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Equipment for working animals, with emphasis on equids in developing countries

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Summary

Power from animal muscles has long been used for agricultural field work and transport. Animals are capable of pulling 10-15% of their body weight and can be teamed with other animals of the same, or different species (albeit with some loss of efficiency). Using animal power for pulling requires a harnessing system (yoke, collar or breastband) whose design will have a crucial impact on system efficiency. Pack animals require different arrangements which are described. Financial analysis of packing systems using the case of equids in Honduras, shows a cost of $US0.20-0.40 for carrying a 50 kg load for 1 km. This compares with the $US0.60 actually charged and so indicates a good awareness of costs and market potential. Pack animals come into their own in situations of poor infrastructure and hilly terrain. Carts increase carrying capacity and are especially useful under conditions of good, hard, smooth surfaces. The carrying capacity will depend on the potential of the animal(s) and the cart's resistance to motion (rolling resistance of the wheels, bearing friction and slope effects). Types of body, wheel and axle arrangements and braking systems are briefly discussed. Highlift harnesses coupled with lightweight implements can dramatically reduce the draught requirements of tillage operations, and so can increase the use of lighter animals (e.g. equids) for this purpose. Bolivian experience in participatory on-farm R&D has shown the commercial potential of the system.

Key words: *equids, carts, packing, highlift harnesses, lightweight implements*

Introduction

Most advances in human development up until the time of the Industrial Revolution depended on man's harnessing of his natural resources and the conversion of the accessible potential energy therein into useful work. There are many examples, such as the use of wind or water flow. However for field and transport use, the power source must be self-mobile and so the only viable sources are human, engines, or animals. There is, therefore, a long history of animal domestication and draught animal use dating back maybe four millennia. Many species are amenable to domestication but for agricultural or transport services, which are the commonest applications, bovines, equids, camelids and buffalo are the most popular, often with certain breeds being favoured for specific purposes. Individually such animals are capable of providing a useful pulling force (usually 10 to 15 % of body weight) but they can also be teamed together to provide a pull many times that of the individual animal. Suitably trained animals can also be teamed, or spanned as it is often called in southern Africa, with those from different species. It is not uncommon to see a camel working alongside a donkey in North Africa, where, it has been said, the camel provides the strength and the donkey the direction. However, there are also many instances of camels working alone and moving in the correct direction.

Converting animal energy to useful work is a simple principle whereby movement of the animal overcomes a resistive force. As animal movement is most easily achieved by walking, the work is done by enabling an animal to walk forwards whilst attached to and overcoming the resistive force. The method of connecting the animal to the resistance, therefore, plays a key role in accessing animal power. The quality of this connection is a key determinant in how effectively draught animal power can be used but, despite centuries of harnessing animals to utilise their power, this connection is rarely of optimal design. The elements of a harnessing system are: a) the yoke, collar, or breastband - the material which is in direct contact with the surface of the animal and against which the animal pulls; b) the draught “chain” (may be a rope), or draw-pole, which is attached to the yoke / collar at one end and to the hitching assembly of the object being pulled at the other end; c) the hitching assembly itself which usually offers various points for attachment to the draught chain. The resistive force is manifest as tension in the draught chain which, in turn, acts as a pressure over the contact area of the yoke or collar on the animal. When more than one animal is used, the animals must be somehow connected together to make best use of their individual pulling capabilities. This complicates the yoke / collar arrangements and, especially, the hitching arrangement.

The focus of this paper is the use of equids, particularly for transport, either by carting or packing. Carrying a pack is not a draught operation but pack animals are still performing a useful function by moving loads from place to place although the work done is not easy to measure in mechanical terms. (It can be determined through metabolic analysis using respirometry – e.g. see Dijkman and Lawrence, 1997). For carting, however, the energetics are clearer, provided that the force in the draught chain and the distance moved (horizontally and vertically) are known. Some typical requirements for donkey carting are shown in Figure 1.

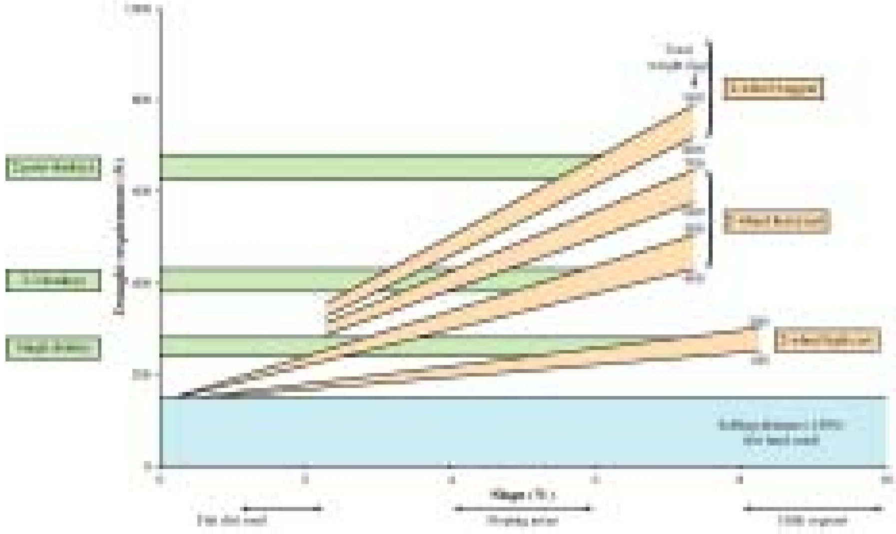

Figure 1. Draught requirements for carting. (Source: O’Neill *et al.*, 1997)

The effort available from a single donkey (240 - 280 N) is that suggested by O’Neill *et al.* (1997). It is unrealistic to scale up proportionately the effort from more than one donkey because of losses in the harnessing system. Even with the best designs, losses of the order of 10% occur when each extra animal is added to the team (Barwell and Ayre, 1982).

The concept of optimal design, rather than best design, was raised above. Generally speaking, the owners and users of working animals tend to be resource-poor and so a compromise between what they can afford, usually fabricated locally from locally available materials, and the best design would be the realistic aspiration. This compromise affects equids more than other species, particularly bovines, because the component that fits on the animal (collar, breast-band) is necessarily more complex than the traditional ox yoke. Examples of good harnessing adapted to local conditions are included in the descriptions of equipment below.

Packsaddles and packing

When using equids for pack transport, the most important goal is to avoid pressure on the spine to reduce to a minimum the possibility of causing sores (Figure 2) where the skin is in close proximity to the vertebrae.

Figure 2. Bolivia: Pack horse with saddle sores.

The basic components of a pack saddle are (Chirgwin *et al*., 2000):

Saddle blanket. This should be of an absorbent, natural, material, e.g. a jute sack which is clean and without creases.
Saddle mat. This is essentially a pad designed to protect the bony spinal protuberances from any pressure. It can be made of felt or sheep skin, although one version from Honduras is made from banana leaf veins (Sims *et al*., 1996).
The saddle mat should also have two cylindrical components (bolsters) whose job is to ensure that the load is kept free of the spine (Figure 3).
A *second blanket* is used to cover the saddle mat.

Figure 3. A pack horse with saddle blanket (jute sack) and saddle padding with cylindrical spine-protectors made from banana leaf veins. Güinope, Honduras.

The elements next used will depend on the type of load to be carried:

A *saddle-pad*, essentially a pair of bags stuffed a slung over the saddle-padding. This, (suggest Chirgwin *et al. op cit.*) can be made from a pair of flour sacks stuffed with straw and sown together (Figure 4).

(4a) **(4b)**

Figure 4. a) Saddle pad made from two flour sacks (Source CEEMAT-FAO, 1972 p186). b) Saddle pads in use beneath loads carried in sacks. Nepal.

The saddle pad is fastened by two straps: a *cinch strap* around the heart girth and a *crupper* or tail strap. This arrangement will give sufficient protection for “soft” loads, for example sacks of fertilizer, cement, sand or flexible water containers.

However for “hard” loads, such as bricks, firewood, milk churns or angular containers such as large oil cans, need other structures. In these cases a rigid pack saddle (such as that shown in Figure 5) which is often made of wood and hide, is placed over the saddle mat and second blanket and secured with one (or sometimes two) cinch straps and a tail strap. Loads can then be tied directly to the carrier or it can be modified to carry specific freight.

Figure 5. Pack saddle construction. The pack saddle is placed over the second blanket and secured with cinch and crupper straps. Wooden hooks can then be added for firewood transport.

Other possibilities that are used once the pack saddle is attached are panniers or wooden frames for milk churns, water barrels, bricks or stones (Figure 6).

Figure 6. A tomato seller attaches barrels to wooden frames tied to the pack saddle.

There are, of course a myriad regional modifications to the general theme described above. In Mexico, for example, a simple wooden frame, in the form of an inverted "V" is placed over the saddle blanket. Loads are then attached to this frame (the *fuste*) with ropes and the animal's spine is protected (Figure 7[a]). Farmers make their own *fustes* without incurring out of pocket expenses although the opportunity cost of labour and wood have been calculated at $5 (Sims and Jácome-Maldonado, 1991). A commercial version of the same arrangement is also available on the market at a price of $400 (Figure 7[b]).

(7a)

(7b)

Figure 7. (a) Home-made pack saddle from Mexico (cost about $5). (b) Commercially available pack saddle cost $400 (source: http://www.difanisbackcountry.com).

Performance of equids in packing

Different transport options become viable, and so are adopted, under different circumstances. However investment in intermediate means of transport (e.g. pack animals) is generally found to be profitable (Starkey, 2002). A study carried out in Honduras (Sims *et al., op cit.*) considered the performance and costs of pack animal-powered transport. Table 1 shows typical body weights and load-carrying capacity of the three species of equid. Table 2 gives information on their work capacities.

Table 1. Body weight and load-carrying capacities for equids. Güinope, Honduras.

Equid	**Body-weight (kg)**	**Load carrying capacity (kg)**
Horse	200-350	80-100
Mule	220-300	100
Donkey	150-220	50-60

Table 2. Speed, working day and distance covered by working equids. Güinope, Honduras

Equid	Walking speed (km h^{-1})	Length of working day (h)	Distance covered (km day^{-1})
Horse	5-6	5-6	15-20
Mule	5-6	7-8	25-35
Donkey	3-4	5-6	10-15

Costs and useful life

In order to do some simple calculations of the costs of transport using pack animals, we need to know how much they cost and how long they can work and how far they can carry loads. The figures in Table 3 are based on survey work and should be adjusted according to the specific conditions encountered in other localities.

Table 3. Costs of pack-equids and associated equipment (US$). Güinope, Honduras

Cost	Horse	Mule	Donkey
Purchase price	100	140	33
Sale price	0	0	0
Working life (yr)	15	23	23
Days worked per year	100	100	100
Hours worked per day	5.5	7.5	5.5
Total hours worked per year	550	750	550
Distance travelled per year (km)	1750	3000	1250
Distance travelled per year loaded	875	1500	625
Cost of complete pack saddle assembly	41	41	41

Table 4 uses standard financial analyses to calculate the costs of operating working equids based on the information gathered. It can be seen that the costs of carrying a 50 kg load for one kilometre range from $US0.2-0.4. This compares with the price of $US0.6 actually charged and indicates a healthy awareness of the costs involved and the potential of the market.

Table 4. Calculation of annual transport costs ($US)

Cost	Horse	Mule	Donkey
Depreciation[1]			
i) Animal	6.7	6.1	1.4
ii) Pack saddle (20% of cost/year)	8.2	8.2	8.2
Repair and maintenance of equipment (10% of cost/year)	4.1	4.1	4.1
Interest on capital[2]	14.1	18.1	7.4
Veterinary costs	10.0	3.0	2.0
Feed supplementation	10.0	5.0	2.0
TOTAL ANNUAL COSTS	53.1	44.5	25.1
Cost per hour	0.10	0.06	0.05
Cost per km loaded	0.06	0.03	0.04
Cost per 50kg load per km[3]	0.03	0.02	0.04

1. Annual depreciation = $\frac{\text{Purchase price - sale price}}{\text{Working life}}$
2. Annual interest = $\frac{\text{Purchase price + sale price}}{2} \times i\%$
3. Average loads from Table 1.

Advantages and limitations

Pack-equids are a renewable resource and offer clear benefits to facilitate the development process, some of these can be classified as follows, although there is, of course, an infinite number of variations:

Farm level transport for:
Irrigation water
Fencing materials
Fodder
Agricultural inputs to the field
Crop harvest from the field

Household level transport for:
Drinking water
Fire-wood
Building materials

Marketing
Agricultural produce for sale
Farm and household inputs purchased
Family produced products (e.g. handicrafts) for sale.

Limitations to the use of pack-animals are few. Being animals they do, of course require constant care, feed and water every day. The economic costs of purchase and upkeep must be justified by the existence of a large enough demand for their services. These are most likely to be found in remote rural areas with poor infrastructure and hilly terrain which precludes the use of other forms of transport (except human).

CARTS

Carts in context

Despite the many advantages of pack animals, particularly for resource poor farmers and transport contractors in difficult terrain, their usefulness is limited by their carrying capacity. Carts and other transport devices such as sleds transfer their load to earth, either directly or through an intermediate paved or prepared surface. At this level they compete with engine powered units ranging from trailers pulled by single- or two-axle tractors, through pick-up trucks to high capacity lorries. In this framework the role of the animal pulled cart will depend on its competitive advantage in a very local context, taking social and financial factors into account as well as the technical factors considered below.

Technical factors

The first consideration must be to match the design of the cart to the pulling capacity of the intended (available) draught animals, following which a suitable specification can be drawn up for the cart.

Pulling capacity of draught animals for cart use

There is reasonable agreement in the literature on the maximum pull which draught animals can exert when used with tillage implements, commonly expressed as a proportion of the animal's weight (pull-weight ratio). Indicated pull/weight ratios for common draught animals in good condition are about 13% for horse, donkey, mule and camel and rather less for buffalo and ox at 12% and 11% respectively. Bearing in mind that work animals, when used for carting, would be expected to move faster and more freely than when used for tillage work it would seem to be judicious to keep well within these ratios, providing a margin for the extra force needed to accelerate a loaded cart and to cope with moderate inclines. It is generally accepted that the individual capability of animals is reduced when used in teams; possibly a reduction in the pull-weight ratio by one percentage point for a team of two *i.e.* to 12%, 11% and 10% for the above figures (CEEMAT – FAO, 1972).

Conformation is an additional relevant variable. Horses particularly have been rigorously selected for particular purposes including riding, racing, carriage pulling, packing, carting and ploughing. In general horses selected for carting and ploughing have a heavier, low built, conformation for which the 13% ratio would be valid while a rather lower ratio (10% or 11%?) would be more appropriate for slender-legged breeds. It should be noted that the horse is regarded as a prestige animal in many countries, for which reason its availability for mundane purposes may be limited.

Drawing up the specification for a cart

The design of a suitable cart is influenced by many interacting factors. Some of the major ones are discussed briefly below.

Carrying capacity

The load carrying capacity of an animal pulled cart (Figure 1) depends on:

- the pulling capacity of the intended animals, estimated according to their weight, using guidelines given above judiciously modified to take account of their conformation and condition.
- The 'motion resistance' of the cart which can be estimated by calculation from:
  - the total weight (W) of the loaded cart (W = weight of the empty cart + weight of the load). The empty weight of typical two-wheel carts in current production varies from about 100 kg to 250 kg or more.
  - The 'rolling resistance' of the wheels which is dependent on their 'coefficient of rolling resistance' (C_{rr}), which is a function of the diameter and width of the wheel, whether solid or pneumatic tyred and the type of surface on which it is operating. For example a pneumatic tyred wheel with an outside diameter of 600 mm will have a C_{rr} of about 0.05 when moving over a good hard surface (metalled road or smooth hard earth) or about 1.15 over a firm settled field surface. The rolling resistance of the cart is then given by $C_{rr} \times W$.
  - Bearing friction, which should be negligible for wheels running on ball or roller bearings in good condition.
  - Slope (or gradient) resistance, dependent on topography and the transport routes taken to surmount them. When moving up a slope additional work is done against the force of gravity acting on the loaded cart. The pull required to overcome the gradient effect is given by
    $W \times \sin\alpha$ where W is the total weight and α is the slope gradient.

A sample calculation can now be made to find the pull needed for a cart weighing 120 kg and carrying a load of 500 kg, (total weight W = 620 kg), on good roads (C_{rr} taken as 0.05).

a) On level ground. The motion resistance is given by:

$$H = C_{rr} \times W + W \times \sin\alpha = 0.05 \times 620 + W \times 0 = 0.05 \times 620 = 31 \text{ kg}$$

b) On a gradient of 5° ($\sin 5^\circ = 0.087$):

$$H = C_{rr} \times W + W \times \sin\alpha = 0.05 \times 620 + 620 \times 0.087 = 85 \text{ kg}$$

How does this match up with the pulling capacity of a 200 kg donkey (13% of 200 kg = 26 kg) or of a 300 kg horse (13% of 300 kg = 39 kg)?

a) The load is rather too much for a single donkey. More acceptable if the load carried is kept at or below 400 kg rather than the desired 500 kg. Acceptable for a single horse.
b) Beyond the capability of a single donkey or horse and slightly more than optimum for a pair of horses, but possibly tolerable. A maximum load of 450 kg would reduce the required pull to the theoretically acceptable level.

The examples emphasise the need when drawing up a cart specification to:

- keep the weight of the cart to a minimum;
- use low friction bearings in the wheel hubs; and
- take account of the terrain - ground conditions **and** slopes - on which the cart and draught animals will be expected to work. Even a modest gradient makes a very big difference to required pull and pack animals show to an increasing advantage as the terrain becomes steeper. The problem of animals controlling loads on downhill slopes is considered below.

Type of body
Essential criteria for most animal pulled carts are light weight, adequate strength and fitness for purpose. A single-axle body is almost universally used for small carts, giving light weight, good manoeuvrability and low cost (Figure 8). A platform body is simple, light, relatively cheap and adaptable for multi-purpose use - it is probably all that is necessary when carrying items such as sacks of grain. Steel rings or loops will make it easier to tie the load on when necessary and can be integral with arrangements for fitting light upright posts and/or boards when carrying particular crops such as forage, straw or cane.

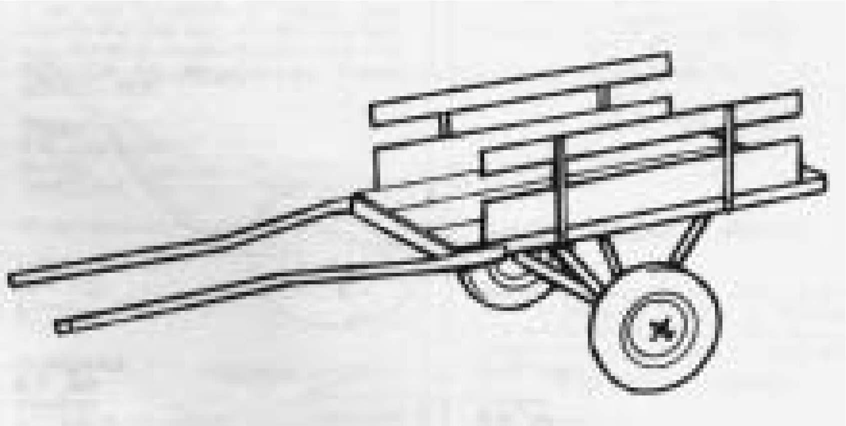

Figure 8. Light cart with a with flat multi-purpose platform - very widely used in many West African countries. (Source IT Publications Ltd., 1992. p176).

Dedicated special purpose bodies will be desirable in some cases, such as for carts carrying water in 200 litre drums or other containers and for specialised contracting on building sites *etc.* (Figure 9).

Figure 9. Cart with a special purpose body: water carrier in the Sudan. A simple design ideal for a young entrepreneur

Axle, wheel and bearing arrangements
Axle, wheel and bearing arrangements have been investigated over many years - virtually *ad infinitum* - but there is agreement on only a few 'guidelines'. Wheels with pneumatic tyres are favoured owing to their relatively low rolling resistance (Figure 10) and shock-absorbing qualities but, against this, they are expensive to buy and maintain (punctures). Ball or roller bearings are favoured for their low frictional resistance but they are somewhat expensive and liable to rapid wear if dirt manages to get into them - which, according to the literature, it usually does.

Figure 10. Cart with a special purpose body: earthmoving in Pakistan - the wide section pneumatic tyres are ideal for soft(ish) soil conditions.

For locally manufactured carts it may be convenient to get round the wheel and axle problem in the short term by using discarded axles from popular small cars. Rear axles of front-wheel-drive cars are reasonably light and easy to fit but may become scarcer and more expensive as demand builds up. However, this expedient would enable a preliminary batch of carts to be constructed and evaluated, allowing time for a longer term solution to be investigated. Minimal weight is essential, perhaps provided by a locally manufactured axle with central tubular section and stub axles welded into each end, fitted with turned plain bronze bush bearings.

Braking

A harness with breech strap, or a false breech fitted between the shafts of the cart behind the animal, will usually provide sufficient braking effect in flat country but a more sophisticated system will be desirable for downhill running, even on modest slopes. If an old car axle is used and its hand brake (usually of the shoe and internal drum type) is in good condition it may be possible to adapt the mechanism for use on the cart, otherwise a band brake (external drum brake) is effective and relatively easy and cheap to make (Figure 11).

Figure 11. Single axle ox cart in Bolivia - fitted with external band brake on each wheel which can be operated when sitting at the front of the cart or when walking along at the rear.

Low draught tillage systems

Highlift harness and lightweight implements

A number of traditional animal powered tillage systems in various parts of the world make use of harnesses which pull tillage implements through traces set at a relatively steep angle. The saddle harness, popular in parts of Latin America, is a typical example. Analytical investigations (Inns, 1990) have shown that such arrangements are theoretically advantageous in reducing the draught of tillage implements and, additionally, that draught can also be reduced by using lighter implements than those in widespread use today.

The theoretical advantages have been confirmed in field experiments - the draught of a chain pulled plough is approximately halved when the pull angle is raised from 20º (as commonly used when ploughing with a yoked pair of animals) to 30º (approximating to the angle of pull provided by a saddle harness). Draught (and hence working depth) can be controlled by selecting a suitable combination of angle of pull and implement weight to give the required result (Inns, 1996). The 'High-Lift Harness and Lightweight Implement (HLH&LI)' tillage system has been formulated to exploit these findings (Figure 12).

Figure 12. Horse with high-lift harness pulling a light-weight plough. Bolivia.

The HLH&LI system is suitable for use with any draught animal. Its commercial viability has been put to the test in Bolivia, starting in 1998. Farmers responded enthusiastically to demonstrations of donkey, horse and ox implements designed for use with simple high lift harnesses. Design staff at the CIFEMA workshops in Cochabamba have held regular consultations with farmers, and designed a range of implements to meet their expressed demands. Many hundreds have been built in the workshops and sold on an unsubsidised basis, with strong demand in areas with good access to markets where commercial crop production is flourishing (Figure 13). It may be concluded that there are excellent prospects for commercial production of equipment using the HLH&LI system, with farmers showing strong preference for such equipment rather than more traditional styles.

Figure 13. Earthing up potatoes using a ridger pulled by a single horse. Bolivia.

The HLH&LI system has proved particularly user friendly - easy to adjust and operate, giving more effective tillage with cheaper implements, greater reliability, less stress on the draught animals and simple harnesses which can be made on-farm.

The HLH&LI system is particularly well suited to use with a single animal - donkey, horse, mule, ox, buffalo or camel - giving compact, manoeuvrable, effective and relatively low-cost working units with a work output approaching that of a teamed pair of animals. It is of special relevance to use on small and medium size farms in less developed countries, empowering many currently disenfranchised groups such as female farmers (Inns *et al.*, 1997). It may well have relevance to some farmers in industrialised countries, perhaps working with smaller, hardy horses in small or irregularly shaped fields, on hillsides or around fjords or to farmers with specialised interests such as biological or 'green' farming.

Overall the design of appropriate high-lift harness and lightweight implement systems has much to offer in formulating user-friendly, profitable and sustainable tillage systems.

Conclusions

- Many breeds of animal are suitable for agricultural and transport work. Working singly is more efficient, but multiple animals increase the available power.
- Harnessing arrangements can crucially affect power transmission system efficiency.
- The golden rule for pack animal welfare: avoid pressure on the spine.
- Intermediate modes of transport (including packing and carting) are generally profitable for the animals' owners.
- The pulling capacity of animals must be matched to the requirement of the cart. (especially important in hilly terrain).
- Highlift harnesses coupled with lightweight implements can increase the potential for smaller animals to perform field work

REFERENCES

Barwell, I and Ayre, M, 1982. The harnessing of draught animals. Intermediate Technology Publications, England. 92p

CEEMAT-FAO, 1972. The employment of draught animals in agriculture. Centre d'Études et d'Expérimentation du Machinisme Agricole Tropical; Food and Agriculture Organization of the United Nations. 249 p.

Chirgwin, J.C., de Roover, P and Dijkman, J.T. 2000. El burro como animal de trabajo. Manual de capacitación. Rome, Italy. Food and Agriculture Organization of the United Nations. Bulletin 146 Animal Production and health. 135p. ISBN 92-5-304455-1.

Dijkman J T and Lawrence, P R, 1997. The energy expenditure of cattle and buffaloes walking and working in different soil conditions. Journal of Agricultural Science, Cambridge, 128, 95-103.

Inns, F.M., 1990. The mechanics of animal draught cultivation implements: part 1 - chain-pulled implements. The Agricultural Engineer 45 (1): 13-17.

Inns, F., 1996. Matching tillage implements to draught animal potential. World animal review 86 (1): 40-49. http://www.fao.org/livestock/agap/war/warall/w0613b/w0613b0g.htm.

Inns, F.M., R.M. Shetto and S. Mkomwa, 1997. A lightweight swing plough for a single donkey: design, operation and the harness. In: Workshop Reader, Vol 2, prepared for the ATNESA workshop on Improving donkey utilisation and management, 5-9 May, Debre Zeit, Ethiopia, published by P. Starkey, Centre for Agricultural Strategy, University of Reading, 16-25.

Intermediate Publications Ltd. 1992. Tools for progress. Fourth Edition. IT Publications Ltd., London. P176. ISBN 1 85339 100X.

O'Neill, D H, Wanders, A A and Mbanje, E, 1997. Technology for donkey utilisation. Lead Paper to "Improving Donkey Utilisation and Management", an International Workshop organised by ATNESA (Animal Traction Network for Eastern and Southern Africa), Debre Zeit, Ethiopia, 5-9 May 1997.

Sims, B.G. and Jácome-Maldonado, S. 1990. Donkeys and other equines in Mexican agriculture. In: Fielding, D. and Pearson, R.A. (eds). Donkeys, mules and horses in tropical agricultural development. Proceedings of an International Colloquium at the Centre for Tropical Veterinary Medicine, University of Edinburgh, Scotland. September 1990. pp 8-12. ISBN 0907146066

Sims, B.G., Giménez, S., and Ellis-Jones, J. 1996. Equines in rural transport in Güinope, Honduras. CEIBA (Honduras) 37(2):299-305. ISSN 0008-8692.

Starkey, P. 2002. Local transport solutions for rural development. Rural Travel and Transport Program (RTTP) and Department for International Development (DFID). London. 48 p. ISBN 1 86192 427 5