 8.2 ± 0.45 per cent and 12.5 ± 0.81 per cent of their live weight.

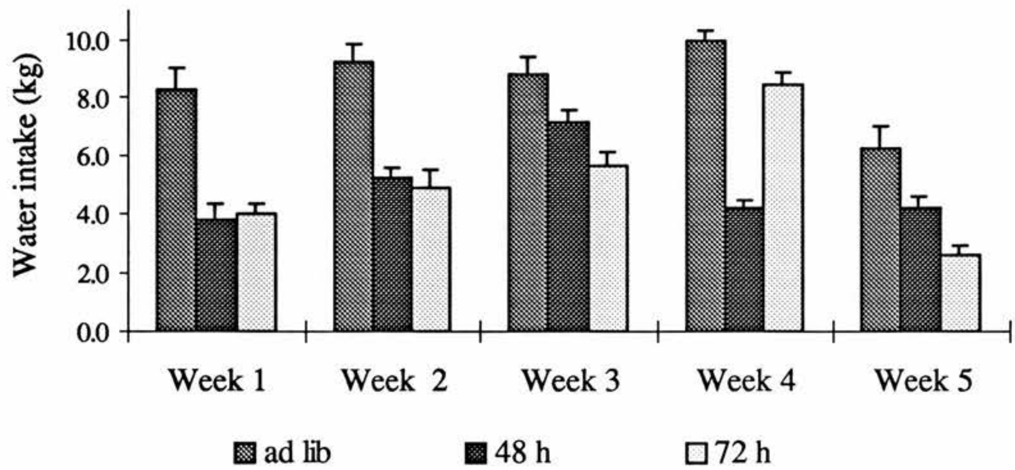
The mean daily water intakes of all donkeys calculated per week are presented in Table 6.4 and Figure 6.1. The mean daily water intake of donkeys in treatment groups 2 and 3 were calculated by dividing the total amount consumed during each week by 7 days rather than the actual number of days when donkeys had access to water. Donkeys with *ad libitum* access to water (treatment group 1) had the highest ($P<0.001$) daily water intake of 8.5 ± 0.61 l/d compared with 4.9 ± 0.30 l/d and 5.1 ± 0.29 l/d, for donkeys with access every 48 h (treatment group 2) and 72 h (treatment group 3), respectively. These data represented decreases in mean daily water intake of 42 per cent and 40 per cent, for donkeys offered water every 48 h and 72 h, respectively, when compared with donkeys with *ad libitum* access to water (Figure 6.3). Donkeys offered water every 48 h and 72 h, had similar calculated mean water intakes ($P>0.05$) in Weeks 1 and 2. Thereafter, calculated mean water intake of donkeys offered water every 48 h tended to be higher than for those offered water every 72 h. In Week 5 ambient temperatures were lower (maximum daily below 20°C) than during the preceding weeks and the donkeys generally consumed less water (Table 6.4 and Figure 6.1). When calculated on a metabolic live weight basis, daily water intake was highest ($P<0.001$) for donkeys with *ad libitum* access (204 ml/kg $LW^{0.75}$) compared with donkeys in treatment groups 2 and 3 (119 ml/kg $LW^{0.75}$ and 124 ml/kg $LW^{0.75}$) respectively.

Table 6.4: Mean daily water intake (litres ± sem) of donkeys fed hay *ad libitum* and offered water either *ad libitum*, every 48 h or 72 h for 35 days[1].

Treatment	Week 1	Week 2	Week 3	Week 4	Week 5[2]	MEAN
1. *ad lib*	8.3 ± 0.77^{a}	9.2 ± 0.63^{a}	8.8 ± 0.66^{a}	10 ± 0.38^{a}	6.3 ± 0.75^{a}	8.5 ± 0.61^{a}
2. 48 h	3.9 ± 0.53^{b}	5.3 ± 0.33^{b}	7.2 ± 0.44^{b}	4.2 ± 0.31^{b}	4.2 ± 0.44^{b}	4.9 ± 0.30^{b}
3. 72 h	4.1 ± 0.34^{b}	4.9 ± 0.64^{b}	5.7 ± 0.47^{c}	8.5 ± 0.42^{c}	2.6 ± 0.35^{c}	5.1 ± 0.29^{b}
Significance of difference	$P<0.001$	$P<0.001$	$P<0.001$	$P<0.001$	$P<0.001$	$P<0.001$

[1] results are means of 6 animals; means in the same column with different superscripts differ at $P<0.05$; [2] see text for explanation of intakes in Week 5.

Figure 6.1: Mean daily water intake (l ± sem) of donkeys offered water *ad libitum*, every 48 h or every 72 h for 35 days.



The chemical compositions of the hay fed to the donkeys and refusals were analysed to determine their nutritive value and the actual quality of feed intake of the donkeys in this study. The results are presented in Table 6.5.

Table 6.5: The chemical composition (g/kg DM) of hay fed to penned donkeys with access to water either *ad libitum*, every 48 h or 72 h.

	DM[1]	CP[2]	NDF[3]	ADF[4]	Ash
Hay (as fed)	936	60	780	460	40

[1] DM = dry matter [2]CP = crude protein [3]NDF = neutral detergent fibre [4]ADF = acid detergent fibre

The digestible energy (DE) content of the hay and subsequent DE intake of the donkeys, were calculated using the following equation (NRC, 1989):

$$\textbf{DE (Mcal/kg)} = 4.22 - 0.11\ (\%ADF) + 0.0332\ (\%CP) + 0.0011\ (\%ADF)^2$$

where ADF is acid detergent fibre and CP is crude protein. Based on this equation the DE content of the hay fed in the present study was estimated at 7.1 MJ/kg DM (1 Mcal = 4.184 MJ).

The DM intakes are presented in Table 6.6 and in Figure 6.2. Donkeys offered water *ad libitum* (treatment 1) had a significantly higher ($P<0.05$) DM intake than those offered water every 48 h (treatment 2) and 72 h (treatment 3) in Weeks 1 and 2. There were no significant differences between donkeys in treatment groups 2 and 3 during Weeks 1 and 2. Thereafter, no significant differences were observed between any treatment groups. However, the overall mean daily DM intakes during the 35-day study period were higher ($P<0.05$) for donkeys in treatment 1 at 3.1 ± 0.14 kg compared with 2.7 ± 0.09 kg for donkeys in treatment 3 but similar to treatment 2 (2.8 ± 0.07 kg). The reductions in DM intake were 9.7 and 12.9 per cent for treatment 2 and 3, respectively (Figure 6.3) when compared with treatment 1. Calculated per kg of metabolic body weight ($LW^{0.75}$), donkeys with *ad libitum* access to water had the highest intake of 75 ± 1.72 g/kg $LW^{0.75}$ compared with 69 ± 2.7 g/kg $LW^{0.75}$ and 66 ± 1.6 g/kg $LW^{0.75}$, for donkeys offered water every 48 h and 72 h. Donkeys with *ad libitum* access to water had the highest ($P<0.001$) ratio of water to DM intake of 2.7 ± 0.12 l/kg DM compared with 1.7 ± 0.08 l/kg DM and 1.9 ± 0.08 l/kg DM, for donkeys offered water every 48 h and 72 h, respectively. There were no significant differences in the water intake to DM intake ratio between donkeys offered water every 48 h and 72 h.

6.3.1.3. FAECAL DM

Donkeys in treatment 3 (watered every 72 h) produced faeces with the highest DM content of 371 ± 6.6 g/kg which was higher ($P<0.01$) than for faeces of donkeys with *ad libitum* access to water, 338 ± 4.9 g/kg but similar ($P>0.05$) to DM content of faeces of donkeys deprived of water for 48 h, 358 ± 6.7 g/kg (Figure 6.4). Donkeys deprived of water for 48 h produced faeces of higher DM content ($P<0.05$) than those with *ad libitum* access to water.

6.3.1.4. LIVE WEIGHT CHANGES

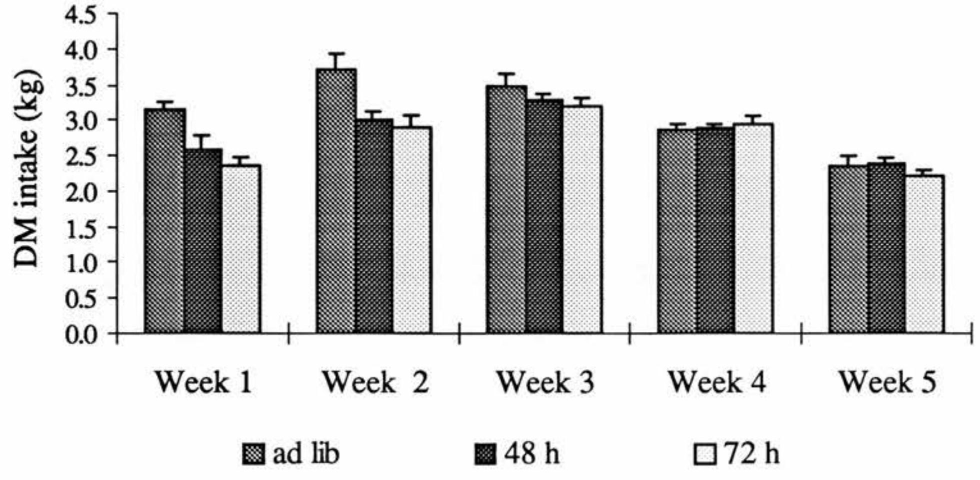
All donkeys lost weight during this study. The highest apparent weight loss was for donkeys deprived of water for 72 h, 5 kg compared with 3 kg and 1 kg for donkeys with *ad libitum* access to water and those deprived of water for 48 h, respectively. However, the differences in live weight loss were not significant.

Table 6.6: Mean daily dry matter intake (kg ± *sem*) of donkeys fed hay *ad libitum* and offered water either *ad libitum*, every 48 h or 72 h[1].

Treatment	Week 1	Week 2	Week 3	Week 4	Week 5	MEAN
ad lib	3.2 ± 0.11^{a}	3.7 ± 0.24^{a}	3.5 ± 0.16	2.9 ± 0.10	2.4 ± 0.15	3.1 ± 0.14^{a}
48 h	2.6 ± 0.20^{b}	3.0 ± 0.13^{b}	3.3 ± 0.07	2.9 ± 0.07	2.4 ± 0.07	$2.8 \pm 0.07^{a,b}$
72 h	2.4 ± 0.10^{b}	2.9 ± 0.17^{b}	3.2 ± 0.12	3.0 ± 0.11	2.2 ± 0.08	2.7 ± 0.09^{b}
Significance of difference	$P<0.004$	$P<0.006$	$P>0.189$	$P>0.786$	$P>0.512$	$P<0.02$

[1] results are means of 6 animals; means in the same column with different superscripts differ at $P<0.05$.

Figure 6.2: Mean daily DM intake (kg ± sem) of donkeys offered water *ad libitum*, every 48 h and 72 h for 35 days.



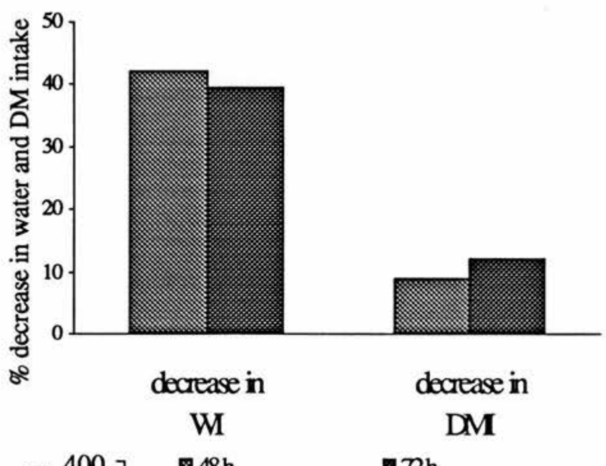


Figure 6.3: Decrease in daily DM intake (DMI) and water intake (WI) of donkeys offered water every 48 h and 72 h (% of intakes of donkeys offered water *ad libitum*) (*ad libitum = 100 %*).

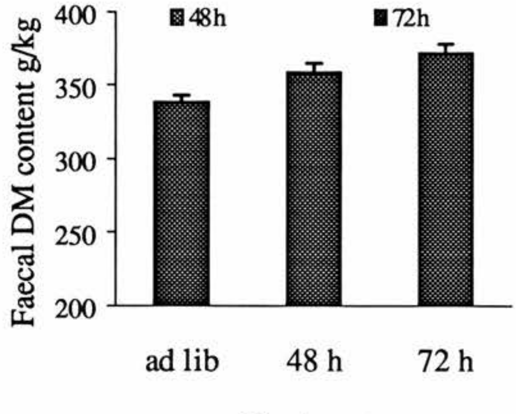


Figure 6.4: Faecal DM content (g/kg ± sem) of donkeys offered water *ad libitum*, every 48 h and 72 h.

6.3.2. WORKING AND FEEDING MANAGEMENT (WORK, TIME OF ACCESS TO FEED, VOLUNTARY FEED INTAKE, DIGESTIBILITY AND GASTRO-INTESTINAL TRANSIT TIME IN DONKEYS)

6.3.2.1. ANIMALS, FEEDING AND HOUSING

The mean live weight of the three teams when allocated to the treatment groups at the start of the study were similar ($P>0.05$); 154 ± 6.9 kg, 154 ± 7.0 kg and 155 ± 2.4 kg for Treatments 1, 2 and 3. All donkeys lost weight during the study. Overall, donkeys in Treatments 1 and 3 lost 6 kg compared with 5 kg for Treatment 2. The composition of the hay is shown in Table 6.5 (Section 6.3.1.2). Although the hay fed was from the same source (Spring Farm, Hay Distributors Ltd., Zimbabwe) and apparently from the same plots as in the first period, the quality of the hay fed during the second and third periods had deteriorated particularly in CP and NDF. The DM (g/kg) and chemical composition (g/kg DM) of the hay fed in Periods 2 and 3 was;

DM = 914; CP = 25.2; NDF = 872; ADF = 518

The donkeys adapted well to individual penning and feeding. During the one hour break between working sessions the donkeys did not always drink the water available.

6.3.2.2. DRY MATTER INTAKE, APPARENT DRY MATTER DIGESTIBILITY AND MEAN RETENTION TIME OF HAY

The results of DM intake, apparent DM digestibility and mean retention time of hay are shown in Table 6.7.

Table 6.7: Dry matter intake per day (kg ± sem), apparent dry matter digestibility (DMD) (% ± sem) and mean retention time (MRT) of hay (h ± sem) of working and non-working donkeys[1].

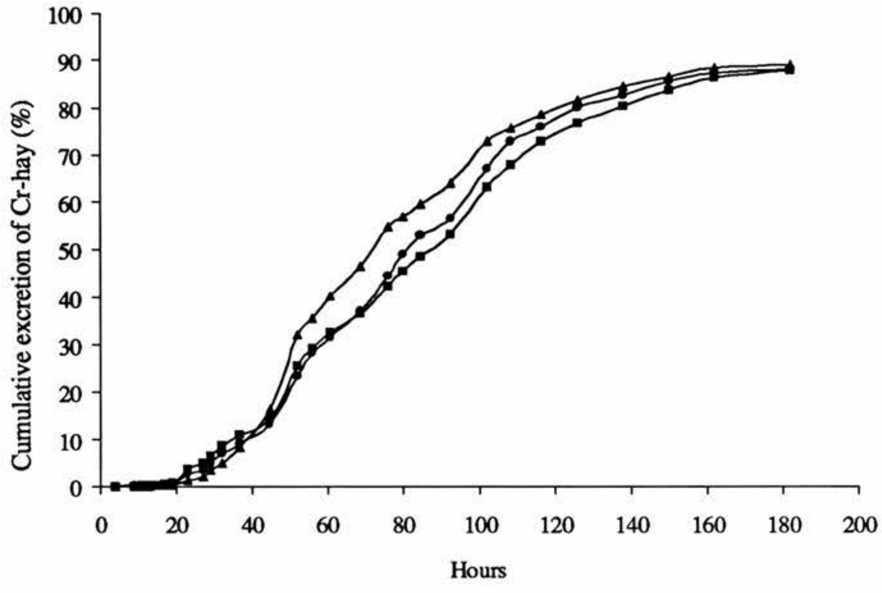
Treatment	DM intake	DMD	MRT (h)
1. Working/not feeding	3.3 ± 0.50	48 ± 0.3	70.4 ± 11.4
2. Not working/not feeding	3.5 ± 0.52	49 ± 0.2	77.6 ± 14.7
3. Not working/feeding	3.3 ± 0.41	41 ± 0.3	74.0 ± 14.3
Significance of difference	P>0.317	P>0.168	P>0.623

[1] results are means of 12 animals

The DM intake of donkeys subjected to work and those not working were similar ($P>0.05$) although those in Treatment 2 (not working/not feeding) tended to have a higher DM intake compared with those in the other treatment groups. Apparent DM digestibility was not affected ($P>0.05$) by the treatments but tended to be higher in working donkeys and those not working and not feeding (Treatments 1 and 2) compared with those not working but feeding (Treatment 3). Although the mean retention time (MRT) tended to be longer for donkeys not working and not feeding (Treatment 2), 77.6 h compared with 70.4 h and 74.0 h for donkeys working (Treatment 1) and those not working and feeding (Treatment 3), the differences were not statistically significant ($P>0.05$). The mean recovery rates of the Cr-hay in the collection and recording period was 90 per cent for all three treatments (Figure 6.5).

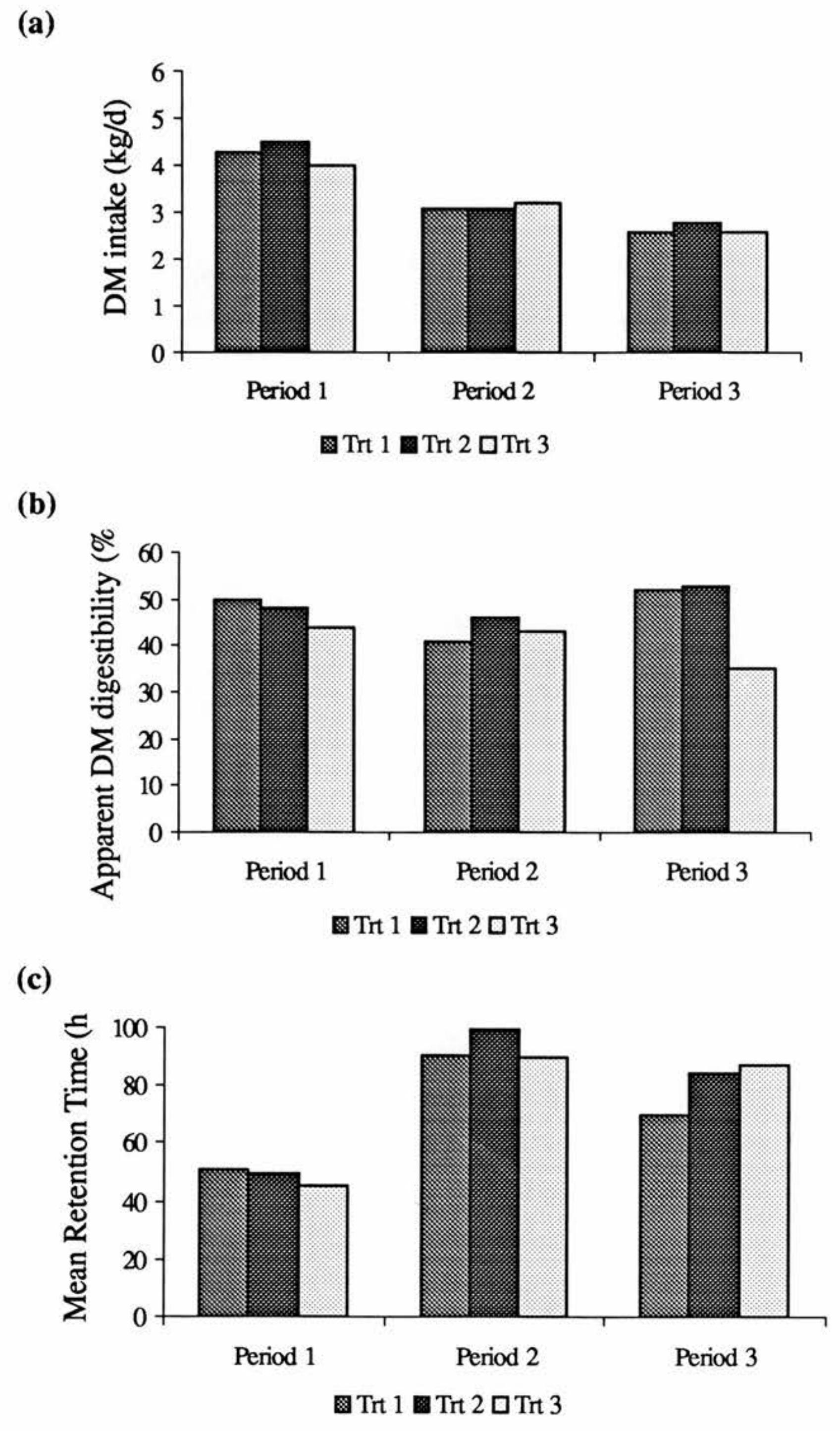
Because of the differences in the quality of the hay between Periods 1 and Periods 2 and 3, the effects of the quality of the hay were analysed per period, regardless of the actual treatments. The ANOVA by GLM procedure showed that DM intake of all donkeys as a group differed significantly between periods and was highest ($P<0.001$) in Period 1 compared with Periods 2 and 3. DM intakes were similar in Periods 2 and 3 (P>0.05). DM digestibility was not affected by period (P>0.05). The MRTs for the donkeys in Period 1 were significantly lower than those calculated in Periods 2 and 3 (P<0.001 and P<0.01), respectively. As a results, all donkeys lost weight in Periods 2 (20 kg) and 3 (2 kg) but had gained in Period 1 (5 kg). The differences between periods had little effect on the pattern of responses of the donkeys on the different treatments, thus the treatment effect was noticeable regardless of the period. DM intake, DM digestibility and MRT tended to be higher for donkeys on Treatment 2 (not working and not feeding) and similar for the other two treatments (Figures 6.6 a, b and c).

Figure 6.5: Cumulative excretion rates (%) of Cr-hay in the faeces of donkeys working (▲ Treatment 1), not working and not feeding (■ Treatment 2) and not working and feeding (● Treatment 3) (for each treatment, n = 12 animals, except Treatment 3, n = 10 animals).



6.3.2.3. TIME OF ACCESS TO FEED AND CARTING SPEED

The total time (including the 1 hour break) donkeys in Treatments 1 and 2 had no access to feed for the three periods, was 5.5 h, 5.1 h and 5.7 h per day. Thus time of access to feed was 18.5, 18.9 and 18.3 hours per day in Periods 1, 2 and 3. There was no effect on DM intake (P>0.05) compared with Treatment 3. The mean carting speeds for Teams 1, 2 and 3 (Periods 1, 2 and 3) were similar (P>0.05), 1.4 ± 0.05 m/s (5 km/h), 1.6 ± 0.12 m/s (5.8 km/h) and 1.3 ± 0.03 m/s (4.7 km/h).



Figures 6.6: The DM intake (kg/d) **(a)**, apparent DM digestibility (%) **(b)** and mean retention time (h) **(c)** of working and non-working donkeys in Periods 1, 2 and 3 (Trt = treatment).

6.4. DISCUSSION

6.4.1. WATER AVAILABILITY AND VOLUNTARY FEED INTAKE

There were no apparent adverse effects on the donkeys due to restricted access to water for 48 h or 72 h. For the three donkeys which sustained 96 and 144 hours without water (Section 6.3.1.2.) no apparent effects were observed. However, there was a marked decline in DM intake (DMI) particularly for the female donkey 1 in Treatment 3 after the initial 72 h without water from 2.2 kg DM/d to 1.2 kg DM/d (Figure 6.7). This donkey then increased its DMI after 96 hours without water, achieving a DMI of 3.1 kg DM/d on the day it drank water. Although DMI for those which had no water for 96 hours was depressed, the magnitude was less than for the donkey which had no water for 144 hours. This demonstrates the adverse effects of absence of water for prolonged periods on DMI of donkeys. Normal feed intake levels were restored by the animal after rehydration. This suggests that the periods of restricted access to water in this study (48 and 72 hours) were probably not excessive and the experimental donkeys were unlikely to suffer any long-term ill-effects. The relatively low ambient temperatures during the study (range -5°C to 26°C) could also have contributed to the absence of apparent adverse effects of the restricted access to water.

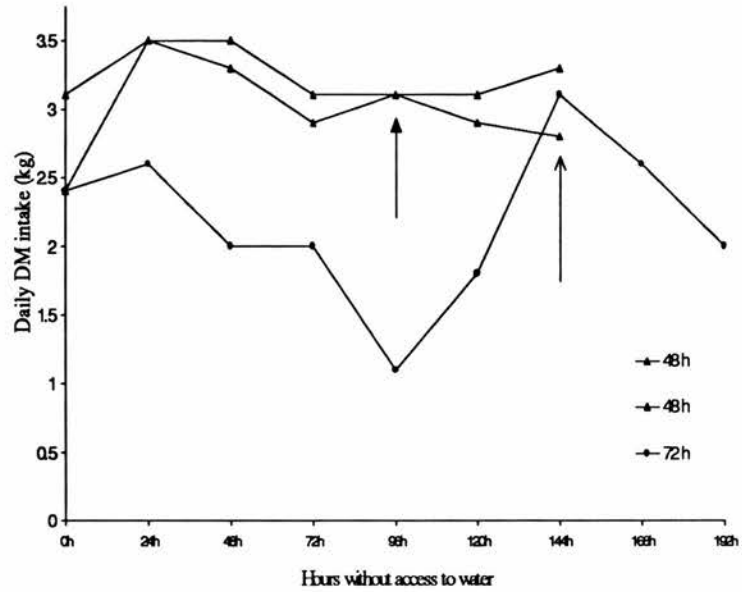


Figure 6.7: The DM intake of donkeys which did not drink water for 96 h (2 donkeys) and 144 h (1 donkey) (solid and open arrows indicate the DM intake on the days when the donkeys drank water after 96 hours and 144 hours, respectively).

The results clearly indicated that donkeys with restricted access to water drank less than donkeys with *ad lib* access (up to 42 per cent reduction). When mean daily water intake was calculated as a proportion of LW, donkeys with *ad lib* access to water consumed 5.9 per cent of LW, higher ($P<0.05$) than the two other treatments watered every 48 h (3.4 per cent) and 72 h (3.6 per cent). These water intake data were lower than reported for donkeys elsewhere. Mueller and Houpt (1991) reported water intakes of 7.6 and 7.0 per cent of LW for donkeys with *ad lib* (water offered every 4 hours) and those without water for 36 hours, respectively. The differences could be due to the adaptations of the donkeys to the different environments where they had evolved (New York and Matopos, respectively). Donkeys in the present study were probably adapted to conditions of limited water supply hence their lower intake as a proportion of LW compared with those adapted to the New York environment where management practices probably ensured that water supply was always plentiful.

Considering that donkeys with restricted access to water only had access for one hour, their ability to rehydrate was high and the results were consistent with those recorded for donkeys elsewhere. In a study by Jones, Houpt and Houpt (1989) donkeys that had no access to water for 19 hours were able to compensate for the deficit within one hour of water being available. In the present study, the period without water was longer and when water was made available, the donkeys drank up 60 per cent of the deficit, based on the water intake of donkeys with *ad lib* access. Indeed the observations during the one hour of drinking showed that the donkeys drank most of the water within the first 10 to 15 minutes. Donkeys have been observed to drink as much as 20.5 litres in 2.5 minutes without harmful effects (Schmidt-Nielsen, 1964; Houpt, 1993) or 24 to 30 litres in 3 to 5 minutes (Maloiy, 1970). This ability not to over-compensate is an advantage that donkeys have over cattle. Cattle appear to be wasteful in their water economy. Their water intake when ambient temperatures are high increases in response to the increased evaporative losses but the intake is generally above their requirements and there are corresponding increases in urine output (Schmidt-Nielsen, 1964). Ponies and horses have also been observed to over-compensate (Jones, Houpt and Houpt 1989) making them prone to water intoxication, a condition when large amounts of water are added to extracellular fluid (ECF), disrupting normal metabolic function of the cells (Houpt, 1993). Water intake is controlled by the hypothalamus and an increase in the tonicity of cerebrospinal fluid is an important stimulus to drinking (Forbes, 1995). According to Yousef, Dill and Mayes (1970) one of the possible mechanisms in the donkey's water economy is the existence of a volumetric inhibitor receptor in the hypothalamus which responds to gastric distension with a turn-off signal. This could explain the donkey's ability to avoid water intoxication after periods of water restriction.

There is a close association between water intake and food intake. Voluntary water intake is normally twice the amount of DM consumed (Forbes, 1995). Thus when access to water is restricted, there is a corresponding decline in food intake. During drought, although both water and food availability are major limiting factors, the effects of water scarcity are more detrimental to the survival of livestock. One of the factors contributing to the ability of donkeys to survive droughts, is their ability to continue feeding despite the scarcity of water (Dill *et al.,* 1980).

The results of the present study showed that donkeys with restricted access to water were indeed capable of maintaining voluntary food intake similar to their counterparts with *ad lib* access, only 13 per cent less, compared with a reduction of 42 per cent in water intake. And considering that the hay fed to the donkeys had a high fibre content (NDF = 780 g/kg DM), the requirement for water would have been greater than if they had been fed a lower fibre diet.

Mueller and Houpt (1991) reported that donkeys deprived of water for 36 h had depressed hay (CP = 72 g/kg DM, NDF = 640 g/kg DM) intake by 13 per cent when compared with the controls (*ad lib* watering) although water intake was only 5 per cent ($P<0.05$) less than the controls indicating that the donkeys almost made up for the deficit incurred during the 36 hours of deprivation. The greater reduction in water intake in the present study could be attributed to the longer duration of water deprivation (48 h and 72 h). As with the water intake, the DM intake as a proportion of LW tended to be lower in this study than in reports elsewhere. For example, they were lower than those reported by Mueller and Houpt (1991), 4.1 and 3.3 per cent of LW for donkeys with *ad lib* access and those deprived for 36 hours, respectively. The DM intake of donkeys in the present study was only 2.2, 2.0 and 1.9 per cent of LW for donkeys with *ad lib,* 48 h and 72 h access respectively. The results are however similar to those of Mueller (1996) who reported DM intakes of donkeys in Niger of 2 per cent of LW or lower, when fed poor quality millet stover and Pearson (1991b) who reported DM intakes of hay (CP = 63 g/kg DM; NDF = 737 g/kg DM) of 2.2 per cent of LW.

The different levels of DM intake are most likely a reflection of the quality of the feed offered. The quality of the hay in the present study was similar to that in the work of Pearson (1991b), slightly better than millet stover (Mueller, 1996) but poorer than that offered in the work of Mueller and Houpt (1991). The donkeys reported on here with restricted access to water required two weeks to adapt their DM intake in response to the water restriction as indicated by the significantly lower DM intake in the first two weeks of the study compared to those with *ad lib* access (Table 6.6 and Figure 6.2).

Other studies have also demonstrated the ability of the donkey to continue feeding despite what would be regarded as severe dehydration in other domestic species. Yousef and Dill (1969) listed among the advantages of the donkey their ability to eat and walk despite dehydration. The continued saliva secretion by dehydrated donkeys has also been identified as one of the reasons for the donkey's ability to continue feeding despite shortage of water (Yousef *et al.*, 1970). The desert adaptation of donkeys make them more likely to survive than cattle in drought-prone regions and of the domestic draught animals, only the camel is more likely to achieve this (Schmidt-Nielsen, 1964; Kawashti, Omar and Mageed, 1979).

Other possible mechanisms for the ability of the donkeys to survive include a reduction of basal metabolic rate leading to a reduction of oxygen demand and therefore reduced respiratory water loss (Louw, 1984) or allowing body temperature to rise during the day and lose the heat during the night by radiation (adaptive hyperthermia) as has been observed to a greater extent in the camel (Schmidt-Nielsen, 1964; Louw, 1984).

Another advantage of donkeys in conditions of limited supply of water is their ability to conserve it by restricting losses from the body. Animals lose water through evaporative losses (sweating), expired gases and through the faeces and urine. Evaporative, expired gases and urine water losses were not measured in this study. However, losses of water through the faeces showed that donkeys were capable of reducing losses when water supply was limited. Donkeys with access to water every 72 hours reduced the faecal water content by about 10 per cent compared to those with *ad lib* access to water ($P<0.01$). Maloiy (1970) showed that in hydrated and dehydrated Somali donkeys exposed to ambient temperatures of 22°C, 50 per cent of the total water lost from the body was faecal water. Thus, the amounts of water lost through the faeces can be high. Therefore, reductions in faecal water losses as achieved by the donkeys in the present study, would conserve body water and increase chances of survival during water scarcity. Maloiy (1973) also found that donkeys with restricted water intake (animals deprived of water until they lost 15 per cent of body weight) produced faeces with 9 to 10 per cent less water than their contemporaries when watered *ad libitum*. This could be due to a greater water resorption capacity in the hindgut when water supply is limited. Cattle do not seem to have this capacity (Forbes, 1995) or any special water conservation mechanisms (Houpt, 1993) which exposes them to drought conditions now prevalent in Zimbabwe and the sub-region. Dehydration to the extent of 10 per cent of live weight is considered severe (Houpt, 1993), yet donkeys and to a greater extent, camels have been shown to survive body weight losses of 30 per cent during dehydration (Maloiy, 1970). Although donkeys in the present study lost weight due to the reduced DM intake resulting from the restricted access to water, the losses of this magnitude, 5 kg and 2 kg in 35 days, for donkeys watered every 48 h and 72 h, were unlikely to have any practical significance on their performance.

6.4.2. WORKING AND FEEDING MANAGEMENT (WORK, TIME OF ACCESS TO FEED, VOLUNTARY FEED INTAKE, DIGESTIBILITY AND GASTRO-INTESTINAL TRANSIT TIME IN DONKEYS)

The study reported here evaluated the responses (feed intake, digestibility and the mean retention time of hay) of donkeys subjected to work and to time of access to feed. It has been shown that in the short term, there are increased energy and nutrient requirements caused by work (Matthewman, Dijkman and Zerbini, 1990) and if working animals are fed at maintenance, they would have to increase intake to match the increased requirements of work which can be 1.3 to 1.8 times maintenance requirements in cattle (Lawrence, 1985). During work animals have no access to feed thus their body reserves (mainly fat and protein) are likely to be depleted and they may lose weight as a result. The results of the present study showed that working donkeys did not increase their feed intake (P>0.05). Feed intake for the working (Treatment 1) was 3.3 kg DM/d compared with 3.5 and 3.3 kg DM/d for not working and not feeding (Treatment 2) and the not working and feeding teams (Treatment 3) (Table 6.7). Pearson and Merritt (1991) found no increase in hay or straw intake when donkeys were subjected to exercise consisting of a 14 km walk and ascending 260 m at 3.6 km/h for 5 days a week. Dry matter intake was 4.3 kg DM/d for exercising and 4 kg DM/d for non-exercising donkeys (P>0.05).

In the present study, the lack of effect on feed intake of the work could be attributed to the poor quality of the hay fed. This is mainly due to the slower breakdown in the GIT of the fibrous components of poor quality roughages which are characterised by a high NDF content. In mature grasses digestibility of roughages is further decreased by the presence of the virtually indigestible lignin (Czerkawski, 1986). Thus, the poorer the quality of the roughage basal diet the less likely will the donkeys increase their intake of the roughage in response to the increased energy and nutrient demands of work. Pearson and Merritt (1991) also attributed the lack of increase in DMI in response to the nutrient and energy demands of work, particularly to the poor quality of the straw. They recommended that the quality of the roughage be improved for working animals to increase their DMI and sustain their live weight and work. Mathers and Otchere (1990) suggested that the particle size of the roughages fed to working cattle could influence the rate at which the particles are comminuted by physical (chewing) attack and microbial digestion. In the study reported here, the hay was fed long and this could have limited the response in DM intake of working donkeys. Thus, the physical form of the roughage can also affect the DM intake of working animals in response to the work.

Studies with horses (Orton *et al.,* 1985) have shown that when subjected to light exercise, they were capable of increasing DMI of moderate quality roughages. The horses were fed diets based on chopped oaten hay and rice (with 6.1 to 14.1 per cent CP). They were exercised by trotting at 12 km/h for one hour, DMI being higher for the exercised than non-exercised horses.

In the present study, although there were no significant differences ($P>0.05$) between working and non-working donkeys in the digestibility of the hay, donkeys in Treatments 1 and 2 (working and not working and not feeding) tended to have higher apparent digestibilities of the hay DM of 48 and 49 per cent compared with 41 per cent for Treatment 3 (not working but feeding) (Table 6.7). Presumably this could have been because working donkeys had no feed for over 5 hours and considering that mean daily DM intakes were similar for all treatments, the volume of the gut contents for working donkeys would have been relatively less than for those with continuous access. The movement during work could have stimulated greater mixing and churning of the digesta with digestive enzymes leading to an improvement in the breakdown of the roughage. This could also explain the relatively high apparent DM digestibility of donkeys in Treatment 2 which although not working, had no access to feed for at least 5 hours, during which time gut contents could have been lower than for donkeys with *ad lib* access to feed. This could have enhanced greater mixing and churning of digesta hence the slightly higher apparent DM digestibility compared with donkeys not working. Soller, Reed and Butterworth (1991) also reported increased apparent DM digestibility in exercised oxen but no increase in feed intake. In cattle and buffalo, increases in feed intake and liquid outflow rates were observed in animals subjected to what was considered heavy work when compared with animals doing lighter work (Bakrie *et al.* 1989). Although liquid digesta outflow rates were not measured in the present study, increases in liquid outflow rates could have been correlated to the observed faster outflow rate of the solid digesta and this could have contributed to the working donkeys at least maintaining similar feed intakes to those not working.

Gut motility was also more likely to increase with working donkeys than those not working probably effecting faster rates of passage of the solid digesta. Clapperton (1964) suggested that because exercise increases body temperature, fermentation rates in exercised sheep in his study could have been enhanced thereby improving digestibility. Although this could not be verified in the present study, it is possible that increased body temperature of the working donkeys due to the carting could have enhanced their hindgut fermentation. Donkeys have the ability to utilise efficiently the soluble carbohydrates of the roughages such as the sugars and also the proteins (Izraely *et al.,* 1989). When donkeys are subjected to work, the increased demands for energy in particular might encourage greater enzymic secretion in response to this demand. Fermentation in the hindgut might also be enhanced during work to meet these increased demands and this would account for the improvement in digestibility.

The results also show that the mean retention times were similar ($P>0.05$), although they tended to be shorter for working donkeys than those not working (70 h, 78 h and 74 h, for treatments 1, 2 and 3). Perhaps, surprisingly in this case, the rate of passage (70 h) for working donkeys which tended to be faster than for donkeys not working, was accompanied by a slightly higher ($P>0.05$) apparent DM digestibility of 48 per cent compared with 41 per cent for donkeys not working. Faster rate of passage is often associated with higher intake, as was observed in horses (Orton *et al.*, 1985) but poorer digestibility. However, in the present study there was no increase in intake but the donkeys appeared to have an ability to digest the roughage well, while maintaining a faster throughput of digesta. Cuddeford *et al.* (1995) observed better digestibilities of fibre for donkeys when compared with other equids (Thoroughbreds, Shetland and Highland ponies) and attributed this to the longer MRTs (slower rates of passage) in donkeys. However, the MRTs for donkeys reported in the study of Cuddeford *et al.* (1995) were lower, even on the straw diet (61.2 h) than those recorded in the present study (lowest MRT of 70.4 h). The differences between the roughages fed in these two studies (chopped molassed oat straw and hay) were the NDF and CP content which were 621 g/kg DM and 48 g/kg DM (Cuddeford *et al.*, 1995) compared with 780 g/kg DM and 60 g/kg DM in the present study. The readily soluble sugars in the molassed oat straw and the particle size of the straw would probably have contributed to the observed lower MRT. Pearson and Merritt (1991) reported that although values for digestibility were higher in exercised donkeys over those not exercised, the differences were not significant.

Although the working donkeys and those not working and not feeding (Treatments 1 and 2) had no access to feed for at least 5 hours, they still maintained DM intake similar to those not working and feeding (Treatment 3) suggesting that the donkeys were able to compensate for the time when they had no access to feed. Therefore, in the conditions of this study, the time of access to feed had no effect on intake. However, in the smallholder farming sector, donkeys are likely to be without access to feed for periods longer than those in this study because apart from working longer hours (up to 7 hours, Chapter 3), donkeys are penned overnight generally for 12 hours or more further decreasing the time of access. If the worst possible situation is assumed, donkeys worked for 7 h/d and penned overnight for 12 hours effectively have only 5 h/d or less for feeding and other activities.

Earlier studies (Nengomasha, Nyama and Mpofu, unpublished data) have shown that in an 8-hour day donkeys spent 60 per cent of the time grazing (4.8 h). Therefore, considering that the donkey has other activities (walking, standing, resting, rolling/grooming) the 5-hour period per day would not be sufficient for the donkeys to graze adequately to meet their daily DE requirements (see below). A study with penned donkeys fed grass and mixed hays (Mueller, 1996) reported that they required 120 ± 12 min to consume a kilogramme of DM. Donkeys grazing on natural pastures would most likely require more time to consume the same amount, due to various other factors including selection of preferred grass species, bite rates, bite sizes, quantity/density of the herbaceous biomass, ambient temperatures. Even assuming donkeys can consume at the rates reported by Mueller (1996), the donkeys would require at least 6 hours of continuous grazing to achieve a DM intake of 3 kg, a DM intake level of 2.2 per cent of LW for the average "Zimbabwean" donkey weighing 142 kg and would probably still not meet their daily DE maintenance requirements of 24 MJ/d, depending on the quality and quantity of the grazing.

The poor quality of the hay with a DE content of 7.1 MJ/kg DM could have resulted in the observed loss of weight by donkeys in all treatments in this study. At a mean DM intake of 3.4 kg for all treatments, the daily DE intake was estimated at 24.1 MJ. Estimated daily DE requirements of donkeys for maintenance have been generally based on estimates for ponies using the following equation (Ellis and Lawrence, 1980):

$$DE\ (kJ/d) = 465\ LW^{0.75}$$

Thus, for the donkeys in this study (mean LW 155 kg), the daily maintenance requirements for DE would be 20.4 MJ/d. Assuming that the maintenance requirements according to Ellis and Lawrence (1980) are applicable to donkeys in the present study, their daily DE intakes were higher (24 MJ/d) and the donkeys should have at least maintained weight. However, considering that energy requirements for work are estimated at 1.3 to 1.8 times maintenance (Lawrence, 1985), even at the lower estimate of 1.3 times maintenance, the donkeys would have required at least 27 MJ/d or 37 MJ/d at the upper estimate of 1.8 times maintenance. McCarthy (1989) suggested that the daily DE requirement for donkeys can be assumed to be about 75 per cent that of horses:

$$DE\ (kJ/d) = 487\ W^{0.75}$$

thus the requirements for donkeys in this study would be estimated to be 21.4 MJ/d, slightly higher than that based on ponies. Mueller (1996) using calorimetric and feeding trial data based on donkeys derived daily DE maintenance requirements of 154 to 155 kJ/kg LW/d and for the donkeys in the present study (mean LW 155 kg) the estimated daily DE requirements would be 23.9 to 24.0 MJ/d. The requirements for maintenance and light work were estimated to be 190 to 193 kJ/kg LW (Mueller, 1996) or calculated to be 29.5 to 29.9 MJ/d for donkeys in the present study. This suggests that the DE intakes of donkeys in the present study were below the requirements for maintenance and light work (Mueller, 1996), as indicated by the weight losses of 5 to 6 kg. Thus, depending on the time of year and DAP requirements, supplementing working donkeys fed poor quality roughages or offering them better quality roughages might be necessary if the donkeys are to maintain their live weight and body condition. The advantage is that donkeys used for ploughing in the wet season would most probably compensate by increasing intake of the better quality grazing normally abundant at the start of ploughing and throughout the growing season.

CHAPTER SEVEN

7. CONCLUSIONS AND RECOMMENDATIONS

7.1. STATUS OF DRAUGHT ANIMAL POWER IN ZIMBABWE

The results of the RRA revealed that smallholder farmers are facing a shortage of DAP, particularly from cattle. The shortage of cattle for DAP has increased the demand and use of donkeys, particularly in the drier Semukwe area and in Chikwanda. Smallholder farmers with access to DAP achieved higher crop yields than those with limited or no access to DAP (Ellis-Jones *et al.,* 1994; Muvirimi, 1997). However, the RRA clearly showed that extension information on good management practices and general welfare of draught animals, particularly donkeys, is urgently required. For example, the use of yokes on donkeys in Chikwanda, exposed the lack of basic extension information on good management of donkeys, contributing to observed poor management practices in this area. Therefore, research and extension information on good management practices for donkeys is necessary if the use of donkeys in these areas is to be improved.

The DAP shortage could be partially alleviated by increased sharing of the available DAP resources. Sharing arrangements of DAP, especially during the peak ploughing season, should be encouraged through increased contract hiring of DAP or farmers pooling their DAP resources as practiced in Semukwe. The benefits of contract ploughing, such as monetary remuneration or provision of labour by those with inadequate DAP should be demonstrated to farmers with more than adequate DAP. Information and training in aspects of business management could be provided to farmers with more than adequate DAP by extension services in conjunction with NGOs.

7.2. CHARACTERIZATION OF THE DONKEY

The results suggest that potentially similar draught performances could be expected from male and female donkeys because the morphological attributes showed little differences between the sexes apart from umbilical girth. The mean live weight of donkeys in this study of 142 ± 1.4 kg and the predominant light grey coat colour and the characteristic shoulder "cross", were indications that these donkeys could indeed have originated from the Nubian wild ass (*Equus asinus africanus*). The donkeys in the present study were fundamentally similar in frame-size to their counterparts in the sub-region and other parts of Africa (Wilson, 1981) e.g. Morocco (Pearson and Ouassat, 1996) implying that these donkey types could be related. Although environmental factors such as ecological zones, nutrition and management of this species could result in features specific to donkeys in the different regions, it is probable that results obtained from one group could apply to their counterparts on the continent, given the similarities between them.

Of the predictive equations for estimating the live weight of adult and growing donkeys in this study, that which included a single variable had heart girth as the most accurate ($r^2 = 0.864$). Heart girth was also one of the easiest measurements to take and when included in predictive equations with other body measurements, for example with body length, was accurate in estimating live weight (adjusted $r^2 = 0.887$). Although umbilical girth was the second best single predictor ($r^2 = 0.753$) of live weight, its accuracy could be compromised by pregnancy and "hay bellies" in donkeys feeding on poor quality roughages. These cause distention of the umbilical girth and result in overestimating of the actual live weight. Weighbands and nomograms produced from the predictive equations with heart girth would be important management tools for smallholder farmers. The other body measurements were less accurate when included individually in predictive equations. Although it may be necessary to verify the accuracy of the predictive equations derived in the present study, the apparent similarities between donkeys in Zimbabwe and those in other parts of Africa and the nutritional and working environments to which they are exposed suggest that these equations could apply to donkeys elsewhere in Africa and vice versa. Predictive equations (e.g. Eley and French, 1993) based on donkeys exposed to environments where nutrition and management are much better than in most parts of Africa such as in Britain, tend to overestimate the live weight of donkeys in Zimbabwe and are therefore not practical to use.

The results of the present study show that seasonal fluctuations in live weight and body condition of donkeys occur in Zimbabwe. The seasonal fluctuations were most probably due to grazing availability. However, donkeys appear more capable of maintaining live weight and body condition than cattle particularly in the dry season. This was reflected in the magnitude of weight loss which was comparatively less in donkeys, 4 per cent in the present study compared with weight losses ranging from 12 to 30 per cent which have been reported in cattle (Ndlovu *et al.,* 1996; T. Smith, pers. comm.). Therefore, donkeys are more likely to be in better condition at the end of the dry season than cattle. Smallholder farmers could take advantage of this ability of donkeys and use them as a viable alternative source of DAP at the start of the ploughing season when the demand for DAP is highest. The use of donkeys could also give the cattle time to regain their live weight and condition when grazing becomes more abundant as the wet season progresses. Since the wet season also coincides with the peak demand for beef, this could be the opportune time for farmers to fatten cattle for marketing while using donkeys for draught purposes.

Although disease manifestations on the live weight and body condition of donkeys were not investigated in this study, the effects of these on draught output of donkeys should be investigated.

7.3. DRAUGHT POTENTIAL OF THE DONKEY

Farmers are encouraged to select the heaviest available donkeys, particularly for ploughing. The results of the present study showed that heavier teams of donkeys produced more power output and worked at faster speeds ($P<0.05$) than lighter teams on all soil types. Thus, the combined live weight of a team has a significant influence on the draught capacity of donkeys. Lighter teams exerted relatively higher draught forces as a proportion of live weight (16 per cent) compared with heavier teams (13 per cent). The greater exertion by the lighter teams resulted in earlier onset of fatigue making these teams less suitable than heavier ones for ploughing, a task which requires endurance.

Live weight had the greatest effect on the draught capacity of donkeys in the present study. Body condition and sex appeared to have had lesser effects than live weight. This was indicated by the similar draught performance of lighter teams of male and female donkeys in the present study. Therefore, for ploughing farmers would benefit more from using heavier donkeys regardless of sex and body condition. However, the effects of pregnancy should not be ignored when jennies are used for work. Although the effects of work on reproduction of the jennies have not been evaluated, it could be assumed that similar to pregnant females of other species, any stress such as work particularly in the last third of gestation, could have adverse effects on the jennies and, in the short-term, induce abortion. Possible long-term effects on jennies probably include lower reproductive rates. This topic requires further investigation.

The effects of castration on the draught performance of male donkeys were not investigated during this study. Although the jack-asses used in on-station and on-farm studies were not considered "temperamental", in general jack-asses tend to be less docile and more difficult to handle than geldings. Farmers should castrate most of their male donkeys and only maintain a few jack-asses for selective breeding. This also minimizes the risk of serious injuries through fighting, typical with jack-asses which often results in serious, even fatal injuries.

The donkey teams appeared to work better with the lighter Walco plough than the heavier conventional ox-drawn plough. Draught requirements were significantly less for the Walco (745 N) than for the conventional ox-drawn plough (811 N). Power output, speed of working, ploughing depth and width were similar for the two ploughs. However, there could be other factors apart from the gravitational weight, for example angle of pull which might affect the draught requirements of ploughs. The Implement Study within the ZIMDAP project investigated some of these aspects.

There is a need for more collaborative research involving agricultural engineers, implement manufacturers and animal scientists to examine the draught requirements of implements in relation to the work output of animals.

Cattle have a higher draught capacity than donkeys, a reflection of the differences in the live weights between the two species. When comparisons were made on a weight to weight (kg LW) or on metabolic body weight (kg $LW^{0.75}$) basis, the draught capacity of teams of donkeys was generally similar to that of the oxen. However, the draught capacity per kg $LW^{0.75}$ of the team of donkeys would have been higher than that of the team of oxen considering the loss of efficiency per animal in a team, 22 per cent for 4 animals (Goe, 1983) (4 animals in the donkey teams compared with 2 animals in the oxen team in the present study). Interestingly, the reduction in the efficiency per animal with an increase in the number of animals in a team would imply that there could be advantages in using smaller teams (provided the total team weight is sufficient to carry out the prescribed draught task) for shorter working periods than larger teams for longer working periods. For example, the overall efficiency (using e.g. EFC, h/ha as a measure of efficiency) of using 4 animals in one team or in two teams of two in a working day could be compared. Farmers would then have options to make the best possible use of the available DAP and other resources, for example labour and time, through better organisation and efficient management of these resources.

The studies on-farm clearly showed the importance of training and experience of animals used for work and to some extent the handling of the animals by the drivers. Better trained and experienced teams did more work than those not properly trained and, or, inexperienced. In Nkayi District the results and observations showed that the effect of training and experience in cattle was more important than the combined weight of the team (see Teams 8 and 2 in Table 5.2). However, at the same level of training and experience, the combined live weight of the team should be dominant. It is difficult to objectively assess level of training in draught animals. Further investigations on the assessment of level of training and experience are necessary.

The observations on the use of coercion on working animals showed that when whipped, animals tended to move faster and produce more power output but only momentarily. However, donkeys were unlikely to sustain working at these higher levels of exertion (assuming constant use of coercion) and their performance would deteriorate due to fatigue. Only "minimal" coercion, necessary to "encourage" the donkeys to work, should be used.

Indications from the results suggest that mixed species teams can be used for ploughing and other draught purposes. The draught capacity of these teams appear to be intermediate when compared with the performance of cattle-only and donkey-only teams. The use of donkeys and cattle in mixed teams combines the abilities of donkeys to lead and follow furrows thereby requiring no leading (less labour requirements) and the greater power generation of the cattle at the rear where tractive effort is apparently higher. It is important that the two species are trained to work together and proper harnessing is used.

Currently available breastband harnesses are appropriate for use with donkeys. However, these could be modified by making the backstraps adjustable (as those used in the present study) to enable proper fitting on all donkey sizes. All edges on the harnesses should be smoothened and bolts and nuts used should not protrude to avoid injuries to the donkeys. Although collar harnesses are also very suitable for donkeys, they are more complicated to manufacture and more expensive than breastband harnesses. Simpler designs of collar harnesses using readily available materials such as rubberized canvas used in conveyor belts could be examined.

7.4. NUTRITION OF THE DONKEY

The results of the present study showed that in ambient temperatures ranging from -5 to 26°C donkeys were capable of continuing to feed despite having no access to water for three days. Although there was a significant reduction in DM intake when donkeys were watered every 48 h and 72 h, of up to 13 per cent when compared with donkeys with *ad libitum* access, the reduction in water intake was greater, up to 42 per cent. This ability of donkeys to continue feeding in the absence of water contributes to their overall survival capacity during drought. This continued feeding was achieved despite the poor quality of the hay offered to the donkeys. Donkeys with restricted access to water were also capable of minimizing the water lost from the body by producing faeces 10 per cent drier than for donkeys with *ad lib* access. This could be another water conservation mechanism beneficial during periods of water scarcity. The donkeys with restricted access to water were capable of rehydrating quickly when water was available, consuming 60 per cent of their deficit within the hour of water availability. These adaptive mechanisms which have been observed in donkeys elsewhere (Schmidt-Nielsen, 1964; Maloiy, 1970; Jones, Houpt and Houpt 1989) make them more suitable than cattle in the semi-arid regions of Zimbabwe.

Work did not have an effect on voluntary feed intake. The apparent lack of effect was primarily attributed to the poor quality and physical form of the hay fed in this study (Table 6.5). Because of the poor quality of the hay, the mean retention time through the GIT was long (70.4 h) and the working donkeys were thus not able to increase intake.

Therefore, working donkeys subjected to long periods of continuous work are unlikely to compensate for the time lost by increasing intake of poor quality roughage. Farmers should therefore allow the donkeys to graze for a longer time or work for shorter periods. A working donkey (mean live weight 142 kg) with a daily DE requirement of about 27 MJ/d consuming a poor quality hay (about 7.1 MJ/kg DM) would need to consume about 3.8 kg DM/d. Assuming a DM intake rate of about 1 kg DM in two hours, these donkeys would require at least 8 hours per day of continuous grazing. When other activities (walking, standing, resting, mating etc.), are considered then donkeys would require more than 13 hours at pasture a day. This would be difficult to achieve if the donkeys have to work for up to 7 hours per day and are penned overnight. To overcome this donkeys could be left to forage at night or increase the energy intake of working donkeys by feeding them supplements.

Although commercial supplements (concentrates) are expensive, small amounts (about 200 g/head/d) fed to working donkeys will increase their energy and protein intake and enhance intake of roughages. Currently in Zimbabwe there are no commercial supplements for donkeys. However, some concentrates formulated for cattle for example dairy and veld fattening meals, have been fed to donkeys and resulted in increased live weight gains (Pluke and Nengomasha, unpublished data). On-farm demonstrations could be carried out to show smallholder farmers the benefits of feeding these concentrates to working donkeys.

Home-grown supplements such as stovers, would be cheaper than commercial supplements. Fruit pods of *Acacia tortillis, Acacia nilotica* which have been fed to sheep (S. Ncube; J. S. Dube, pers. comm.) could also be fed as supplements to working donkeys. Other supplements include brewing by-products *masese,* which would provide supplementary energy and protein.

The physical form of the roughage will also affect the voluntary intake of roughages by working donkeys. Accordingly, if stovers are offered to working donkeys, they should be chopped to reduce particle size, probably increasing voluntary intake.

Future studies could investigate the responses of donkeys to roughages of different quality and form; promoting the use of commercially available concentrates as supplements and formulating low-cost concentrates for donkeys.

7.5. CONCLUSION

The studies reported in this thesis have highlighted the important role of donkeys in the semi-arid regions of Zimbabwe. The importance of donkeys is likely to increase in these areas, where the susceptibility of cattle to the recurrent droughts has been exposed. Thus, farmers in these areas would benefit more from using donkeys for DAP than cattle. From the results of this study, typically a smallholder farmer would require four donkeys or two oxen for DAP requirements. Assuming that the team of four "heavy" male donkeys (mean live weight 156 kg) used in the on-station study (Chapter 5), was "optimal" for ploughing, some comparisons based on the results of this study and also general observations are made between this and the team of two oxen used on-station. These are presented in Table 7.1. The one major disadvantage of the donkey is lack of residual value. However, this also means that its working life can be much longer than for cattle. The advantages of donkeys generally outweigh the disadvantages.

The results of this study can serve as a basis for further investigations into the potential of donkeys ultimately optimizing the use of this species as an alternative or supplementary source of DAP to cattle in the semi-arid areas where it is best suited. It is envisaged that future research work on donkeys could investigate the following topics:

1. the effects of endo and ectoparasites on the draught performance of donkeys
2. the effects of castration on the draught potential of male donkeys
3. the efficiency of using mixed species teams for DAP
4. the efficiency of using varying numbers of donkeys in a team

5. the effects of quality of feed on voluntary feed intake and work output of donkeys

6. the effect of training and experience on the draught performance of donkeys

7. formulation of low-cost and use of home-grown supplements for donkeys

8. the long-term effects of work on the reproductive capacity of jennies

Table 7.1: Some comparisons, based on current results and general observations, between draught teams of 4 donkeys (considered "optimal") and 2 oxen used in the on-station study.

	4 donkeys	2 oxen	Remarks
Mean live weight (kg)	156	339	
Energy requirements (DE) for maintenance/day[1]	97 MJ	100 MJ	similar total maintenance requirements for team
Energy requirements (DE) for work[2]	136 MJ	140 MJ	when fed limited quantities of poor quality roughages, donkeys are more likely to meet energy requirements for work by increasing intake through faster rate of passage of digesta (see Janis, 1976)
Ploughing capacity (h/ha)	14.2	14.5	capacity similar ($P>0.05$)
Power output (W)	689	920	power output similar($P>0.05$)
Days to plough a 3 ha plot[3]	10.7	10.9	similar efficiency
Condition at start of ploughing season	better	worse	donkeys can be used for ploughing earlier than cattle at the start of wet season
Susceptibility to drought	lower	higher	donkeys more capable of feeding without water than cattle and therefore better suited to drought conditions in semi-arid areas
Susceptibility to disease	lower	higher	donkeys generally less prone to diseases and therefore more reliable
Working life	longer	shorter	in the long-term donkeys can supply more DAP than cattle
Purchase price	lower (Z$800/head)	higher (Z$3 000/head)	donkeys much cheaper to acquire

[1] energy requirements for maintenance for donkeys calculated as 155 kJ DE/kg LW (Mueller, 1996) and for the oxen calculated as 40 MJ ME/d (after Smith, 1991); requirements for oxen converted from ME to DE equivalent for comparisons. [2] requirements for work estimated as 1.4 times maintenance (Lawrence, 1985) for donkeys and cattle [3] assuming a 4 hour working day.

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APPENDICES

Appendices for Chapter 3 (Appendices I):

Appendix I: Working programme for RRA team from 14th to 26th August, 1994 (adapted from Ellis-Jones *et al.*, 1994).

Date.	Activity
14.08.	Initial team meeting at Matopos Research Station
15.08.	Travel to Matobo District am: Meet AGRITEX officers am: Meet Animal Health Inspectors pm: Meet Chief and Councillor in Semukwe Communal Area
16.08.	Travel to Matobo District am: Meet farmers and AEW at Sontala Primary School (Semukwe) pm: Meet farmers at St. Anna Primary School (Semukwe) pm: Meet individual farmers
17.08.	Travel to Esigodini (*en-route* to Masvingo Province) am: Meet DAEO for Matobo District pm: Travel to Gwanda, meet Matabeleland South Provisional AGRITEX staff pm: Travel to Masvingo (Masvingo Province) pm: RRA team meeting to discuss findings in Semukwe
18.08.	am: Meet Masvingo Provisional AGRITEX staff pm: Travel to Gutu District, meet District AGRITEX staff
19.08.	am: Meet local leaders Chikwanda Communal area pm: Meet farmers and AEWs
20.08.	am: Meet individual farmers pm: Travel to Matopos Research Station pm: RRA team meeting to discuss findings in Chikwanda
21.08.	FREE
22.08.	Travel to Gweru (Midlands Province) am: Meet Provincial AGRITEX staff pm: Travel to Gokwe South, meet Animal Health Inspector pm: Travel to Sanyati
23.08.	am: Meet Gokwe North District AGRITEX staff pm: Meet local leaders Sebungwe Communal area
24.08.	am: Meet farmers in Sebungwe pm: RRA team meeting to discuss findings in Sebungwe
25.08.	Travel to Kadoma Cotton Training Centre (CTC) am: Meet CTC staff pm: Travel to Matopos Research Station
26.08.	RRA team meeting at Matopos Research Station to discuss findings of RRA and draft working document.

Appendix I: Table 1: Some aspects of draught animal use, management and perceptions of farmers using DAP.

	SEMUKWE		CHIKWANDA		SEBUNGWE	
	Cattle	Donkeys	Cattle	Donkeys	Cattle	Donkeys
Use	decreasing	increasing	steady	increasing	increasing	decreasing
Management/health[1]	good	improving	good	worse	good	poor
Harnessing	yoke	harness	yoke	yoke	yoke	yoke/harness
Perceptions	high	high	high	lower	high	lower

[1] *depending on available resources*

Appendices for Chapter 4 (Appendices II):

Appendix II: Table 2.1: Tables of t-tests for comparisons between the live weights (LW) of different monitoring periods of 38 selected male and female donkeys from January 1995 to August 1996.

Two Sample T-Test and Confidence Interval

1. Twosample T for LW Jan/Feb. 1995 vs LW Apr/May 1995

	N	Mean	StDev	SE Mean
Jan/Feb.	32	135.2	30.3	5.4
Apr/May	31	142.5	24.4	4.4

95% C.I. for mu Jan/Feb - mu Apr/May: (-21.1, 6.5)
T-Test mu Jan/Feb = mu Apr/May(vs not =): T= -1.06 P=0.30 DF= 59

2. Twosample T for LW Apr/May 1995 vs LW Jul/Aug.1995

	N	Mean	StDev	SE Mean
Apr/May	31	142.5	24.4	4.4
Jul/Aug.	34	157.6	27.4	4.7

95% C.I. for mu Apr/May - mu Jul/Aug: (-27.8, -2.2)
T-Test mu Apr/May = mu Jul/Aug(vs not =): T= -2.34 P=0.023 DF= 62

3. Twosample T for LW Jul/Aug. 1995 vs LW Oct/Nov. 1995

	N	Mean	StDev	SE Mean
Jul/Aug.	34	157.6	27.4	4.7
Oct/Nov.	37	151.9	29.9	4.9

95% C.I. for mu Jul/Aug - mu Oct/Nov: (-7.9, 19.2)
T-Test mu Jul/Aug = mu Oct/Nov (vs not =): T= 0.83 P=0.41 DF= 68

4. Twosample T for LW Oct/Nov 1995 vs LW Jan/Feb. 1996

	N	Mean	StDev	SE Mean
Oct/Nov.	37	151.9	29.9	4.9
Jan/Feb.	32	151.6	24.9	4.4

95% C.I. for mu Oct/Nov - mu Jan/Feb: (-12.9, 13.5)
T-Test mu Oct/Nov = mu Jan/Feb (vs not =): T= 0.05 P=0.96 DF= 66

5. Twosample T for LW Jan/Feb. 1996 vs LW Apr/May 1996

	N	Mean	StDev	SE Mean
Jan/Feb.	32	151.6	24.9	4.4
Apr/May	33	156.9	21.9	3.8

95% C.I. for mu Jan/Feb - mu Apr/May: (-16.9, 6.4)
T-Test mu Jan/Feb = mu Apr/May(vs not =): T= -0.91 P=0.37 DF= 61

6. Twosample T for LW6 Apr/May 1996 vs LW Jul/Aug. 1996

	N	Mean	StDev	SE Mean
Apr/May	33	156.9	21.9	3.8
Jul/Aug.	31	154.9	23.7	4.3

95% C.I. for mu Apr/May - mu Jul/Aug: (-9.4, 13.4)
T-Test mu Apr/May = mu Jul/Aug. (vs not =): T= 0.35 P=0.73 DF= 60

7. Twosample T for lowest LW (Jan/Feb. 1995) vs highest LW (Apr/May 1996)

	N	Mean	StDev	SE Mean
Jan/Feb.	32	135.2	30.3	5.4
Apr/May	33	156.9	21.9	3.8

95% C.I. for mu Jan/Feb - mu Apr/May: (-34.8, -8.4)
T-Test mu Jan/Feb = mu Apr/May (vs not =): T= -3.29 P=0.0018 DF= 56

Appendix II: Table 2.2: Tables of Mann-Whitney Confidence Interval and Test for comparisons between body condition scores (BCS) of 19 male and 19 female donkeys from January 1995 (BCS 1) to August 1996 (BCS 7).

1. BCS Males vs BCS Females (Jan/Feb. 1995)
Mann-Whitney Confidence Interval and Test

Males	N = 16	Median = 5.500
Females	N = 16	Median = 4.500

Point estimate for ETA1-ETA2 is 1.000
95.2 Percent C.I. for ETA1-ETA2 is (0.000, 2.000)
W = 328.5
Test of ETA1 = ETA2 vs. ETA1 ~= ETA2 is significant at 0.0159
The test is significant at 0.0120 (adjusted for ties)

2. BCS Males vs BCS Females (April/May 1995)
Mann-Whitney Confidence Interval and Test

Males	N = 17	Median = 6.000
Females	N = 14	Median = 5.000

Point estimate for ETA1-ETA2 is 1.000
95.1 Percent C.I. for ETA1-ETA2 is (0.000,1.000)
W = 312.5
Test of ETA1 = ETA2 vs. ETA1 ~= ETA2 is significant at 0.1123
The test is significant at 0.0938 (adjusted for ties)

3. BCS Males vs BCS Females July/Aug. 1995)
Mann-Whitney Confidence Interval and Test

Males	N = 16	Median = 6.000
Females	N = 18	Median = 6.000

Point estimate for ETA1-ETA2 is 0.000
95.3 Percent C.I. for ETA1-ETA2 is (-1.000,1.000)
W = 276.0
Test of ETA1 = ETA2 vs. ETA1 ~= ETA2 is significant at 0.9039
The test is significant at 0.8965 (adjusted for ties)

4. BCS Males vs BCS Females (Oct/Nov. 1995)
Mann-Whitney Confidence Interval and Test

Males	N = 18	Median = 6.000
Females	N = 19	Median = 5.000

Point estimate for ETA1-ETA2 is 0.000
95.3 Percent C.I. for ETA1-ETA2 is (0.000,1.000)
W = 367.0
Test of ETA1 = ETA2 vs. ETA1 ~= ETA2 is significant at 0.4566
The test is significant at 0.4236 (adjusted for ties)

5. BCS Males vs BCS Females (Jan/Feb. 1996)
Mann-Whitney Confidence Interval and Test

Males	N = 15	Median = 5.0000
Females	N = 17	Median = 6.0000

Point estimate for ETA1-ETA2 is -0.0000
95.0 Percent C.I. for ETA1-ETA2 is (-0.9997,0.0001)
W = 226.5
Test of ETA1 = ETA2 vs. ETA1 ~= ETA2 is significant at 0.4389
The test is significant at 0.3962 (adjusted for ties)

6. BCS Males vs BCS Females (Apr/May 1996)
Mann-Whitney Confidence Interval and Test

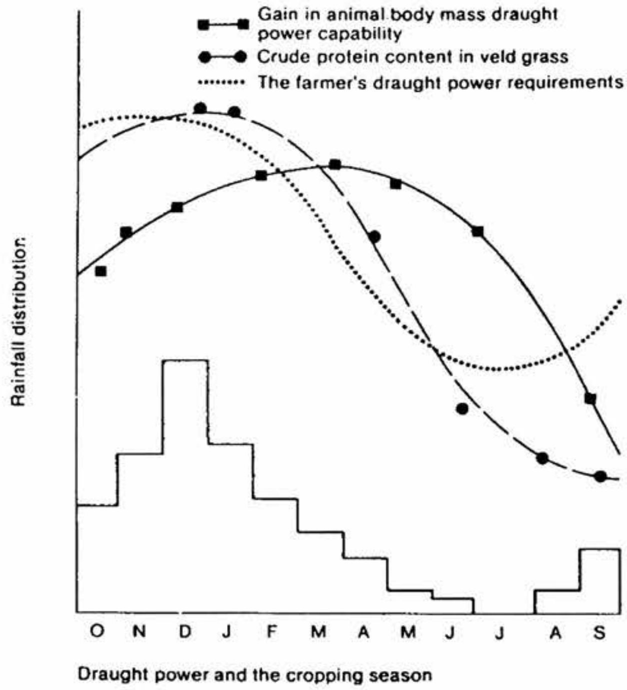
Males	N = 17	Median = 6.000
Females	N = 16	Median = 5.000

Point estimate for ETA1-ETA2 is -0.000
95.0 Percent C.I. for ETA1-ETA2 is (-0.000,1.000)
W = 316.0
Test of ETA1 = ETA2 vs. ETA1 ~= ETA2 is significant at 0.3398
The test is significant at 0.2885 (adjusted for ties)

7. BCS Males vs BCS Females (Jul/Aug. 1996)
Mann-Whitney Confidence Interval and Test

Males	N = 15	Median = 5.000
Females	N = 16	Median = 5.000

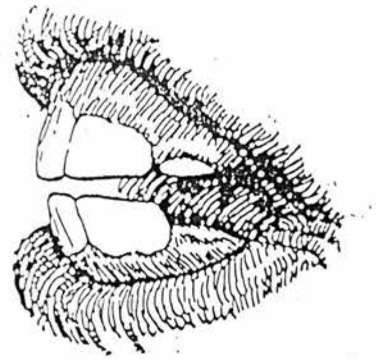
Point estimate for ETA1-ETA2 is -0.000
95.4 Percent C.I. for ETA1-ETA2 is (-0.000,1.000)
W = 254.0
Test of ETA1 = ETA2 vs. ETA1 ~= ETA2 is significant at 0.5936
The test is significant at 0.5531 (adjusted for ties)



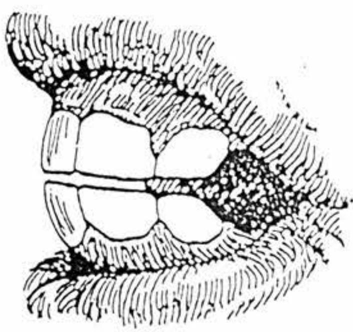
Appendix II: Figure 2.1. The seasonal variation in live-weight change, crude protein content of veld grasses, rainfall and draught animal power demands (Tembo, 1989).

Appendix II: Figure 2.2: A guide to estimation of age by examination of the teeth (Tutt, 1987).

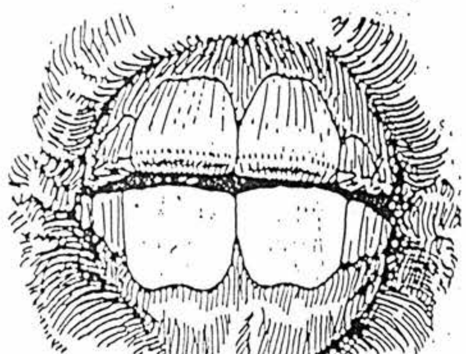
The incisor teeth at birth. The central nippers have just erupted.



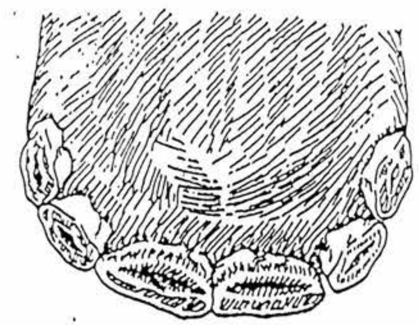
Six months. Corner temporary incisors are erupting.



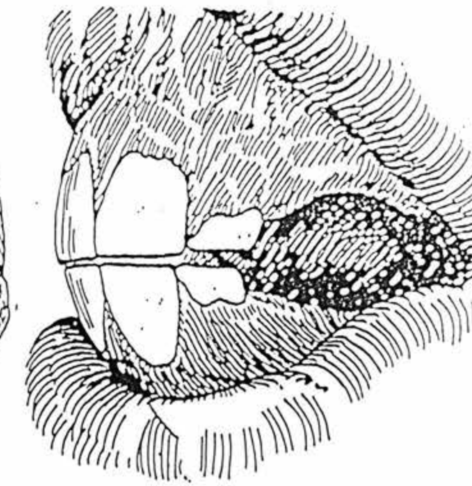
Two years.



Three years.

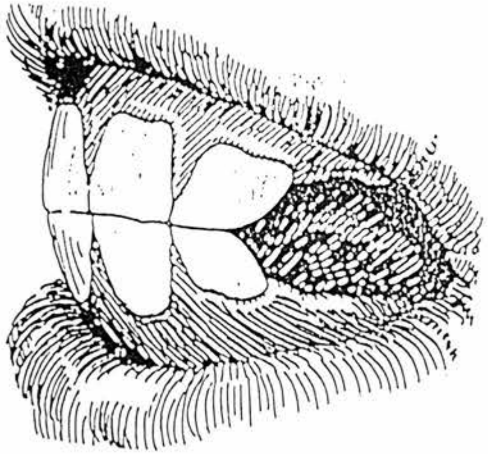


Three years.

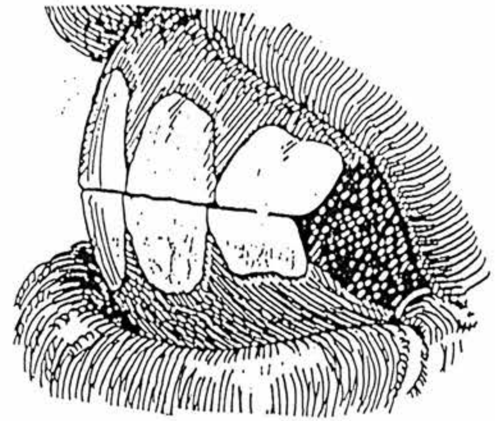


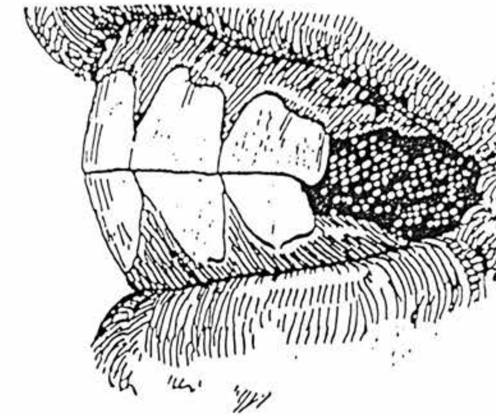
Four years.

Appendix II: Figure 2.2: A guide to estimation of age by examination of the teeth (Tutt, 1987) (continued)



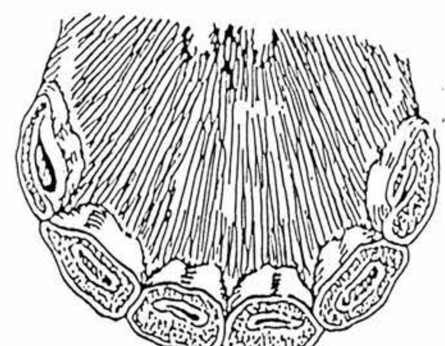
Five years. Corner permanent incisor in wear.





At seven years. Note the notch or hook on posterior edge of top corner incisor tooth referred to in text.

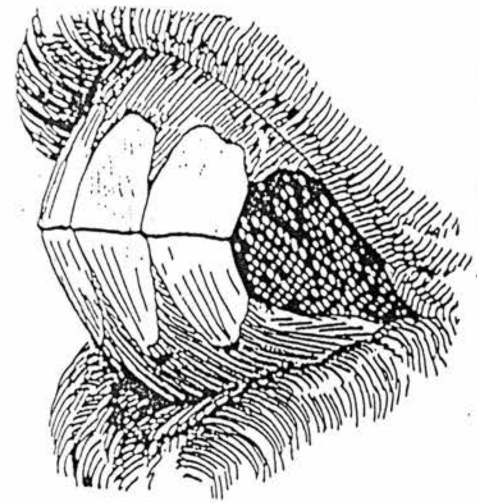
Five years.



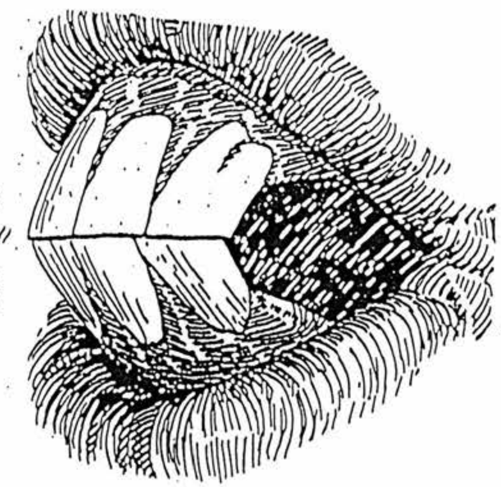
Six years.

Seven years.

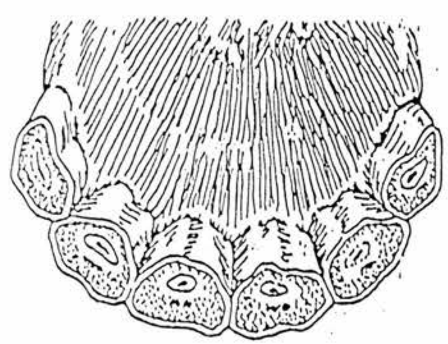
Appendix II: Figure 2.2: A guide to estimation of age by examination of the teeth (Tutt, 1987) (continued)



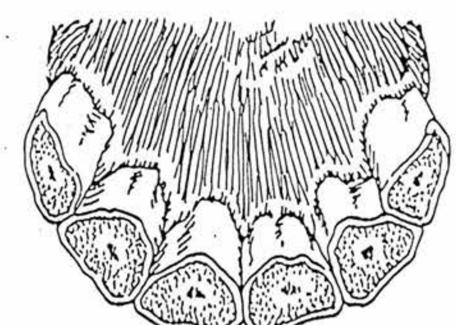
Ten years.



Fourteen years.

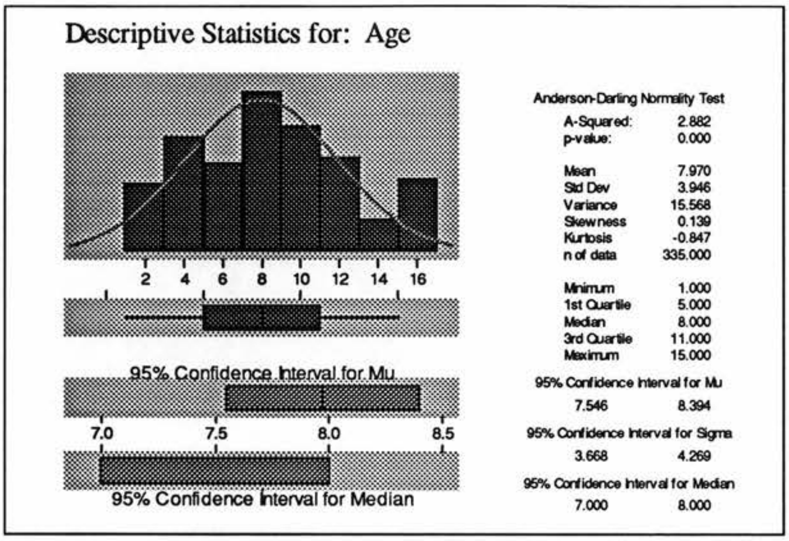


Ten years.

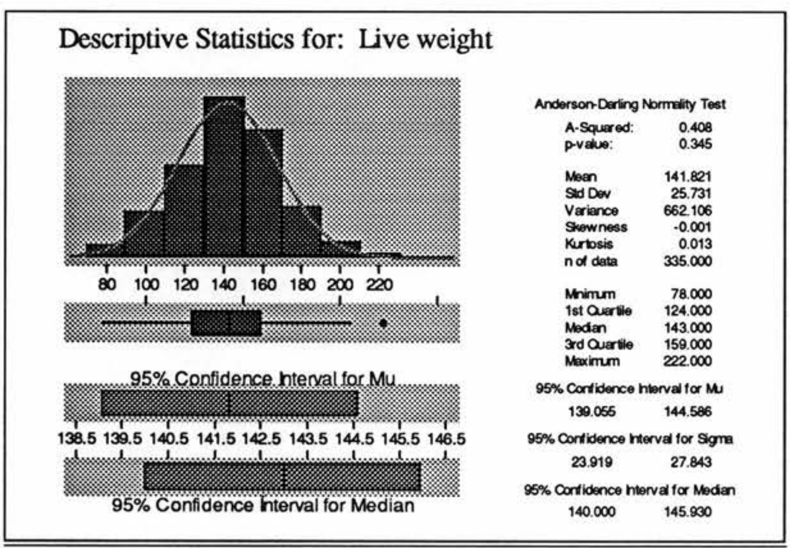


Fourteen years.

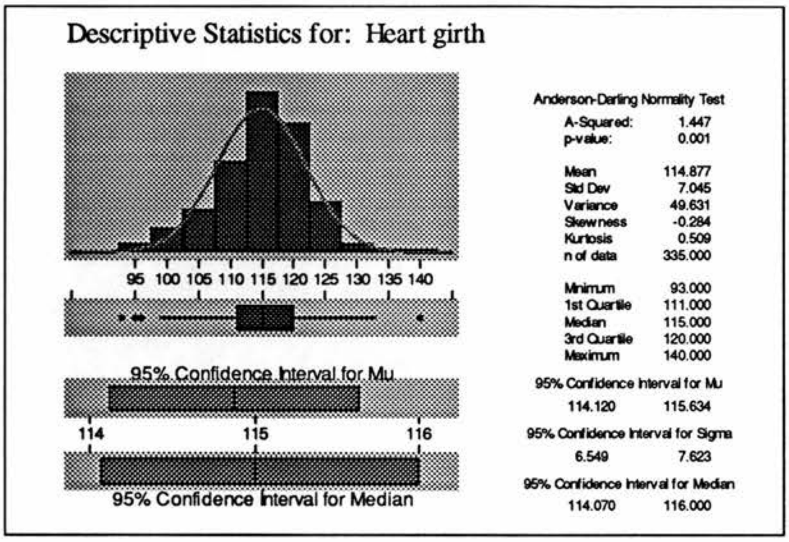
Appendix II: Figure 2.3a: Anderson-Darling Normality Test results for age.



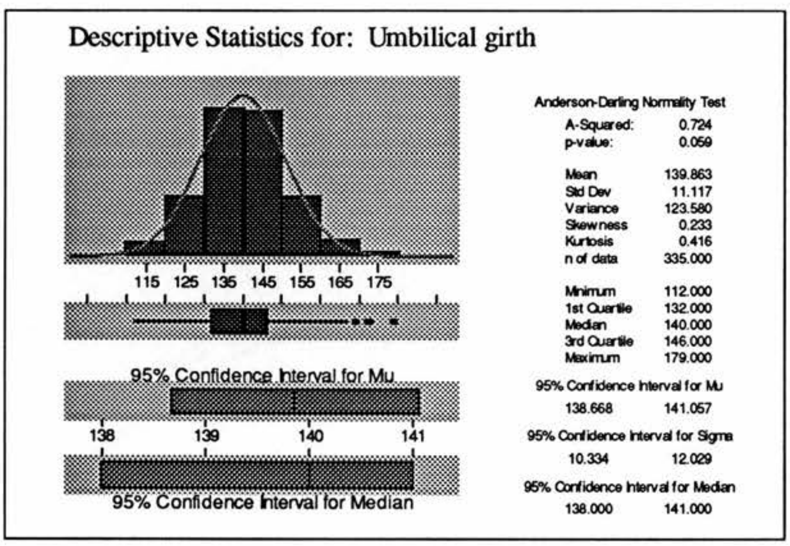
Appendix II: Figure 2.3b: Anderson-Darling Normality Test results for live weight



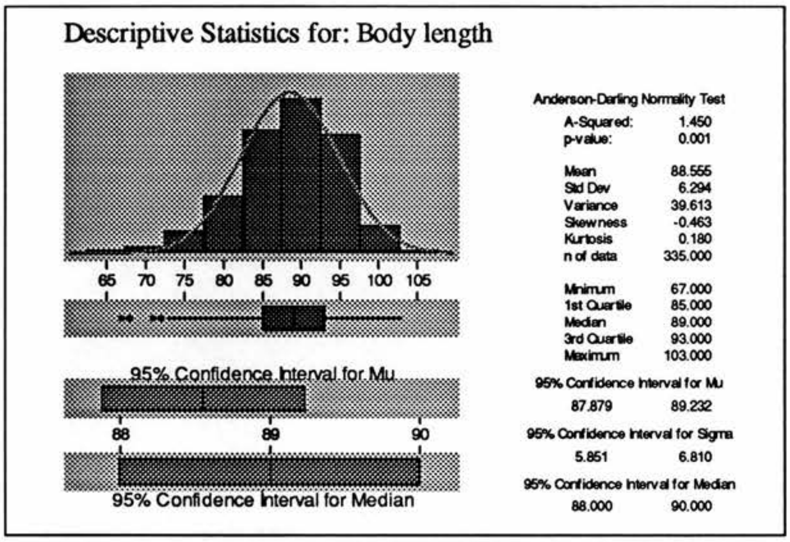
Appendix II: Figure 2.3c: Anderson-Darling Normality Test results for heart girth.



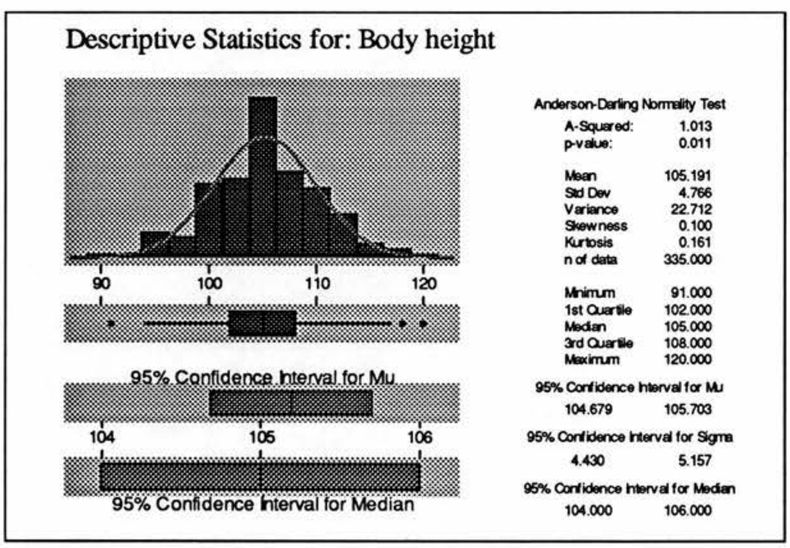
Appendix II: Figure 2.3d: Anderson-Darling Normality Test results for umbilical girth.



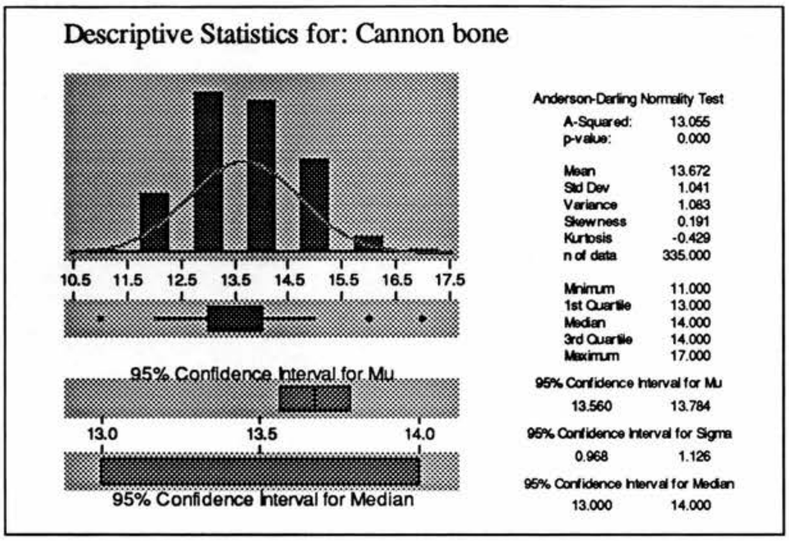
Appendix II: Figure 2.3e: Anderson-Darling Normality Test results for body length.



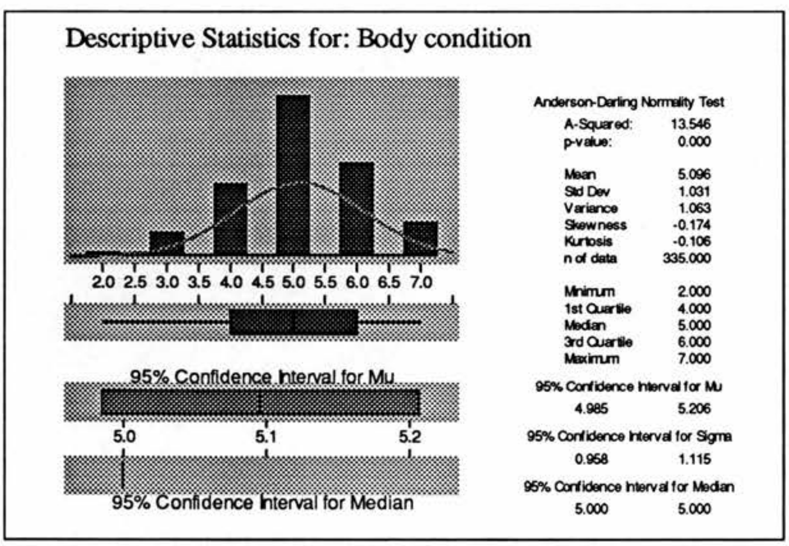
Appendix II: Figure 2.3f: Anderson-Darling Normality Test results for height at withers.



Appendix II: Figure 2.3g: Anderson-Darling Normality Test results for cannon bone circumference.



Appendix II: Figure 2.3h: Anderson-Darling Normality Test results for body condition score.



Appendix II: Table 2.3: Seasonal mean live weight (kg ± sem) changes of 38 male and female donkeys monitored in Matobo District from January 1995 to August 1996.

	Live weight January 1995	Live weight April 1995	Live weight July 1995	Live weight October 1995	Live weight January 1996	Live weight April 1996	Live weight August 1996
Males	(n = 16)[1]	(n = 17)	(n = 16)	(n = 18)	(n = 15)	(n = 17)	(n = 15)
	132 ± 8.0	142 ± 6.3	152 ± 6.9	144 ± 5.9	143 ± 6.0	153 ± 5.2	151 ± 5.1
Females	(n = 16)	(n = 14)	(n = 18)	(n = 19)	(n = 17)	(n = 16)	(n = 16)
	138 ± 7.4	143 ± 6.2	163 ± 6.4	160 ± 7.5	159 ± 6.1	161 ± 5.6	159 ± 6.7
Signif.	P>0.831	P>0.779	P>0.960	P>0.653	P>0.931	P>0.601	P>0.744
Weighted	(n = 32)	(n = 31)	(n = 34)	(n = 37)	(n = 32)	(n = 33)	(n = 31)
means[2]	$135^a \pm 5.4$	$143^a \pm 4.4$	$158^b \pm 4.7$	$152^b \pm 4.9$	$152^b \pm 4.4$	$157^b \pm 3.8$	$155^b \pm 4.3$

[1]number of animals monitored

[2]means in the same row with different superscripts differ significantly ($P<0.05$).

Appendix II: Table 2.4: Seasonal body condition score changes of 38 male and female donkeys monitored in Matobo District from January 1995 to August 1996 (medians) (Pearson and Ouassat, 1996 scoring system of 1 to 9) (medians).

	Body condition score January 1995	Body condition score April 1995	Body condition score July 1995	Body condition score October 1995	Body condition score January 1996	Body condition score April 1996	Body condition score August 1996
Males	(n = 16)[1]	(n = 17)	(n = 16)	(n = 18)	(n = 15)	(n = 17)	(n = 15)
	5.5	6.0	6.0	6.0	5.0	6.0	5.0
Females	(n = 16)	(n = 14)	(n = 18)	(n = 19)	(n = 17)	(n = 16)	(n = 16)
	4.5	5.0	6.0	5.0	6.0	5.0	5.0
Significance of differences between sexes	$P<0.012$	$P>0.112$	$P>0.903$	$P>0.457$	$P>0.439$	$P>0.340$	$P>0.594$
Median	(n = 32)	(n = 31)	(n = 34)	(n = 37)	(n = 32)	(n = 33)	(n = 31)
	5.0	5.0	6.0	6.0	6.0	5.0	5.0

[1]number of animals monitored

Appendices for Chapter 5 (Appendices III):

Appendix III: Table 3.1: Draught parameters of four donkey and oxen teams ploughing on clay, redsoil, sandy and sandy clay soils at Matopos Research Station.

Team	Spp	n	Plg	TLW	$TLW^{0.75}$	Soil	Work	Dist.	EWT	Dpth	Wdth	Area	DF	Spd	Pow	EFC	DF/kg	Pow/kg	$DF/^{0.75}$	$Pow/^{0.75}$	DF%LW
1	1	4	1	678	188	2	2792	3587	4269	15	26	924	753	0.86	649	12.8	1.11	0.96	4.01	3.45	11.1
1	1	4	1	618	175	3	2906	3628	3973	12	24	616	809	0.89	714	18.2	1.31	1.16	4.62	4.08	13.1
1	1	4	1	604	172	1	1745	1641	2375	18	28	417	967	0.68	663	15.6	1.60	1.10	5.62	3.85	16.0
1	1	4	1	598	171	4	4022	4341	4264	12	27	929	924	1.02	945	12.8	1.55	1.58	5.40	5.53	15.5
2	1	4	1	462	141	2	1429	1977	3263	13	25	576	719	0.61	435	15.6	1.56	0.94	5.10	3.09	15.6
2	1	4	1	478	145	3	1953	2645	4016	12	24	366	735	0.66	487	30.3	1.54	1.02	5.07	3.36	15.4
2	1	4	1	457	140	1	680	832	1639	13	24	245	820	0.51	417	18.5	1.79	0.91	5.86	2.98	17.9
2	1	4	1	482	145	4	2559	2800	4913	13	27	538	914	0.57	521	25.6	1.90	1.08	6.30	3.59	19.0
3	2	2	1	646	152	2	5647	6825	8039	16	28	1508	811	0.85	702	14.8	1.26	1.09	5.34	4.62	12.6
3	2	2	1	625	149	3	1758	2507	2545	12	23	497	701	0.99	691	14.2	1.12	1.11	4.70	4.64	11.2
3	2	2	1	675	158	1	1190	1030	967	21	29	289	1147	1.06	1220	9.3	1.70	1.81	7.26	7.72	17.0
3	2	2	1	783	176	4	4240	4556	3976	14	28	696	988	1.15	1139	15.9	1.26	1.46	5.61	6.47	12.6
4	1	4	1	499	149	4	2699	3415	5379	12	26	634	782	0.63	497	23.8	1.567	1.00	5.25	3.34	15.7

Spp.: 1 = donkey; 2 = cattle; **n** = number of animals per team; **Plg** = **plough;** 1 = conventional; 2 = Walco; **TLW** = total live weight; **$TLW^{0.75}$** = total metabolic body weight of team; **Soil:** 1 = sandy, 2 = clay; 3 = redsoil; 4 = sandy clay; **Work** in kJ; **Dist.** = distance in m; **EWT** = elapsed working time (s); **Dpth** = ploughing depth (cm); **Wdth** = ploughing width (cm); **Area** = area ploughed (m^2); **DF** = draught force (N); **Spd** = speed (m/s); **Pow** = power output (W); **EFC** = effective field capacity (h/ha); **DF/kg** = draught force per kg live weight; **Pow/kg** = power output per kg live weight; **$DF/^{0.75}$** = draught force per kg metabolic body weight; **$Pow/^{0.75}$** = power output per metabolic body weight; **DF%LW** = draught force as a percentage of live weight.

Appendix III: Table 3.1: (continued) Draught parameters of four donkey and oxen teams ploughing on clay, redsoil, sandy and sandy clay soils at Matopos Research Station.

Team	Spp.	n	Plg	TLW	$TLW^{0.75}$	Soil	Work	Dist.	EWT	Dpth	Wdth	Area	DF	Spd	Pow	EFC	DF/kg	Pow/kg	$DF/^{0.75}$	$Pow/^{0.75}$	DF%LW
1	1	4	2	678	188	2	3166	3852	4905	13	26	1159	819	0.78	640	11.8	1.21	0.94	4.36	3.40	12.1
2	1	4	2	462	141	2	1558	2391	4332	12	23	559	652	0.55	355	21.7	1.41	0.77	4.62	2.52	14.1
1	1	4	2	618	175	3	2552	3298	3512	10	23	517	751	0.94	705	18.5	1.22	1.14	4.29	4.03	12.2
2	1	4	2	478	145	3	1341	2217	3118	10	20	350	608	0.71	431	25.0	1.27	0.90	4.19	2.97	12.7
1	1	4	2	604	172	1	2027	2732	3413	16	26	490	742	0.83	622	18.5	1.23	1.03	4.31	3.62	12.3
2	1	4	2	457	140	1	1275	1786	2678	15	26	284	718	0.69	494	25.0	1.57	1.08	5.13	3.53	15.7
1	1	4	2	598	171	4	4060	5556	6098	12	27	1057	727	0.91	658	16.1	1.22	1.10	4.25	3.85	12.2
2	1	4	2	499	149	4	2102	2651	4417	12	31	564	782	0.59	458	21.7	1.57	0.92	5.25	3.07	15.7
4	1	4	2	499	149	4	1596	1983	3739	10	25	474	799	0.53	424	21.7	1.60	0.85	5.36	2.85	16.0
3	2	2	2	646	152	2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
3	2	2	2	625	149	3	1905	2546	2580	12	25	517	727	0.99	721	13.9	1.16	1.15	4.88	4.84	11.6
3	2	2	2	633	150	1	1050	1314	1207	18	27	292	780	1.09	851	11.5	1.23	1.34	5.20	5.67	12.3
3	2	2	2	783	176	4	3272	4369	4436	13	26	718	749	0.99	745	17.2	0.96	0.95	4.26	4.23	9.6

Spp.: 1 = donkey; 2 = cattle; **n** = number of animals per team; **Plg = plough;** 1 = conventional; 2 = Walco; **TLW** = total live weight; **$TLW^{0.75}$** = total metabolic body weight of team; **Soil:** 1 = sandy, 2 = clay; 3 = redsoil; 4 = sandy clay; **Work** in kJ; **Dist.** = distance in m; **EWT** = elapsed working time (s); **Dpth** = ploughing depth (cm); **Wdth** = ploughing width (cm); **Area** = area ploughed (m^2); **DF** = draught force (N); **Spd** = speed (m/s); **Pow** = power output (W); **EFC** = effective field capacity (h/ha); **DF/kg** = draught force per kg live weight; **Pow/kg** = power output per kg live weight; **$DF/^{0.75}$** = draught force per kg metabolic body weight; **$Pow/^{0.75}$** = power output per metabolic body weight; **DF%LW** = draught force as a percentage of live weight; * missing data.

Appendix III: Table 3.2a: Draught parameters of 10 cattle, donkey and mixed cattle:donkey teams ploughing on redsoil at Fanisoni Irrigation Scheme (Nkayi District).

Team	Spp.	n	TLW	$TLW^{0.75}$	Work	Dist.	EWT	Dpth	Wdth	Area	DF	Spd	Pow	EFC	Pow/kg	DF/kg	$DF/^{0.75}$	$Pow/^{0.75}$
3	1	4	1709	376	1956	1365	1744	16	33	445	1451	0.78	1137	10.9	0.67	0.85	3.86	3.03
1	1	4	1609	359	3800	4148	5448	15	28	1060	908	0.76	692	14.3	0.43	0.56	2.53	1.93
7	1	4	1387	321	4304	4290	3994	15	32	1048	1009	1.08	1086	10.6	0.78	0.73	3.14	3.38
8	1	4	1102	270	3822	3319	4100	15	27	1051	1149	0.81	929	10.8	0.84	1.04	4.25	3.43
9	1	4	974	246	4091	3249	3998	13	32	886	1233	0.82	1007	12.5	1.03	1.27	5.00	4.08
2	3	4	898	228	4077	3635	4825	14	32	991	1119	0.75	842	13.5	0.94	1.25	4.92	3.70
4	1	2	893	194	3740	3312	4350	16	31	1004	1143	0.77	898	12.0	1.01	1.28	5.88	4.63
10	1	2	879	192	3198	4045	3936	14	28	1211	756	1.02	775	9.0	0.88	0.86	3.94	4.04
6	2	4	658	184	2841	3466	5585	16	30	1050	823	0.62	510	14.8	0.78	1.25	4.48	2.78
5	1	2	558	137	2320	2760	4248	15	30	1080	832	0.63	527	10.9	0.95	1.49	6.10	3.86

Spp.: 1 = donkey; 2 = cattle; 3 = donkey:cattle; **n** = number of animals per team; **TLW** = total live weight; **$TLW^{0.75}$** = total metabolic body weight of team; **Work** in kJ; **Dist.** = distance in m; **EWT** = elapsed working time (s); **Dpth** = ploughing depth (cm); **Wdth** = ploughing width (cm); **Area** = area ploughed (m^2); **DF** = draught force (N); **Spd** = speed (m/s); **Pow** = power output (W); **EFC** = effective field capacity (h/ha); **DF/kg** = draught force per kg live weight; **Pow/kg** = power output per kg live weight; **$DF/^{0.75}$** = draught force per kg metabolic body weight; **$Pow/^{0.75}$** = power output per metabolic body weight; **DF%LW** = draught force as a percentage of live weight.

Appendix III: Table 3.2b: Draught parameters of 10 donkey teams ploughing on sandy, clay, redsoil and sandy clay soils in Matobo District.

Team	n	TLW	$TLW^{0.75}$	Soil	Work	Dist.	EWT	TWT	Dpth	Wdth	Area	DF	Spd	Pow	EFC	DF/kg	Pow/kg	$DF/^{0.75}$	$Pow/^{0.75}$
1	7	1007	291	1	4063	4990	6725	125	13	30	1952	812	0.74	601	9.6	0.81	0.60	2.79	2.07
2	6	854	247	2	1889	2374	3974	77	12	25	894	794	0.60	475	12.3	0.93	0.56	3.22	1.92
3	6	796	234	1	2792	3350	4261	105	11	29	1070	836	0.78	653	11.1	1.05	0.82	3.57	2.79
4	6	773	229	1	2581	4257	5446	103	9	27	844	605	0.78	469	17.9	0.78	0.61	2.64	2.05
5	6	772	229	1	571	793	885	23	9	30	301	709	0.92	651	8.2	0.92	0.84	3.10	2.84
6	4	614	174	4	1669	1720	2923	68	*	*	532	970	0.59	571	15.3	1.58	0.93	5.57	3.28
7	4	492	147	1	1062	1906	3276	64	12	30	496	557	0.58	324	18.3	1.13	0.66	3.79	2.20
8	3	428	124	1	880	1321	2024	53	*	*	377	671	0.65	438	14.9	1.57	1.02	5.42	3.54
9	3	340	103	3	1298	2124	3273	76	*	*	368	609	0.65	395	24.7	1.79	1.16	5.89	3.82
10	3	319	99	3	607	1145	1774	40	9	25	276	534	0.65	347	17.9	1.67	1.09	5.37	3.49

n = number of animals per team; **TLW** = total live weight; **$TLW^{0.75}$** = total metabolic body weight of team; **Soil:** 1 = sandy, 2 = clay; 3 = redsoil; 4 = sandy clay; **Work** in kJ; **Dist.** = distance in m; **EWT** = elapsed working time (s); **Dpth** = ploughing depth (cm); **Wdth** = ploughing width (cm); **Area** = area ploughed (m^2); **DF** = draught force (N); **Spd** = speed (m/s); **Pow** = power output (W); **EFC** = effective field capacity (h/ha); **DF/kg** = draught force per kg live weight; **Pow/kg** = power output per kg live weight; **$DF/^{0.75}$** = draught force per kg metabolic body weight; **$Pow/^{0.75}$** = power output per metabolic body weight; **DF%LW** = draught force as a percentage of live weight; * missing data.

Appendix III: Table 3.3: Draught parameters of six cattle-only, donkeys-only and donkey:cattle teams used for ploughing on sandy clay soils at Matopos Research Station.

Team	Species	$LW^{0.75}$	TotalLW	Work	Dist	EWT	Dpth	Wdth	Area	DF	Spd	Pow	EFC	Pow/kg	DF/kg
	4Ox	284	1178	2674	1816	1782	11	26	475	1437	1.01	1458	10.4	1.24	1.22
2	2D,2Ox	235	920	3426	2824	2728	11	25	632	1196	1.02	1224	12.0	1.33	1.30
3	2D,2Ox	226	879	2670	2334	2327	10	24	338	1121	0.98	1103	19.1	1.26	1.28
4	2D,2Ox	226	875	4019	3229	3354	12	24	782	1232	0.96	1184	11.9	1.35	1.41
5	4D	176	622	3186	2730	3553	10	24	655	1162	0.76	885	15.1	1.42	1.87
6	2Ox	137	559	2179	1822	1858	12	24	369	1200	0.98	1180	14.0	2.11	2.15

Species: D = donkey; Ox = cattle; **TotalLW** = total live weight; **$LW^{0.75}$** = total metabolic body weight of team; **Dist.** = distance in m; **EWT** = elapsed working time (s); **Dpth** = ploughing depth (cm); **Wdth** = ploughing width (cm); **Area** = area ploughed (m^2); **DF** = draught force (N); **Spd** = speed (m/s); **Pow** = power output (W); **EFC** = effective field capacity (h/ha); **DF/kg** = draught force per kg live weight; **Pow/kg** = power output per kg live weight.

Appendix III: Description of swingle tree and evener (after Krause, 1993).

Swingle tree: A wooden pole to which traces attach at each end and the work-load attaches at the centre. This allows the harness to move with the shoulders, reducing rubbing (abrasion) and also act as a shock-absorber. Also known as a splinter or swing bar or single tree (American)

Evener: A wooden pole to which swingle trees of multiple animals attach, a much longer swingle to balance the pull from each animal. Sometimes referred to as double tree (American) or 2-horse baulk (Yorkshire).

Appendix III: Table 3.4: Examples of Kruskal-Wallis tables for donkey and oxen teams working with a conventional plough on all soil types at Matopos Research Station (MINITAB Inc. 1994).

MTB > Kruskal-Wallis 'Draught Force' 'Team'.

Kruskal-Wallis Test

LEVEL	NOBS	MEDIAN	AVE. RANK	Z VALUE
1	4	866.5	7.0	0.34
2	4	777.5	5.0	-1.02
4	4	899.5	7.5	0.68
OVERALL	12		6.5	

H = 1.08 d.f. = 2 p = 0.584

* NOTE * One or more small samples

MTB > Kruskal-Wallis 'Speed' 'Team'.

Kruskal-Wallis Test

LEVEL	NOBS	MEDIAN	AVE. RANK	Z VALUE
1	4	874.0	7.5	0.68
2	4	589.5	2.5	-2.72
4	4	1025.5	9.5	2.04
OVERALL	12		6.5	

H = 8.00 d.f. = 2 p = 0.019

* NOTE * One or more small samples

MTB > Kruskal-Wallis 'Power' 'Team'.

Kruskal-Wallis Test

LEVEL	NOBS	MEDIAN	AVE. RANK	Z VALUE
1	4	688.5	7.5	0.68
2	4	461.0	2.5	-2.72
4	4	920.5	9.5	2.04
OVERALL	12		6.5	

H = 8.00 d.f. = 2 p = 0.019

* NOTE * One or more small samples

MTB > Kruskal-Wallis 'EFCh/ha' 'Team'.

Kruskal-Wallis Test

LEVEL	NOBS	MEDIAN	AVE. RANK	Z VALUE
1	4	14.20	5.1	-0.93
2	4	22.05	9.9	2.29
4	4	14.50	4.5	-1.36
OVERALL	12		6.5	

H = 5.32 d.f. = 2 p = 0.071
H = 5.35 d.f. = 2 p = 0.069 (adjusted for ties)

* NOTE * One or more small samples

Appendices for Chapter 6 (Appendices IV):

Appendix IV: Table 4.1: Watering programme for donkeys offered water *ad libitum,* every 48 h or 72 h.

WATER AND FEED INTAKE OF DONKEYS WITH ACCESS TO WATER *AD LIB*, EVERY 48h AND 72h								
	WEEK 1							
	MON.	TUE.	WED.	THURS.	FRID.	SAT.	SUN.	
	10.06.96	11.06.96	12.06.96	13.06.96	14.06.96	15.06.96	16.06.96	
Trt.1 (*ad lib*)	water throughout the week							
	08:00h							
Trt.2 (48h)			08:00h		09:00h		10:00h	
			water for 1h		water for 1h		water for 1h	
			weigh before and after		weigh before and after		weigh before and after	
Trt.3 (72h)				08:00h			09:00h	
				water for 1h			water for 1h	
				weigh before and after			weigh before and after	

Appendix IV: Table 4.1: (continued)

	WEEK 2							
	MON.	TUE.	WED.	THURS.	FRID.	SAT.	SUN.	
	17.06.96	18.06.96	19.06.96	20.06.96	21.06.96	22.06.96	23.06.96	
Trt.1 (*ad lib*)	water throughout the week							
Trt.2 (48h)		11:00h		12:00h		13:00h		
		water for 1h		water for 1h		water for 1h		
		weigh before and after		weigh before and after		weigh before and after		
Trt.3 (72h)			10:00h			11:00h		
			water for 1h			water for 1h		
			weigh before and after			weigh before and after		

Appendix IV: Table 4.1: (continued)

	WEEK 3							
	MON.	TUE.	WED.	THURS.	FRID.	SAT.	SUN.	
	24.06.96	25.06.96	26.06.96	27.06.96	28.06.96	29.06.96	30.06.96	
Trt.1 (*ad lib*)	water throughout the week							
Trt. 2 (48h)	14:00h		15:00h		16:00h		17:00h	
	water for 1h		water for 1h		water for 1h		water for 1h	
Trt. 3 (72h)		12:00h			13:00h			
		water for 1h			water for 1h			

Appendix IV: Table 4.1: (continued)

	WEEK 4							
	MON.	TUE.	WED.	THURS.	FRID.	SAT.	SUN.	
	1.07.96	02.07.96	03.07.96	04.07.96	05.07.96	06.07.96	07.07.96	
Trt.1 (*ad lib*)	water throughout the week							
Trt.2 (48h)		18:00h		19:00h		20:00h		
		water for 1h		water for 1h		water for 1h		
Trt.3 (72h)	14:00h			15:00h			16:00h	
				water for 1h			water for 1h	

Appendix IV: Table 4.1: (continued)

	WEEK 5							
	MON.	TUE.	WED.	THURS.	FRID.	SAT.	SUN.	
	08.07.96	09.07.96	10.07.96	11.07.96	12.07.96	13.07.96	14.07.96	
Trt.1 (*ad lib*)	water throughout the week							
Trt.2 (48h)	21:00h		22:00h		23:00h		24:00h	
	water for 1h		water for 1h		water for 1h		water for 1h	
							END	
Trt.3 (72h)			17:00h			18:00h		
			water for 1h			water for 1h		

Appendix IV: Figure 4.1: Allocation of donkeys in different treatment groups to individual pens.

72h	72h	72h		48 h	48 h	48 h		*ad lib*	*ad lib*	*ad lib*

Feeding and watering corridor

72h	72h	72h		48 h	48 h	48 h		*ad lib*	*ad lib*	*ad lib*

Appendix IV: Table 4.2: Daily dry matter intake (DMI, kg) and water intake (WI, l) donkeys (9 males and 9 females) penned for 35 days.

Anim.	Sex	Trt.	DMI	WI	ILW	FLW
12	1	1	3.3	8.8	138	137
21	1	1	3.5	10.6	170	165
27	1	1	3.1	9.7	149	138
15	2	1	2.9	7.2	133	130
13	2	1	2.6	6.7	109	112
4	2	1	3.4	8.1	181	178
18	1	2	2.7	5.0	141	138
22	1	2	3.0	5.2	154	150
15	1	2	3.0	5.5	144	145
5	2	2	2.6	3.6	130	132
12	2	2	2.8	4.7	115	118
10	2	2	2.9	5.6	186	180
28	1	3	2.7	5.3	137	128
11	1	3	2.9	5.6	153	145
3	1	3	3.0	5.8	160	152
2	2	3	2.7	4.4	142	137
1	2	3	2.4	4.1	141	141
3	2	3	2.5	5.6	141	141

Anim. = animal; **Sex** 1 = male; 2 = female; **Trt.** = treatment; **ILW** = initial live weight; **FLW** = final live weight

Appendix IV: Table 4.3: Dry matter intake (DMI, kg), dry matter digestibility (DMD, %), mean retention time (MRT, h), final live weight (FLW, kg) and live weight gain (LWG, kg) of 12 working and non-working male donkeys.

Anim.	Period	Trt.	DMI	DMD	MRT	FLW	LWG
17	1	1	3.8	59	47.3	156	8
16	1	1	4.4	53	53.7	152	6
8	1	1	4.4	45	52.5	179	4
1	1	1	4.5	43	50.0	148	0
25	1	2	4.7	52	43.0	148	10
4	1	2	4.9	47	57.3	177	5
6	1	2	4.4	45	53.3	155	4
7	1	2	4.1	47	44.5	157	4
9	1	3	3.2	*	*	160	1
19	1	3	4.2	43	46.9	160	4
26	1	3	4.5	41	48.1	163	7
5	1	3	3.9	47	41.6	152	4
17	2	3	2.9	40	101.9	140	-16
16	2	3	3.3	48	99.2	133	-19
8	2	3	3.1	37	*	157	-22
1	2	3	3.6	40	68.2	130	-18
25	2	1	2.7	39	98.5	127	-21
4	2	1	3.4	37	77.4	151	-26
6	2	1	3.5	40	93.1	136	-19
7	2	1	2.8	49	92.3	136	-21
9	2	2	2.9	39	95.8	140	-20
19	2	2	3.2	47	100.3	141	-19
26	2	2	3.4	50	98.8	144	-19
5	2	2	3.1	46	102.0	135	-17
17	3	2	2.5	58	95.2	136	-4
16	3	2	2.5	52	69.3	132	-1
8	3	2	2.8	50	99.5	155	-2
1	3	2	3.3	52	72.4	130	0
25	3	3	2.2	38	80.0	123	-4
4	3	3	3.0	30	86.0	146	-5
6	3	3	3.2	41	92.9	139	3
7	3	3	1.9	33	88.3	136	0
9	3	1	2.9	48	49.6	143	3
19	3	1	2.4	53	87.5	137	-4
26	3	1	2.7	55	69.1	139	-5
5	3	1	2.2	52	74.3	132	-3

Anim. = animal; **Trt.** = treatment (1 = working/not feeding; 2 = not working/not feeding; 3 = not working); **FLW** = final live weight; **LWG** = live weight gain; * missing data.

Appendix IV: Table 4.4: ANOVA tables from the GLM with treatment (Trt)and sex as the sources of variation, for dry matter intake (DMI), water intake (WI), faecal DM (FDM) and water intake per kg DM (WI/kg DM)

MTB > GLM 'MEAN DMI' 'MEAN WI' 'Faecal DM' 'WI/kgDM' = TRT SEX.

GENERAL LINEAR MODEL

Factor	Levels	Values		
TRT	3	1	2	3
SEX	2	1	2	

Analysis of Variance for DMI

Source	DF	Seq SS	Adj SS	Adj MS	F	P
TRT	2	0.59111	0.59111	0.29556	6.40	0.011
SEX	1	0.32000	0.32000	0.32000	6.93	0.020
Error	14	0.64667	0.64667	0.04619		
Total	17	1.55778				

Unusual Observations for DMI

Obs.	DMI	Fit Stdev.	FitResidual	St.Resid	
5	2.60000	3.00000	0.10131	-0.40000	-2.11R
6	3.40000	3.00000	0.10131	0.40000	2.11R

R denotes an obs. with a large st. resid.

Analysis of Variance for WI

Source	DF	Seq SS	Adj SS	Adj MS	F	P
TRT	2	48.654	48.654	24.327	38.41	0.000
SEX	1	7.347	7.347	7.347	11.60	0.004
Error	14	8.868	8.868	0.633		
Total	17	64.869				

Unusual Observations for WI

Obs.	WI	Fit Stdev.	Fit Residual	St.Resid	
2	10.6000	9.1556	0.3752	1.4444	2.06R

R denotes an obs. with a large st. resid.

Analysis of Variance for Faecal DM

Source	DF	Seq SS	Adj SS	Adj MS	F	P
TRT	2	33.514	33.514	16.757	7.08	0.008
SEX	1	0.889	0.889	0.889	0.38	0.550
Error	14	33.128	33.128	2.366		
Total	17	67.531				

Analysis of Variance for WI/kgDM

Source	DF	Seq SS	Adj SS	Adj MS	F	P
TRT	2	3.3667	3.3667	1.6834	38.67	0.000
SEX	1	0.2449	0.2449	0.2449	5.63	0.033
Error	14	0.6094	0.6094	0.0435		
Total	17	4.2210				

Unusual Observations for WI/kgDM

Obs.	WI/kgDM	Fit Stdev.	Fit Residual	St.Resid	
18	2.18210	1.77088	0.09835	0.41123	2.23R

R denotes an obs. with a large st. resid.

Appendix IV: Table 4.5: ANOVA tables from the GLM with treatment (Trt.) and period as sources of variation, for dry matter intake (DMI), dry matter digestibility (DMD), mean retention time (MRT) and time of access to feed (VFI_t)(using team).

MTB > GLM 'DMI'-'VFI_t' = Team Period Trt..

GENERAL LINEAR MODEL

Factor	Levels	Values		
Team	3	1	2	3
Period	3	1	2	3
Trt.	3	1	2	3

Analysis of Variance for DMI

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Team	2	0.06889	0.06889	0.03444	2.38	0.295
Period	2	4.06222	4.06222	2.03111	140.62	0.007
Trt.	2	0.06222	0.06222	0.03111	2.15	0.317
Error	2	0.02889	0.02889	0.01444		
Total	8	4.22222				

Analysis of Variance for DMD

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Team	2	0.009156	0.009156	0.004578	3.78	0.209
Period	2	0.002756	0.002756	0.001378	1.14	0.468
Trt.	2	0.012022	0.012022	0.006011	4.96	0.168
Error	2	0.002422	0.002422	0.001211		
Total	8	0.026356				

Analysis of Variance for MRT

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Team	2	26.62	26.62	13.31	0.21	0.828
Period	2	3146.94	3146.94	1573.47	24.58	0.039
Trt.	2	77.62	77.62	38.81	0.61	0.623
Error	2	128.02	128.02	64.01		
Total	8	3379.19				

Analysis of Variance for VFI_t

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Team	2	272	272	136	1.00	0.500
Period	2	1089	1089	544	4.00	0.200
Trt.	2	213422	213422	106711	784.00	0.001
Error	2	272	272	136		
Total	8	215056				

Appendix IV: Table 4.6: ANOVA tables from the GLM with treatment (Trt.) and period as sources of variation, for dry matter intake (DMI), dry matter digestibility (DMD) and mean retention time (MRT) (using individual animals).

MTB > GLM 'DMI'-'MRT(h)' = ANNO PERIOD TRT.

GENERAL LINEAR MODEL

Factor	Levels	Values							
Animal	12	1	4	5	6	7	8	9	16
		17	19	25	26				
Period	3	1	2	3					
Trt.	3	1	2	3					

Analysis of Variance for DMI

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Animal	11	3.2224	2.6992	0.2454	4.02	0.004
Period	2	16.9262	16.7781	8.3890	137.53	0.000
Trt.	2	0.1958	0.1958	0.0979	1.61	0.228
Error	18	1.0980	1.0980	0.0610		
Total	33	21.4424				

Unusual Observations for DMI

Obs.	DMI	Fit Stdev.	Fit Residual	St.Resid	
5	4.70000	4.26159	0.16589	0.43841	2.40R
21	2.90000	3.25583	0.18914	-0.35583	-2.24R
33	2.90000	2.54417	0.18914	0.35583	2.24R

R denotes an obs. with a large st. resid.

Analysis of Variance for DMD

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Animal	11	0.055460	0.058819	0.005347	2.84	0.024
Period	2	0.010683	0.012974	0.006487	3.44	0.054
Trt.	2	0.053351	0.053351	0.026675	14.15	0.000
Error	18	0.033933	0.033933	0.001885		
Total	33	0.153426				

Analysis of Variance for MRT

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Animal	11	675.3	1356.4	123.3	1.14	0.386
Period	2	12227.3	12216.6	6108.3	56.69	0.000
Trt.	2	311.3	311.3	155.7	1.44	0.262
Error	18	1939.3	1939.3	107.7		
Total	33	15153.3				

Unusual Observations for MRT

Obs.	MRT	Fit Stdev.	Fit Residual	St.Resid	
4	49.960	33.250	6.972	16.710	2.17R
16	68.230	84.184	7.106	-15.954	-2.11R

R denotes an obs. with a large st. resid.