Section 3

Diversified Uses of Animal Traction

Research on Diversified Uses of Work Animals : Needs, Experiences and Methods

Terry Thomas, Colin Oram and Gaban Tembo*

Abstract

Draught animal power has been applied to stationary processes, principally water-lifting, for thousands of years - but not in sub-Saharan Africa. Increasing pressure on rural labour (primarily female) in this area, demands another power source: draught animals may be able to supply this energy in many circumstances. World-wide, two traditions of stationary animal power are apparent: Asian use of specialist equipment designed for one task only, and a later Western trend towards a gearbox producing power at relatively high shaft speed (200rpm), which could be connected to many specialist implements. Use of high shaft speed frequently allows smaller, lighter and cheaper implements, but at the cost of an increase in manufacturing sophistication. However the choice is unlikely to be between one or the other of these two traditions: many processes cannot be performed by small light equipment moving at high speed. Nevertheless it is clear that in a situation where many tasks have to be carried out, each lasting only a few weeks per year, small high speed machinery holds out the potential for cost economy. What will be required is a range of designs of equipment, each at a different technological level of sophistication, that can be manufactured and maintained by local entrepreneurs or artisans. Further, such artisans must be accessible by the farmer or user of the equipment so that the producer is fully aware of any inadequacies in it. Only a little research is going on relating to animal-powered machines in Africa and some of this is taking place outside Africa. Water- lifting and grain-milling are the applications attracting most effort in research. In neither application has there yet been much impact in sub-Saharan Africa, but economic conditions are changing in a direction favourable to animal power.

Introduction

The purpose of this paper is to review the state of the art in applying draught animals to power processes other than cultivation or transport, and to report on current research in this area.

The advantages and disadvantages of using animals to provide mobile work energy for cultivation or transport are well known, whereas the viability of animal power for stationary processes is rarely examined. Animals have however been used to raise water and to process crops for 2000 years. Historically, all rural economies based on animal power have combined mobile and stationary applications. Thus whilst the mobility of animals is a particularly valuable quality, it is not their only advantage as a work source. Even for stationary applications, animal power can often compare favourably with its rivals (human power, engine power and electrical power) in poor countries or in rural areas.

Moreover mobile applications are often highly seasonal, so that it may be possible to improve the annual load factor for a particular animal by employing it for both stationary and mobile tasks.

In much of sub-Saharan Africa, animal power has been in use for less than a century. In some locations it has been employed only in the last few years, following the general failure of African agriculture to leap directly from hoe cultivation to full mechanisation. Nowhere can one yet find large scale use of either bovines or equines to drive stationary processes: the few applications that do exist are essentially experimental and transitory. There are in fact several constraints on diversifying uses of work animals, and their application to

*Development Technology Unit, University of Warwick, UK and Ramat Polytechnic, Kano, Nigeria

stationary processes requires at least the following four conditions to be satisfied:

- the existence of processes that match the power output of one or two animals (equivalent to the power of between perhaps 3 and 20 humans)
- the presence of suitably trained and nourished animals
- the availability of equipment to interconnect the animals and the process to be driven
- an overall favourable economic balance after the extra costs of equipment and feeding have been set against labour savings.

Most of the (rather little) research into diversified uses of draught animals carried out in the last decade has centred upon the third condition above because traditional equipment from Europe or Asia does not fit contemporary conditions in Africa. New lighter faster and simpler designs of 'animal gears' are needed if animal driving of stationary processes is to become common.

The main body of this paper is divided into three parts. In the second part there is a discussion of power needs (potential applications) and of the constraints on animal power. Next follows a description of the different ways by which animals might be (or have been) linked to drive stationary processes including a sketchy quantity survey of two animal gears. Finally current research in this field, especially that with an African orientation, is reviewed.

Applications and constraints

Animals produce significant amounts of work power, although it is not closely controllable and it usually entails the animal moving – which is inconvenient when driving stationary equipment. Although animals have some intelligence they are unsuited for tasks which require them to make unsupervised decisions; thus animal power should be considered as 'brute' power and is not suitable for tasks requiring dexterity or fine judgement. Animals will perform some simple tasks unsupervised, although human encouragement is required if they are to exert their full power.

Linking a moving animal to a stationary device requires equipment that can be costly. Such equipment ranges from a rope and one pulley, at its simplest, to multi-stage gearing at its most complex. It is more expensive per set than corresponding manual equipment would be and more expensive per kilowatt than the transmission/gearing between an engine and any device that it might drive. So a key factor in determining whether animal power is economic is the comparison between the capital cost of the animal gear and the labour or fuel savings achieved by not using human beings or engines. In practice this means that animal power is unlikely to be economic unless each gear can save some hundreds of hours per year of human drudgery. All applications of animal power, whether stationary or mobile, constitute an intermediate technology that should be used only when it is cheaper than either manual or motorised technologies.

In identifying tasks suited to stationary animal drive we need to know what power can be obtained from different breeds and weights of animal. For some processes - slow speed ones - the power from the animal mostly goes into the process: for other applications a significant fraction of the animal's output gets lost in the transmission system. Thus a simple cane-crusher might put 80% of an ox's effort into the cane, whilst a prototype electricity generator using two oxen appears to have an animal-to-electricity efficiency of under 20% (Natapajan, 1990).

There is considerable current research (University of Hohenheim in Germany, University of Edinburgh in Scotland and the Agriculture and Forestry Research Council in England etc) into how much power an animal can give ; however, this research is orientated to the use of work animals in cultivation. Most of the figures published for animal power outputs are too high for general use and are probably based on large healthy creatures working for short periods (Ramaswami, 1983). The lower limits in the table below should be reduced by about 40% when applied to African animals on a normal African diet.

In practice few processes have to be operated at a particular power level; however,all available **equipment** is designed for a particular level, typically 30W for manual devices and 5kW for engine driven devices. To use such equipment with draught animals it may be possible to run it faster or slower than normal or to use a team of animals. Really effective employment of animal power requires the driven equipment to be suitable for the animals. Alhough gearing can change speeds to achieve better matching, it cannot increase the power - which is the rate of work throughput. Not surprisingly, therefore, most animal-driven equipment has been specifically designed for the purpose. Only in late 19th century Europe/ America were so many devices suited to a drive of 0.1 to 1.0 kW available that 'animal engines' were viable. The two approaches implied here - that of integrated equipment and 'animal engines' are shown and discussed further in the final section.

Table 1. Draught Animal Power Outputs (Fraenkel, 1986)

Animal	Body Weight [kg]	Power Output [kW]	Working Day [hours]
Ox	500–900	350–500	5–6
Donkey	150–300	75–200	3–5
Camel	500–1000	400–700	?

Potential Applications

We now have a preliminary specification for any stationary process sensibly to use animal power. It should be in a location where trained animals are present and electricity is not; it should take hundreds of hours of manual labour per year yet be difficult to operate reliably with diesel engines and it should be capable of running with a power input of 0.1 to 1.0kW. The main processes that satisfy this brief, on a large scale, are water-lifting and crop processing (especially milling); however on a smaller or more localised basis we can include :

- mineral processing such as rock-crushing and clay-pugging
- timber processing by sawing
- other suitable tasks such as electricity-generation, operating forge-bellows and clothes-washing.

Water-lifting has attracted the most attention over the centuries and many mechanisms have been developed for the purpose (Lowe, 1986, Fraenkel, 1986) and some of these are mentioned below. In Africa it is growing in importance in all its major applications - irrigation, domestic water and water for livestock.

Crop-processing can be divided into two classes, **year-round** activities (like milling or oil-pressing in the humid tropics) and **seasonal activities** (like threshing and sugar-cane crushing). The first are likely to be more economically animal-driven than the latter, at least until the latter are sufficiently various to justify an animal engine. A different division is by scale. Much crop-processing is performed on a household scale and is a major contribution to the massive and rising workload experienced by African women (Mackintosh, 1982 and Gould, 1990). However this scale, even though it represents 300 women-hours per year, is too small to carry the cost of animal equipment. Crop-processing therefore can be 'animalised' only on a communal, large household or petty commercial basis. This contrasts with water-lifting for irrigation where a single smallholding may need a gear of its own. Unfortunately, the transfer of female tasks from the unpaid domestic economy to the monetary artisanal economy entails complex changes within the family and village.

Rather than distinguishing between water-lifting, crop-processing and other tasks, we could divide equipment on the basis of its speed. In low-speed applications, high forces and torques are required and the most convenient arrangement is usually to have the animal harnessed directly to a vertical low-speed shaft. Most machines of this category are already fairly compact because of the high loads inside them during operation: they achieve their effect by squeezing the product and the inertia of the latter is not important. It is difficult to

Table 2. Power Transmitted into lifting water by Persian wheels/Noria. (Lowe, 1986, p. 29).

Situation	Watts
Tired unattended donkey	44
One ox, driven constantly	120
Two oxen, short term, whipped	500

Lowe (1986) reports *output* powers in so-called 'water watts' of various combinations of animal- and water-lifting device and some of them are shown in Table 2, above.

imagine improvements and reductions in the bulk and amount of material needed for many of them. Power and torque demand will be very variable and smoothness of speed and control are not important. The ability of the animals to generate high torque peaks is very useful here. Overall it is likely that animal endurance will control productivity in these applications and therefore will determine the economic viability of any scheme.

In high speed applications such as threshing, electricity generation, grain milling and feed chopping, the inertia of the material being processed is often made use of. It is therefore necessary to provide high shaft speed for the process to be carried out. Again for some processes, particularly the first and second, speed constancy or regulation is very important, but controllability is not. Water raising has been normally performed using low speed equipment. Recently efforts have been made to employ small centrifugal pumps for low-lift applications. For these high and constant speeds are required.

On the face of it there is much scope for substituting animal energy for human energy in situations of agricultural intensification especially when equipment cannot be imported. However certain constraints on the use of animals should be taken into account. Besides those already mentioned, there are the need for attendance, variability of speed, limitations on usage per day, the need for adequate nutrition and most critically the cost of equipment.

Potential Constraints

The literature is not helpful on whether animals need constant supervision and hence the attendance of a driver - adult or child. For most processes, however, a human is likely to be present and able to combine animal-driving with other tasks such as milling control.

Speed variability affects some processes more than others. Long term variability, as animals tire during their working day, has already been mentioned. Animals also vary their pace slightly from minute to minute, this being superimposed upon their natural cadence or stepping rate. In addition animal drives exhibit high frequency fluctuations in force and speed due to the interaction of the machine's inertia, the animal's inertia and the elasticity of the harness etc. (Incidentally no research has been carried out into the power lost in the damping of the harness and in the animal's structure or anatomy, in such variations). Further variation may arise from the nature of any drive train used, from such things as polygonal belt wheels. In certain applications these oscillations may be damaging.

Table 1 and other sources cite the periods an animal can be used each day. Such periods depend on climate, shading, health and nutrition. There is evidence that steady working, as in machine driving, tires them less than the same power applied to a fluctuating load like a plough, however some animal handlers believe that variety of load prevents the animals getting bored!

Animals convert biomass into work, some of which can be harnessed to drive equipment. Not all food eaten is digested and only a modest fraction (max 25%) of digested food is converted to work (Mathers 1985). Employing animals for for only a fraction of a year, as in ploughing, can result in an overall energy efficiency as low as 2%. This low efficiency figure may be compared with the 25% typical of a diesel engine. Under many circumstances it would be possible to obtain more work from a given area of land via a fuel oil crop and a diesel engine than via a fodder crop and animals. More immediately the combination of no time for foraging and the need for a more nutritious diet can pose problems for any operator of animal-driven machines. The labour of providing for a zero-grazed animal can also be substantial.

Animal engine techniques

Use of animals to power machinery for agricultural purposes, for water pumping and grain milling, goes back to some of the earliest historical records. Animal powered machines have clearly exercised the minds of many over the centuries and a large number of solutions have emerged, each optimised to local and individual conditions. Two general approaches to the problem have been made:

- special machines for performing a single function - 'animal-driven equipment'.
- general purpose devices that are attachable to a range of equipment the 'animal engine'.

Historically most equipment was of the first category, but it was often very inefficient and frequently very large and costly (equipment to perform work at say 1/2 kW filled buildings). In he late 19th century,however, as will be discussed below, attention moved to the second category, the discrete 'animal gear', producing power at say 200rpm. To be successful,however,this approach requires ready availability of process equipment designed to accept power at this speed - a speed which is intermediate between the slow speeds of the Asian tradition and the modern day internal combustion engine or electric motor.

Machine Types

It may be helpful at this stage to enlarge on the the methods which have been, or are being used presently to harness animal power in static or quasi-static applications. A simple method of classification is division according to the type of motion of the animal or animals. One may further examine the type of mechanism used to transmit the power, and to transform its torque/speed characteristic.

Linear or quasi-linear

This method is frequently used to raise water: the animal walks in a straight line away from a well, pulling a bucket up the well-shaft. At the end of the travel the animal is stopped and turned around. During the return to the well the animal is unloaded and productivity zero - indeed there is a significant waste of energy since the bucket and rope have significant weight and the energy associated with this will almost certainly be totally lost regenerative braking is not significant in animal muscle.

A refinement of some consequence to this first method is to provide a counterbalance so that the animal works on its return trip. A second bucket makes a good counterweight and its inclusion in the equipment more or less doubles efficiency and output for a fairly modest increase in complication.

A second refinement is to arrange that the animal does not stop when the bucket reaches the top or bottom of its travel, but executes some looped path whose shape may be determined by the sharpest turning radius which the animal can negotiate without excessive disturbance to its cadence. Taking this to its limit is the 'moat' or 'stony moat', in which the animal walks around a circular track and power is converted to linear motion by ropes which act effectively as 'connecting rods' - as in a piston engine.

Rotary Sweep

A second category is concerned primarily with the extraction of rotary motion though this motion may almost immediately be returned to linear in, for instance, the animal-powered vertical-axis windlass. Usually power is extracted at about 2 revolutions per minute as the animal walks around a track (most of which tracks are between 5m and 8m diameter) harnessed to a radial arm powering the central mechanism.

This central mechanism or animal gear has been the subject of substantial research world-wide and has had significant industrial development, though most of this development took place last century. Most solutions, both industrialised and indigenous, use a multi-stage speed-up gearbox to produce horizontal axis high speed (200rpm plus) output shaft power. This power is usually transmitted via multiple cardan shafts under the animal track, to the driven machine. Alternatively the power may be exported at high level by belt or shaft as mentioned above.

Gearing in most indigenous machines is of wood and some ingenuity has been expended to facilitate repair or replacement of gear teeth, with designs allowing new wearing sections to be introduced simply by inching a section of tooth through its mounting in the wheel. Industrialised development has concentrated on cast iron gearing because this technology was predominant at the time of peak animal gear usage in Europe and the United States.

More recently some attempts have been made to use more modern gearing materials (for example the Monopump Company commissioned a leading UK gear company to produce a box to drive its vertical shaft borehole pumps), but the result is not considered to be economic, costing over £1000 at 1984 prices and weighing over 250kg. Very approximate weights for this machine are given below.

AFRC Silsoe UK produced two designs some years ago based, in the first case, on commercially available concrete-mixer gears, and more interestingly in the second prototype, on fabricated gears. However the results were not particularly encouraging, again because of cost in the first case and because of low efficiency and high wear in the latter.

There are still some gearing techniques which have not yet been tried on animal gears. For example, epicyclic systems may prove useful in sharing the large and potentially destructive input torque among several much smaller second stage systems, and conformal or Novikov gearing is beginning to be used in helicopter rotor gearboxes, where large gear ratios and high torques are also handled. This latter type of gear tooth allows large gear ratios to be obtained in one stage and thus holds out hope of simplification of design and manufacture, though at the cost of slightly non- constant speed ratio unless the gears are helically cut.

A second class of speed-up boxes is based on belts or chains. One design of this type that has begun to be successful is that of Rural Industries Innovation Centre in Botswana (RIIC 1988) where development was started in 1982. In this class of machine too, multiple chain engagement may be able to reduce chain and bearing loads in a manner analagous to the epicyclic geartrain. At Warwick some preliminary work has been carried out on steel rope friction belt systems which may eliminate the need to cut teeth of any form - work is continuing on this.

Most striking of the features common to all centrally-based machines is the massive construction needed to handle the large torques developed-especially if the animal is startled or disturbed. As an example of this input or primary shafts on such machines may need to be up to 100mm diameter. A promising technique and alternative to these centrally intensive systems is the 'rope engine' presented at the last animal traction workshop in this series (Thomas 1988). See below for a comparison of steel requirements for this machine with that of the Monopump gearbox. Work is continuing on this rope engine system too. Another and important system of animal engine, and one again that avoids the high torque and central concentration problem, is that of the radial arm carrying a friction wheel running on a wall. Several such systems have undergone preliminary and intermediate development in recent years and the system has some attractive features. The GATE grain-milling equipment programme in Senegal is of this type and is mentioned in the final part of this paper. Use of a friction drive immediately introduces de facto a very significant degree of overload protection; power input to the transmission system starts at a more useful 20rpm; and provision of a seat for the animal driver is straightforward. The only problem with the technique is that power is produced from a wheel which moves with respect to the ground. However, reciprocating borehole pumps have been powered using this kind of system by the use of a crank at the centre.

A factor important in all animal gears, and indeed in much renewable energy equipment, is the efficiency of the drive train. Whilst it is accurate to consider the efficiency of a single stage of spur gearing to be say 98% minus some bearing losses, say, 95% overall, it should not be forgotten that these losses are based on the rated power of the machine and not necessarily the power transmitted by the machine at any instant. In such applications as animal gears, gearing must be made with a much higher overload factor or service factor to cope with unknown effects such as the vagaries of animal behaviour. In these conditions gearing losses as a proportion of input power may be considerable.

Because of the intensity of use of the animal's track on all these circular path systems, it may be necessary to improve the durability of the trodden area: it may also be well worthwhile since animal efficiency has been shown to deteriorate markedly in poor walking conditions.

Treadmills, discs and drums (squirrel cages).

The third class, also one of rotary power extraction, is where the animal does not move but power is extracted by moving the surface upon which the animal stands. Drums, inclined axis discs and moving belts have all been tried, but all such systems suffer from their requirement for bearings to support the weight of the animal in addition to any bearing load arising from an unbalanced torque arm. Additionally all such systems are bulky and require large quantities of structural material although squirrel cage and disc systems at least have very few moving parts. Moving belt systems began to be popular towards the end of the era of western usage of animal drives but had a reputation for unreliability. No doubt if they were developed further today they would benefit greatly from the modern ability to produce sophisticated composite belts from steel, other textiles and rubber.

Trade-Offs

Dominant in all the discussion of these animal engine techniques is the trade-off between the amount and type of materials required and the sophistication of the manufacturing techniques necessary for their use. Considering the commercial extension or dissemination of this equipment, it is probably necessary to consider the compactness and transportability of such systems and it may be useful to remember that commercial exploitation frequently needs some form of exclusivity or uniqueness - some 'magic' component - to provide protection in the absence of effective patents, at least initially, to the entrepreneur. A crucial but often implicit decision with many systems considered today, is whether to put effort into producing high-speed low-torque shaft power for use by an existing piece of equipment (usually designed for use with an internal combustion engine or electric motor), or to develop special and probably heavy equipment (to cater for the higher torque) to take the power directly - that is to take the path of the 'animal engine' or of the 'animal-driven equipment'.

Examining the patterns of development of stationary animal power in the West and in Asia, it is clear that before the introduction of small stationary steam and internal combustion engines, the West was progressing in the direction of multipurpose animal gears of the rotary sweep type. The choice of high-torque/low-speed machinery versus low-torque/high-speed would appear to be determined by the quality and type of materials and the sophistication of manufacturing and fabrication techniques available. As these technologies advanced, higher speeds were used and equipment became smaller and lighter but had also to be made of higher quality material, and to more exacting manufacturing standards.

The crucial question might then be 'what level of skill is available'? This will determine the appropriate technology at any moment. If one may presume to take the optimistic view, namely that skills will increase over time, characteristic speed will increase over time also and the mass and bulk of equipment may be reduced in proportion. However the question of skill level is perhaps not the only one. Such considerations as the number of machines to be made in an area 'machines per square kilometre' should be considered, for the availability of material and skills may be influenced by demand.

Design Comparison: Monopump Ltd Gearbox and Warwick DTU Rope Engine

The table below shows a simple schedule of materials used in the construction of two rotary sweep type animal power gears. We have included these two systems as examples of the expensive material and accurate manufacturing method typical of Western attempts on the one hand, and of the dispersed techniques, which may be more representative of traditional approaches, on the other.

The above analysis should not be taken to imply the superiority of the latter method: the two solutions are different in their abilities and strengths.

Table 3a. Monomump Ltd Gearbox

Item	Material	AmountUsed
Input shaft	EN24 steel	12 kg
second motion shaft	EN24 steel	4 kg
third motion shaft	EN24 steel	1 kg
output shaft	EN24 steel	1 kg
primary gear	EN24 steel	141 kg
secondary gear	EN24 steel	39 kg
tertiary gear	EN24 steel	17 kg
bearings		7 kg
casing	s.g. iron	54 kg
total steel		276 kg

Table 3b. Warwick DTU rope engine

Item	Material	Mass/Vol Used
pegs	1-1/4" pipe	39 kg
radial beam	sq.box	19 kg
mast & support	2" w.pipe	4 kg
pulley straps	40mm x 5mm	1 kg
studding	8,12,16,20d	8 kg
bearing pins	25mm dia	1 kg
bearing rollers	10mm dia	3 kg
rope catchers	50x75mm	9 litres
pulleys	200x40mm	15 litres
total steel		74 kg
total wood		24 litres

The former gearbox would probably operate for 20 years or more with no more than an oil-change assuming that it were not abused. However, should trouble be experienced, very little maintenance could be accomplished in the field using local labour. The rope engine might require very frequent attention, perhaps on an hourly basis, although this attention could be from someone with a much lower skill level. Additionally, should it be required to move it, a high skill level would be required though of a level lower than for the gearbox described above.

Review of recent research

It is hard to make a sharp distinction between research and design development, or between the latter and technology transfer. There are a few examples of the transfer of unmodified animal-powered machinery into Africa. The importation of Indian cane crushers into Nigeria might be placed in this category, as might the transfer of donkey-powered rope-and-bucket methods of water lifting from Morocco to Mali. Historically there has been the migration southwards of Persian wheels or animal driven noria up the Nile from Egypt to the Sudan.

The largest programme promoting alternative uses of work animals in Africa, that of the German technical assistance organisation GATE, combines research, design and technology transfer. The programme is focused on 4 devices: a communal grain mill, a direct pull system of raising water from deep wells ('gueroult' in French), a rotary system for driving a piston pump to irrigate from shallow wells ('sahore' in French, circular moat in English) and a rice huller.

The mill, usually adapted for millet-grinding, contains grinding stones rotating at about 150 rpm (Boie 1988). The assembly is too expensive for a single household and communal sharing has been encouraged. Each user brings with her to the mill both her grain and her own animal - usually a mule. Development of the equipment has involved collaboration with the local artisans who are to manufacture it: considerable simplification of the design has been achieved, but more may be needed before the technology becomes self-propogating. The mill has been tested or promoted throughout the Sahel and more recently also in Zambia. Flour quality, throughput (now up to 20kg/h), and the nature of women's organisations in villages have been important issues affecting the mill's viability.

The gueroult is a simple but not always cheap device which appears to be attaining sustainability in Senegal. Its economic viability depends heavily upon the depth of the well from which it draws: for very deep wells it may barely be able to raise enough water to grow the extra feed its oxen require. The sahore is more complex in concept but may be made in small sizes. GATE has identified a demand for a sahore driving a closed (suction and pressure) pump and is working on this modification in Mali.

The rice-huller is a much higher speed machine running at 800 rpm to produce unpolished rice. Development and testing is underway in Niger under the supervision of staff from Hohenheim University in Germany. The huller itself is a centrifugal Japanese machine.

The GATE programme is thus involved with a variety of machine types in several countries. It has not yet reached the point where any of its hardware is in widescale unsubsidised use, but it has significantly advanced the state of the art in animal powered machines for use in rural Africa. As the References show, GATE's parent body GTZ has been the principal recent publisher of books about the subject.

In Southern Africa, the Rural Industries Innovation Centre at Kanye in Botswana has been for a decade the most active developer of animal gears(RIIC 1988). It has 5 of its high-power high-speed gears in operation driving pumps. Tests have indicated that a 10-year life between major overhauls is possible with this animal-drawn pump (ADP), which could be run up to 1500 rpm but is normally operated with 6 donkeys at 800 rpm. RIIC concluded in 1988 that it would take a doubling of diesel prices to make the device competitive. This is not surprising, since the massive chain and belt gearing result in a unit cost around $2000 and Botswana has relatively plentiful foreign exchange for fuel imports.

RIIC has also developed its 'Thebe' manual pump which is operated by driving a bar round a circular path. Occasionally donkeys, rather than humans, are used with this device. In Zimbabwe, by contrast, a farmer testing an animal-adapted rope-and-washer pump reported last month that he was satisfied with it but preferred to employ his children to drive it! This machine was developed by the Universities of Zimbabwe and Loughborough (UK) within a programme to facilitate dry season cultivation of 'dambos' - peaty areas with a high water table that are common in central Africa. Both these machines are very low speed but require the drive to be transmitted through 90 degrees.

Another pump, driven by 4 mules, has been the subject of some development under the Desertification Control Programme of UNEP in Nairobi. Testing started in Mali, but may have been suspended. A machine, representative of a number of 'one-off' designs in different African countries, was built by Family Farms in Zambia and ran for some time near Lake Kariba. This entailed oxen rotating a heavy wooden disk having a wavy edge supporting rollers attached to two pump piston rods.There are probably a considerable number of such experimental machines to be found, derelict, in Southern and Central Africa.

Outside Africa, but looking in, several organisations have experimented with animal gears or other stationary equipment. Warwick University is continuing design and testing of a low-cost gear for local fabrication (a 'rope-engine') three years after first trials in Zambia (Thomas 1990). Its objective is to understand the conditions necessary for the economic success of animal-propelled machines, and to get the cost of an easily maintainable 100:1 animal gear below $200. The University's Development Technology Unit is also developing a mechanism for an animal-powered rock crusher (following a Tanzanian enquiry) and is testing low-precision roller bearings for use in gears (and ox carts). At the last WAATN Workshop in Senegal in 1988, an informal network of people with interests in developing animal- powered machines was formed in the hope of obtaining joint research funding from the EEC, Warwick acting as secretariat. The Africans involved in discussions came from Botswana, Cameroun, Morocco, Nigeria and Zambia. A large programme was outlined, involving 7 countries, but proved too costly to finance and the network is not currently active. Animal machines may feature in the programme of a 5-year Warwick-Maiduguri link just established.

Another outsider has been The Tillers, an AT organisation in the USA with strong African sympathies whose house journal is a source of information on animal machines.

The various programmes listed above do not make up a substantial assault on the problems impeding the take-up of animal machines technology in Africa. Like most research into rural technologies, that on animal gears is driven more by enthusiasm than adequate resources and professional management. Enthusiasm is cheap but suffers from poor judgement! Two ingredients are still in very short supply, namely good designs (cheap, suitable for local production and of adequate performance) and a clear understanding of the social, biological and economic constraints on the alternative uses of draught animals. Lowe concludes his book with a set of general propositions concerning the viability of animal powered systems. Some need testing and others need translation into a usable form; both of these are research tasks. Design development is not research and there are dangers in treating it as such. Animal power research in Africa has been unhealthily dominated by outsiders: in this field as in others a process of transferring control and funding to African institutions must be given a high priority; that in turn requires that the many impediments to performing effective research in those institutions must be reduced. Animal traction is a peculiar field of enquiry,to progress well it requires an unusually close cooperation between different disciplines and different sorts of people (farmers, researchers, artisans, designers, herders, merchants, rural women...). Because it is not dominated by complex concepts, the scope for grass roots participation in both research and design is high.

Résumé

Connue depuis des millénaires, l'application de la traction animale à des procédés à poste fixe, tels que l'exhaure de l'eau, n'est jamais apparue en Afrique subsaharienne. Or, les pressions croissantes qui s'exercent désormais sur la main-d'oeuvre rurale (essentiellement féminine) du sous-continent obligent de faire appel à une nouvelle source d'énergie. Dans bien des circonstances, celle-ci pourrait provenir de la traction animale. Il existe dans le monde deux tendances relatives à l'utilisation à poste fixe de la traction animale: une tendance asiatique, qui consiste à utiliser du matériel spécialisé conçu pour l'exécution d'une seule tâche, et une tendance occidentale plus récente, qui consiste à utiliser une boîte de vitesse produisant de la puissance à une vitesse relativement rapide (200 t/min) et pouvant être reliée à un grand nombre d'outils spécialisés. Avec une grande vitesse de transmission, il est souvent possible d'utiliser des instruments plus petits, plus légers et moins coûteux, mais au prix d'un perfectionnement de fabrication accru. On peut cependant se demander s'il y aura lieu de choisir entre ces deux tendances, puisqu'un matériel petit et léger animé d'une grande

vitesse permet rarement de réaliser toutes les opérations requises. Il n'en demeure pas moins que dans une situation caractérisée par la nécessité d'accomplir un grand nombre de tâches, qui ne prennent chacune que quelques semaines par an, les petites machines à grande vitesse offrent toutes sortes de possibilités de réductions de frais. Ce dont on a besoin, c'est d'un éventail de schémas de matériels qui diffèrent quant au niveau de leur élaboration technologique et qui sont susceptibles d'être fabriqués et entretenus par les entrepreneurs et les artisans locaux. Il importe d'autre part que le paysan ou l'utilisateur du matériel aient accès auprès de ces artisans, afin de pouvoir les informer de tout défaut que ce matériel comporterait. Les études effectuées sur les machines à traction animale sont peu nombreuses en Afrique, et certaines d'entre elles sont entreprises hors du continent. Les deux domaines d'application sur lesquels portent l'essentiel des efforts de recherche sont l'exhaure de l'eau et la minoterie, mais aucun impact important n'est encore intervenu dans l'un et l'autre de ces domaines. Il n'empêche que l'évolution du contexte économique est propice à l'utilisation de l'énergie animale.

References

Boie, W. 1988. Introduction to Animal-powered Cereal Mills. GTZ/Vieweg, Eschborn, Germany.

Fraenkel, P. 1986, Water Pumping Devices, IT Publications, London.

Gould,J. 1990. Luapula, Zambian Geographical Association/Scandanavian Institute for Development Studies, Lusaka/Uppsala.

Hawkins,A.M.and Thomas,T. 1990. Animal Derived Shaft Power for Rural Africa, (to be published), World Renewable Energy Congress, Reading, UK, Sept 1990.

Loewe, P. 1986. Animal Powered Systems. GTZ and Vieweg, Eschborn, Germany.

Mackintosh, M. 1979. Domestic Labour: Production and Reproduction. In Allen, C. (ed.) Sociology of Developing Societies: Sub-Saharan Africa. Macmillan, London. 46–52.

Mathers, J.C. et al. 1985. The use of draught cows in agricultural systems with particular reference to their nutritional needs. In Smith, A.J. (ed.) Milk Production in Developing Countries. Edinburgh University Press, UK.

Natapajan, T.V.and Pamani, S. 1990. Electricity Generation Using a Pair of Oxen. National Institute of Training for Industrial Engineering, Vihar Lake, P.O. Nitie, Bombay. World Renewable Energy Congress, Reading, UK, Sept 1990. (In press)

Ramaswami,N.S. 1983. Draught Animal Power Systems, Urja (India), Sept 1983, 221-224.

RIIC. 1988. Durability of RIIC's Animal Drawn Pump Demonstrated. Dikgang Tsa Maranyane – Joint Newsletter of Rural Industries Innovation Centre, Rural Industries Promotions and Botswana Technology Centre.

Roosenberg, R. 1987. Animal-driven Shaft Power Revisited. The Tillers Report, Summer '87, Kalamazoo, MI49007 USA. pp 6,7,8, 13,14.

Thomas, T.H. 1990. Animal Power Production, Mechanisms for Linking Animals to Machines. In Starkey, P. (ed.) Animal Traction for Agricultural Development: GTZ/Vieweg, Eschborn, Germany.