CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Draught animals are an important component of the smallholder farming system in most developing countries. In Zimbabwe, like in other countries in the sub-Saharan Africa, cattle are the most used draught animals in providing farm power. About 400 million draught animals (cattle and donkeys) are used in agriculture worldwide. It is estimated that 5% of draught animals are used in sub-Saharan Africa (Mrema, 1991) cited by Ndlovu and Francis, (1997). Muvirimi and Ellis-Jones (1999) noted that a review by Mrema and Mrema (1993) showed that about 80% of draught oxen in use in sub-Saharan Africa are found in five countries; Ethiopia (53%), Zimbabwe (7%), Kenya (6%), Tanzania and Uganda (5% each).

The general constraints experienced by smallholder farmers in using DAP and animal-drawn implements are known but there is limited information on the specific nature of the problems (DFID, 1999). Some of the constraints to the use of DAP by smallholder farmers include lack of implements, shortage of DAP, disease outbreaks, poor grazing and inadequate feeding during dry months, inappropriate DAP technology, and inadequate extension on DAP-related issues (Ndlovu and Francis, 1997). The importance of DAP and its correlation to crop production in smallhoder farming systems in Zimbabwe, has been reported by other researchers (Mudimu, 1983; Shumba, 1984; Rusike, 1988; Muchena, 1989; Francis, 1993; Ndlovu and Francis, 1997; Zindi, 1999).

Considerable research has been undertaken in the area of livestock feeding for improving DAP. Ndlovu and Francis (*op cit*) made this observation and acknowledged that agricultural research has neglected DAP and yet shortages of DAP and manure are critical crop production constraints at smallholder level. Previous work mainly focused on work performance of Mashona oxen (Mupeta,

Ndlovu and Prasad, 1990; Francis, Ndlovu and Nkuuhe, 1992; Francis and Ndlovu, 1993; Prasad, Khombe and Nyathi, 1994) and limited work on donkeys (Prasad, Marovanidze and Nyathi, 1991; Bwakura, Ndlovu and Topps, 1995; Nengomasha and Jele, 1995; and Nengomasha, 1997).

There is limited information on the performance of animal-drawn implements owned by smallholder farmers, implement condition, how smallholder farmers use, repair and maintain animal-drawn implements. The focus of the study was on comparing the return from the use of renovated implements with that of typical DAP tillage systems used by smallholder farmers. The work also sought to identify possible options to optimise DAP utilisation for cropping.

2.2 Overview of the use of DAP by smallholder farmers in Zimbabwe

Draught animals are the main source of power for the majority of smallholder farmers, who comprise 75% of the population in Zimbabwe. Although cattle are commonly used, donkeys have become important in providing draught (Francis, 1996). Shortage of DAP is one of the main constraints to increased crop production in communal areas (Tembo and Elliot, 1988; Tembo, 1989). DAP availability was made worse by the 1991-1992 drought which reduced cattle from about four million to less than three million while donkeys were reduced from about 400 000 to less than 300 000 (Muvirimi and Jones, 1999).

Earlier findings showed that 60% of the national cattle herd was found in communal areas and up to 65% of communal farmers owned cattle (Mudimu, 1983; Bratton, 1984; Shumba, 1984; Rusike, 1988; CSO, 1997). However, cattle owned do not reveal the level of available draught power since not all animals are old enough or have the capacity or are adequately trained to pull implements (Tembo and Elliot, 1988).

The common farm operations carried out by smallholder farmers include ploughing, harrowing, row marking, cultivating (weeding), ridging and ripping. The majority of smallholder farmers in Zimbabwe own arable land ranging from 2 to 5 ha (Tembo and Elliot, 1988; Barrett, O'Neill and Pearson, 1992) and produce about 70% and 80% of the national cotton and of maize, respectively. The mean total value and share of maize crop production in the communal areas were 8% and 20% of commercial sector respectively, during the period from 1983 to 1999 (Ministry of Lands, Agriculture and Rural Resettlement, 2001). Yields for maize and cotton achieved by communal farmers in Masvingo province are low, about 0.7 t/ha and 0.4 t/ha, respectively (CSO, 2001).

Most farmers start ploughing in November to December at the onset of rains. At that time draught animals are usually not in a healthy condition due to poor grazing conditions and there will be a high demand for draught power for primary tillage (Francis, 1993; Ndlovu and Francis 1997). Donkeys can be worse off in terms of their body condition for draught work as they get very little supplementary feeding and health care from their owners (Bwakura, 1994).

2.3 Main components of a DAP tillage system

The draught animal, harness, implement, operator and the soil are the five components in an animal draught tillage system. Each of these components has its specific characteristics and the performance of the system depends on how these components interact (Inns, 1994). The five components of DAP systems are discussed below, with reference to the smallholder farming sector in Zimbabwe.

2.3.1 Draught animals

2.3.1.1 Availability and distribution of draught animals

The main source of power equivalent to 90% for agricultural purposes is provided by draught animals (Elliot, 1989; Ministry of Lands and Agriculture, 1995). Elliot (*op cit*) cites Bratton (1984), as having found that communal farmers expressed the view that four oxen were required to form a draught team and that two oxen were inadequate. About 30% to 45% of communal area farmers have four or more oxen for DAP (Elliot, *op cit*; Christensen and Zindi, 1991; Ellis-Jones, 1999). Donkeys are more concentrated in the southern and western areas than in the northern areas of Zimbabwe (Christensen and Zindi, *op cit*). CSO (1997) indicated an uneven distribution of draught animals in communal areas. Matabeleland South province had the least number of draught cattle (6%), while Midlands province had the highest number (25%). Mashonaland Central province had the least number of donkeys (1%) while Matabeleland South province had the highest (29%). Shortage of DAP has remained a constraint and 40% to 47% of households in Masvingo province did not own cattle (Gambiza *et al*, 1987; Ellis-Jones, *op cit*). Farmers cultivate larger areas and obtain better yields when DAP is available and therefore, food availability at household level is partly conditioned by livestock ownership (Zindi, *op cit*).

2.3.1.2 Uses of DAP

Draught animals are used for tillage operations and transport. Both cattle and donkeys provide draught for tillage but donkeys are preferred to provide transport. Oxen are generally preferred, but due to shortage of DAP, cows and donkeys are used for draught (Muchena, 1989; Francis, 1993). Gambiza *et al* (*op cit*) identified uses of cattle in order of importance as follows: draught power, milk, manure, cash, meat, lobola, carting, hides and spiritual ceremonies.

2.3.1.3 Selection and estimation of live weight of draught animals

Depending on the ownership of animals, a farmer may select the most suitable draught animals from the available herd. Selection of draught animals must be done before training and using them. Selection of cattle for draught work must be carried out when animals are between 18 and 36 months of age and weighing between 200 and 300 kg (Institute of Agricultural Engineering (IAE), 1986a). The suitability of animals for draught work is determined by breed, health, age, weight, conformation of legs and temperament (IAE, *op cit*). The draught performance of a working animal depends on training, breed, general fitness, body live weight, age, health status, nutrition, endurance, work experience, recent work schedule, temperament and mood (IAE, *op cit*; Starkey, 1989; Sims, 1994; Inns, 1995; O'Niell, 1999).

The live weight of an animal is proportional to its draught capability. Animal live weight can be estimated by measuring lineal body dimensions. The following expression can be used for bovines (Smith, Sims and O'Neill, 1994):

$$\text{Live weight (kg)} = G^2 \times L \times 92.46$$

where G = heart girth in metres

L = body length from front shoulder to base of tail in metres

When estimating live weight for donkeys, the following expression can be used (Pearson and Ouassat, 2000):

$$\text{Live weight (kg)} = (\text{heart girth})^{2.12} \times (\text{length})^{0.688}/3801$$

where girth (cm) is measured around the body just behind the front legs

length (cm) is the distance from the pin bone to the elbow in a straight line

Figure 2.1 shows lineal body measurements that can be used for estimating animal live mass.

a) Measurements for cattle	b) Measurements for donkeys

Figure 2.1: Lineal body dimensions for estimating live mass for cattle and donkeys

Cattle/oxen can continuously produce optimum draught of between 10% and 12% of their body weight. Donkeys can produce draught of about 15% of their body weight continuously (Elliot, 1989; Nengomasha, 1997). The pull exerted by a draught animal can be estimated by using the following expression:

$$\text{Draught (N)} = (0.10) \times \text{mass (kg)} \times g$$

where g = gravitational acceleration

The mean weight of mature donkeys in Zimbabwe is about 150 kg ranging from 105 kg to 185 kg (Bwakura, 1994; Bwakura, Ndlovu, and Topps, 1995). Previous tests conducted locally in red clay and sandy clay soils showed that the minimum draught requirement of the standard conventional mouldboard plough was about 1 kN (IAE, 1985; Nengomasha, 1997; Mbanje and O'Neill, 1997).

2.3.1.4 Training of draught animals

After selecting the most suitable animals for draught work, the next aspect is training. Training develops the animal's strength so that it can perform efficiently and obediently. Well-trained animals carry out field operations accurately, they are easy to control and can work for longer periods. Animals should be given enough time to fully adapt to necessary training steps and they must not be subjected to field tasks until they have gone through all training stages for draught work (IAE,1986a). Draught animals can be trained to respond to a set of voice commands in one language at a time. The IAE Animal Power 1 training manual lists thirteen commands which cover basic words that animals can understand after training (IAE, *op cit*). Draught animals need to exercise and have to be subjected to regular draught tasks so that they are kept fit for work. The methods used by farmers to train draught animals are not documented and may possibly differ between households and locations.

2.3.1.5 Management of draught animals

In order to get full draught potential of work animals, they need to be maintained in a healthy condition. Grazing is generally inadequate and is most scarce at the time when draught animals are expected to do most work, i.e. during land preparation at the start of the ploughing season.

Regular draught work improves the animals' strength, respiration and appetite (IAE, *op cit*) and increases efficiency of animal power (Pearson and Smith, 1994). There is little evidence to suggest that animals in good body condition do more work than those in lean body condition, provided the critical weight required for pulling an implement is not compromised (Pearson, 1997).

Donkeys are increasingly becoming an important source of draught but issues relating to their health are not well known by their owners, researchers and extension staff. Health problems, include those

due to poor harnessing, hoof care and poor or incorrect hitching (Krecek, 1997) and donkeys are susceptible to parasitic and infectious diseases than other equids but are resistant to diseases such as trypanosomaisis (Pearson, Nengomasha and Krecek, 1999).

2.3.2 Harnessing of draught animals

Animal harnesses serve the purpose of linking draught animals and the implement and transmitting draught to the implement. Harnesses help to control and direct animals during work. Properly harnessed draught animals can produce more useful draught output and this improves the efficiency of the animal-implement system (Barwell and Ayre, 1982). In Zimbabwe, draught cattle are harnessed using traditional wooden double neck yokes, skeis and strops (IAE, 1987; Starkey, 1989). Harnesses should be designed to ensure that the animals' strongest muscles are effectively utilised and the animals can put full strength into the work. They should be designed to bring the line of pull as close to the horizontal line as possible. Good harnessing systems reduce unnecessary wastage of animals' effort, energy and minimises injuries, which impair work output (O'Neill, 1999). Figure 2.2 shows the force being applied by an animal at the yoke.

Figure 2.2: An ox applying a pull force (P) at the yoke

From Figure 2.2, a force (P) is applied at the yoke at an angle θ to the horizontal. This force (P) can be resolved into two components:

(a) F, the useful draught force acting horizontally

(b) R, the vertical force supporting the yoke

As the line of pull gets close to the horizontal by decreasing the angle of pull (θ), the useful draught (F) increases and the force acting on the animals neck decreases, thus increasing the draught efficiency (Barwell and Ayre, *op cit*). The angle of pull may be reduced by extending the trek chain without over-extending it beyond recommended dimensions and is dependent on the height at yoke and length of trek chain. A short chain increases the angle of pull and Cosθ becomes smaller than when a longer chain is used. Better stability and control of the plough is achieved by using a longer chain than a shorter one.

Tandem hitching (one donkey behind the other) seem to be more efficient where donkey teams are concerned, particularly for turning purposes and load sharing but some farmers seem to prefer to put up to four donkeys abreast (Jones, 1997). Tandem hitching makes it possible and simpler for the evener behind front pair of donkeys to be connected to the evener of the donkeys behind. Figure 2.3 shows tandem pairs of donkeys for pulling an implement.

The main draught strength of donkeys is in the shoulders and breasts. Thus, cattle neck yokes are not suitable for donkeys. Donkeys are commonly used with withers yokes for cattle. One reason for yoking donkeys is for convenience and simplicity where yokes are already available (Starkey, 1989). The common types of donkey harnesses that can be used are the breast band harness and the full collar harnesses.

Figure 2.3: Tandem pairs of donkeys for pulling an implement

2.3.3 Soil condition

The primary purpose of an animal draught tillage system is to change the original state of the soil to a new desired condition. The initial condition of the soil determines the force to be provided by draught animals. Soil cutting forces have been described by Reece (1965) according to McKyes (1985), and these depend on factors that include soil density, acceleration due to gravity, tool working depth below the surface, soil cohesion strength, vertical surcharge pressure on the soil surface, tool width and factors that depend on soil frictional strength, tool geometry and tool-soil strength properties.

Soil type and soil physical characteristics such as shear strength, penetration resistance and hydraulic properties influence the interaction between the animal draught tillage system components and subsequent plant growth. These properties affect the rate of plant root growth and the flow and availability of water and nutrients for plant use (McKyes, *op cit*).

Soil working properties depend on texture and organic matter content. Soil tillage is normally recommended to be carried out when soil is in the friable range of consistency. In the friable state, soil is moist, soft and has lower implement draught requirement than when it is dry and hard. Therefore changes in soil consistency influences the timing of tillage operations and related bearing strengths of different soil types.

2.3.4 Implements

2.3.4.1 Implement ownership and management

Farmers source implements from various wholesalers and retailers. Smallholder farmers own a range of animal-drawn tillage implements that include ploughs, cultivators, planters, ridgers and harrows. Most of the locally made tillage implements are sold without operating instructions. There is no information available to smallholder farmers on the proper use and maintenance of animal-drawn implements (Francis, Mudamburi and Chikwanda, *op cit*; Koza, Mudamburi, Ellis-Jones and O'Neill, 2001). Eighty percent of smallholder farmers own a plough (Tembo and Elliot, 1988). Table 2.1 summarises the distribution of implements owned by smallholder farmers in the eight provinces of Zimbabwe (Francis, 1996).

Table 2.1: Ownership of animal-drawn implements by smallholder farmers in Zimbabwe

Implement	Provinces							
	Manicaland	Mash Central	Mash –East	Mash-West	Masvingo	Mat. North	Mat South	Midlands
Ploughs (%)	78.5	74.5	90.3	87.1	59.6	81.6	96.8	99
Cultivators (%)	20.3	53.2	51.7	52.7	21.3	31.9	40.9	75.5
Planters (%)	2.2	7.6	3.2	4.3	4.5	3.9	5.4	16.5
Ridgers (%)	1.3	2.5	5.5	5.4	0	1.3	2.2	7.8
Scotch carts (%)	40.5	45.6	50.5	50.5	29.2	43.5	73.1	78.6

Source: Francis (1996)

Findings by Chatizwa and Ellis-Jones (1997), showed that only 15% of farmers could explain the functions of plough parts and setting of ploughs and about 60% of ploughs and 70% of cultivators owned by smallholder farmers were in poor condition. A study in Masvingo province revealed that

about 77% of animal-drawn ploughs had missing drawbars (Mujuru, 1998). When the hitch assembly is removed, depth and width cannot be correctly set. According to Culpin (1981), correct plough setting leads to better standard of work and when a mouldboard plough is properly set, it should run steadily along, cutting a clean surface on the furrow wall and bottom. Although animal-drawn implements are easy to repair and maintain, most smallholder farmers do not maintain them properly (Chatizwa and Koza, 1998).

Francis (1993) noted that smallholder farmers normally ploughed to depths that were below 15 cm. Shallow ploughing often results in poor quality seedbed preparation due to reduced soil inversion and inadequate burial of weeds and crop residues, pan formation, poor water infiltration, increased runoff and erosion (Nyagumbo, 2002). Tests conducted by Chatizwa and Khumalo (1996) indicated that up to 10% more energy is expended when the plough is used without regulators.

2.3.4.2 Local manufacture of animal-drawn implements

Until recently, the manufacture of animal-drawn implements was done by two large companies, Zimplow Limited and Bulawayo Steel Products. The two companies, both based in Bulawayo, Zimbabwe, merged to form Zimplow Limited. Currently Hästt Zimbabwe, formally Tinto Industries, is the other large manufacturer of animal-drawn implements in Zimbabwe. The IAE has developed and tested various types of animal-drawn equipment from local manufacturers that include ploughs, cultivators, ridgers, rippers, planters and dam scoops. Testing of implements was done mainly to evaluate if implements conformed to expected field performance standards and to assess quality of manufacture, durability and suitability under local farming conditions and it is an on-going activity (IAE, 1985).

2.3.4.3 Alternative tillage options for land preparation

Mouldboard ploughing is the common practice for land preparation at smallholder level. Arex recommends a ploughing depth of 20 cm for improved yield (Grant, 1968) but most farmers practise shallow ploughing (Francis, 1993). Conventional ploughing is an intensive technique associated with soil degradation, high draught requirement and loss of crop productivity (Vogel, 1994) and is considered unsustainable due to high surface run-off and soil erosion (Elwell, 1991). Five tillage systems that included hand hoeing, mouldboard ploughing, clean ripping, mulch ripping and no-till tied ridging with a view to promote sustainable (low cost, low draught and labour saving) crop production systems have been evaluated (Vogel, *op cit*). Although ripping and no till tied ridging methods gave better yields than mouldboard ploughing, the initial input for no till tied ridging posed a constraint for adoption with less than 1% of smallholder farmers practising conservation tillage (Nyagumbo, 1998). Low draught requirement techniques such as ripping can be practised since a shortage of DAP affects a considerable number of smallholder farmers.

2.3.5 Implement operators and training in the use of DAP

At household level, the farmers themselves are the operators of the implements. Depending on the household set-up and composition, men, women and children work with draught animals and operate implements, particularly during ploughing and weeding operations. Mwoyowehama (1995) cited by Francis, Mudamburi and Chikwanda, (1999) reported that ploughing is regarded a men's role in African agriculture with 95% level of participation when compared to women. Since most households own ploughs in Zimbabwe, men would normally and traditionally be responsible for ploughing.

Approximately 31% of rural households in Africa are female-headed (Rwelamira and Sylwander, 1999). Male migration causes labour shortages particularly for land preparation. The reduction of

male labour increases the reliance of women on child labour, especially boys who would normally be expected to operate implements.

Formal DAP courses are conducted at the IAE for Agricultural Extension Workers (AEWs) so that they in turn train farmers. Training of agricultural extension officers in the use of DAP started in 1964 at Domboshawa Training Centre (Mudamburi, 1989) and was moved to the IAE in 1985, (Fischer, 1986; Mudamburi, *op cit*). Two of the basic animal power (AP) courses run at IAE cover: AP1-Selection, care and training of draught animal; and AP2-Ploughing using draught animals (IAE, 1986a; IAE,1986b). An evaluation of impact of training in animal-drawn implement used by farmers in Murewa district showed that trained farmers could use implements better than those untrained (Mudamburi, *op cit*).

The aim of the study was to assess household capital resource base and evaluate the use of available DAP and tillage implements at smallholder level in order to identify possible options for improving the performance of draught animal tillage systems for crop production. The study focused on evaluating the effect of implement renovation on field performance of ploughs and cultivators. It also evaluated the effect of implement renovation on soil physical characteristics and crop yield. The study also demonstrated the value of correct implement setting, operation, repair and maintenance to farmers in order to achieve better return from the use of DAP in land preparation.