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Resource requirements for draught animal power

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Abstract

The place of draught animal power on farms in tropical agriculture is discussed. In some areas of the world draught animal power is traditional, in others it is a relatively new technology. There are situations which fall between the two, but when thinking about resolving technical and more particularly socio-economic constraints it is often useful to be aware of these two categories. While some of the problems encountered are universal, other problems can be more specific to a particular situation or country.

In this paper some of the issues are discussed. These include the energy requirements for work, the provision of food, particularly in 'new' draught animal areas, the consequences of using draught cows in traditional systems, disease treatment and two examples of country specific problems. In some cases strategies to cope with these issues are available, largely as a result of research, in others it is apparent that more information is required.

Introduction

The use of draught animals to provide power in agricultural systems provides one of the most remarkable interactions between crops and livestock. Draught animals need 'fuel' in the form of chemical energy from crops and forage to work, but in many areas in order to produce a crop successfully animal power is required. One cannot do without the other. Where animal power is used the amount of work an animal is capable of doing ultimately affects the area cropped and the yield per farm, particularly where growing seasons are short. Animal power is used in virtually every environment and in every continent in the world, and constraints depend very much on location and the type of animal being used.

Oxen are numerically the most important draught animals, being common on small farms in Africa, Asia and parts of Latin America. Water buffalo are the next most important and are found mainly in Asia, particularly in the wetter, more humid areas. Donkeys, camels, horses, mules, yaks, llamas, and even sheep and goats are also used for work in a variety of different operations from transport and cultivation to harvest operations and water lifting.

Animal power probably makes its greatest contribution in agriculture although animal use for transport is extremely important. Draught animals provide proportionately about 0·8 of the power input on third-world farms. In fields which tractors cannot reach, such as terraced hillsides or muddy river valleys and on farms where size and scale of enterprise as well as finance rule out the purchase of tractors, then animal power is the only means that the farmer has of cultivating his land, other than hand labour.

Patterns of draught animal use in agriculture

There are many areas of the world where traditional draught animal power is now being replaced by mechanized power. In parts of East Asia mechanization has been rapid over the last 10 to 15 years (Watanabe, Muramatsu and Oishi, 1985; Siriweera, 1989) and tractor use has for example, more than doubled from 1975 to 1985 in China, India, Malaysia and Vietnam (Campbell, 1989). Nevertheless, there are many situations, where it is difficult to see farmers ever being able to adopt mechanical power to replace animal power.

In several areas in Africa and Latin America the trend is for farmers to compromise. Those who can afford to do so are using tractors alongside animals. The tractor for instance may be hired for hard work such as ploughing and then the farmers use their own animals for secondary cultivation, seeding, weeding and harvesting the crop. This usually proves to be an excellent compromise, with the difficult jobs being accomplished quickly, but without the farmer having to incur a large debt investing in an expensive tractor. The farmer still has his animals to fall back on and money saved can then be spent on other improvements or goods.

Some farmers are returning from draught animals to manual cultivation. For example in a sample of farmers questioned in Niger, 10% of animal-traction users had given up their draught animals and returned to manual cultivation (Pearson, Lawrence and Jansen, 1990). There are several reasons for this. Where the size of farmers' land holdings are shrinking either due to increases in population pressure or decreases in soil fertility, then often keeping draught animal(s) is less attractive than hiring labour, either manual or animal. Where renting of draught animals is not a common practice and timeliness of cultivation is critical, then farmers have to resort to manual methods.

Although the future for draught animals on some farms may be limited for various reasons, such as more accessible mechanization or changes in size of land holdings, in other places the use of draught animal power is expanding. These places tend to be in parts of the world where human power has predominated in agriculture. In the past in many areas of Africa animal diseases prevented the keeping of oxen and manual labour was often the only option for the small farmer to produce his crops. However disease control and prevention measures have now extended the range over which animals can be kept and the use of animal power to replace human power has been possible in many areas, where finance and farm size inhibit the use of mechanization.

In plantation agriculture and forestry, which are often highly mechanized, animals can be integrated into a mechanized system. They can be usefully employed in moving the product whether it be logs or oil palm fruits for instance, from the site of mechanical harvest to the roadside for collection by a motor vehicle. While some plantations have mechanized their operations completely, others are now finding that draught animals make economic sense for these types of operations. For example, Unilever are expanding their use of buffalo and ox carts on their oil palm plantations in Colombia and Malaysia for harvesting the oil palm crop (J. T. Dijkman, personal communication), while interest in the use of oxen for logging in new forestry plantations in Tanzania and Malawi is under investigation (R. Skaar and Ole Meiludie, personal communication).

The above examples serve to show the main situations in which draught animals are used on farms. However they do present a rather simplistic picture. In reality there is a complex number of issues that can influence the relative proportions of human, animal and mechanical power that are present in any particular area. For example, where expansion of arable land at the expense of grazing land occurs due to high population pressure, a change in availability of animal power can result and many farmers have to resort to a higher proportion of manual labour. Tembo (1989) states that shortages of animal power in the communal lands in Zimbabwe are a major constraint to increased productivity of these areas. A shortage of animal power is often made worse by drought and disease outbreaks when numbers of draught animals, as well as other animals decline. In good years mechanized power is more available as farmers can afford to contract out cultivation to tractor operators or hire equipment themselves. It is important to remember that, although the 'technology' of animal (and mechnical) power may be available within an area, other factors can restrict its use. Very often farmers switch from one power source to another on their farms as economics dictate, consequently the source of farm power can be in constant flux in an area.

Traditional or new technology?

In areas of the world where draught animals are part of the traditional way of cultivating the land, for instance in India, Nepal, Indonesia, Ethiopia, North Africa and in most of Latin America, people are accustomed to keeping, training and managing their draught animals. Implements are readily available locally, usually made from local materials, with a local system to repair and replace them. Farm size and family structure tend to determine whether individual farmers keep animals themselves or make use of those available locally on loan or for hire. For example in the Koshi hills in Nepal, 85% of farmers keep adult male oxen, mainly for draught purposes. They usually keep one or even two pairs, which they commonly lend or hire out (Gurung, Gatenby, Neopane, Shrestha and Chemjong, 1989). In a survey carried out in 1989, 72% of farmers had hired or borrowed oxen and lending and borrowing was often a reciprocal arrangement (Gatenby, Pearson and Limbu, 1990). In Tanjungwangi village near Subang in west Java, Indonesia, only 7·5% of draught animal 'rearers' use their animals solely to prepare their own crops, over 50% also rent them out and 30% both rent out and use their animals for shared work where they combine efforts with other farmers and cultivate together to speed up operations. One such example of this is the ploughing of flooded rice fields when water is too scarce to allow flooding of all fields at the same time (Santoso, Sumanto, Perkins, and Petheram, 1987).

Table 1 *Prices of various implements (US$) in Niger, Nepal and Ethiopia*

		US$
Niger	10" plough	150
	Fine-tooth harrow (Canadian)	106
	Donkey harrow	83
	Ox cart	379
	Donkey cart	320
Ethiopia	'Maresha' plough	20
Nepal	'Ard' yoke	12
	Ox cart	110

Source: Pearson, Lawrence and Jansen, 1990.

In areas of the world where draught animal power is a relatively new technology, in many parts of West Africa for example, while the merits of using animal power such as 'increased farm yields', 'reduced drudgery' and more 'free time' are sung, there is not necessarily the infrastructure available locally to train and manage animals or produce and repair appropriate implements. As a result the animals and implements available are expensive and involve considerable investment by the farmer, before he can see the benefits and the drawbacks for himself. In Table 1, the costs of implements in Nepal and Ethiopia (areas of traditional animal traction) are compared with those in Niger (an area where animal traction received little attention until the 1950s). It is not surprising that uptake of animal traction is sometimes low in these newer areas. The introduction of largely wooden implements made and repaired in the village or by the farmers themselves would provide another layer of development to bridge the technological and financial gap between hand labour and expensive, factory produced, steel implements.

Obviously there are situations which fall between the two categories, such as areas where animal power is being reintroduced after a drought or after economic factors have led to an absence of machinery, but when thinking about resolving technical and more particularly socio-economic constraints it is often useful to be aware of these two categories. While some of the problems encountered are universal, others can be specific to a particular situation or country.

In the following sections some of the common and the more specific requirements are discussed. In some cases solutions are available, in others it is apparent that more information is required. Lack of space restricts the discussion mainly to animal production, however animal power also encompasses agronomic, engineering and socio-economic issues and these can have as significant an effect on output as the animal itself.

Food requirements of draught animals for work

A feeding system for draught ruminants

Despite the prevalence of draught ruminants in the world, and the fundamental requirement to provide them with enough food at the times of the year when it is most needed, until relatively recently no feeding system existed which could be easily and accurately applied to working ruminants. For this reason at the Centre for Tropical Veterinary Medicine (CTVM) a systematic study of the energy requirements of draught oxen and buffalo has been undertaken over the last decade and a system to predict requirements and the consequences of undernutrition has been developed (Lawrence, 1985 and 1990).

Most of the food eaten by a draught animal is used to provide energy. Requirements of working animals for protein, vitamins and minerals other than for maintenance are negligible, unless of course the animal is also growing or is pregnant or lactating. The net energy costs of the various activities which occur during work — walking, carrying, pulling loads and walking uphill — have been measured for several of the species used for draught purposes — cattle, buffalo (Lawrence and Stibbards, 1990), donkeys (Yousef, Dill and Freeland, 1972; Dijkman, 1991), camels (Yousef, Webster and Yousef, 1989). From a knowledge of these work activities over the working day in the field, a factorial approach has then been used to estimate energy expenditure (Lawrence, 1985). Until relatively recently technical difficulties prevented the direct measurement of oxygen consumption (and from it the determination of energy expenditure) in working animals in the field (Lawrence and Pearson, 1989; Lawrence, Pearson and Dijkman, 1991).

Expressed as a multiple of maintenance, the extra costs for work are relatively low. Even under conditions of optimum feeding and management oxen rarely expend more than 1·8 × maintenance on a working day (Lawrence, 1985; Pearson, 1989a; Pearson, Lawrence and Ghimire, 1989) which is similar to that seen in beef or dairy cattle (Table 2).

Information gathered on oxen and buffalo at the CTVM and elsewhere has been used by Lawrence (1990) to produce tables predicting total energy requirements of draught oxen, food intake and changes in live weight, taking into account live weight, quality of diet normally offered to draught ruminants, the decrease in energy expenditure over

Table 2 *Energy expenditure expressed as a multiple of maintenance of draught animals under various production systems compared with beef and dairy animals*

Type of animal	Function	Estimated energy expenditure as a multiple of maintenance
250-kg draught ox	5 h ploughing small hill terraces as a pair in Nepal	1·30 to 1·38
400-kg draught buffalo	5 to 6 h pulling loads over level tracks as a pair in Nepal	1·76 to 1·79
620-kg draught ox	5·5 h cultivating large fields as a pair in Costa Rica	1·42 to 1·67
650-kg draught horse	8 h pulling a loaded cart singly in Chile	1·86 to 2·35
300-kg dairy cow†	producing 3 l milk per day	1·4
500-kg dairy cow†	producing 10 l milk per day	2·0
400-kg beef steer†	gaining 0·20 kg/day	1·2
500-kg beef steer†	gaining 0·75 kg/day	1·7

† Theoretical calculations from Ministry of Agriculture, Fisheries and Food (1984).

the working day and the effect of work on resting metabolic rate. The tables (for example Table 3) can be universally applied where quality and availability of food for draught animals are known.

There is now a need to verify these predictions in the field by monitoring intake, work output and live weight of groups of draught animals over the year, at least, in places where the working season is short and in places where it is long.

A feeding system for draught equines

The last two decades have seen a surge of interest in the nutrition of the horse in the developed countries. However, the feeding systems produced have the drawback of being based almost entirely on performance and intakes of racehorses and sports horses receiving good-quality, high-density rations and the systems are difficult to apply to the tropical draught horse or donkey on high-roughage diets. For draught horses in temperate countries Brody (1945) suggested increasing maintenance requirements by proportionately 0·10 for 1 h of field work. Recent observations in Chile suggest that this may be an underestimate when large draught horses (650 kg) are carting loads and values of 2·4 × maintenance over an 8-h working day have been estimated to more truly reflect requirement. Information on requirements of donkeys and small horses for work is largely anecdotal.

There is tremendous scope for research into the inputs and outputs of systems employing draught equines in tropical agriculture. In many countries, in sub-Saharan Africa in particular, the donkey is often the first source of power the least wealthy farmer can afford other than family labour. Donkey power also has an important rôle in dry sandy areas of uncertain rainfall, where cultivation is a risky business with a high chance of crop failure and even the purchase and maintenance of draught oxen is economically difficult. The donkey is able to replace hand labour and speed up cultivation times in these areas, many of which have a low power requirement for

Table 3 *Predicted changes in live weight (g/day) of an ox working a 5·5 h day†*

Live weight (kg)	ME content of diet (MJ/kg)										
			6	6·5		7·5	8	8·5	9	9·5	10
200	−965	−797	−639	−493	−357	−231	−115	−7	99	204	305
250	−1130	−929	−740	−565	−402	−251	−111	17	133	246	356
300	−1289	−1058	−842	−640	−453	−280	−120	25	148	266	381
350	−1444	−1187	−945	−721	−512	−319	−141	21	147	269	387
400	−1597	−1315	−1052	−807	−579	−369	−174	6	134	258	378
450	−1747	−1445	−1161	−898	−654	−428	−219	−24	113	238	358
500	−1896	−1575	−1274	−995	−736	−497	−275	−68	84	209	330
550	−2043	−1706	−1390	−1097	−825	−574	−341	−124	50	175	295
600	−2189	−1838	−1509	−1203	−920	−658	−416	−191	11	135	255
650	−2335	−1971	−1630	−1313	−1021	−750	−500	−268	−51	92	210
700	−2479	−2104	−1753	−1428	−1127	−849	−591	−353	−131	45	162
750	−2623	−2239	−1879	−1546	−1237	−953	−690	−446	−219	−7	111

Source: Lawrence, 1990.

† Negative values are calculated as 1 kg live weight = 27·8 MJ metabolizable energy (ME).

cultivation anyway, not necessitating the more expensive, higher power output of a team of oxen.

Provision of food

Probably the key issue farmers are faced with when keeping draught animals is the provision of food of sufficient quantity and quality at the time when the animals are required to do the most work. The start of the cultivation season is usually the time when food stocks are at their lowest particularly in areas where the dry season is long. In many areas the quality of food is so low that animals can only just maintain their live weight, even when they are not working. When working, they lose weight.

There is some evidence that horses increase their intake of moderate-roughage diets when working for short periods (Orton, Hume and Leng, 1985), however oxen (Lawrence, 1985; Pearson, 1990), buffalo (Wanapat and Wachirapakorn, 1987; Bamualim and Ffoulkes, 1988) and donkeys (Pearson and Merritt, 1991) when receiving high-roughage diets do not increase their intake of food to match their increased energy demands. When work occupies a time period of 5 or 6 h/day intake may even decrease, as the time available for eating decreases (Pearson, 1990). Only by increasing the quality of the diet can both work and live weight be sustained. Where the quality of the food is very poor it is often better to have two animals doing what little they can, rather than one large animal.

Are weight and body condition important?

Since many animals lose weight when working, particularly over a long season when the food available is of low quality, it is not surprising that live weight and body condition become important issues in determining the optimum management of draught animals. More so because the amount of work an animal can do is proportional to its live weight, the larger the animal the higher the draught force it can generate. This means that the larger the animal (regardless of body condition) the more easily it will be able to carry out a particular task and the less stressed it will be when doing this than a smaller animal. A large-framed animal may also be better able to respond to an increasing supply of food over a rainy season than a smaller, fatter one. However, animals in good condition have 'fuel' in reserve, which may be mobilized to make up any shortages in food which may occur, for example at the start of the cultivation season when food is in short supply. Thin animals do not have this reserve. Kartiarso, Martin and Teleni (1989), in a study of the pattern of utilization of free fatty acids by working cattle and buffalo of different body conditions, suggested that in a short working period (30 to 50 days) when animals are in good condition, they can be worked on their fat reserves with minimal nutritional input, whereas when thin they would probably do best on a diet of high gluconeogenic potential.

Despite the apparent benefits of having heavy animals in good condition at the start of work, studies in which animals have been supplemented over the dry season have not always shown any significant benefit in crop yields or work output. For example, studies by Bartholomew (1988 and 1989) on-station and in villages in Mali, showed that supplementation of work oxen during the dry season increased their body weight and condition, but at heavier weights, better condition was not associated with a higher work output (Table 4). Since dry-season weight gain did not seem to improve subsequent work output, Bartholomew (1989) suggested that there may be little benefit to be gained by dry-season supplementation of draught oxen in these areas. The implication would seem to be that feeding during work has a greater impact on performance. In the village studies in Mali, animals actually gained an average of 170 g/kg body weight from the start of field work to the end of the rainy season work at the end of September, presumably due to the improvement in food supply.

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 in some areas where working periods are short, e.g. where animals only work for 20 to 30 days, in other areas where animals work for longer periods or spend considerable time transporting loads during the drier parts of the year, the economic return of such a practice may be considerable.

Table 4 *Mean daily work output (MJ) of single oxen in Mali, according to live weight and condition score*†

Condition score	Live weight (kg) 310	360	Mean
Medium†	0·95	3·49	2·22
Low†	2·55	3·44	2·94

Source: Bartholomew, 1988.
† Work involved pulling a loaded sledge with an average draught force of 374 N for up to 10 km around a flat circuit. Differences between live weights and between condition scores and the interaction between live weight and condition score were significant ($P < 0{\cdot}001$).

The level of feeding and management during the working season not surprisingly has a marked effect on work achieved. When the work output of a team is compared under different feeding and management conditions then weight loss during work, unless body condition score is high at the start of work, is almost always associated with a fall in work output and willingness to work regularly, whereas increases in nutrient intake, live weight and body condition produce increased work output. For example, Lawrence (1985) observed that under conditions of moderate feeding three pairs of oxen during regular work in Costa Rica maintained weight and used energy equivalent to 1·51 × maintenance when working a 5·5-h day. However, the same oxen on a poorer diet, such that they lost substantial amounts of weight, only used energy equivalent to 1·42 × maintenance. This response was more evident when inexperienced animals were being used. In Nepal, buffalo carting loads regularly over a 3-month period showed improvements in work rate with time which were associated with good feeding and improved body condition (Pearson, 1989a). When food is in short supply some farmers prefer to give supplements to their draught oxen at the expense of other livestock to ensure the animals can work regularly enough to meet cultivation requirements. In Sri Lanka, farmers preferentially give draught animals food over other livestock in drought conditions (Tennakoon, 1986).

When studying the effects of body weight and condition on the performance of draught animals it is important to define the parameters measured carefully, otherwise observations may be misleading. For example, in Indonesia, Winugroho, Juwarini and Teleni (1989) observed buffalo subjected to work for 4 h/day lost an average of 11 kg over an 80-day working period while non-working animals gained 14 kg when both were given a basal diet of rice straw plus some concentrate (1·5 to 2·5 kg/day). They observed that when subjected to the same work (4 h/day), lighter buffaloes would lose less live weight than would heavier animals. However, the distance travelled and work done by each group was not given. It is possible that the heavier buffaloes worked at a faster rate so achieving more work, expending more energy, and losing more weight in the given time.

All these observations show that there are effects of live weight, condition and nutrient intake of draught animals on their work output. Investigation of these issues would seem to be of high priority in areas where seasonal fluctuations in food quality and supply are considerable and where feeding strategies need to consider the number and frequency of working days required of the draught animals. It is in these areas that draught animal power is often being encouraged as a new technology to increase farm productivity and positive guidelines on food allocation are needed, perhaps more so than in areas where farmers have traditionally kept working animals.

Is there a place for draught cows?

In some areas where animal power is traditional in agriculture, cows are becoming increasingly important as draught animals. Increasing population pressure in some areas and reduced farm sizes have forced people to consider whether they should keep draught animals at all. In Bangladesh and Indonesia, for example, where pressure on land is high and the ratio of pasture to cultivated land is decreasing, the use of cows for draught purposes is one way of reducing the numbers of animals kept. The International Livestock Centre for Africa (ILCA), in an economic survey of traditional (two-ox), single-ox and cow traction in the Ethiopian highlands, observed that cow traction was the most efficient in terms of resource use and productivity and that further research on cow traction was warranted (Table 5). In the optimum solutions of the various farm models, cow traction gave the highest net farm income and greatest land and labour productivity. The optimal land-use strategy for the cow-traction model was to plant all arable land with teff and wheat, with proportionately 0·9 of the total area allocated to teff (ILCA, 1988).

Table 5 *Optimal solutions obtained by linear programming for representative farms in the Ethiopian highlands using traditional, single-ox and cow-traction for power (2 Ethiopian birr = 1 US$)*

	Optimal farm plans		
Item	Traditional	Single-ox	Cow traction
Net farm income (birr)	848·7	438·5	2535·0
Total arable land (ha)	2·55	2·55	2·55
Area cropped (ha)			
teff	0·68	0·68	2·28
wheat	1·66	0·27	0·27
faba beans	0·21	1·42	0·00
Area left fallow (ha)	0·00	0·18	0·00
Total labour use (man-equivalent hours)	1098·8	981·4	1881·0
Productivity			
land (birr per ha)	332·8	172·0	994·1
labour (birr per h of family labour)	0·77	0·45	1·35

Source: Bartholomew, 1988.

Cows can therefore be used for animal traction although this is not without a cost. If a cow is to work, produce a calf and a good supply of milk then it needs good-quality food. In a study in Costa Rica, cows in mid lactation needed to be given food energy equvalent to 2·2 × maintenance to work and maintain milk production (Lawrence, 1985). In virtually all instances, to achieve this energy intake requires supplementation of the basal diet with considerable amounts of concentrates. These are not always available or are too expensive. Hence most famers have to accept they are unlikely to maintain production if they also require work from their cows.

Reports in the literature show a variable effect of work on milk production. Jabbar (1983) in Bangladesh suggested a fall in milk yield when cows are used for draught. Goe (1983) reported that on work days, cows can show a 0·1 to 0·2 proportional decrease in milk yield. Similarly, Matthewman (1989), in a series of three experiments with Hereford × Friesian crossbred cows, found that milk yields fell, as did the yields of lactose and protein during exercise, but recovered following 2 days of rest. Yield of milk fat remained unchanged with exercise. When supplements based on barley, fish meal or sugar beet (gluconeogenic, aminogenic or lipogenic) were offered with straw diets, the nature of the dietary supplement did not seem to have any significant effect on the impact of exercise on lactational performance. Rizwan-ul-Muqtadir, Ahmad and Ahmad (1975) in Pakistan showed no reduction in daily milk production during work. Zerbini (1991) in Ethiopia found that work (4 h/day pulling sledges at an average draught force of 400 N for 4 days/week) did not have a marked effect on milk production, when crossbred dairy cows worked over a period of 90 days, starting 2 weeks after calving. However, he noted that work had a dramatic effect on cow weight loss. Three months after giving birth, working cows had lost an average of 26 kg, whereas non-working cows had lost less than 11 kg. Supplementary feeding with *Guizotia abyssinica* cake, wheat millings, salt and bone meal did not eliminate these weight losses. The differences in response reported may well be a reflexion of differences in availability of nutrients and competition for these nutrients between the mammary gland and muscle. Any situation which increases this competition is likely to result in a reduction in milk production and/or live weight, since muscle contraction is a basic tax on the nutrient economy of the animal (Teleni and Hogan, 1989).

In some parts of Indonesia, even if work during the later stages of pregnancy and lactation is avoided, there is evidence that calving intervals are getting longer (Robinson, 1977; Petheram, Liem, Yayat Priyatna and Mathuridi, 1982) and there is a danger that supply of replacement milk and draught animals will not match demand in the future. This apparent suppression of reproductive activity in working cows is borne out by recent research results. In Ethiopia, Franceschini (1991) reported that oestrus occurred on fewer occasions in working than in non-working cows. Although supplementary feeding increased oestrous activity, some of the supplemented working cows cycled during their resting period, but none of the unsupplemented cows did so. Similarly, in Indonesia, Bamualim, Ffoulkes and Fletcher (1987) reported reduced ovarian activity in working compared with non-working buffalo cows. Even if working cows do show oestrus, they may be working and miss the chance of service with a chosen bull.

The partition of food energy between maintenance, body reserves, milk production, work and pregnancy is clearly one aspect which requires greater understanding if cows are to be successfully used for work at minimum cost to their other functions on the farm.

Prevention *v.* cure

A dead draught animal cannot work and land cultivation and crop production suffer. In places where a farmer relies on a single animal (in south-east Asia many of the work animals are single buffalo) this can have serious consequences. Even when one animal from a pair is lost, especially near or in the working season, the situation can be critical. Some efforts to prevent the acute diseases in an area would seem to be economically justified by a farmer who keeps draught animals, whether it be by management, local medicines or purchased drugs. The subclinical diseases are more difficult to cope with, they may not kill the animal, but can severely reduce its productivity.

There has been some evidence and much conjecture in the literature that subclinical diseases reduce work output and equally that the additional stress of work can predispose draught animals to disease (Hoffmann and Dalgliesh, 1985; Wells, 1986). Pearson (1989b) suggested the reduced power output and inability to work of otherwise well-fed and apparently healthy buffaloes may have been due to chronic fasciolosis. Payne, Djauhari, Partoutomo, Jones and Pearson (1991) observed that although exercise did not appear to exacerbate the effect of *Trypanosoma evansi* infection in buffaloes, the infection had a marked effect on body temperature and packed cell volume profiles of infected buffaloes, both of which could adversely affect an infected animal's work output and tolerance. Helminth parasites are thought to be a major cause of unthriftiness and low life expectancy of working donkeys. In Morocco (Khallaayoune, 1991) and in Greece (Bliss, Svendsen, Georgoulakis, Grossmanidis, Taylor and Jordan, 1985) for example, anthelmintic treatments resulted in healthier and stronger donkeys. The study of Samui and Hugh-Jones (1990) is one of the few to attempt to quantify the financial and production losses due to disease in draught animals. They estimated conservatively that the cost of draught oxen being affected by bovine dermatophilosis in Zambia was K 428 (US$ 193) per affected animal. This was based on loss due to reduction in area of land ploughed and loss of income from hire of the animals.

Systematic studies are now underway in West Africa and Indonesia to investigate the consequences of subclinical diseases on work, and conversely work on disease. In both these areas trypanosomiasis is the first disease to be studied in this context. The basic questions that are being asked are: what are the risks involved in not treating the draught animals to prevent disease and is there an increase in work output and farm income that justifies the expense involved in treatment? The problems in trying to produce results to answer these questions quickly become apparent in setting up such studies. It is not surprising that this is a topic that has received little attention from research workers in the past.

Requirements which are specific to particular areas

Some requirements associated with draught animal power are of a universal nature others are more specific. Several draught animal research projects have been designed to solve relatively small issues, which are specific to a country or region. Two examples are included in this section, others can be found in the literature.

Jersey crossbred oxen as draught animals?
In the hills of Nepal, Jersey bulls have been imported for crossing with local cows to improve milk yield, but farmers were concerned about the effect of this on the performance of their draught oxen. In this mainly Hindu community the male offspring and not the female is used for work purposes, and there is no market for meat. A comparison of Jersey crossbred and local oxen was carried out when teams ploughed dry land on local farms (Pearson, 1991). The Jersey crossbreds, particularly the longer legged type, had a higher rate of work than the local oxen. They did significantly more work and covered a greater distance during the day. The absence of a hump in the crossbreds had no effect on the position of the yoke or the way the crossbred oxen pulled when ploughing. However there were disadvantages in using Jersey crossbreds, a faster rate of work made the oxen more liable to heat stress and when fed according to local practices and given similar amounts of food as local oxen, Jersey crossbeds tended to do less well. During the ploughing months, the local oxen gained weight, whilst the crossbreds remained at the same or lost some weight presumably partly at least due to the higher rate of work.

Although there were disadvantages to keeping Jersey crossbreds for work in this area, their favourable work output, compared with local oxen, suggested farmers could be reassured that the policy of crossing local cows with Jersey bulls in the hills was not producing inferior work oxen.

Reducing soil loss on small farms in Chile
Horses and oxen are commonly used to cultivate land on small farms in Chile. In some hilly regions soil loss is a big problem due to heavy rain on the sloping fields in the growing season. On some fields proportional losses of 0·10 to 0·25 have been reported over the season, with the major losses occurring after ploughing (E. Hetz, personal communication). Scientists at the University of Concepcion, Department of Agricultural Engineering and the Chilean Ministry of Agriculture, Institute of Agricultural Research have spent considerable research effort in developing a spring-tine cultivator to replace the plough and minimize soil tillage. The implement improves soil water holding capacity, reducing water run-off and consequently reduces soil movement. Initial trials in Nuble province looking at soil erosion and crop yields of wheat and lentils have been encouraging. As well as reducing soil loss, an additional advantage of the implement has been that it is quicker than the plough, speeding up cultivation and so shortening cultivation time, an advantage in the short growing season (Riquelme, Ruiz and Aliaga, 1991). The implement is now being promoted by the extension services.

Development of draught animal power on small farms

Wider application of draught animal power has been suggested by many as one way in which to raise output and increase income on small farms. This can be achieved in two ways.

1. *Encouraging more people to use draught animal power instead of hand labour*
Over the years many people who cultivate their land

by hand have been encouraged to turn to animal power as a way of increasing productivity or reducing drudgery on their farms. In many cases the advantages are apparent in better timeliness, reduced bottle-necks at weeding, increased cropped area and higher farm yields, but in other cases, particularly in rain-fed areas where crop production is a high-risk enterprise, disadvantages become apparent. A farmer may commit himself to a large loan and purchase two draught oxen and several pieces of equipment, perhaps a cultivator, seeder (so he can plant in rows) and a weeder, whereas low financial-input cropping of a smaller area may provide greater rewards. An increased awareness of both the advantages and the disadvantages of animal traction is required. Some schemes to develop animal traction have failed. There is often a complex number of reasons why this has been the case. Very often failure has been where insufficient thought has been given to the scheme: where the cost of the implement(s) promoted is high, exceeding by some considerable amount the cost of the animal(s); where inappropriate implements have been provided both for the animals or the soil; and where insufficient thought has been given to implement maintenance and ease of repair or replacement. It is hoped that these are problems of the past as researchers and extension officers become more sensitive to farmers needs.

2. *Encouraging other uses for draught animals*
Traction animals are frequently also used as milking animals but there is also scope for a dual rôle for meat animals. After the initial financial outlay on animals, farmers can if they wish gain a regular income from astute selling of their oxen and buffalo at 6 to 8 years of age for meat, replacing them with younger (2 to 3 year old), cheaper, but initially less experienced stock.

In areas where the draught animal is unlikely to be replaced on farms there is potential to look for other uses for draught animals, particularly where social customs prevent the use of female animals for work and restrict the meat market. A reduction in the number of idle days in the year is a relatively easy way to increase efficiency of animal power on a farm. Water-lifting, milling, and other stationary power devices have been designed and built throughout the world incorporating animal power, some more elaborate than others. Earth moving and road building are other less conventional uses which have application in some places. Nevertheless, it is usually the simplest idea or design that is the most successful as it is the one that can be most easily adopted. Traditional animal power is flexible, it is easily taken to even the most inaccessible fields, and the working components (implements, harnesses and animals) can be easily obtained locally. Any improvements or new developments in animal power that fail to recognize these factors have a very much reduced chance of success.

Whatever the outcome of innovations, promotions and new schemes it seems highly likely that animals will continue to provide a considerable proportion of the power on small farms for the foreseeable future as they have done for centuries in the past.

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