

Draught Animals and their Management: The Future in Rain-fed Agriculture

R.A. Pearson

Centre for Tropical Veterinary Medicine (CTVM), Easter Bush, Roslin,
Midlothian, EH25 9RG, Scotland, U.K.

Abstract: The use of animal power in rain-fed crop production can increase farm productivity, through increased area cultivated, yield per farm and improved access to markets. Farmers maintaining animals for work need to ensure that they integrate effectively into their farming system, to make the best use of feed resources, bearing in mind the diminishing availability of grazing land, increasing population pressure and changing demands for meat and milk. Low quality forage is a feature of most systems and the diet of working animals can be constrained by low feed supplies at the end of the dry season, the time when the animals are often required to do most work. This review examines the ways in which farmers can modify their feeding and management practices to cope with the above factors and maintain agricultural productivity. Some examples of management systems where animals are kept for work alone, and for work and meat/milk production, are also described.

Key words: Draught animals, crop yields, feed requirement, feed resources, crop production, transport.

Draught animals continue to play an important role in agricultural production and transport in many tropical countries. Although draught animal power has been superseded by tractors on many of the large commercial farms in the tropics, it continues to be a relevant technology in small scale agriculture. This is on farms where it is not economic or practical to use motorized forms of power. Draught animals are maintained over a wide range of agro-ecological zones, but are particularly common on small mixed farms where rain-fed crops are grown mainly for food production. In this paper recent research on the feeding and management of animals used for work is discussed in the light of the current needs of farmers and the contribution that draught animals can make to crop production in

rain-fed systems. Some examples of management systems found in semi-arid areas are given to illustrate the general points made.

The Contribution of Animal Power in Cropping Systems

Area cultivated

In semi-arid areas, farmers owning draught animals tend to have larger farms than those not owning animals. For example, in Tanga region, Tanzania, a survey in 1990 showed that most farms were under 2 ha while only a small number had over 3 ha. However, the farmers owning animals tended to have farms over 3 ha (Starkey and Grimm, 1994). This pattern can be attributed to two factors: (a) animal power requires greater investment than is needed

in manual labor, so making it less attractive to farmers on the smaller farms (Reddy, 1988), and (b) farmers with access to animal power increase the area they cultivate (Francis, 1988; Panin and de Haen, 1989; Sumberg and Gilbert, 1992). The implication is that there is a positive correlation between cultivated area and use of animal power.

Clearly, expansion is possible with animal power in semi-arid areas that are farmed extensively, if only because farmers take less time to prepare and plant land if they use animal power than if they use manual tillage methods. Labor savings can be considerable. For example, in a comparison of manual and animal power, inputs into rice and maize production in central Nigeria land preparation took about 315 hr ha⁻¹ for rice (ploughing and harrowing) and 65.5 hr ha⁻¹ for maize (ridging) using manual labor, but only 94 hr ha⁻¹ for rice and 28 hr ha⁻¹ for maize when oxen were used (Lawrence *et al.*, 1997). When the use of animal power results in less suitable, marginal land being taken into cultivation, then it can encourage soil erosion and land degradation as well as poor crop yields. Kruit (1994) suggests that this has been the case in Niger, where animal power has been largely used to extend cropping area in order to increase total production. Stocking (1988) has highlighted similar problems in other countries using animal power in crop production.

Expansion is only possible where there is potential to expand. In the more intensively farmed humid areas, in Java and Bangladesh for example, where most cultivatable land is already under crops, it is virtually impossible to increase the area

planted; however, animal power can improve farm activities and increase yields.

Crop yields

Farmers with access to animal power tend to opt for more extensive production than those using hand-tillage techniques (Francis, 1988), with a resulting lower yield per hectare. However, provided the area cultivated is increased, output from the farm can increase.

Adoption of animal power in crop production is often associated with use of other inputs such as improved seeds and fertilizers, and so it will be difficult to distinguish which one had maximum effect. In the cotton growing regions of West Africa, for example, where animal power was encouraged by the cotton companies, food grain production increased in some areas when animal power was introduced. The production of food crops benefited not just from more timely tillage, but from the fertilizers which were applied to the cotton cash crop (Mahdavi, 1992).

The use of animal power can improve timeliness of planting (Shumba, 1984), and therefore, can optimize yields per hectare in areas where growing seasons are short and time of planting is crucial to ensure a good crop. However, in areas where weeds are a problem, and good weed control is essential to optimize crop yields, use of animal power may result in lower yields per hectare. This can be due to two factors: (a) soil inversion using an animal drawn implement (mouldboard plough or ridger for example) does not result in as good a weed smother as when soil inversion is done by hand, and (b) increased area cultivated means that weeding may be done

less frequently after crop emergence, resulting in a lower yield per hectare.

In a comparison of manual labor and animal power, in the cultivation of rice and maize in an inland valley region in central Nigeria, weed infestation was heavier and weeding took longer on the ox-cultivated plots in both rice and maize. This did not significantly affect yields on the weeded plots, but when weeding was not done, yields were almost halved for rice, and were almost non-existent for maize, whether animal power or manual labor had been used for land preparation (Lawrence *et al.*, 1997).

In northern Nigeria, on different soil types, use of animal power had a beneficial effect on weed control. Use of ox-drawn implements for ridging and remolding ridges for millet and sorghum production resulted in plots of land which required less weeding than those prepared using the traditional hand hoe techniques (Olukosi and Ogungbile, 1994). The above two examples illustrate the inadvisability of attempting to generalize when assessing the impact of animal power on crop yields. Responses will vary depending on soil type, crop and rainfall pattern.

Transport - crop harvesting and marketing

Carts, although more expensive than a plough, can be used most of the year for a range of activities, which can be income generating. Animal transport can reduce post-harvest losses from pests by allowing timely removal of crops from the fields (Anderson and Dennis, 1994). Farmers with a cart seem to make better use of crop residues than those farmers that do not have access to a cart and are better able

to market their goods. Several studies have shown that farmers with a cart can get a higher price for their goods, since they can sell direct to markets and avoid having to sell to a 'middleman' visiting the village (Scheinman, 1986). Farmers with a cart also find it easier to move manure or purchased fertilizer to the field to boost soil fertility. Greater use of fertilizer and manure has been recorded on farms which own an animal cart (Scheinman, 1986; Anderson and Dennis, 1994).

Similar benefits have been observed on a smaller scale in semi-arid areas where farmers own a donkey and it is used to carry manure or fertilizer to the field, to take residues from it and carry crops to market, whether or not these animals are also used in land preparation.

Changing Needs of Draught Animal Power Farmers

The world population is predicted to increase from 5.4 billion to about 10 billion within a few decades, largely in developing countries. To feed this additional population, more land will need to be devoted to crops, reducing the land available for pasture and fodder (Sansoucy, 1995). This should mean that more crop residues and agro-industrial by-products will become available for feeding livestock. Farmers keeping livestock in these cropping systems, where grazing land is decreasing, will have to re-evaluate their feeding strategies and may have to adopt different feeding systems. In Africa, numbers of small ruminants have tended to increase as a proportion of the livestock on farms as farm size and grazing areas have declined. This is except in those areas where draught animal power is used for

cropping and transport (Leeuw and Rey, 1995). For example, Coe (1991) found that in the southern portion of the semi-arid zone and in most of the sub-humid zone of Senegal, although population pressure is increasing, work oxen still dominate the livestock enterprise of mixed farmers. In areas where draught animal power has been a feature of mixed farming enterprises, the strategies to overcome the reduced quantity and quality of grazing land have been to move to motorized power, or to modify animal husbandry practices.

In parts of South Asia, which have high population pressures and are farmed intensively (e.g., in Vietnam, Thailand, Malaysia), the reduction in grazing land has meant, in many of the rice growing areas, a change over from buffalo to motorized power, in the form of two-wheeled power tillers and small tractors. However, on small farms of less than 3 ha, it is unlikely that draught animal power will disappear as it can compete economically with petrol-driven tractors under these conditions, both in Asia (Campbell, 1993) and Africa (Panin, 1995). On farms where motorized power is not feasible, many farmers are modifying their herd structure. The use of 'multi-purpose' animals for work, i.e., the farm cows and beef animals, removes the need to keep work oxen and hence, saves on feed requirements. This is an increasingly common sight on draught animal farms, not just in Asia, but also in Africa, where grazing land is declining. For example, surveys by several member countries of the Animal Traction Network for Eastern and Southern Africa (ATNESA) have shown a steady increase in the use of cows for work in many areas. With the exception

of places where it is culturally unacceptable to use cows for work, or cattle for meat, the modern draught ruminant is usually now truly multi-purpose, providing milk, and/or ultimately meat, in addition to work and of course, manure as fertilizer or fuel. In many semi-arid parts of the world, Africa in particular, donkeys are increasingly being used instead of oxen for land preparation and cultivation. They are easier to feed, and are hardy.

As more marginal land is brought into cultivation, to meet the increasing demands for food, soil and water conservation is essential. Many farmers are becoming increasingly conscious of the need to maintain soil fertility and aware of the damage that erosion can cause. Engineers and soil scientists are working together with farmers in the development of implements and tillage techniques that can help to conserve soil and water, particularly in marginal areas. Some of the practices recommended for conservation tillage increase the demand for both labor and animal power (Ellis-Jones and Mudhara, 1998). This has implications in the selection of animals for work, and also on the acceptability of conservation methods by farmers with no opportunities to choose large animals for work.

Farmers are modifying their animal husbandry practices in the more intensively farmed and densely populated areas of Asia and Africa. In these areas, animals are tending to be tethered or kraaled for longer, both for security and reduction in available grazing land. They are often fed on stored crop residues, collected fresh forage or purchased feeds. Therefore, more time is spent in collecting and carrying food for the animals in the year than previously in these

farming systems. Greater reliance on crop residues and purchased high quality feeds, for those that can afford them, and greater pressure on communally owned grazing resources have frequently been reported as systems being more intensive. Often greater reliance is also placed on locally reared stock, rather than those brought in from grazing systems.

A sufficiency of grazing land in the past has generally meant that draught animals have been left to forage on rangelands, particularly out of season, and supervision of feeding has been minimal. The greater control that cut-and-carry methods of feeding can bring, can involve the farmers in more decision-making. They can, if they wish, decide on the amount and type of feed that each class of livestock will receive in any season. The farmers need sufficient information on the outcomes of this 'strategic' feeding to make best use of the farm feed resources. There is now considerable data available on the needs and consequences of feeding on the performance of draught animals to enable farmers to make informed decisions when managing these animals. This information can be used by local advisers to produce focused recommendations on management strategies for today's animals used for work.

Management of Working Animals

The management of draught animals should include efficient management of the power itself, both when it is required in seasonal tasks and over the rest of the year so that the resource is not wasted. Number of days worked depends on cropping patterns, animal availability and land ownership. For example, in E Java work

periods for draught cattle varied widely from 10 to 110 days per year even in one village (Komarudin-Ma'sum *et al.*, 1993), while in Tanzania, use can vary from 60 to 180 days per year, within a relatively small area (Mgaya *et al.*, 1994), and ownership of a cart can mean a further increase in use. In southern Nepal and the plains in India, it is not uncommon for farmers to make use of their ox-carts for travel and transport on almost every day of the year, when the animals are not required for field tasks, and roads remain passable. Lending and borrowing and communal use of animals to ensure tasks are completed at the right time are practices that have been adopted by farmers to make the most of the animal power they have in an area.

Management of working animals does not just depend on the requirements for work, but also on the other outputs that are expected, in addition to work. In areas where religion prevents the use of cows for work or the rearing of cattle for meat, draught animals are only expected to provide manure in addition to work. The male animals in use have generally reached maturity. Compared to other productive outputs from cattle, a 450 kg ox doing a day's work of 5-6 hr requires an energy intake equivalent to that needed to produce about 0.75 kg live weight gain or about 5-6 L of milk. Management is easier for these draught animals since the farmers only need to consider the work load and live weight of their animals. The same animals are often kept by one farmer for many years.

In areas where meat markets are good, some farmers regularly replace their working animals every 3-5 years. They buy

young animals at 3-4 years of age, train and work them until they are 8-9 years old and sell them for meat. For approximately the price of one 8-year-old steer, farmers can buy two young animals again. Farmers are prepared to accept a reduced work output from the new animals for 1-2 years as they gain experience. Some farmers even sell after only 1-2 years of work. This system of maintaining working animals can be found throughout Asia, Africa and Latin America, where reliable markets for meat exist, and is becoming an increasingly popular way of managing working ruminants.

Diminishing land resources to maintain animals has led to an increase in the use of female animals for work (Matthewman, 1987). Management strategies become more complex when a farmer wishes to use his cows (or mares) for work and expects them also to produce an offspring. Supplementary feeding of low quality forage is necessary to avoid weight loss and ensure good body condition before parturition so that early return to oestrus is possible. The aim should be to feed to maintain live weight, but this is not always possible, when requirements for pregnancy and lactation, as well as for work have to be met. Live weight loss in working female cattle and buffalo can lead to reduced ovarian activity and longer calving intervals (Winugroho and Situmorang, 1989; Zerbini *et al.*, 1993). However, in some countries, breed differences in the effects of nutritional stress on ovarian activity have been observed. Bali cattle appeared more sensitive than the Madura, Ongole and Brahman cross cattle in Indonesia (Wijono *et al.*, 1993). Total milk yield can also decrease on work-

ing days (Matthewman *et al.*, 1993). Farmers who recognize that they cannot feed sufficient nutrients to maintain cow live weight, often compromise. They accept that they are unlikely to maintain production (milk yield and calving interval), if they also use their cows for work.

Feed Requirements for Work

Detailed reviews of the research undertaken to quantify the nutrient requirements for work have been undertaken over the last ten years (Lawrence, 1985; Teleni and Hogan, 1989; Pearson and Dijkman, 1994). Most of the food eaten by a working animal is used to provide energy. Requirements for protein, vitamins and minerals, other than for maintenance are negligible in the adult draught animal (Lawrence, 1985; Pearson and Lawrence, 1992). Working animals have an increased requirement for water. The amount needed will depend on the duration of work, and the climatic conditions prevailing. For example, the water intake of 300 kg oxen working for 5 hr per day in temperatures of about 30°C in Niger increased from about 23.7 to 31.5 L day⁻¹ (Fall, 1995). Provision of water can be a problem in semi-arid areas where the water supply may be some distance from the farm. Water deprivation can reduce food intake, and therefore, exacerbate the low nutrient supply from poor quality forage.

The amount of extra energy expended on a working day, above that required for maintenance, depends on the work done. Several factors determine this, all of which interact. Firstly, the draught force generated, which is dependent on the size, health, temperament and ability of the animal(s),

the implements used, and in some cases, the operator. Secondly, the surface over which the animal is working, which will determine the extra energy the animal has to use for moving, and thirdly, the distance covered when working, which will be determined by the operator, the task being undertaken, the length of the working day, the weather and the health and temperament of the animal. The energy used for walking by oxen for example can vary from 1.5 J kg⁻¹ m⁻¹ on a firm level sealed road to 8.6 J kg⁻¹ m⁻¹ on waterlogged soil (Dijkman and Lawrence, 1997). It is not surprising that the estimated daily energy used for work varies in different situations (Table 1). Energy costs of walking per unit of live weight in camels and donkeys tend to be lower than those measured in cattle and buffaloes (Yousef *et al.*, 1972; Yousef *et al.*, 1989; Dijkman, 1992; Maloiy and Rugangazi, 1993). Camels also have a lower energy requirement for maintenance than cattle (Guerouali and Zine Filali, 1992). Horses, because of their high speed of walking, and therefore, ability to cover long distances during work, tend to have a higher daily energy requirement when working than the ruminants (Table 1). In Mexico, for example, horses weeding maize often walk 35-40 km in a day's work (Arriaga-Jordan, pers. comm.).

Feed resources and their management

One of the most common problems farmers are faced with, when keeping working animals, is the provision of food of sufficient quantity and quality at the time when the animals are required to do most work. The start of the cultivation season is usually the time when feed stocks are at their lowest,

particularly when the dry season is long. This is when the browsing ability of the camel and donkey can be an advantage. The feeds given to working animals depend mainly on season and location. Most management systems make use of some of the following during the year: native grasses on permanent pasture, fallows and forested areas (on public land, communally owned land or on the farm), roadside grasses, crop residues remaining after the harvest and to a lesser extent, agro-industrial by-products, tree fodder and browse. Santoso *et al.* (1993), for example, listed 28 different forages used by farmers in West Java to feed their working animals of which only seven were described as 'good quality'. Studies of feeding practices in other areas of the world reveal a similar picture. Therefore, for most of the year, working animals in the tropics consume poor quality forage diets that have a high cell wall content, low nitrogen content and poor digestibility. The ME content of these diets is rarely higher than 9 MJ ME kg⁻¹ dry matter (Parra and Escobar, 1985; Tahar and Mahyuddin, 1993; Topps and Oliver, 1993).

Intake and digestibility of these poor quality diets can be low. In the case of ruminants this is often because poor nitrogen content and low rumen degradable nitrogen levels limit the rate of microbial synthesis in the rumen and thus the capacity for fiber digestion and intake. Oxen, buffalo and donkeys consuming high roughage diets do not tend to increase their intake of food to match their increased energy demands on a working day (Teleni, 1993; Lawrence and Becker, 1994; Pearson and Dijkman, 1994). When work occupies over 5-6 hours in the day, intake may even decrease, as

Table 1. Performance and estimated daily energy expenditure, expressed as a percentage of maintenance requirements, per animal of pairs of cattle and buffalo, and teams of four donkeys working under various production systems

Task	Animal type	Average live animal weight (kg)	Hours spent in work	Location	Average speed of working (m s ⁻¹)	Average power output (W)	Estimated energy expenditure
Ploughing wet land	buffalo		4	Indonesia	0.50	290	1.24-1.37 ^a
Ploughing dry land	cattle		3	Indonesia	0.95	580	1.71-1.76 ^a
Ploughing dry land	cattle	250	5	Nepal	0.33	150	1.25-1.46 ^b
Ploughing dry land	cattle	150	3-4	Bangladesh	0.64	170	1.4-1.5 ^c
Ploughing dry land	cows	125	2-3	Bangladesh	0.61	125	1.3 ^c
Ploughing sandy soil	donkeys	130	2-3	Zimbabwe	0.72	220	1.5 ⁱ
Ploughing dry land	donkeys	150	2-3	Zimbabwe	0.62	128	1.4 ⁱ
Ploughing rice field	horses	530	6	Chile	1.39	1120	1.7-2.4 ^d
Ridging	cattle	300	4-5	Mali	0.74	590	1.44 ^e
1st weeding millet	cattle	260	4-5	Gambia	0.80	315	1.78 ^f
Harrowing dry land	cattle	620	5	Costa Rica	1.10	900	1.6-1.8 ^g
Carting loads	cattle	620	5-6	Costa Rica	1.03	210	1.6 - 1.8 ^g
Carting loads	buffalo	400	5-6	Nepal	0.94	320	1.76-1.80 ^h
Carting loads	horses	650	8	Chile	1.60	570	1.86-2.40 ^d

^aBakrie and Ma'sum, 1993; ^bPearson *et al.*, 1989; ^cBarton, 1987; ^dPerez *et al.*, 1996; ^eBartholomew *et al.*, 1995; ^fAlford, 1994; ^gLawrence, 1985; ^hPearson, 1989; ⁱNengomasha, 1997.

the time available for eating and ruminating decreases. Effects of work on digestibility of feed are inconclusive. In the long term, when working animals are in regular work, some changes in intake may be seen. Over three months of regular but intermittent work, a gradual increase in average weekly intake was seen in lactating cows (Zerbini *et al.*, 1993), while steady increases in intake over time on working days as animals adapt, have been seen in oxen (Fall *et al.*, 1997) and donkeys (Nengomasha, 1997).

Any increase in rate of eating, or improvement in digestibility associated with work, is not sufficient to meet all the additional energy requirements for most types of work. In practice most farmers expect

their animals to lose weight during the working season. They are generally reluctant to spend money on commercial feeds or feed supplements. To be acceptable improvements in the diet have to make use of local foodstuffs and require little extra labor input.

In grazing systems on semi-arid pastures, camels are able to avoid competition with cattle and sheep by browsing larger bushes and trees in addition to grazing. They have the advantage of being able to select medium and high quality plants, which are not used by cattle or equids. However, when camels are fed exclusively on low quality, high fiber diets, they can improve digestion of fiber by increasing feed particle retention

Table 2. Labor used in feeding cattle and buffalo used for work during the wet and dry seasons in two villages in Subang, West Java (from Teleni *et al.*, 1993)

Feeding systems	Hours per day			
	Wet season		Dry season	
	Buffalo	Cattle	Buffalo	Cattle
Village 1				
Cut-and-carry	3.2	4.6	2.7	4.4
Herding	5.0	8.3	8.3	9.1
Village 2				
Cut-and-carry	2.5	2.2	3.0	2.6
Herding	5.0	5.6	6.4	6.6

time in the forestomachs (Von Engelhardt *et al.*, 1992). Their ability to tolerate long periods without water, which enables them to cover long distances and therefore use grazing areas inaccessible to other domestic livestock is a further advantage in harsh environments (Von Engelhardt *et al.*, 1992).

In cut-and-carry systems strategic feeding is often adopted by farmers who do not have the means or desire to supplement the staple forages. When given sufficient forage to enable a good degree of selection of material then working animals can, in some cases, maintain weight on forages that would normally be expected to provide insufficient energy for maintenance, e.g., millet stover leaves may have a crude protein content of 70-100 g kg⁻¹ dry matter (DM), whereas the whole stover plant including the stem can have a mean crude protein content of only 40 g kg⁻¹ DM (Fall, 1995). Some farmers, particularly in the working season, allow their working animals access to the crop residues first in the day, before letting their other livestock eat.

Time of feeding can be important to minimize heat load during the working period. Supplementary feeding after work in ruminants, minimizes intraruminal heat production in the working period. It has also

been suggested that feeding at least 2 hr before work insures a ready supply of energy-yielding substrates for working muscle, particularly in horses and donkeys. Farmers adopt both these strategies when feeding draught animals; however it is not clear whether this is an informed decision, or due to an acceptance of traditional practices, by those unaware of any alternatives.

Labor needed to feed working animals can be considerable and may differ in different seasons (Table 2). In the semi-arid areas of Niger in the dry season, animals can be grazed away from the home for periods up to 11 hr day⁻¹. Children have an important role in the supervision of grazing animals, and in collection of field and roadside grasses in cut-and-carry systems on smallholder farms. Provision of schooling for children in many areas can leave the farmer with a shortage of labor, reducing grazing time and/or the amount of forage cut for each animal. In some areas men are also away working and the women now run the farm. While this increases household income, it also places constraints on the availability of daily labor to manage the animals. Any recommendations on modification to management

practices need to take into account these changes in the labor pool.

Feeding Management Systems

The diversity of the agro-ecological zones in which draught animals are found and the differences in cropping patterns even within a small area make it difficult to make specific recommendations concerning feeding practices. Accepting that considerable variation exists even between farmers in the same village, some examples of feeding systems in contrasting situations are given below.

Draught oxen in the hills of eastern Nepal

The Hindu religion is prominent in Nepal and so cattle are not kept for meat, nor are female cattle used for work. Oxen are used in pairs for a variety of tasks in most months of the year and are often kept well into old age. Working buffalo are not used. An ard plough is used for ploughing. Other tasks include harrowing, threshing rice, sowing maize behind the plough, ploughing after seeding and leveling the rice field. The steep nature of the terrain makes the use of carts impossible. Cattle are fed in cut-and-carry systems for most of the year, with crop residues (maize stover and rice straw) being collected off the fields and stored before cattle are allowed to graze the stubbles. Cattle are small, 200-300 kg when in good condition, but have to work at average draught forces of 15-19 kg dry fodder 100 kg^{-1} live weight to accomplish most tasks (Pearson *et al.*, 1989). Hence little weight loss is possible before performance is affected. As elsewhere, the quality of the staple feed is insufficient to meet requirements for all but a small

amount of work. Tree fodders have a role as supplementary feed on many of these farms. Supplementation of staple diets may not always prevent weight loss during work, but it can speed up live weight gain after work. For example, draught oxen in Nepal fed *ad libitum* on rice straw (nitrogen content 5 g kg^{-1} DM) supplemented with 4 kg fresh weight of the tree *Ficus auriculata* (nitrogen content 22 g kg^{-1} DM) gained weight more rapidly after the work period than cattle receiving only the rice straw diet (Pearson, 1990).

Draught animals in West Africa

Draught cattle and sometimes donkeys and horses are used to cultivate the land. Tillage practices vary depending on soil type and rainfall, from the use of a mould-board plough on the wet lands (for example in the cultivation of the fadamas and uplands in the sub-humid zone of Northern Nigeria, draught forces required 1200-1400 N, Lawrence *et al.*, 1997) to the use of ridging and reduced tillage techniques to conserve water and reduce erosion in the sandy soils at the edge of the Sahara. The latter can often require greater draught forces to operate than those required for ploughing and ridging. When thinking about the size of animals required for work, as a general rule of thumb it is said oxen can sustain a pull equivalent to 12-15 kg dry fodder 100 kg^{-1} live weight over a prolonged period of work (4-6 hr day^{-1}) and donkeys 15-17 kg dry fodder 100 kg^{-1} live weight (2-4 hr day^{-1}). However, actual values are often higher than this. In villages in the semi-arid zone in Mali for example the following tasks were undertaken in a year by a pair of 280-330 kg oxen (Bartholomew *et al.*, 1995): 2-3 days ploughing (825N), 16 days

ridging (835N), 1 day seeding (292N), 11 days weeding (656N) and 3-4 days earthing up (708N). Timeliness of cultivation is important so, although cattle may work for only short periods (some as little as 35 day in year in semi-arid areas as above), there is little opportunity for a rest day during the planting season. Donkeys and horses are often used for the lighter tasks such as sowing and weeding to help meet the requirements for power at the busy times of the year.

Working animals in West Africa graze on natural rangeland during the rainy season. However, according to Kowal and Kassin (1978) estimated annual rangeland dry matter productivity is low in the areas where animal power is popular (1082 kg ha⁻¹ Northern Sahel, 1742 kg ha⁻¹ Southern Sahel, 2324 kg ha⁻¹ Sudan, 3097 kg ha⁻¹ Northern Guinea, 3889 kg ha⁻¹ Southern Guinea Savanna). The cattle are generally kraaled at night for security, and manure collection. The quality of available grasses at the start of the rainy season is high (crude protein content 80-90 g kg⁻¹ DM, Saleem, 1986) but biomass is low. As the rainy season progresses, forage biomass and lignin content increase, but there is a reduction in crude protein and digestibility (Mathers and Otchere, 1993). In Sierra Leone, where green pasture is available virtually year-round, feeding of animals for traction is not a problem. However, further north in Nigeria and Mali for example, where the rainy season is of a shorter duration (often less than 4 months), dry season feeding is a problem (Otchere *et al.*, 1988; Reddy, 1988; Sangare *et al.*, 1988). Live weight losses on the natural pasture in the dry season can be considerable. For example

in the Northern Guinea Savanna of Nigeria over a six month dry season cattle on natural grazing lost 40 g head⁻¹ day⁻¹ while supplemented groups on the same natural forage gained 350 g head⁻¹ day⁻¹. Stocking rate was at 150 kg live weight per ha. In another study in the same zone cattle lost 300-400 g head⁻¹ day⁻¹, while mature Bunaji cows in the Southern Guinea Savanna in the sub-humid zone of Nigeria lost proportionately about 0.16 of their live weight in one dry season (Mathers and Otchere, 1993).

Millet, sorghum, rice and maize are the staple crops grown in rain-fed agriculture in West Africa, depending on the reliability and quantity of the rainfall in the areas. Hence, residues from these crops form a major component of the forage available for draught animals after the harvest on many farms. However, quality can vary depending on the component of the plant consumed and the length of time that the crop residue remains in the field after harvesting (Table 3). Groundnut and cowpea residues provide additional forage to reduce the shortfall in feed supply between successive rainy seasons, and/or to provide supplementary feeding during work, to minimize weight loss. For example, in a study of draught oxen used to produce millet and groundnut crops in villages in the Gambia, Alford (1994) observed that groundnut hay (9 MJ ME kg⁻¹ DM) provided the only source of feeding for much of the working season. Grazing of natural pasture only occurred for 2-4 hr daily as hay supplies ran out. Cattle of 260 kg live weight worked for about 5 hr day⁻¹, with a total daily energy requirement of 60 MJ ME. When animals were given an average of 6.3 kg

Table 3. Dry matter (DM) digestibility (DMD) and crude protein (CP) content of forage from millet and sorghum fields at the start of grazing in the sub-humid zone of Nigeria (from Powell, 1986)

Component of plant	Millet DMD	Millet CP (g kg ⁻¹ DM)	Sorghum DMD	Sorghum CP (g kg ⁻¹ DM)
Immature panicle	0.65	126	0.60	78
Upper leaves	0.60	114	0.60	73
Lower leaves	0.59	76	0.54	33
Upper stalk	0.48	24	0.49	14
Lower stalk	0.46	25	0.45	13
Total cereal	0.50	41	0.48	28
Grasses and weeds	0.55	70	0.55	70
Average	0.51	68	0.50	42

DM groundnut hay per day, weight losses were at about 300 g head⁻¹ day⁻¹, with oxen losing an average of 22 kg over the 60 day working season. Dry season feeding of hay was limited to ensure that the hay lasted well into the working season (Alford, 1994).

Although it has often been suggested that draught animals should be in good condition, with adequate fat reserves, to work efficiently, there is little conclusive evidence to show that animals in good body condition work faster and/or longer than those in poor condition at the start of the work season. Nor is there convincing evidence that crop yields are improved by dry season supplementation of oxen. Studies in Mali (Bartholomew *et al.*, 1994) and Niger (Fall *et al.*, 1997) suggest that body weight and not condition is the main determinant of work capacity in oxen. For example, in Niger, thin animals (360 kg, body condition score 2.5 on a scale from 1 emaciated to 9 obese, Nicholson and Butterworth, 1986) were able to do as much or more work per day (8262 kJ) as ones in better condition (body score 4-6, work

output 7437-7876 kJ), of similar live weight. Regardless of body condition the heavier animals did the most work in a day. A similar conclusion was reached by Teleni (1993) studying buffalo in Asia. He suggested that weight loss in buffalo during the work season is not a problem provided the critical weight for sustained draught load is not compromised (proportionately about 0.12-0.15 live weight).

In villages in Mali, urea was used at a rate of 4% to improve the feeding value of bush hay during the dry season. In comparison with an unsupplemented control group, cattle (280-330 kg) benefiting from the urea-treated hay showed a slight reduction in weight loss during the dry season (100 g head⁻¹ day⁻¹ compared with 200 g head⁻¹ day⁻¹ in the control group). Oxen which received the treated hay plus an additional supplement of 1 kg day⁻¹ of cotton seed residues achieved daily grains of 200 g head⁻¹ day⁻¹ between April and June (Khibe and Bartholomew, 1993). However, no effect of dry season supplementation on work output in the following cropping season was observed.

Clearly the economics of dry season feeding have to be considered in each area. While it may not be economic to carry out supplementary feeding in the dry season where work periods are short, where animals work for longer periods or are also being fattened for meat, the economic return of such a practice may be worthwhile.

Draught cattle in Ethiopia

Many farmers in the Ethiopian highlands use draught cattle. Tillage is mostly carried out using the traditional wooden ard plough, the maresha. The maresha is used to cultivate several crops at different elevations in the highlands. These include the cereals - barley, wheat, teff, sorghum, maize, bulrush and millet; pulses - for example cowpea, lentils and faba bean, and oil crops - for example linseed, nough (*Guizota abyssinica*), safflower and cotton seed. Two or three ploughings are usually needed for plots, depending on previous use and the type of crop currently being planted. Measurements on farms in the Debre Berhan area showed that local oxen with average weights of 280 to 300 kg generated draught forces equivalent to proportionately 0.16-0.18 of body weight when ploughing short term fallow land (Goe, 1990).

In Ethiopia, as in Mali, oxen may only work for a short period each year (40-60 days). Farmers normally work their oxen for 6-7 years, starting when they are about three years old. After this they are usually fattened, before being sold for meat. A feeding trial to establish the effects of age on changes in live weight and condition for draught oxen was undertaken by Osuji and Capper (1992) to find the most appropriate system of management. Animals

were group-fed an experimental diet of 551 g concentrate (259 g kg⁻¹ wheat bran, 3 g kg⁻¹ salt, 38 g kg⁻¹ bone meal, 251 g kg⁻¹ cotton seed cake) and 449 g teff straw at a rate of 2.5 kg per 100 kg live weight for 18 weeks. Age affected live weight gains. The average daily gains were 620, 510 and 410 g head⁻¹ day⁻¹ for animals aged 4-5, 7-8 and 10-11 years, respectively. Oxen in poor condition at the beginning of the fattening period gained more weight than those in good condition (69 vs. 55 kg), despite their lower daily feed intake (2.15 vs. 2.99 kg DM/100 kg live weight). The authors concluded that farmers should consider fattening their oxen for sale much earlier than at present, after only 2-3 seasons of work. It seems that the opportunity cost of work as a by-product of fattening animals may be less than anticipated because animals that are lean at the beginning of the fattening period show better feed conversion (Osuji and Capper, 1992).

Integrating work with fattening is one way to improve income. Alternatively, farmers can work their dairy cows. In the Ethiopian highlands comprehensive studies of the feeding of crossbred cows for work have been undertaken (Zerbini *et al.*, 1993). These cows were larger than the local draught oxen (355 kg vs. 290 kg) and therefore better able to do the work required. Zerbini *et al.* (1993) in a long term study looked at the consequences of feeding on productivity of these cows when used for work. The cows were fed a basal diet of hay (7 MJ ME kg⁻¹ DM, 65 g kg⁻¹ crude protein) and allotted to one of four groups: SW (supplement and work), SNW (supplement and not worked), NSW (No supplement and work) and NSNW (no sup-

Table 4. Mean values for milk yield from calving to 150 days post-partum and percentage of cows showing oestrous, or conception by 200 and 365 days in Ethiopian crossbred dairy cows used for work

Treatment ^a	Mean milk yield (kg)	Oestrous (% of cows)		Conception (% of cows)	
		200 days	365 days	200 days	365 days
SNW	931.3	70	100	70	100
SW		50	100	40	90
NSNW	592.0	60	60	50	60
NSW		10	20	10	20

^a SNW = Supplemented no work; SW = supplemented work; NSNW = no supplement no work; NSW = no supplement work, see text for details of treatments (Zerbini *et al.*, 1993).

plement no work). The supplement (11.5 MJ ME kg⁻¹ DM, 250 g kg⁻¹ crude protein) consisted of 3 kg concentrate (mix of 800 g kg⁻¹ noug cake, 150 g kg⁻¹ wheat middlings, 20 g kg⁻¹ bone meal and 30g kg⁻¹ salt). Work involved pulling a sledge for 4 hr day⁻¹ at 350-450N for 4 days week⁻¹. Animals worked a total of 100 days in two 50 day periods, starting 14 and 194 days after calving. The results (Table 4) showed that milk yield and reproductive performance were impaired more by lack of supplementation than by work and that work had proportionally more effect on the unsupplemented cows than on the supplemented ones. Body condition score and live weight changes showed a similar trend (Zerbini *et al.*, 1993). The study illustrates the importance of maintaining live weight of working cows to prevent reproductive efficiency being impaired.

In Ethiopia, as in other tropical areas, staple feedstuff are not of a sufficient quality to provide enough nutrients for work and other productive functions. Goe (1987) reported apparent digestible DM coefficient and ME of hay and crop residue straws averaged 0.55 and 8 MJ ME kg⁻¹ DM from bimonthly sampling over two years on 24 smallholder farms. Crude protein

averaged 60-80 g kg⁻¹ DM for hay and 50 g kg⁻¹ DM for crop residues. Forage sampled from grazing areas in the dry season had 0.55 DM digestibility coefficient, 63.0 g kg⁻¹ DM crude protein and 8.6 MJ ME kg⁻¹ DM. This increased in quality to 0.62 digestibility coefficient, 120 g kg⁻¹ DM crude protein and 9.7 MJ ME kg⁻¹ DM following the rains. Considering the examples of level of feeding necessary to ensure multipurpose use above, only in the rains does the quality of the feed approach that necessary to meet requirements for live weight gain or milk in addition to work. This emphasizes the importance of encouraging schemes to enhance the quality of feed resources available when multipurpose use of work animals is being promoted.

Future Prospects for Working Animals

Some farmers in small scale agricultural production are changing to motorized power for cropping and transport, particularly when cash crops are grown alongside the food crops. Tractors do, however, require considerable capital investment. There are many farmers for whom motorized power is not an economic option to improve productivity. Devendra (1989) suggested that in order

to raise power inputs in developing countries to achieve agricultural growth, greater reliance on working animals will be necessary. He said 'draught animals are likely to assume much greater importance in farming systems in developing countries in the future'. It is realistic to assume that at least in smallholder mixed farming systems, working cattle, buffalo, donkeys and horses will continue to play a role, with cattle predominating where draught, and meat/milk, requirements are high and equids predominating where soils are light and draught needs are correspondingly lower. Continued investigation of the management of working animals in the different agro-ecological zones in which they are found would seem to be justified by researchers.

The main challenges to the researchers, and those involved in development, are to translate the understanding of systems into a form in which the knowledge can be put to practical use by the farmers. This will enable them to improve the effectiveness with which they use animal power for crop production and transport. These research and extension activities have to be undertaken in an environment in which population is increasing, grazing land is diminishing and labor expectations are changing.

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