9. Less conventional equipment

9.1 Introduction

This chapter deals with animal-drawn equipment that is not commonly used by small farmers. The restricted use may be because:

- the application is highly specialized;
- the technology is quite new and has not yet had a chance to diffuse;
- the equipment is economically, socially or technically inappropriate for small farms.

Some other books have included examples of such equipment within the context of a general presentation. This has some merit in illustrating a broad continuum of equipment applications and designs, but has unfortunately also given an unjustified impression of widespread acceptance or use. In this book it is intended that these less common technologies be thought of separately, with the clear understanding that such equipment may pose particular problems if introduced without careful planning. In the following pages the technologies themselves will be discussed quite briefly, but sources of further information will be cited. In this way it is hoped to sound a note of caution, while allowing people interested in developing such technologies to constructively build on previous experiences.

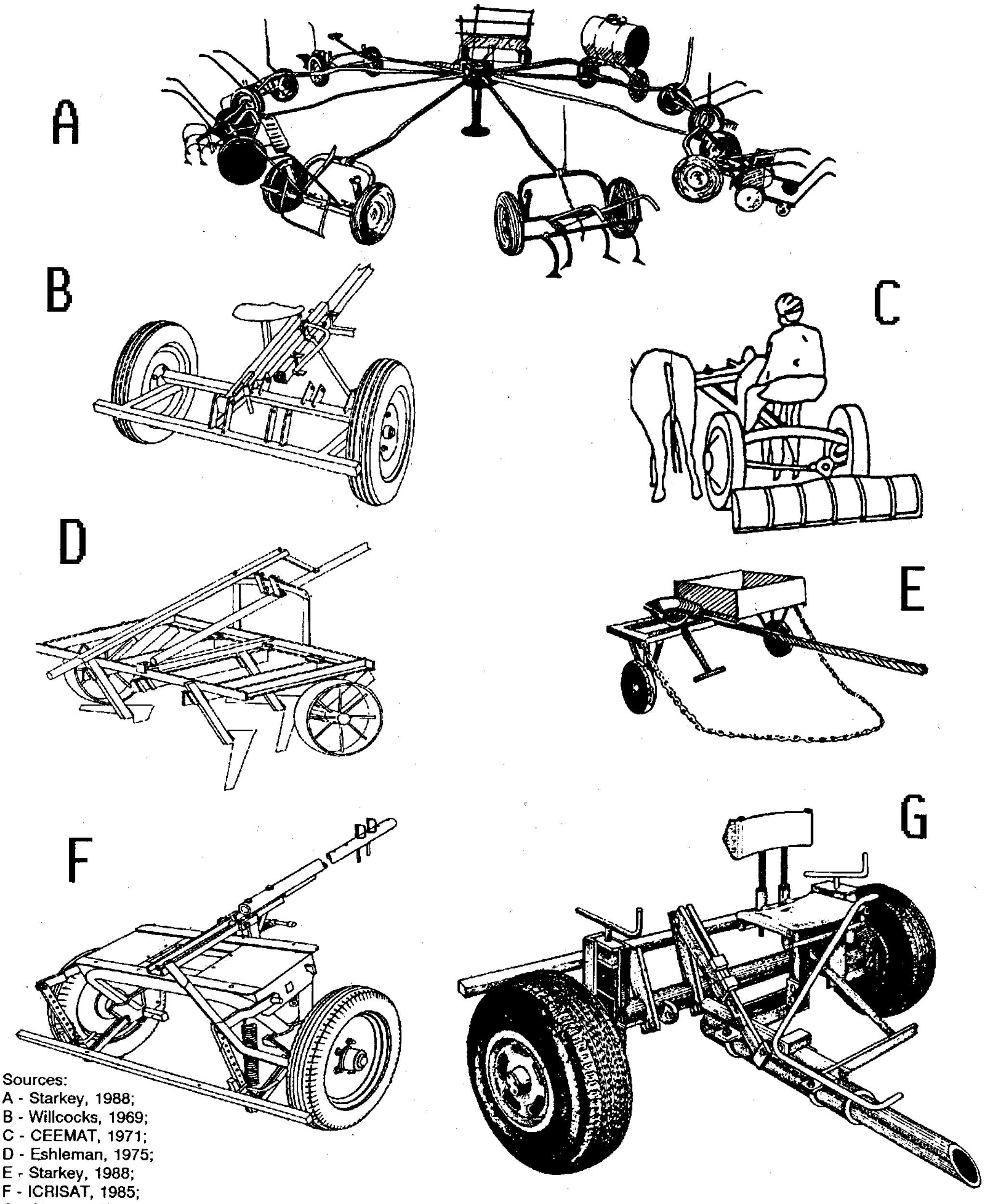
9.2 Wheeled toolcarriers

Animal-drawn wheeled toolcarriers are multipurpose implements that can be used for plowing, seeding, weeding and transport. They are usually ride-on implements, and are often thought of as "bullock-tractors". This image makes them very attractive to politicians and donor agencies. At least fifty designs of wheeled toolcarrier of varying degrees of complexity were developed in various countries from 1955 to 1987.

Most wheeled toolcarriers comprise a steel chassis and drawbar mounted on two wheels,

Fig. 9-1: "Nikart" type wheeled toolcarrier with double furrow plow being evaluated by a farmer in Mali in 1986. The farmer saw advantages in the toolcarrier, but the following year it was left unused.

Photo: Bart de Steenhuysen Piters



Sources:
A - Starkey, 1988;
B - Willcocks, 1969;
C - CEEMAT, 1971;
D - Eshleman, 1975;
E - Starkey, 1988;
F - ICRISAT, 1985;
G - Sims et al, 1985.

Fig. 9-2: Some wheeled toolcarriers.
A - Polyculteur, developed by Jean Nolle in Senegal 1955-60 (a display of nine with different attachments); B - National Institute of Agricultural Engineering (NIAE) animal-drawn toolbar, developed in UK, 1959-68; C - Nair toolcarrier, developed in India, 1960-63; D - Mochudi toolcarrier, developed in Botswana, 1973-79; E - Lioness toolcarrier, developed in UK, 1982-83; F - Tropicultor, developed by Jean Nolle in Madagascar and France, 1962, and at ICRISAT in India, 1975-87; G - Yunticultor, based on Nikart design developed in India by ICRISAT and AFRC-Engineering, 1978-1986, and further developed in Mexico, 1982-1987.

often with pneumatic tyres from cars. The chassis supports a toolbar which can be raised and lowered. Onto the toolbar clamp a wide range of implements, such as plows, harrowing tines or ridging bodies. There is generally an operator's seat, and most have a detachable cart body.

A pioneering design was developed in Senegal by the French agricultural engineer Jean Nolle in 1955 (Nolle, 1986). Nolle's most famous designs were the *Polyculteur* and the *Tropicultor* which have been tested in at least 25 countries. In 1960 the British National Institute of Agricultural Engineering (NIAE) in UK tested its own prototype design in East Africa, and derivatives of these were sent to at least 20 countries (Willcocks, 1969). More recently from 1974 to 1986 the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) started a major programme of research involving the use of wheeled toolcarriers in a crop cultivation system based on broadbeds. This resulted in the enhancement of the *Tropicultor* and also the development of a new design of wheeled toolcarrier, known in India as the *Nikart* (Bansal and Thierstein, 1982; ICRISAT, 1983; Kemp, 1983 and 1987).

The history of wheeled toolcarrier development has recently been reviewed in detail by Starkey (1988). He concluded that while about 10,000 toolcarriers had been manufactured between 1956 and 1986, the number that were ever used by farmers as multipurpose implements for several years was *negligible*. The majority were either abandoned or used as very expensive carts which, because of multipurpose design constraints, were actually less efficient than purpose-built carts. Wheeled toolcarriers have been rejected because of their high cost, heavy weight, lack of manoeuvrability, inconvenience in operation, complication of adjustment and difficulty in changing between modes. By combining many operations into one machine they have increased risk and reduced flexibility compared with a range of single-purpose implements. Their design has been a compromise between the many different requirements. In many cases for a similar (or lower) cost farmers could use single-purpose plows, seeders, multipurpose cultivators and carts to achieve similar (or better) results with greater convenience and with less risk.

Starkey (1988) argued that farmer rejection had been apparent since the early 1960s, yet as recently as 1986 most people working in aid agencies, international centres and national agricultural programmes were under the *impression* that wheeled toolcarriers had been widely adopted in some countries. These impressions derived from the circulation of numerous encouraging and highly optimistic reports. All wheeled toolcarriers developed have been proven competent and often very effective, providing excellent precision in operations under the optimal conditions of research stations. Most published reports derive from such experience. Published economic models have shown that the use of such implements is theoretically profitable, given many optimal assumptions relating to farm size and utilization patterns. In contrast there have been virtually no publications available describing the actual problems experienced by farmers under conditions of environmental and economic reality.

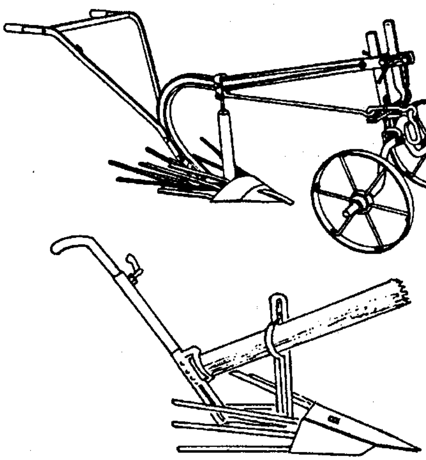
The concept of wheeled toolcarriers is clearly attractive and several technically competent designs are available. Nevertheless Starkey (1988) concluded that prospects for such implements within existing farming systems in Africa, Asia and Latin America seem poor. Organizations wishing to evaluate or redesign wheeled toolcarriers would do well to review in some detail the experience of previous schemes. Details of many of these are provided in the book on the subject by Starkey (1988) and the addresses of some organizations in Africa that have evaluated this technology can be found in the GATE Animal Traction Directory: Africa (Starkey, 1988).

9.3 Harvesting equipment

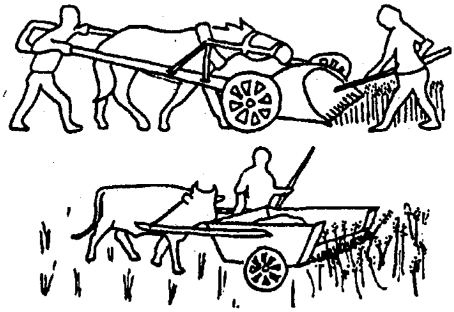
Animal-drawn groundnut lifters were discussed in an earlier chapter (section 7.8). Such implements are quite widely used, some being single-purpose tools, while others are attachments to simple multipurpose toolbars.

Root lifters are not common in the tropics. Cassava is not well adapted to lifting with animal power since it is a woody and deep-rooted crop that is often harvested when the soil is hard. The draft requirement for a lifting blade to pass under the roots in such circumstances would be very high. The cutting back of the plant to allow animal lifting would reduce the potential to make use of the long stems for manual raising of stubborn roots. Yams are usually grown in areas where few draft animals are used. Trials have been undertaken in Côte d'Ivoire on growing small varieties of yams in ridges and lifting yams using animal power, but problems were experienced in combining effective crop cultivation practices, socially acceptable varieties and ease of lifting (Bigot *et al.*, 1983). Potatoes grown on ridges are more amenable to lifting equipment and several commercially produced designs of animal-drawn lifters are available from China, India, Morocco, Poland, and UK (ITP, 1985).

Fig. 9-3: Potato lifters.
Top: Long-standing European design.
Bottom: Prototype developed for Peru.



Sources: CEEMAT, 1971; Herrandina, 1987



Source: Gill, 1977

Fig. 9-4: Ancient designs of animal-pushed reapers.

Animal-powered equipment for harvesting cereals has been available for a long time. There are reports of "Gallo-Roman" reaping machines which were animal-*pushed*, two-wheeled carts, with an adjustable comb and blade at the front. As the reaper was pushed through the grain field, the heads of the crop would be broken off, and fall into the cart, leaving much of the straw standing in the field. Since no examples of this technology remain in existence, it is difficult to judge the problems of clogging and wastage that would have occurred with such an implement (Smith, 1979; Gill, 1977). Derivatives of such designs were used in the UK in the eighteenth century but were considered only suited to flat areas where there was excess straw (Smith, 1979). More complicated animal-*drawn* grass mowers and reapers for small-strawed cereals, such as wheat and barley, were developed to a high degree in Europe and North America between about 1840 and 1930. They required both high draft power and reasonable speed, and so were generally used with strong horses rather than oxen (Binswanger, 1984). During much of this time motorized harvesting was not a realistic option.

Some illustrations and details of horse-drawn harvesting machinery were provided by

Sources: after Viebig, 1982, Devnani, 1980 Nolle, 1986

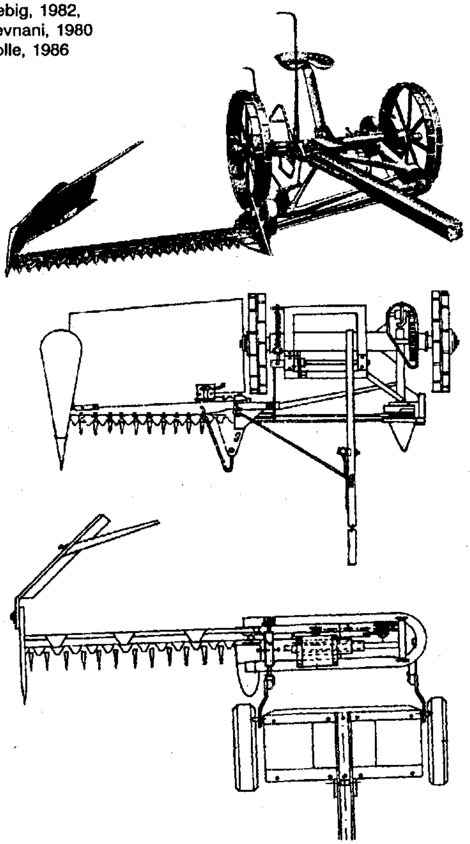


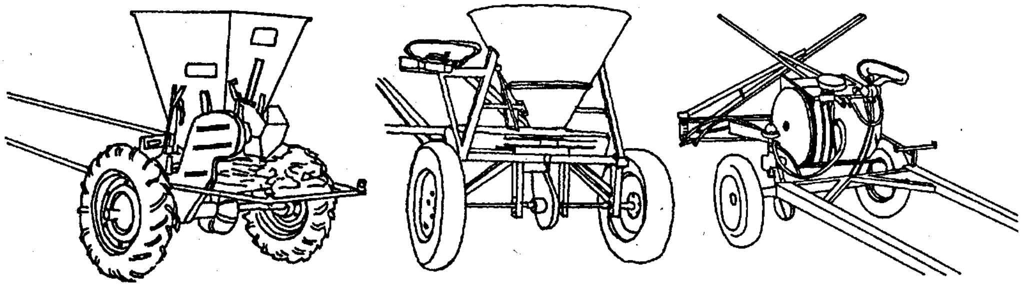
Fig. 9-5: Animal-drawn mowers.
Top: Long-standing European design.
Middle: Prototype designed in Punjab, India.
Below: Mower developed for use with a Tropicultor wheeled toolcarrier: the mower blades are driven by a small petrol engine mounted behind the toolcarrier.

CEEMAT (1971), FAO/CEEMAT (1972) and Viebig (1982). However despite some trials with such equipment in the tropics, there are virtually no records of their use in developing countries, where cattle provide most of the farm power and many rainfed cereals (sorghum, maize, millet) have large stems. The main reasons for their lack of acceptability appear to be:

- their high cost, which is unlikely to be justified from the profits of one small farm,
- their complexity which necessitates considerable investment in training time,
- the fact that they are easily damaged by stumps and ground obstructions, making them only suitable for use in well cleared land,
- their heavy weight and requirement for both power and speed.

Those conditions that might be favourable for animal-drawn harvesting equipment (for example where farm income is high, technical knowledge is available and land is well cleared) may also be suitable for motorized harvesting equipment. Similarly those circumstances that might favour communal ownership or entrepreneurial hiring of animal-drawn harvesting equipment, are also likely to favour motorized alternatives. This should not be taken to imply that no animal-drawn harvesting equipment will ever be appropriate in developing countries, but enthusiasts for European or North American horse-drawn implements should not expect to be able to easily transpose such designs into the smallholder farming systems of Africa.

There have been cases of animal drawn carts or toolcarriers fitted with motorized mowers (Nolle, 1986). These have had the advantage of requiring only a small motor for the mower as the power for transport was provided by the animals. The relative cost of small petrol engines has been falling in recent years, but the problems of developing countries obtaining foreign exchange to purchase them have increased. More significantly mowing is not a common operation in the tropics, where hay and silage production is difficult and where many pastures have thick grasses. To date the use of such equipment appears to have been confined to research stations where they may simplify experimental work on forage production. While there is little hard information for or against such implements at farm level, they may well represent another example of a research idea that has not been found appropriate to the needs of small farmers.



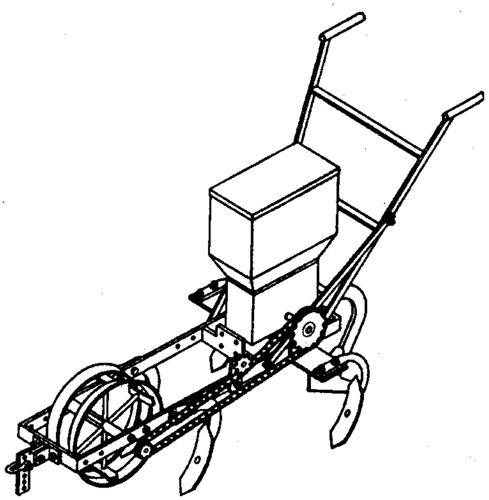
Source: ITP, 1985

Fig. 9-6: Commercially available animal-drawn fertilizer applicators and a crop sprayer: a large area of crops would have to be treated to justify the investment in such implements.

9.4 Fertilizer applicators

Most chemical fertilizers on small farms in the tropics are applied by hand (Hopfen, 1969). Single-purpose animal-drawn fertilizer applicators are not common, although they are commercially available and were used in Europe and North America earlier in this century (ITDG, 1985). Reasons for their limited use in developing countries include low levels of chemical fertilizer application and the relative ease of broadcasting fertilizer by hand. It is also likely to be associated with the limited adoption of precision planting to facilitate accurate fertilizer placement in rows, and also the economies of fertilizer use that can be obtained through application to individual plants or stands.

Fig. 9-7: A combined top-dressing fertilizer applicator and weeder developed experimentally in Botswana. Based on the chassis of a seeder, the fertilizer unit can also be mounted with the seeder unit to make a combined planter-fertilizer applicator.



Source: ILO, 1983g

Quite complex dual-purpose combined seeders and fertilizer applicators have been developed in many countries but adoption rates have been low (Munzinger, 1985). This may be associated with their high cost and complexity and the relative ease of performing operations by hand. On-station trials have usually demonstrated the benefits of such implements under optimal conditions. Farmers have often had problems in maintaining correct seed and fertilizer placement under the less uniform and more rigorous conditions of their own fields. One problem relates to the hygroscopic nature of many fertilizers. This causes the granules to become sticky as they absorb water from the atmosphere, making metering mechanisms inefficient. Related to this is the very rapid corrosion of metal implements used for fertilizer distribution.

In contrast to the expensive precision implements, some very simple units have been developed in India, comprising small wooden bowls with PVC tubes that connect to simple share openers. The seeds or fertilizers are hand metered by dropping appropriate quan-

Photo: ICRISAT archives

Fig. 9-8: A Tropicultor wheeled toolcarrier being used for combined weeding and fertilizer application on the ICRISAT research station. The fertilizer is hand-metered and passes down plastic tubes to hollow tines.

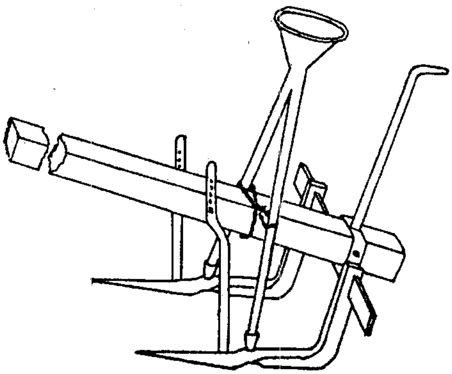


Fig. 9-9: Simple hand-metered tube distribution mechanism on an Indian 2-row "Duphan" seeder which can be adapted for fertilizer placement.

Source: Gite and Patra, 1981

tities into the bowl. Such units may be connected to existing plows for combined seeding and fertilizer placement, or to weeders for fertilizer placement during weeding (Fig. 9-8).

It is not the intention to discourage work relating to animal-drawn implements for fertilizer placement, for the benefits of accurate and timely fertilizer placement are well known. Nevertheless enthusiastic agricultural engineers in at least 20 different African states and many more countries worldwide have already invested much time in developing their own prototype seeder-fertilizer applicators, with minimal uptake of their labours. This repetition of similar experiences is wasteful of resources and suggests that *ad hoc* work on implement design itself is not sufficient to make an impact in this particular area.

Photo: AFRC-Engineering archives

Fig. 9-10: Ridge-tying on a research station in The Gambia.

9.5 Ridge-tiers

Joining ridges to form a grid of mounds and hollows can assist in soil and water conservation particularly in those semi-arid regions that have 400-700 mm of annual rainfall. Large yield effects attributable to tied-ridging have been demonstrated on research stations. Several designs of animal-drawn ridge-tiers have been developed, but to date there seems little evidence of farmer adoption. Simple designs developed and tested in Nigeria in the 1960s (Stokes, 1963: ITDG, undated) and The Gambia in the 1970s (Matthews and Pullen, 1974) scraped the hollows between ridges and had to be lifted every few metres over the accumulated soil to obtain the ridge-tie. This was hard work for the farmer and animals, and few farmers appeared convinced that the benefits justified this effort. More recently two prototype animal-drawn

Fig. 9-11: An operator lifts a ridge-tying implement and so forms a ridge-tie. The "Unibar" multipurpose toolbar fitted with the ridge-tier was being tested on a research station in The Gambia.

Photo: AFRC-Engineering archives

Source: Wright and Rodriquez, 1986

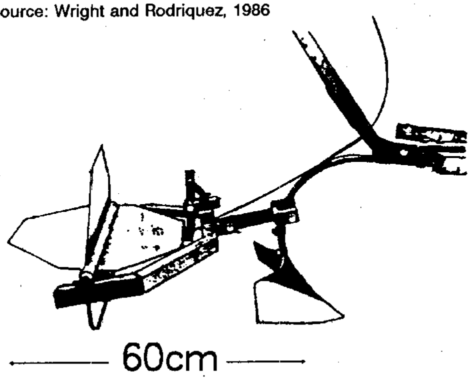


Fig. 9-12: Prototype ridge-tying attachment developed by SAFGRAD/IITA in Burkina Faso. A cycle cable is used to trip the ridge-tier to enable it to rotate.

ridge-tiers have been developed in Burkina Faso. One developed by ICRISAT researchers is based on a ridger with a large eccentric ground wheel that changes the working depth cyclically and so creates very gradual ties; the other developed by researchers from IITA and SAFGRAD has four blades arranged at right angles, and the operator trips the blade to allow it to rotate by 90°, so depositing the soil and forming a ridge (Wright and Rodriquez, 1986). A ridge-tier has also being developed by CPATSA, EMPRAPA and CEEMAT in Brazil, as an option for the CEMAG Policultor wheeled toolcarrier (Duret *et al.*, 1986).

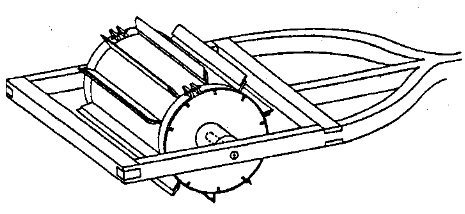
It should be stressed that while researchers are optimistic about animal-drawn ridge-tiers, no implement design has yet passed the test of farmer adoption. Further information on current research can be obtained from ICRISAT and SAFGRAD in Burkina Faso.

9.6 Weeder rollers

The use of large, heavy rollers fitted with cutting blades has been tested by GTZ-supported projects in Tanzania and Cameroon (Becker, 1987; IAD, 1987). The rollers are 60-100 cm wide and are fitted with rotating steel frames supporting 6-12 knives (Fig 9.13). As the rollers are pulled along the rotating knives cut up grasses, small shrubs and surface trash leaving a mulch of chopped vegetation. Weight estimates for the implements range from a low 80 kg, reported for an eight-blade model in Cameroon (IAD, 1987) to a high 450 kg for a 10-blade prototype in Tanzania (Becker, 1987). In preliminary trials in Cameroon and Tanzania such rollers were used for clearing stover and weeds from fields prior to cultivation. Reported work rates are in the region of 5-6 team-days per hectare (based on a 4-5 hour working day), while to achieve similar clearance would require 27-30 person-days. The weeders have been found particularly useful for weed suppression within orchards and under tree plantations and there are suggestions that the rollers might be usefully employed in alley cropping systems.

In early 1989 these implements were still at an early stage of development, although small-scale production had started in Cameroon. It is too early to say whether weeder rollers will be adopted but one can conjecture possible constraints to eventual farmer adoption. High implement cost combined with limited annual use may well make it difficult for small farmers to justify buying such equipment. Alternatives to individual purchases, such as entrepreneurial hire schemes or group ownership, have often been suggested as means of disseminating expensive animal traction implements, but in practice few such schemes have ever developed. Farmers may be discouraged by the implements' heavy weight, poor manoeuvrability within their fields and plantations and the difficulties in transporting

Fig. 9-13:
Prototype weeder-roller with wooden frame (concept).



Source: Becker, 1987

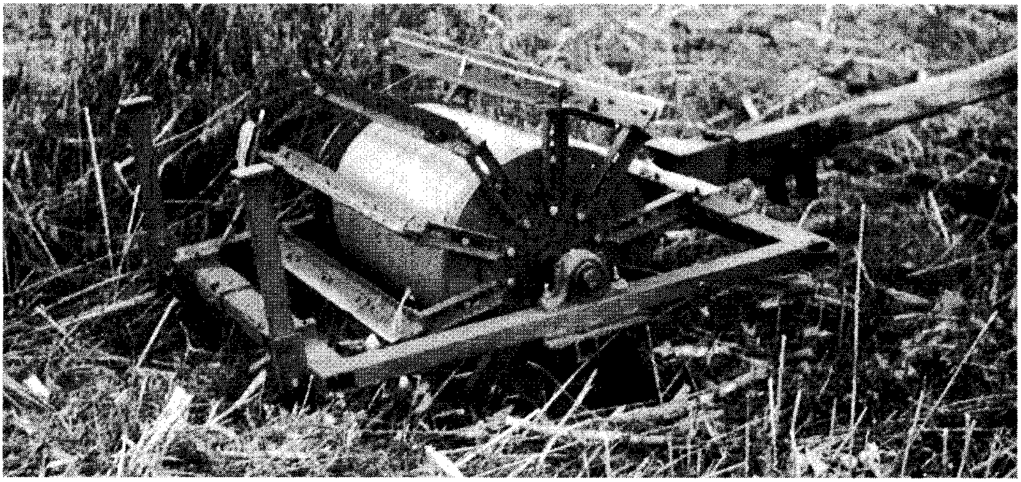


Photo: Henner Becker

Fig. 9-14: Prototype weeder roller with steel frame developed in Tanzania.

such units between different fields. Their use for control of thick grass and light bush could pose a threat to the health of the animals that have to walk through the brush ahead of the roller since lignified grass stalks and shrubs could puncture the animals' skin or eyes. In normal use the frame surrounding the rolling blades should prevent human feet from accidently being cut, although caution would be always be required during manoeuvring.

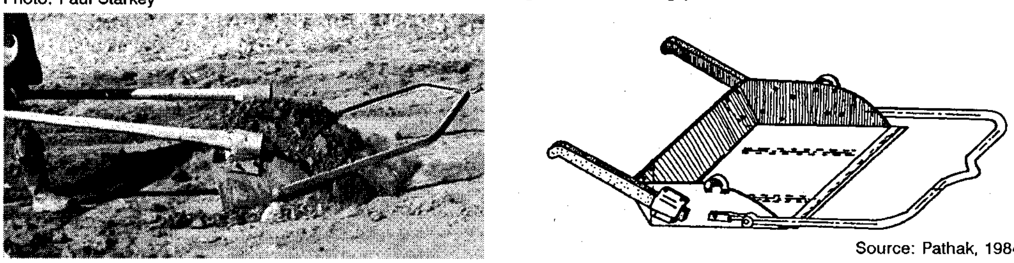
Reports of initial trials have expressed considerable optimism for the potential for these weeding rollers, which are to be further evaluated in Brazil, Cameroon, Ghana and Tanzania in conjunction with GTZ and the University of Giessen. However at the time of writing this equipment had not been proved by farmer adoption, and persons interested in this technology should obtain updated information before following up these ideas. It will be particularly important to learn whether farmers perceive such implements to be technically appropriate and economically affordable in their specific farming systems. Further information can be obtained from GTZ, Germany, TIRDEP, Tanzania and PAFSAT, Cameroon (for addresses see Appendix and GATE Animal Traction Directory).

9.7 Land formation equipment

Animal-drawn scoops for levelling fields or for "water harvesting" have been used in Africa and elsewhere for many years (Hopfen, 1960). Scoops are made from sheet steel to which are attached two steering handles and a movable U-shaped steel drawbar (Fig. 9-15).

*Fig. 9-15: Earth-moving scoops used for land formation, pond construction and water harvesting. Left: Scoop used by ILCA, Ethiopia. **Right.** Scoop from India.*

Photo: Paul Starkey



Source: Pathak, 1984

Source: Pathak, 1984

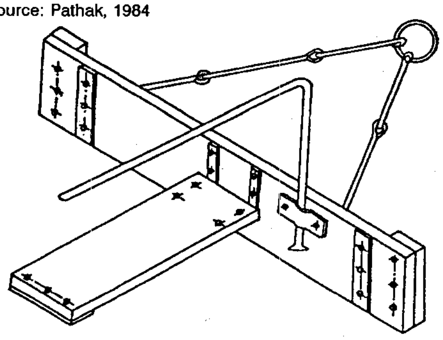


Fig. 9-16: Ride-on levelling board or "buck scraper".

Source: after CEEMAT, 1971

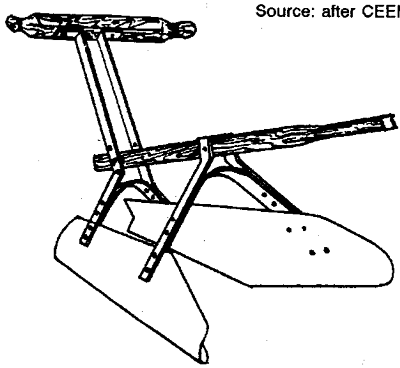


Fig. 9-17: Wooden bund former.

Unless the soil is very light and sandy, it has to be first loosened by plowing or tine cultivation. Recently such scoops have been used with donkeys in Kenya for waterharvesting (ITDG, 1985) and in Ethiopia for pond excavation using oxen. In Ethiopia ox-teams can remove about 8-10 m^3 per day (Abiye Astatke, Bunning and Anderson, 1986). Although scoops are robust, they are relatively expensive and require considerable draft power. For this reason they are often used in communal schemes.

Simple ride-on boards or logs are widely used for levelling fields between plowing and planting, particularly fields that are to be irrigated. Animal-drawn bund forming implements have long been used in Asia to prepare small contour ridges in irrigated fields (Hopfen, 1969). Models based on two boards in the shape of a

Fig. 9-18: Levelling with a wooden earth-moving scoop in Egypt.

Photo: Paul Starkey

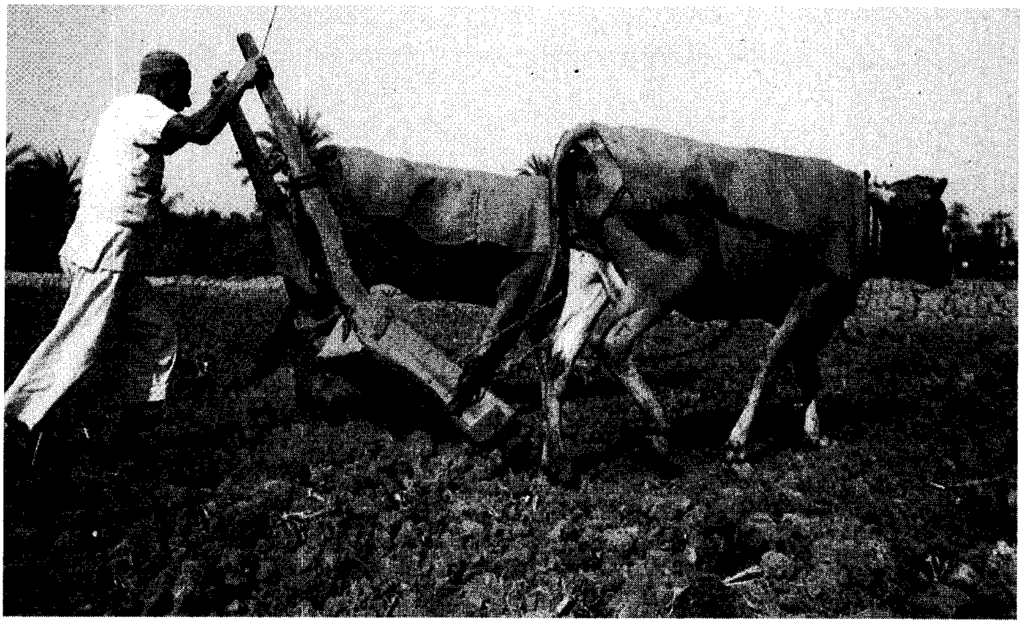


Photo: ILCA Highlands Programme

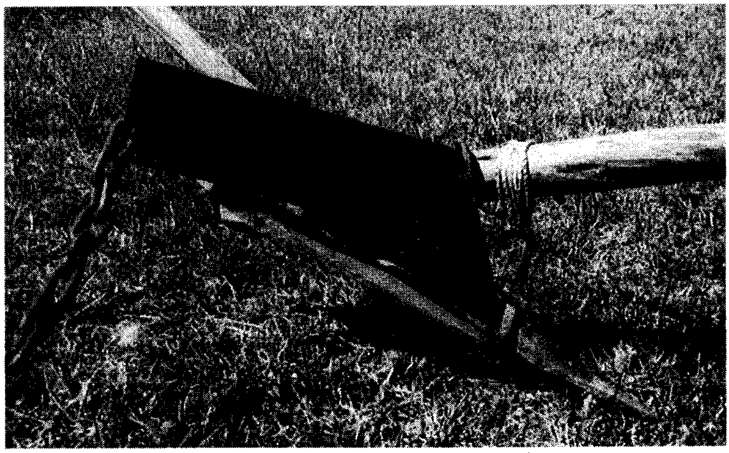
Fig. 9-19: A GOM wheeled toolcarrier ("Nikart" type) with ridgers and levelling board being evaluated on an ILCA research station in Ethiopia. It was considered too expensive for forming broad-beds in local farming systems, and so emphasis was placed on modifying the maresha ard to form comparable broad-beds.

"V" have been tested in Africa, but are not widely used except in Madagascar. Lack of uptake may be associated with limited use of draft animals for irrigated crop production in Africa, the heavy draft of the implements, and the fact that ridges made with bund-formers have little persistence in storms.

A combination of conventional mouldboard plows, ridgers, harrows and levellers can be used for terrace formation, bund-formation and other types of land shaping for soil and water conservation. Research by ICRISAT in India and ILCA in Ethiopia has indicated that large flat ridges (broad-beds) can greatly improve the drainage of heavy black soils (Vertisols), providing higher and/or more reliable yields in on-farm trials. ICRISAT developed systems of broad-bed cultivation using wheeled toolcarriers, but although experimental results were encouraging (Ryan and von Oppen, 1983), farmer adoption was minimal (Starkey, 1988). In Ethiopia, ILCA briefly evaluated wheeled toolcarriers but decided to modify existing local implements for land-forming operations. Jutzi, Anderson and Astatke

Fig. 9-20: Mouldboard added experimentally to a traditional Ethiopian maresha ard to allow the formation of terraces and broad-beds.

Photo: Paul Starkey



Source: ILCA, 1988

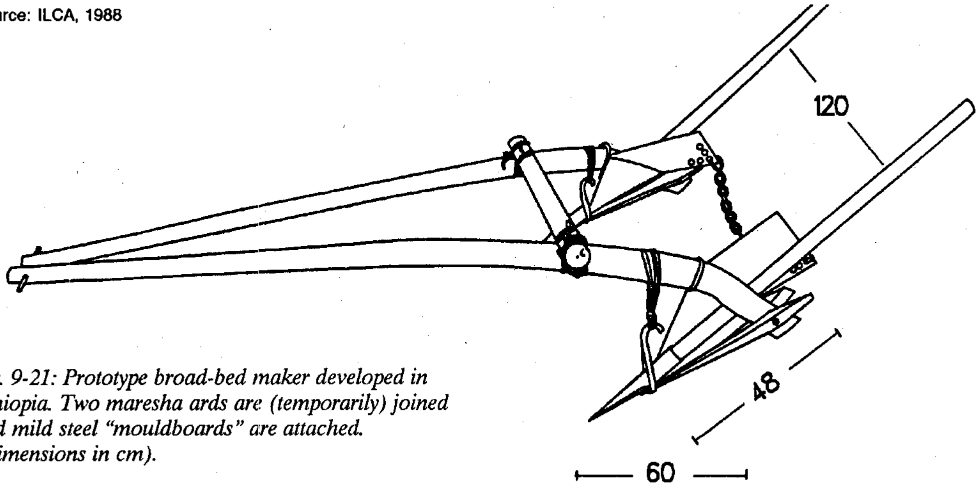
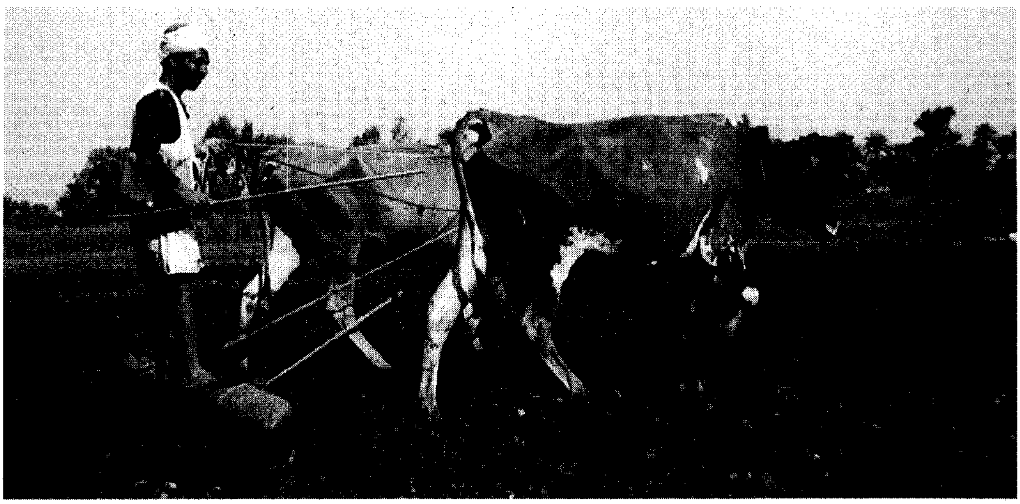


Fig. 9-21: Prototype broad-bed maker developed in Ethiopia. Two maresha ards are (temporarily) joined and mild steel "mouldboards" are attached. (Dimensions in cm).

(1986, 1988) described the development of modified *maresha* ards in Ethiopia for use in terrace construction and broad-bed formation. Initially two ards were used to construct a new broad-bed former, but this was difficult to transport and the ards used to make a broad-bed former could not then be used for normal plowing. A new design was therefore developed in which two ards are only temporarily joined to form a single implement (ILCA, 1988; Fig. 9-21). Simple steel mouldboards are attached to the ards to facilitate the formation of bunds and broad-beds. The work, which is being carried out by ILCA, the Ethiopian Ministry of Agriculture and local farmers is still at an early stage, and it is too early to judge whether the technology will become widely adopted. On the positive side the broad-bed maker requires only local materials and existing skills. Initial agronomic results are favourable and suggest that even with minimal inputs, the broad-bed and fur-

Fig. 9-22: Levelling a plowed field in Egypt prior to irrigation and planting. The simple ride-on leveller is made from a log of wood.

Photo: Paul Starkey



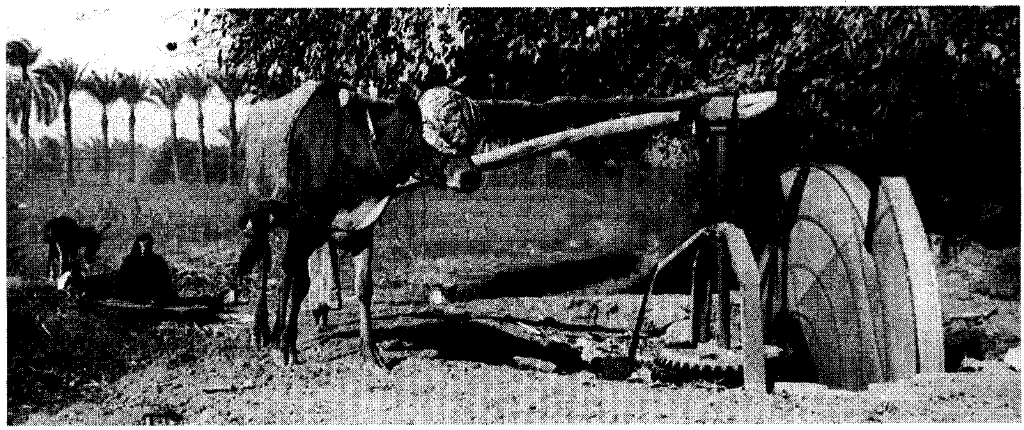


Photo: Paul Starkey

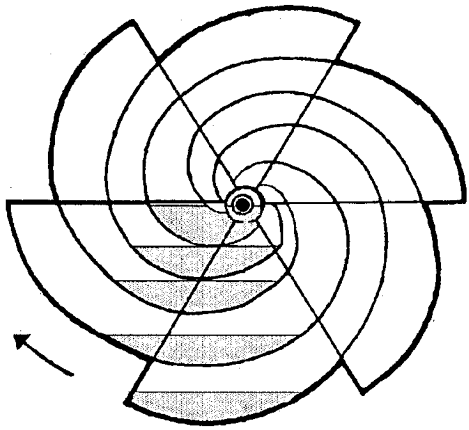
Fig. 9-23: A cow turns a sakia water wheel to irrigate crops in Egypt. Many thousands of such devices are used to raise water from shallow wells and irrigation canals.

row technique provides more reliable harvests than traditional systems. On the negative side, the broad-bed maker requires more time to set up and has a greater draft during operation than the unmodified *maresha* and is less manoeuvrable on the field. Some research is being undertaken on simple seeders, blade-weeders and fertilizer distributers that can be fitted to the broad-bed makers. However in early 1989 such designs were still at a prototype stage, and it is by no means certain that the maresha broad-bed maker will be developed into a multipurpose implement analogous to the wheeled toolcarrier. Further information on the modified *maresha* and the broad-bed maker can be obtained from ILCA, Addis Ababa.

9.8 Water-raising equipment

Traditional designs of animal-powered water wheels and other devices that provide relatively continuous delivery of irrigation water have been employed in North Africa and Asia for centuries (Löwe, 1986; Kennedy and Rogers, 1985; Inter Tropiques, 1985). Such systems make use of available materials and local energy sources, and can be made and maintained by local artisans. Among the well proven designs are the "Persian wheel" and the Egyptian "sakia". The Persian wheel comprises a continuous loop of containers that scoop into the water, rise up, and empty out the water just after reaching the top of the wheel. The loop of pots can be quite long, so extraction from depths of 5-20 m is possible. For raising water to irrigation ditches from shallow wells the sakia is more efficient. This is because unlike many other irrigation devices, water is not "over-lifted". Water is scooped up in a series of spirals, and discharged into the irrigation ditch from the cen-

Fig. 9-24: The wheel of a sakia. As the wheel rotates, water is continually scooped into the compartments of the spiral, and released by the central hub. In this way water is not lifted higher than necessary.



Source: Kennedy and Rogers, 1985

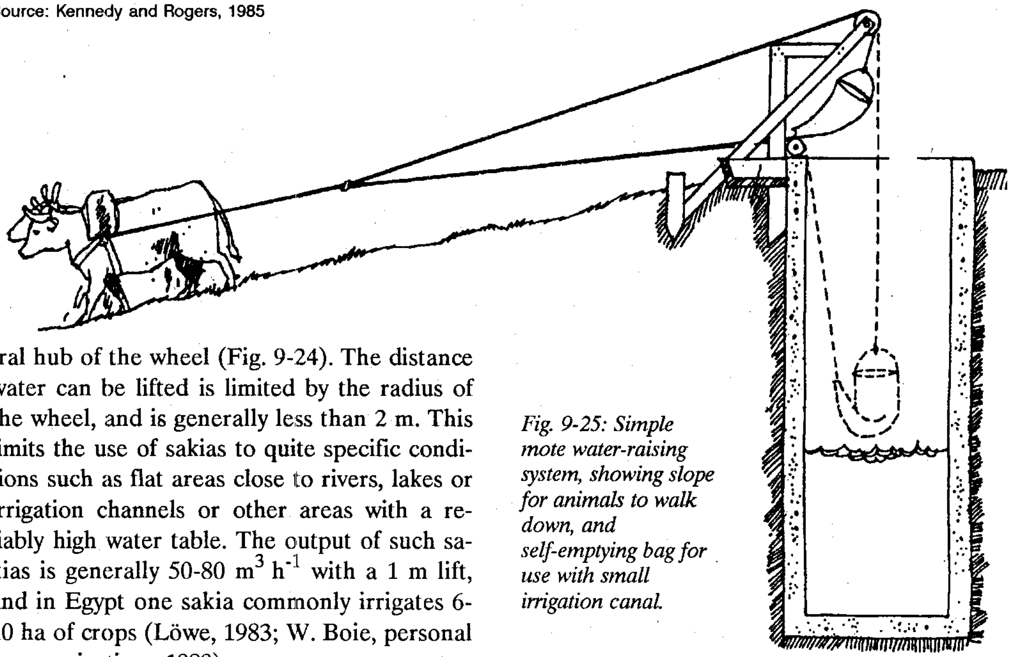


Fig. 9-25: Simple mote water-raising system, showing slope for animals to walk down, and self-emptying bag for use with small irrigation canal.

tral hub of the wheel (Fig. 9-24). The distance water can be lifted is limited by the radius of the wheel, and is generally less than 2 m. This limits the use of sakias to quite specific conditions such as flat areas close to rivers, lakes or irrigation channels or other areas with a reliably high water table. The output of such sakias is generally 50-80 $m^3 h^{-1}$ with a 1 m lift, and in Egypt one sakia commonly irrigates 6-10 ha of crops (Löwe, 1983; W. Boie, personal communication, 1989).

In some regions where traditional designs of water-raising systems are used, development projects and appropriate technology organizations have tried to improve those traditional designs and in some cases have produced entirely new prototype systems (Tainsh and Bursey, 1985; Kennedy and Rogers, 1985; Baqui, 1986). However in some developing countries, including India and Egypt, electric or diesel pumpsets are quite rapidly replacing the widely used traditional animal-powered water-raising systems. Some such moves away from animal-powered systems have been encouraged and subsidized by government agencies.

Source: Löwe, 1986

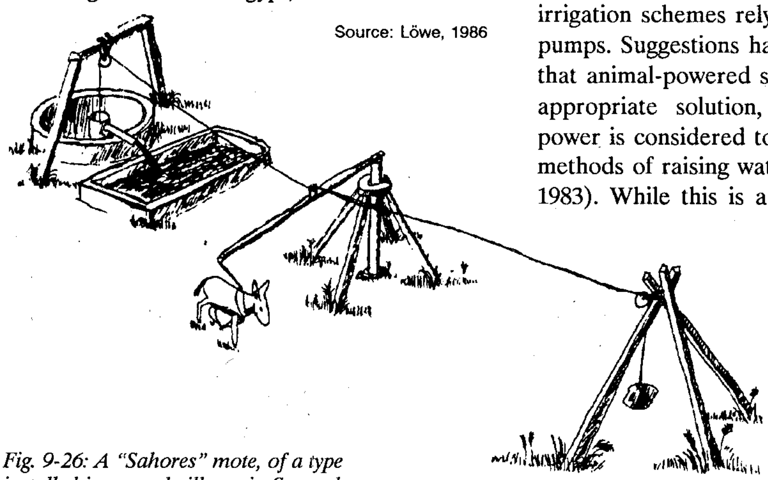


Fig. 9-26: A "Sahores" mote, of a type installed in several villages in Senegal.

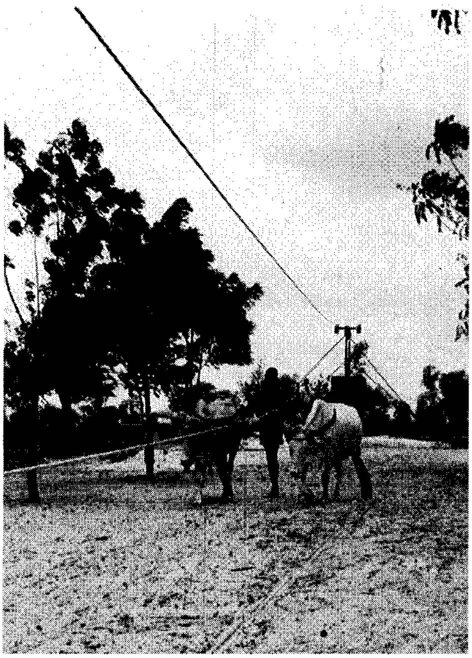
In most of Sub-Saharan Africa, animal-powered water raising systems are absent or rare, yet in several countries there have been serious problems in affording or maintaining irrigation schemes relying on diesel or electric pumps. Suggestions have therefore been made that animal-powered systems could provide an appropriate solution, particularly as animal power is considered to be one of the cheapest methods of raising water at low lifts (Halcrow, 1983). While this is a sensible option to consider, it is one that needs to be approached with caution. If the required "traditional" skills are not readily available, the installation of "traditional" designs may necessitate spe-

Photo: Paul Starkey

Fig. 9-27: A simple and cheap animal-powered water-lifting system in Niger. The animals walk about 80m (the depth of the well) pulling a rope to which is attached a 25 litre bag. When the bag reaches the top of the well it is manually emptied, and dropped down the well again as the animals return for the next lift.

Fig. 9-28: Raising water from a deep well in Senegal using a "Guéroult" system of gantries and overhead lines installed by ENDA. The animals walk about 80m (the depth of the well) pulling up one 50 litre steel container, and then pull up a second 50 litre container on the return to the well.

Photo: Paul Starkey



cial training and supervision. No mechanical water-raising system is maintenance-free, and the introduction of animal-powered irrigation techniques may require significant training for local artisans to ensure the systems are maintained in working order (Löwe, 1986). One FAO project designed to overcome these problems involved Moroccan artisans training their counterparts in Mauritania to make and maintain traditional Moroccan designs of water-raising equipment (Bourarach, 1987).

While there are several aid projects in Sahelian countries interested in the potential for using animal power for irrigation, there is, as yet, not enough positive evidence to suggest that such techniques can be effectively introduced in present social and economic circumstances. Thus while it is an interesting option, any organization contemplating such a scheme would be advised to contact the relevant projects and information sources for an up-to-date assessment of this specialized area.

For domestic requirements, for providing water for animals and for small vegetable gardens, the raising of water from wells using animals to pull on ropes is a well proven and quite simple technology (Fig. 9-27). Such a

Source: Löwe, 1986

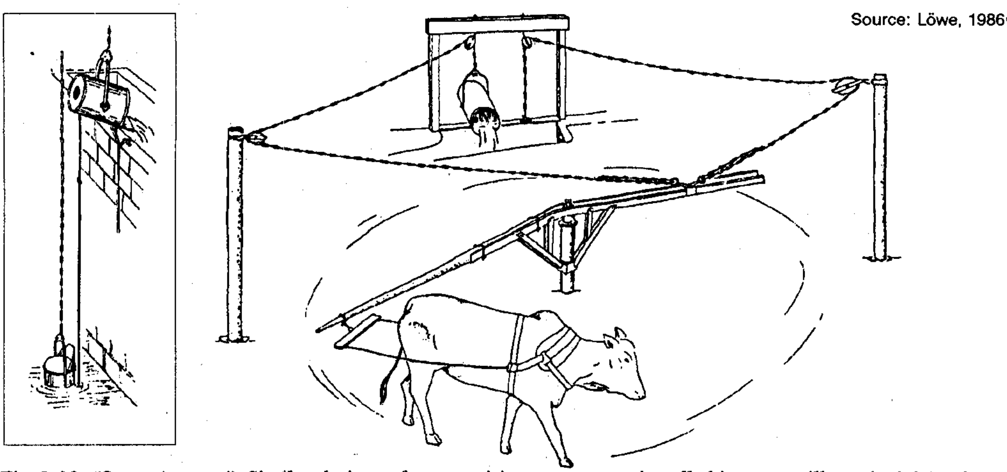
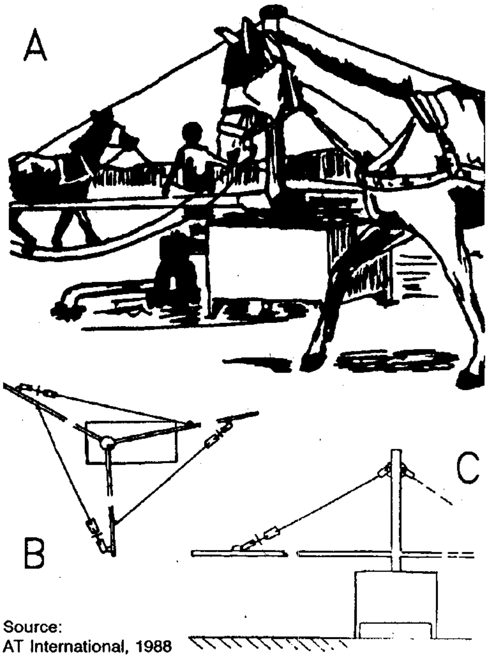


Fig. 9-29: "Stoney's mote". Similar designs of water raising systems are installed in many villages in Sri Lanka. As the animal walks round, the two buckets continually (and alternately) rise and fall. The buckets are designed to fill and empty themselves without supervision.

system can be used with wells of any depth, but it is most useful for very deep wells for which pumping systems can be difficult and for which manual raising is extremely tedious. In several Sahelian countries pairs of oxen may be seen walking away from wells pulling ropes 80-100 metres long. When the container reaches the top, the animals turn and walk back in order to start the working part of the cycle again. Although such a system may appear laborious and slow, it illustrates how animal power can be utilized very simply to allow essential water to be raised. In a traditional system known as a *Delou* (or *mote* in India) the pulling of the water container is made more efficient by making the animal(s) walk down a slope (Fig. 9-25: Kennedy and Rogers, 1985; Löwe, 1986). The need for the animals to walk to and fro is reduced in the *Guéroult* version of the Delou developed by ISRA and ENDA in Senegal (Goubert, 1982; Jacobi and Löwe, 1984; Deshayes, 1988). This has ropes or wires mounted above the animals, so that they can walk in a large oval, continuing to supply useful energy on the return journey as well as the outward one (Fig. 9-28). Extraction rates with a Guéroult can be up to 4 m^3 per hour at 40 metres, dropping to 2 m^3 per hour at 80 metres (Löwe, 1986). In circular motes or "Stoney's mote" (Fig. 9-29), as used in Sri Lanka, one or more animal walks in a circular path, and a beam attached to overhead lines acts as a crank, converting circular movement into the vertical lift and fall of two



Source:
AT International, 1988

Fig. 9-30: Prototype animal-powered piston pump in Botswana. It uses the power of up to nine donkeys to pump water from deep wells.
A. General impression. B. Plan. C. Elevation.

water containers (Löwe, 1986). A recent adaptation of this principle is seen in the *Manège Sahores* developed in Senegal. An animal (usually a donkey) pulls a beam round in a circular path causing an overhead, counterbalanced rope to operate a simple piston pump. Extraction rates can be 6 m^3 per hour at 6 metres dropping to 1.8 m^3 h^{-1} at 20 metres.

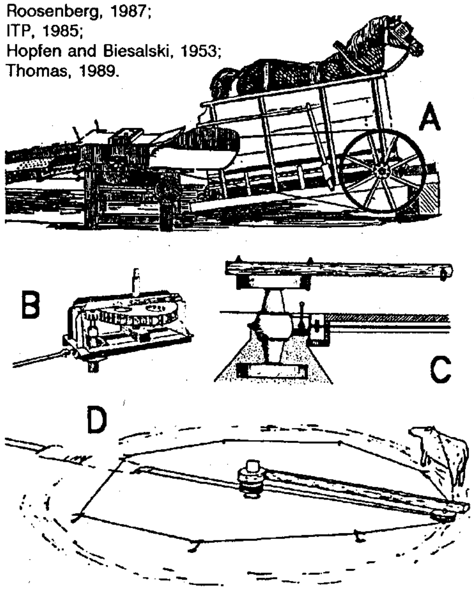
Animal power has been used to drive adaptations of commercially available pumps. In one test in Botswana eight donkeys pumped 5.3 m^3 in an hour over a head of 38 metres using a British "Monopump" (Maseng and Jacobs, 1985). Using a commercial pump and a multipurpose gear, two small oxen were capable of pumping 2 m^3 h^{-1} through a head of 16 m in Sierra Leone (Koroma and Boie, 1988). In India, two heavy water buffaloes were reported to be capable of pumping 20 m^3 h^{-1} through an 8 m lift using a Danish "Bünger" pump (Burton, 1987).

Animal-powered water raising systems may be used for small scale irrigation, for example for vegetable production. Unfortunately in many of the rural areas where animal-power might be usefully employed for irrigation, marketing can be a major constraint and local produce prices may not be sufficient to economically justify the investment in any type of irrigation equipment. Although animal-powered systems are relatively simple, there are significant costs in time and materials to erect and maintain overhead lines and the circular sweeps. For domestic use, one unit can serve a small village, but this requires considerable cooperation for it is impracticable for each person to bring their own animal to draw water. The implications for communities that such systems may have on the partition of labour and responsibilities by sex, age and social group need to be carefully considered (Jacobi, 1985).

In several African countries prototype animal-powered water-raising systems have been built, but examples of recent, successful introduction are quite few. In some cases the problem has been the technical failure or the inefficiency of the prototype systems installed. In other cases systems have appeared to work satisfactorily, but diffusion of the technology has still not been widespread. For example in Senegal some systems have been operating in villages for over ten years, but the total number in use is still low. In some cases the water-raising systems may improve the quality-of-life of people but not alter their incomes and this may well have implications for the way such installations are funded in impoverished communities. Animal-powered water-raising is not as simple as it may seem at first sight, and there is much to be gained from the careful study of previous experiences. Sources of relevant information include ENDA (Senegal), GATE (Germany), IAE (Zimbabwe), IT-Dello (France), ITDG (UK) and RIIC (Botswana). The addresses of these organizations are provided in the Appendix and the GATE Animal Traction Directory: Africa.

Fig. 9-31:
Some mechanisms for linking animals to machines.
A. Treadmill. B. Commercially available gear system.
C. Gear system based on vehicle differential.
D. Rope engine (concept).

Sources: after
Roosenberg, 1987;
ITP, 1985;
Hopfen and Biesalski, 1953;
Thomas, 1989.



Source: ITDG, undated

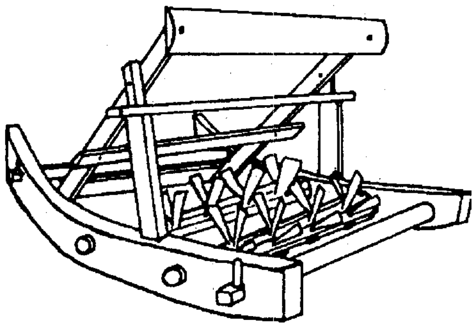


Fig. 9-32: Animal-pulled threshing sledge.

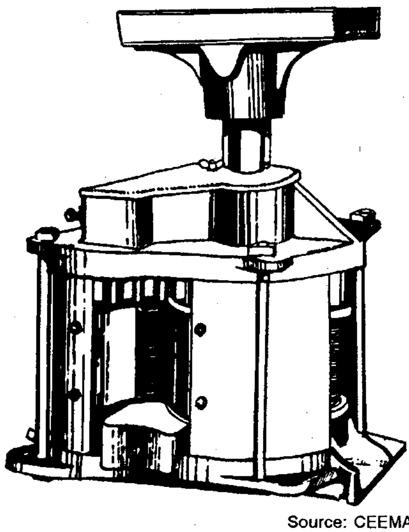
9.9 Animal-powered gears and post-harvest operations

For centuries animal power has been usefully employed for crop processing. Some cereal crops can be threshed without any special equipment, merely by the trampling of animals. However basic threshing can be more efficient with the use of animal-pulled threshers similar in appearance to rotary puddlers or disk harrows; such implements can be found in several north African countries. Simple traditional mills requiring slow speed but high torque are well suited to being turned by animals. In northeast Africa camels are employed to turn uncomplicated mills based on a large wooden pestle and mortar designed to press oil-seeds such as sesame. Animal-powered sugarcane crushers, which also require only low speeds and high torque, are widely used in parts of Asia and Latin America and are commercially available in India (ITP, 1985). They were adopted to a limited extent in Madagascar (CEEMAT, 1971) and have been commercially produced in Kenya (ITP, 1985).

Animals can also be used to power a wide variety of more complex grinding mills and various types of crop processing machinery that require high speed rotation and relatively low torque. The mechanisms for harnessing the power of the animals sometimes involve treadmills (Fig. 9-31) but more commonly they are based on long, animal-turned drives or sweeps (*manèges* in French). As the animal(s) walk round in circles, power is transmitted through a system of gears or belts to the output machine. A useful review of this subject was provided by Löwe (1986), who discussed historical precedents and modern applications. Other publications giving details of long-standing designs of animal-powered systems include Partridge (1974), Major (1985) and CEEMAT (1971).

Complete purpose-built gear units were sold for many years in North America and Europe, and in recent years have been available in Pakistan (ITP, 1985) and Poland (United Nations, 1975). There continues to be interest in designing single- or multi-purpose gear systems for use in developing countries. Many systems designed during the past fifty years have involved animals walking in circles around the differentials of axles from old vehicles which have provided the basis for the gearing system (Hopfen and Biesalski, 1953; Hopfen, 1969; Finn, 1986; Symington, 1986; Roosenberg, 1987; Mueller, 1987). One unit developed by AFRC-Engineering was based on the gears of a cement mixer. A different

Fig. 9-33: Animal-turned sugarcane press.



Source: CEEMAT, 1971

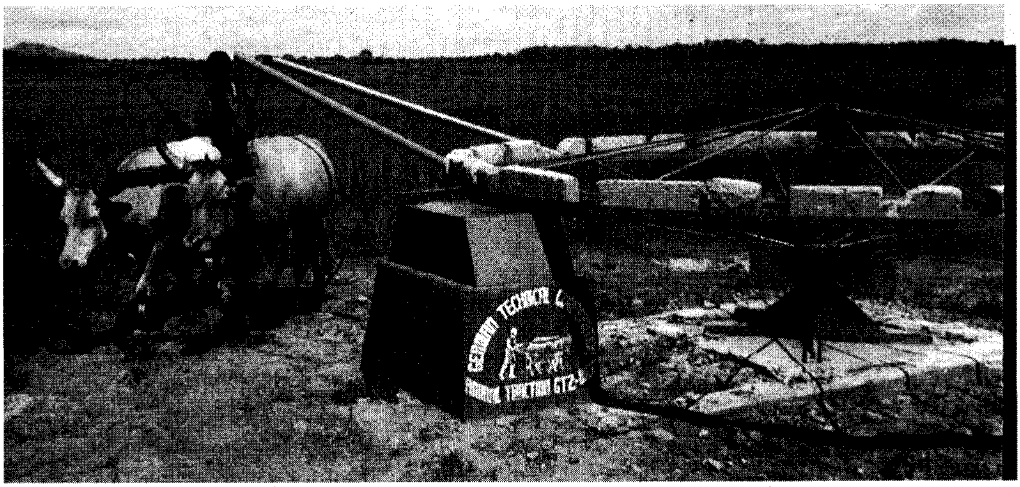
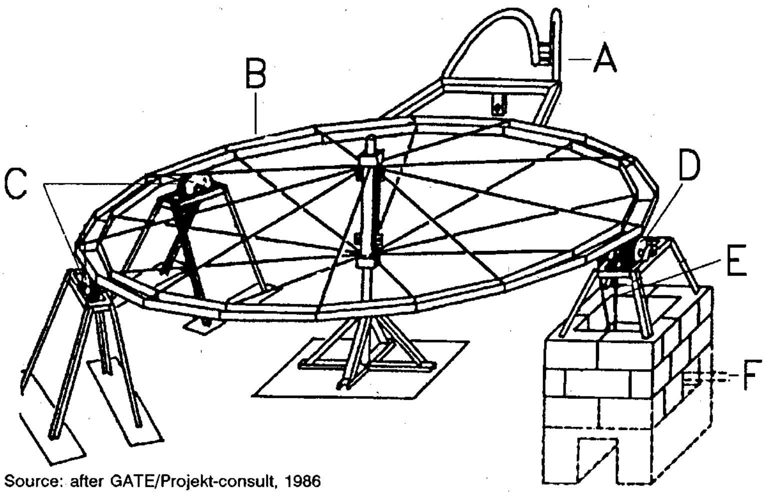


Photo: Paul Starkey

Fig. 9-34: A prototype animal-powered multipurpose gear system installed at the Rolako Work Oxen Centre in Sierra Leone. The horizontal wheel has been weighed down to increase friction with the offtake supporting wheel (centre of photo). The output shaft runs below the fore-ground of the photo.

approach has been taken by the Development Technology Unit of the University of Warwick which has being trying to develop animal-powered rope engines. In these the animal walks round a circle of rope, pulling a beam on which is a pulley. As the pulley runs round the rope, the rotational movement of the pulley is transmitted to a second rope, and so to the final output (Thomas, 1989). A key problem faced by such systems is dealing with the expansion characteristics of long ropes.

In the early 1980s, GATE undertook a pilot project that involved installing animal-powered systems for raising water or grinding cereals in about twenty locations in West Africa (Busquets, 1986). While some units were designed for specific applications (pumping or milling) one system was a multipurpose drive that could power a range of pumping, hulling and grinding equipment (Fig. 9-34, 35). The requirement to perform several different functions made the multipurpose unit the most



Source: after GATE/Projekt-consult, 1986

Fig. 9-35: A multipurpose gear system developed by the GATE project. The animal(s) (A) turn a large horizontal wheel (B) of 4 m diameter which is supported by two neutral supporting wheels (C). As the horizontal wheel rotates its weight causes the third supporting wheel (D) to turn. This drives a chain (E) connected to the final output shaft (F) which may be situated below ground level to allow the animals to step over it easily.

Photo: Paul Starkey

Fig. 9-36: A prototype animal-powered mill installed in a village in Senegal following collaboration between the villagers, ENDA, GATE and a local blacksmith.

expensive of these gear systems. One multi-purpose unit is being evaluated in Sierra Leone where it pumps water for an animal-traction station and also hulls rice. A prototype cassava grater is being developed for this gear system (Koroma and Boie, 1988).

A completely different type of animal-powered equipment was also developed by the GATE project: this was a *single-purpose* grinding mill, mounted on a rotating beam (Fig. 9-37). Power for the mill is supplied by a short chain driven from a ground wheel running on a low circular wall of 5-6 metres diameter. The wheel rotates at about ten times the rotational speed of the sweep as the animal walks round in circles (Bielenberg, 1988). Using a single donkey, this unit fitted with grinding stones is capable of grinding about 5-15 kg of millet per hour into relatively fine, food-quality flour (Boie, 1989). With horses or oxen rates of up to 20 kg per hour of relatively coarse maize flour can be ground. In

Sources:after ENDA, 1986 and Bielenberg, 1988

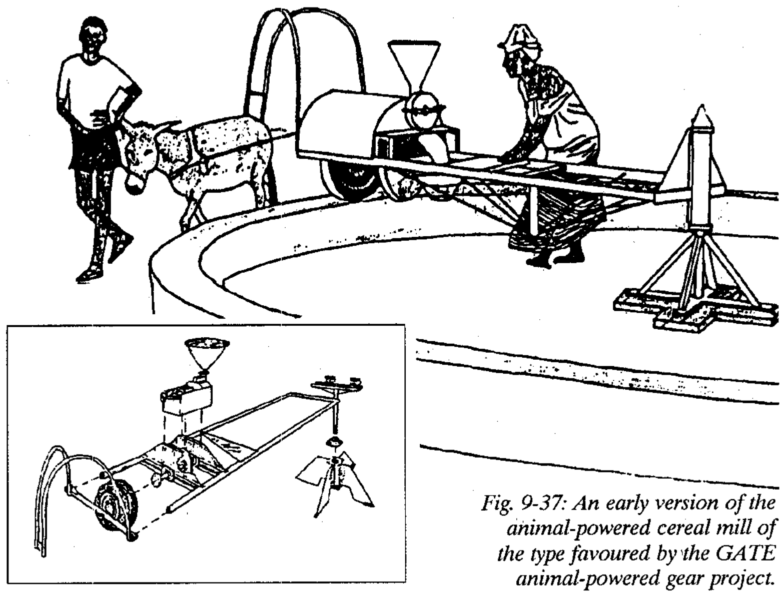
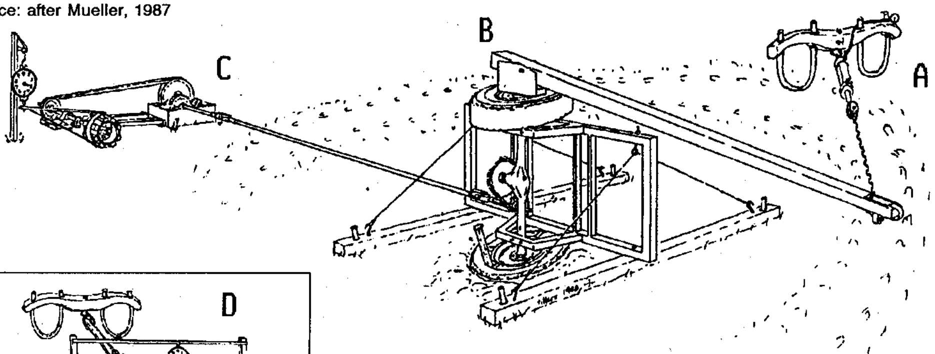
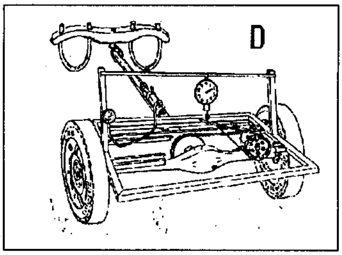


Fig. 9-37: An early version of the animal-powered cereal mill of the type favoured by the GATE animal-powered gear project.

Source: after Mueller, 1987





The animals (A) turn, at about 2 r.p.m., a long sweep linked to the secured "sweep cart" based on an old vehicle differential (B). The differential turns a sprocket and chain, which drives the output shaft, which in turn drives a gearbox (C), leading to a system of belts and pulleys that give a final output of about 500 r.p.m. The sweep cart (D) can also be used to provide power driven from the ground wheels.

Fig. 9-38: An example of a prototype animal-powered gear system based on a vehicle differential. This particular prototype was developed at the Tillers Small Farm Program, USA, and comparable prototype systems have been developed in several countries.

one village in Senegal the installed mill (Fig. 9-36) worked for about 6 hours per day, and women brought their own donkeys or horses to provide the power to grind their own millet (Busquets, 1986; Boie, 1989). It was found that grain milled using animal power had to be dry (drier than for pounding or diesel-powered mills). This required a change in the daily schedule of women to allow grain to dry overnight, but the dried grain or flour could be stored. It was a matter of debate whether pounding, animal power or motor power produced the better flour, and overall judgements involved both objective and subjective opinions. The early prototype animal-powered mills tended to produce coarse flour but subsequent designs have attempted to rectify this. There were some social and organizational problems relating to the communal nature of the mill: for example obtaining the use of the mill and an animal at a convenient time. However the women felt that the mill saved them the considerable drudgery involved either in pounding or in travelling to the nearest power mill (Starkey and Faye, 1988). The animal-powered mill has been designed for local construction, and about 20 units have been made and installed by local artisans in Senegal (ENDA, 1987). Initially all grinding units were imported, but some complete mills have been locally produced in Senegal (Boie, 1989). In socioeconomic feasibility studies it was suggested that the widespread use of such systems in rural areas in West Africa could have a marked impact on the quality of life while saving fossil fuel and foreign exchange compared with motorized alternatives. However it has yet to be demonstrated that such systems can be constructed and operated independently of development agencies. Futher details of the design and operation of these animal-powered mills are provided in the book of Boie (1989).

In several publications and project proposals it has been claimed that animal-powered gears, treadmills, sweeps, rope engines or other mechanisms could be introduced into African countries to drive crop processing equipment (grinders, threshers and driers), workshop equipment (lathes, grinders and saws) and even refrigeration or electricity generation units. Although there have been several different initiatives and various designs of equipment and techniques developed, there is insuffciient evidence to judge whether such schemes could have any long-term impact in developing countries. No programme has yet managed to demonstrate that stationary animal-powered gear systems can be adopted to a significant extent in Africa. The difficulties are both technical and socio-economic. Animals walk around gears and sweeps at the rate of about 2-3 revolutions per minute, and yet many machines require axles rotating at 200-1000 r.p.m. or more. Thus high gearing is necessary with inevitable frictional losses and this makes animal-powered gear systems relatively inefficient. Low-friction gearing and bearing systems are usually expensive. Work animals are powerful and heavy and it has proved particularly difficult to devise efficient and low-cost gearing systems that are strong enough to withstand the very large, sudden and asymmetrical forces that even docile animals can apply to a gear system. Furthermore it can be difficult to obtain output devices (mills, hullers, pumps etc.) suitable for use with animal power, for most modern mass-produced machines have been designed for consistent, high rotational speeds. Where it has proved technically possible to solve these problems, this has been quite costly, and most gear units are still relatively expensive to install.

Animal-powered gear systems were once widely operated in Europe and North America, and some units are still in use today. However although the technology has been historically proven, most animal-powered systems were developed in the absence of realistic alternatives such as small stationary engines. Today small petrol and diesel engines and electric motors are becoming increasingly available throughout the world, although their price is often high relative to rural incomes. In many parts of Asia, villages have electricity and electric motors can be used for crop processing, pumping and workshop applications. Even in rural areas in Africa, where electrification is uncommon, small motors of various types are increasingly being used, sometimes as a result of development inititatives supported by aid agencies. Motors may be difficult and expensive to acquire and maintain, but it is apparent from the success of "bush-taxis" and private motorcycles that the technical and economic constraints to running engines in remote areas can be overcome if there are sufficient incentives. Small motors can often achieve in a relatively short time the work that would take an animal (and its supervisor) several hours. In such circumstances farmers, or entrepreneurs, are unlikely to favour the animal-powered option unless it is *significantly* cheaper to purchase, operate and maintain. Certainly, once installed, the daily running costs of animal-powered gear systems may be low compared with systems using fossil fuel, but it should not be assumed that the animal-energy is "free". Even where there are no direct economic costs to animal use, the various social costs and benefits of animal management and supervision have to be compared with the costs and benefits of alternative manual or motor systems.

Some of the arguments for and against animal-power gears are identical to those for and against animal-power for tillage, and in many African countries animal-power for tillage is proving to be a chosen option. However there are major differences between the operational requirements for low-speed tillage (for which animals are generally well suited) and stationary applications requiring high speed rotation. As a result of such differences, and their effects on price, efficiency and convenience the overall comparative advantage of animal power over motor power tends to be lower for stationary applications. Historically some of the first operations to move from animal power to motorized power have been water pumps and grinding equipment. This has been observed in Europe and North America, and it can be seen by present patterns of adoption of motorized pumps and mills in animal-using parts of Asia and north Africa (Binswanger, 1984). In these situations well-proven and long-accepted animal-powered machines already installed in villages have been abandoned and replaced by motorized alternatives (in some recent cases in Asia and Egypt these changes have been encouraged through the provision of credit and subsidies). In most of sub-Saharan Africa the population densities and the infrastructure differ markedly from the regions where animal power systems have been widely used, and so direct comparisons are problematic. Nevertheless it is clear that considerable financial costs and training effort would be needed to install animal-powered gears in villages and this would have to be done in the face of increasing competition from engine-powered alternatives, which may themselves be subsidized by aid agencies. In addition to the potential technical and economic constraints, Löwe (1986) warned that as concern for animal welfare grows in donor countries, the idea of animals having to walk on treadmills or repeatedly turn in a circle is beginning to cause unease (even though the animal may be saving much human drudgery). For national and international agencies dependent on public support in developed countries, this point could prove increasingly important.

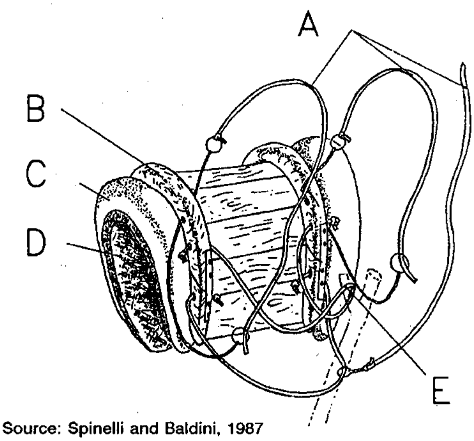
In conclusion, animal-powered gears can be effective and they have been widely used in some countries. There are few recent examples of such systems being adopted on a significant scale. While systems differ considerably in their costs, work efficiencies and maintainence requirements, they are quite expensive to install and like all machines, they can fail if they are not correctly maintained. They are generally suited for use by a number of people, either through community ownership or through the initiative of a private entrepreneur, and this may have important social implications. In recent years many designs have been tested in Europe, Asia, Africa and the Americas, and organizations considering the use of such systems should investigate not just the technical aspects of these, but their survival rates under village conditions after installation.

Further information on animal-powered gears and their applications can be obtained through GATE (Germany), GRDR/GRET (France) and ENDA (Senegal), Tillers International (USA) and University of Warwick (UK). Addresses of several organizations in Africa that have evaluated animal-powered devices are provided in the Animal Traction Directory: Africa (Starkey, 1988).

9.10 Forestry and road-building

One specialized but effective use of animal power is for the extraction of timber from forests. Even where motorized alternatives are available, animal power may be both efficient and cost-effective for moving tree trunks from felling sites to forest roads. Indeed the use of horses and/or mules for logging in parts of Scandinavia and the United States (Potter, 1986) appears to be economically attractive. In some parts of Asia elephants are employed for logging (Kerr, 1986) and in several parts of Europe horses work in forests (Chivers, 1988; Vis, 1989). In Latin America techniques for using oxen for logging have been discussed

Fig. 9-39:
Saddle used for logging with mules in Italy.
A. Load fastening straps. B. Wooden frame.
C. Straw padding. D. Felt padding. E. Loading strap.



Source: Spinelli and Baldini, 1987

Source: after Nolle, 1986

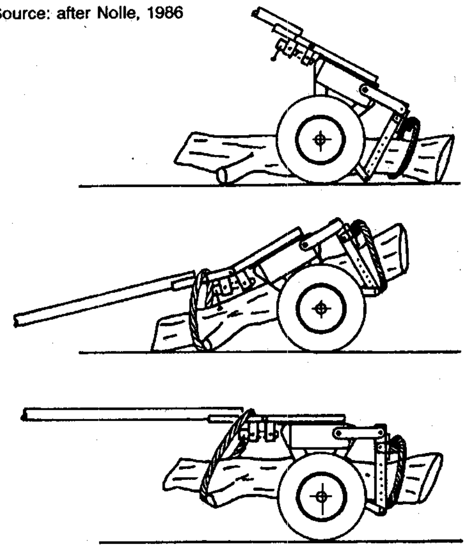


Fig. 9-40: Illustration of the potential to use a Tropicultor wheeled toolcarrier as a logging sulky.

in detail by Rodriguez (1984), Cordero (1985, 1986, 1988), Bonilla Mora (1986) and Mata Acuña (1987). The use of animals for pulling logs out of dense forest requires little specialized equipment other than comfortable harnessing, chains and hooks (Fig. 9-41). Simple animal-drawn wheeled "sulkies" can be employed to move large logs along tracks, and in well-cleared areas they can also be used to assist primary extraction. Sulkies are simple bars, frames or cranked axles which are supported by two wheels and pulled by means of a drawbar (Fig. 9-42). Provided they have high clearance, wheeled toolcarriers can be used as sulkies, although such applications are rarely observed (Fig. 9-40).

Source: after Zaremba, 1976

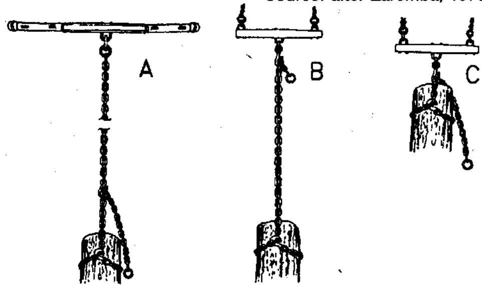


Fig. 9-41: Skidding logs with chains.
A.Long-chain skidding with a yoked pair.
B. Long-chain skidding with a single animal.
C. Short-chain skidding with a single animal.

In parts of Italy mules are employed to carry small logs on their backs using special pack saddles (Fig. 9-39). Larger logs can be attached to the saddles and dragged. A well-illustrated description of the mule-logging techniques currently employed in Italy was written by Marquart (1988) and further details were provided by Spinelli and Baldini (1987).

There has been some very well documented work on the use of mules for logging in southern Africa (Zaremba, 1976). At the Usutu Pulp Company in Swaziland a mule and two labourers can extract and stack about 160 logs (20 tonnes) per day over distances of 80-150 metres. In this case the logs are quite small being 1.5-2.4 metres, with a maximum diameter of 45 cm. In Malawi pairs of oxen controlled by one person can extract seven cubic metres (7 m^3) of larger logs a day over distances of 100-300 metres, although rates of 5 m^3/day are more common. The animals used are often crossbreds of Malawi Zebu and

Fig. 9-42: Simple forestry sulkies for moving large logs with oxen in Cost Rica.

Sources: after Bonilla Mora, 1986 and Mata Acuña, 1987

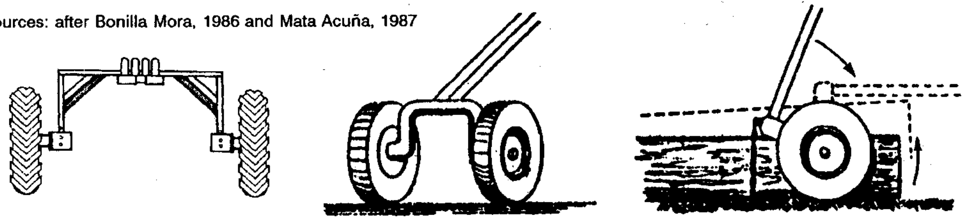


Photo: Paul Starkey

Fig. 9-43: Logging with a pair of oxen in Malawi.

larger exotic breeds, such as Friesian, although pure indigenous and pure exotic animals are also used (Fig. 9-43). Details on the employment of oxen for logging in Malawi were provided by Cornelius and Broadley (1974) and Solberg and Skaar (1987). Trials on the use of oxen for logging in northern Nigeria were described by Allen (1972).

Another specialized application of animal power is for rural road construction for which bovines, equines and camels can be employed. Comfortable harnesses are essential and carts capable of tipping their loads easily may be desirable. In countries with a long tradition of animal power use, including those of North Africa and Asia, traditional haulage techniques may have already been adapted to road construction. In other countries where those involved in planning assume capital-intensive machinery is a prerequisite for rural road construction, justification trials using animal-drawn equipment may be necessary. Recent trials in this field have been carried out in Botswana (McCutcheon, 1985) and Honduras (Kliver, 1987).

9.11 Further information

The technologies covered in this section are either unusual or still at research stage. Some key references have been cited in context, and these may be useful starting points for obtaining further background details. However to obtain a more up-to-date picture, people seriously contemplating work in one of these fields are recommended to contact some of the organizations or individuals presently working on these technologies. Where practicable the names of relevant organizations have been provided and further sources of information and addresses are provided in the Appendix and in the GATE Animal Traction Directory: Africa (Starkey, 1988). Finally, it is sensible to bear in mind that those enthusiastically working in an area of specialization may be excellent at providing specific details, but they may find it difficult to provide an unbiased perspective. Therefore crosschecking optimistic impressions given by protagonists with the realism and experience of farmers or hardened fieldworkers could well be useful.