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Animal traction in sub-Saharan Africa

Agriculture has registered poorer performance than any other economic sector in sub-Saharan Africa during recent decades. Average crop production increased by only 2% per year between 1963 and 1975, compared to a 2.8% increase in population, resulting in a decline in per capita output. According to an ILCA study (de Montgolfier-Kouévi and Vlavonou, 1981), the increased output seems to result more from expansion of the area under cultivation than from improved productivity.

African countries have tended to follow two different routes to agricultural mechanization, adopting either tractor or animal power. Neither has led to success. In 1978 the sub-Saharan African tractor fleet numbered under 100,000 units (FAO, 1978). Jahnke (1980) recently estimated that there were less than 10 million draught animals in sub-Saharan Africa (Table 1), excluding animals used mostly for transport such as camels and equines. Thus draught animals probably account for only about 7.5% of the cattle herd.

Table 1. *Estimated number of draught animals per region in sub-Saharan Africa.*

		–in 000–
Region	Number	%
Sahel[a]	1 297	13
Other West Africa[b]	204	2
Central Africa[c]	54	1
Eastern Africa[d]	7 088	72
Southern Africa[e]	1 147	12
Sub-Saharan Africa	9790	100

a. Senegal, Gambia, Mauritania, Mali, Upper Volta, Niger, Chad and Sudan.
b. Guinea. Ghana. Ivory Coast, Liberia, Sierra Leone, Benin. Togo and Nigeria.
c. Gabon. Congo, Cameroon, Central African Republic and Zaire.
d. Ethiopia, Somalia, Kenya, Tanzania, Uganda and Madagascar.
e. Zambia, Zimbabwe. Malawi. Botswana. Angola and Mozambique.
Source: Jahnke (1980).

To meet the rising demand for food products during coming years, agricultural output will have to grow much faster than it has in the past. The productivity increase required, if demand is to be met by the year 2000, was set by de Montgolfier-Kouévi and Vlavonou (1981) at between 50 and 100%. Progress of this kind presupposes fundamental changes in the technology used by African farmers, which will be reflected in growing demand for inputs such as fertilizers and farm equipment.

ILCA estimates indicate that such productivity increases would require several million tractors (de Montgolfier-Kouévi and Vlavonou, 1981). Such a figure implies a substantial foreign exchange drain, difficult implementation problems, and a high risk of failure. A better use of animal resources is a much more sensible alternative for African countries. It would enable them to mechanize their agriculture at relatively low cost, while making use of a technology more appropriate to the needs of African farmers.

Contribution of animal traction to agriculture

The contribution of animal traction to agriculture can be assessed in two ways: the number of hectares an ox or a pair of oxen can cover each year can be estimated, or alternatively, the power provided by animals can be calculated and represented as a proportion of the total power input.

Although the first approach shows the distribution of animal traction over farm holdings it does not take into account, as does the second, the fact that crop operations are carried out by both men and animals together. It is important to establish not only the separate output of each of these power sources but also the total extent of their joint effort. How much output a given pair of oxen contribute over a given area also varies considerably according to the degree to which they are used. Theoretically, draught animals can contribute to almost all operations—soil preparation, sowing, muck spreading, weeding, harvesting—as long as the farmers possess the right equipment. But for various reasons, this is not what usually happens in sub-Saharan Africa.

Present contribution

Draught animals are estimated by ILCA to number just under 10 million in sub-Saharan Africa. The area cultivated by animal traction is probably about 15 million ha, or around 15% of total cultivated land (Table 2). This average figure masks considerable fluctuations at regional level: the proportion cultivated by animal traction varies from under 2% in central and West Africa to 42% in eastern Africa, reaching almost 90 to 100% in Ethiopia and Botswana.

Table 2. *Proportion of land cultivated by animal traction in sub-Saharan Africa.*

Region	Land cultivated ('000 ha)		Share of land cultivated by animal traction(%)
	Total	By animal traction	
Sahel	20 689	2 920	14
West Africa	36 200	510	1
Central Africa	8 825	135	2
Eastern Africa	24 186	10 150	42
Southern Africa	9 471	1 544	16
Sub-Saharan Africa	99 371	15 259	15

Source: Jahnke (1980), FAO (1979a).

An average ox works in the field for at least 42 to 50 days per year, in other words the equivalent of 104 to 130 man-days (FAO, 1979a; Adelheim and Schmidt, 1975). The power currently provided by draught animals would therefore be about 1 billion man-day equivalents, or 7% of power inputs as estimated by FAO (1979a). Here again the share of inputs from different energy sources fluctuates enormously from one region to another (Table 3). Inputs from animal traction meet some 13% of total energy demand in eastern Africa, but less than 1% in West and central Africa. They average 6% in the Sahel, including the Sudan and 5% in

southern Africa, where engine power inputs, at 6%, are apparently the highest in sub-Saharan Africa. Although fairly widespread in some regions, especially eastern Africa, animal traction thus makes only a small contribution to the overall power requirements of African agriculture, which is still about 90% dependent on manual labour, and nearly 100% dependent in several West and central African countries. The resulting bottlenecks at peak labour periods—soil preparation, weeding and harvesting—limit not only yields but also the potential for expanding the area under cultivation.

Table 3. *Distribution of power inputs according to energy source in sub-Saharan Africa.*

			–in %–
Region	Tractors	Animals[a]	Men
Sahel	1.0	6.0	93.0
West Africa	1.0	1.0	98.0
Central Africa	0.5	0.5	99.0
Eastern Africa	1.0	13.0	86.0
Southern Africa	6.0	5.0	89.0
Sub-Saharan Africa	1.0	7.0	92.0

a. On the basis of a herd of 10 million head working 40 days/year.
Source: de Montgolfier-Kouévi and Vlavonou (1981).

Prospects

The extent to which regular use of animal traction could help meet mechanization requirements for African agriculture between now and the year 2000 was evaluated by de Montgolfier-Kouévi and Vlavonou (1981). Two avenues for improvement were identified: raising the number of animals used for traction and increasing their work efficiency. Given these improvements, draught animals could constitute about 20 to 30% of the cattle herd by the year 2000, while their work output per head could be 20 to 30% higher, depending on the region, than during the baseline year of the projection (1975).

Using these assumptions, de Montgolfier-Kouévi and Vlavonou (1981) predicted that animal traction could supply African agriculture in the year 2000 with four times more energy than it did in1975. The extent to which it might bridge the future gap between power supply and demand appears even more significant. To calculate the power deficit, separate projections of supply and demand were made. Past trends for various energy sources (manpower, tractors, animal traction) were used to estimate future power supply, and projections of increased food demand were used as the basis for future power demand. It was found that, to satisfy demand in the year 2000, power inputs will have to grow much faster than can be forecast on the basis of past trends: the potential power shortfall might reach at least 20% of demand by the year 2000. However, if animal traction were developed according to the above assumptions, over half this deficit might be made up. Furthermore, the share of animal traction in bridging the gap in eastern Africa and the Sahel could well be over 60%, while in southern Africa it might even be higher than the forecast deficit (Table 4).

Table 4. *Potential contribution of animal traction to the power requirements of agriculture in sub-Saharan Africa by the year 2000.*

Region	Potential contribution by the year 2000[a]	Contribution to demand (%)	
		Total[b]	Shortfall[c]
Sahel	1 040	20	67
West Africa	446	6	48
Central Africa	244	6	12
Eastern Africa	2 108	17	61
Southern Africa	898	39	167
Sub-Saharan Africa	4 736	15	55

a. In thousands of man-day equivalents, assuming that animal numbers will be 20 % of the cattle herd as projected for the year 2000, and that animal performance will have improved by 30 % in eastern, southern and central Africa and by 20 % in the Sahel and the rest of West Africa.
b. Percentage contribution to the total power required to enable agricultural output in the year 2000 to meet the potential demand for food products arising from a population increase of 3 % per year and a rise in GDP per capita of about 2 % per year.
c. Percentage contribution to the shortfall between power supply and demand, with supply estimated on the basis of trends for active rural population, animal population and availability of tractors. The contribution of animal traction is expressed as the proportion of extra inputs which the promotion of animal traction would subtract from the deficit between supply and demand.
Source: de Montgolfier-Kouévi and Vlavonou (1981).

To sum up it appears that animal traction, if promoted, might make a very positive contribution to agricultural development in several sub-Saharan African countries. One of its greatest advantages to farmers, who are mostly poor and have limited cash, is that its cost is low. The loss of foreign exchange would also be low, because the animals are locally available, or could rapidly be made so, and the necessary equipment and spare parts could be locally manufactured, giving rise to domestic industrial growth in the form of small-scale manufacturing activities. Properly developed, animal traction would also gradually be able to take its rightful place in the broader process of integration of crop and livestock production.

Farmers' applications of animal traction

Animal traction has only recently begun to spread in sub-Saharan Africa, except in Ethiopia, where animals have traditionally been used for draught. Attempts to introduce it for cultivation operations were nevertheless made in sub-Saharan Africa during the colonial era, when draught power still played an important part in the agriculture of the colonial powers. The earliest attempts were in the 19th century in Senegal (1850) and Botswana (1880), and probably also in Angola and Mozambique. A second series of attempts seems to have been made before the First World War in the former German colonies, Tanzania, Cameroon and Togo. However, it was not until the period between the two world wars especially the 1930s, that the efforts gained

real momentum both in francophone countries—Madagascar, Guinea, Mali, Senegal and Upper Volta—and in anglophone ones—Kenya, Ghana, Nigeria, Zambia, Malawi and Zimbabwe.

In all these cases development efforts took place in areas that already possessed animal resources; the entire humid zone of Africa and part of its subhumid zone, which are infested with tsetse fly, were excluded. This largely explains the insignificant share of land cultivated by draught animals in the non-Sahel countries of West and central Africa, where animal traction is mostly confined to a few northern areas.

At the other end of the scale are Ethiopia and Botswana, where for totally different reasons animal traction is widely used. Ethiopia's agricultural history stands apart from that of the rest of sub-Saharan Africa, being far more akin to the Middle East's, where animal traction is an ancient tradition. In Botswana, where teams of four or six oxen are often used, only 38% of farmers own draught animals but more than 90% use them for cropping operations. The high concentration of animals in this country and the fact that planting has to be accurately timed owing to the short growing season, explain this widespread use.

In other parts of sub-Saharan Africa where livestock are raised (the Sahel, eastern Africa apart from Ethiopia, and southern Africa), animal traction is probably used for over 15 to 20% of the area cultivated. However, estimates gathered on a country-by-country basis, or even from area to area within a country, show that this distribution is highly skewed, with some areas using it extensively and others not at all.

Many different factors, often interconnected, have influenced the ways in which animal traction is used. Of these, at least three appear crucial—bio-climatic, traditional and historical factors.

Bio-climatic factors

Soil and climate conditions are crucial because they determine the relative importance of different cropping operations and thus affect the labour bottlenecks that animal traction helps to relieve. Thus in areas of low rainfall where the growing season is short, sowing has to be carried out as soon as possible after the first rains, and rapid but superficial soil preparation is generally advantageous.

In such cases the young plants soon find themselves competing with weeds because the seedbed has not been properly prepared. Early weeding becomes vital. In semi-arid areas it is therefore best to use light implements, which also help to reduce stress on farm workers, during the two peak labour periods of sowing and first weeding. In any case, in such areas ploughing would often not be suitable because it increases the risk of soil degradation through wind erosion and runoff, and reduces soil moisture. Light implements like mechanical hoes are therefore usually preferred in the semi-arid zone, and as these have low power requirements they can easily be drawn by horse or donkey instead of the traditional ox-team.

When the growing season is prolonged by greater rainfall and early sowing becomes less urgent, ploughing has at least three advantages over flat soil preparation by hand with hoe-type implements. First, soil tilth is improved, even when the ploughing depth is only 10 cm, while with increasing depth plant development also benefits. Secondly, because ploughing normally leaves a good clean seedbed, the plant has an early advantage over weeds, so that a longer period can be left between sowing and first weeding. Thirdly, ploughing buries organic matter such as compost, dung, green manure and the grass growing on the surface at the time of soil

preparation. For all these reasons ploughing is advantageous and can be repeated to increase its beneficial effects. In heavy soils with favourable moisture conditions, however, deep ploughing is hampered by inadequate tractive power, the nature of the soil, the furrow depth and—especially in humid zones—excessive root development.

Traditional factors

Traditional cropping practices have prevented the use of the mouldboard plough in some areas of sub-Saharan Africa. Some African farming groups do not practise flat cultivation but use ridges or mounds instead. These alleviate erosion and allow soils to be worked more deeply, improving water penetration while making the manual task of weeding easier and ensuring effective drainage of waterlogged soils (von Rotenham, 1968).

The tractive force needed to build the higher ridges or mounds, which may for example reach 60 cm in Sukamaland (Tanzania), is beyond the capacity of an ordinary team of draught oxen, or even one of four to six animals (von Rotenham, 1968). When animal traction can be used, ridges are made with a kind of doubleplough (a ridger) which turns the earth with two symmetrically placed ploughshares and mouldboards to form two half-ridges (CEEMAT, 1975). In addition, ridging makes it more difficult to spread the mechanization of weeding.

Historical factors

The third group of factors, mainly historical, revolve around the ancient tradition of animal traction in Ethiopia and the practices introduced by colonial regimes in pursuit of specific objectives.

Although the *maresha* is used throughout the Ethiopian highlands it is not strictly speaking a plough, since it does not invert the soil; it is more properly an ard. The *maresha* can be used—and often is in Ethiopia—for weeding. In Harargue Province, for example, it is used for inter-row cultivation when the plants are 30 to 40 cm high. The spaces between rows are then weeded, either manually or by "plough" (McCown et al, 1979). In other areas, such as the northeast, weeding is carried out entirely by hand (Kline et al, 1969).

The introduction of animal traction by colonial regimes accounts for some of the regional differences which can still be observed today in the uses of animal traction. In most West and central African countries animal traction has been geared to cash crop promotion and was introduced to ease labour bottlenecks. The most typical examples are Senegal and Mali. In Senegal first donkeys and then horses were harnessed in order to speed up the drilling of groundnut crops. In Mali, as also in Guinea, the ox-drawn plough made soil preparation for rice cultivation substantially easier[1]. Animal traction was subsequently taken up for cotton cropping by a number of francophone countries (Mali, Ivory Coast, Cameroon, Chad and the Republic of Central Africa). The only sizeable experiments with animal traction in subsistence cropping took place in the semi-arid zone of Upper Volta and involved millet and sorghum.

1. Animal traction was promoted for similar purposes in Madagascar, where rice cultivation is traditional.

Animal traction applications are rather different in eastern and southern Africa, where the arable land potential is sometimes high and farming conditions are closer to those of temperate zones,

especially in the highlands. In these countries the best land was occupied and farmed by Europeans during the colonial era. These farmers brought their methods with them, centred on the use of the mould-board plough. Later this type of plough became more widespread in indigenous farming areas as the more innovative farmers tried to follow the Europeans' example, sometimes with government support.

The plough is used not only for initial soil turning but also for subsequent seedbed preparation, carried out by repeated ploughing (Alexander, 1975). It may also be used for burying weeds found between the furrows (de Wilde, 1967). Heyer (1975) observed that the narrow range of traction equipment owned by farmers investigated in the Makueni area (Machakos District) was typical of the Kenyan situation. There animal traction is widely used both for food crops, such as millet, sorghum and beans, and cash crops, such as cotton[2]. Most farmers using animal traction for soil preparation also used it for planting and weeding. According to the same survey, in the Bungoma area of the western highlands the plough was primarily devoted to soil preparation for maize, beans and sunflower cropping, with most other operations carried out by hand, even when farmers owned a tractor. Similarly, in Sukamaland (Tanzania), farmers using a mould-board plough for the flat cultivation of cotton weeded entirely by hand, according to von Rotenham (1968). He also noted that although using a plough saved time in relation to ridging, the gains were totally offset by the hours that had to be spent later on manual weeding.

2. Ninety per cent of farmers surveyed in 1974/75 in this semi-arid area possessed a plough, 18% had a cart and only 3% owned other kinds of equipment.

Although Botswana lies in the arid zone, the mouldboard plough is used extensively for cereal and groundnut cropping, in both soil preparation and weeding. In northern Malawi, farmers use animal traction in ridging and weeding, using a cultivator that also reridges during weeding with tines (Jellema, 1975).

To sum up, in contrast to West Africa animal traction in eastern and southern Africa is characterized by a narrow range of equipment and a marked tendency to use heavy plough-like implements, which sometimes need two or three pairs of oxen to draw them. This practice is unknown in West Africa, including northern Ghana and Nigeria where ridging ploughs require considerable tractive power. As noted, this tendency is found even in the semi-arid zones where soils are fragile and lighter implements are more usually recommended.

On the other hand, animal traction in these regions has been applied to a diverse range of crops. Although frequently used for cash crops (for example, cotton in Uganda and in the Sukamaland region of Tanzania), animal traction also seems to be used as much for subsistence crops. The eastern African situation thus further contrasts with that found in West and central Africa, which has been influenced by the French.

Finally, whether in terms of implements used or crops grown, animal traction applications in sub-Saharan Africa seem geographically diverse, although they rely on simple implements able to perform only a limited number of cropping operations. In many cases this diversification can be explained by largely incidental factors, with the result that the implements used are too often poorly adapted to farmers' needs. For instance, the *maresha* is used throughout the Ethiopian highlands, where the length of the growing season and the nature of the soils would more often imply the use of much heavier implements for soil preparation in areas of high crop yield potential. In contrast, a mould-board plough is used for soil preparation in the semi-arid zones of eastern and southern Africa, although lighter implements would meet farmers' needs far better.

After independence several African governments, among them Kenya, Zambia and Tanzania, opted to promote the use of tractors in agriculture to accelerate development. Animal traction was considered an unpromising area for innovation, and research on it declined. But efforts to promote tractor use ran into serious difficulty, especially in Zambia, and this has recently rekindled interest in animal traction. The development and use of multi-purpose cultivation equipment reflects this renewed interest. The aim is to manufacture implements that are a) light, and so better suited to certain soil types and to the traction methods used, b) multi-purpose, enabling farmers to perform all the various farm tasks, possibly including transport, with a single basic toolbar to which the different implements can be hitched. Different models along these lines have been designed in West Africa and Botswana.

The constraints

In addition to increasing yield per unit area, a major objective in mechanizing cropping operations via animal traction is to expand the area under cultivation and reduce labour bottlenecks, freeing manpower for other work. The implements used, whether light or heavy, should theoretically improve both quality and speed of work on traditional tasks such as soil preparation, sowing, crop maintenance, harvesting and transport. This would not only create opportunities to cultivate larger areas, but also enable new tasks crucial for improving agricultural productivity to be carried out. These include transporting and spreading manure or fertilizer, crop spraying, land clearing to make ploughing and drilling easier—drilling, rather than broadcast sowing, is essential if weeding implements are to be properly used—and improving ploughing efficiency by increasing furrow depth and burying green manure.

The annual labour requirements are not necessarily reduced as a result of mechanization. Indeed, they may even rise, although they will be distributed differently over the year. Cultivation operations can begin earlier, with land clearance, and labour bottlenecks can be appreciably reduced, freeing manpower for other activities. On the other hand cropping operations may be increased at harvest time because the yields obtained are greater, and this may lead to the mechanization of harvesting to guarantee that the improved system remains viable. Mechanization through animal traction also demands that the animals used be well fed[3], and thus the forage component in the cropping system must be improved.

3. During or after this stage of development the farmer can also think in terms of improving the offtake of draught animals, accelerating their turnover as working animals and developing a fattening enterprise for those that are culled.

Like any other development effort, therefore, the promotion of animal traction can both increase labour productivity and pave the way for innovations whose beneficial effects are cumulative and combine to improve the productivity of land. Increased yields and areas cultivated should lead to higher incomes for mechanized farmers, who would then be able to cover the costs of buying inputs and paying off loans on the equipment purchased (including cattle), while their standard of living improves. This development path nevertheless implies that the subsistence-oriented farm must become more cash-oriented.

However, as noted earlier, despite development efforts often dating back more than 50 years, animal traction is still underused in tropical Africa. The tsetse fly has restricted its use in heavily infested areas because of the shortage of animals there, while a number of other constraints have hindered its extension over the rest of Africa and reduced its efficiency in those areas where it is practised.

Local breeds

The *Bos taurus* and *Bos indicus* breeds indigenous to sub-Saharan Africa have an adult liveweight of between 250 and 400 kg. Among the former, the humpless N'Dama dwarf breeds are particularly suited to traction: they are sturdy animals with short, powerful legs and a thickset neck, usually docile and thus highly suitable for work. Although their physical shape is less suitable, particularly their long necks and humps, zebu breeds are also much used for traction in trypanosomiasis-free areas. Their larger size is an advantage.

A well-trained, healthy and mature animal can usually exert a force equivalent to 10 to 14% of its body weight while travelling at a speed of 2.5 to 4 km per hour. Work duration is between 2 and 8 hours, commonly starting early in the morning, followed by a rest at midday and then continuing in the later part of the afternoon. Over short periods an animal can exert a force much greater than average. Lighter animals generate less power than heavier ones, but their gross energetic efficiency[4] is nevertheless relatively higher. In other words, the heavier the animal, the greater the overall energy required to perform a given task. These differences in the efficiency of small and large animals decline as the amount of work accomplished increases (Table 5). However, African cattle are often unable to perform work efficiently because of disease, heat stress, variability in feed and poorly-designed harnesses, yokes or implements (Goe and McDowell, 1980).

4. Ratio between work accomplished and energy provided.

Table 5. *Utilization and performance of various African draught cattle breeds.*

–in kg–						
Breed	Adult liveweight	Draught per pair for an effort per animal of:		Maximum effort/team	Carting capacity per pair	Utilization
		10% of body weight	14% of body weight			
Fulani Zebu	330	61	84	565	450–540[a]	General traction.
Lugware	350–400	65–74	91–104	–	700–800[b]	Tillage and carting.
N'Dama	260–360	48–67	67–93	–	–	Ploughing and haulage; not suited to work over long periods.
Ankole	340–365	62–68	88–94	–	800[c]	Energetic animal; can plough hard soil for 4 to 5 hours.
Tanzania short-horned Zebu	200–260	37–48	52–67	–	–	Ploughing
Madagascar Zebu	400–450	74–83	104–117	345	350–500[d]	A team of 6 oxen can plough o.5 ha. in a 5-hour-day
Bambey crossbred	540	100	140	432	–	–

a. At 3.2 km/hour for 6–8 hours/day.
b. At 4 km/hour for 4 hours/day.
c. Rubber-tyred cart for 16 km/day.

d. Up to 4 km/hour, covering 30 km/day.
Source: Goe and McDowell (1980), and Hamon (1971).

The low weight of tropical African animals in turn limits the weight and size of implements they can draw, especially when soil conditions dictate, as they often do, greater tractive efforts. In some instances, the draught required to pull implements in heavy soils is greater than that which a pair of oxen can exert, resulting in a less than desired depth of tillage. This is the case with the chisel tine developed by the Centre de recherches agronomiques de Bambey (CRA, Senegal) or the mould-board plough used in eastern Africa. Additional tilling or the hitching of several pairs of animals together is therefore often necessary.

Agricultural land is not always well prepared in Africa. Stumps, roots and stones are often not properly cleared, and the land is frequently covered with shoots from small shrubs and grasses, forcing cattle to provide far more strenuous efforts: This kind of work tires them out much more quickly than when a constant effort over well managed land is required. In addition, many peasants, in northern Nigeria for example, use animals that are too young, bought at low cost for resale at a profit 3 to 4 years later. These animals have not yet reached their maximum liveweight and are not adequately trained by the time they begin work, so that their potential for traction is very restricted (Boyd and Ayok, 1974). Even when the best animals are reserved for traction, as happens in Ethiopia, their feed intake is generally too low to provide maximum power.

Flat cultivation by draught usually requires a pulling force of between 70 and 100 kg, about the maximum a pair of indigenous cattle can provide (Tables 5 and 6). Of course, several pairs of oxen can be harnessed together to form a team with greatly increased total draught power, but this requires more capital (to buy the cattle and feed them) and greater skill in animal control, while also leading to a loss in relative efficiency. Ridge cultivation needs still greater efforts, because of the large amounts of earth that have to be lifted. Because the animals are not strong enough, the ideal tool, a mould-board ridger, usually cannot be used even though it would allow cultivation in good straight rows leading to better crop maintenance (Boyd and Ayok, 1974).

Table 6. *Tractive efforts recorded for various types of implement.*

Type of implement	Work	Tractive effort (kg)
Plough	Burying	80
2 twin seed drills	Sowing	27
Disc ridger	Ridging[a]	152
Plough	Ridging[b]	75
Four-bladed hoe	Hoeing (groundnuts)[c]	60
Five-bladed hoe	Hoeing (millet)[d]	70
Lifter	Lifting (groundnuts, creeping variety)	80–85
Lifter	Lifting (groundnuts, erect variety)	40–45

Source: Moonier (1965).
a. Soil ploughed 2 weeks previously; width of ridge base: 66 cm; height: 40 cm.
b. Unploughed land; with at ridge base:40cm; height:20cm

c. One inter-row cultivation.
d. Two inter-row cultivation

Efforts to improve the efficiency of animal traction will therefore have to focus on the animals themselves. Various approaches can be adopted. First of all, exotic x indigenous crossbreds can be used. These larger, heavier animals are better suited to traction, and trials have shown that in tropical countries crossbred oxen are able to perform well for periods of 4 to 6 hours if worked from early in the morning (Goe and McDowell, 1980). Nevertheless, they show low tolerance to high temperatures. In addition, crossbred animals have yet to be introduced on any scale in many African countries. A second approach would be to make local stock more suitable for traction. Little research in this field has been carried out in sub-Saharan Africa, apart from CRA experiments to develop a zebu x N'Dama crossbred combining the zebus larger size with the N'Dama's trypanotolerance and work aptitude (Hamon, 1971). Thirdly, it is up to the peasant to make the most of his animals. The energy efficiency of a draught animal increases as draught and speed increase, until an optimum rate of work is reached (Goe and McDowell, 1980). A farmer who understands the capacity of his animals should be able to work them in such a way that the maximum amount of work is done in a day without wearing them out (Table 7).

Table 7. *Estimated tractive capacity of oxen working at low and high speed.*

Animal	Weight (kg)	Low speed			High speed		
		Speed (km/hour)	Draught (kg)	Hp	Speed (km/hour)	Draught (kg)	Hp
Light ox	210	2.4	30	0.3	4.0	21	0.3
Average ox	450	2.4	64	0.6	4.0	45	0.7
Heavy ox	900	2.4	129	1.1	4.0	90	1.3

Source: Goe and McDowell (1980).

Beyond the limitations linked to the nature of the cattle found in sub-Saharan Africa there is a further major problem: availability. Within the foreseeable future the best prospects for developing animal traction will probably lie in the subhumid and highland zones. Although the supply of draught cattle does not pose any serious problems in the highlands, the situation is different in the subhumid zone, which contains few trypanotolerant animals and where the introduction of purebred zebus carries considerable risk of trypanosomiasis.

Equipment

Animal traction equipment can be divided into two categories: yokes and harnessing equipment and implements for cultivation. Two kinds of yoke are used in sub-Saharan Africa: head and neck yokes. The neck yoke is more acceptable to African peasants and thus facilitates the introduction of animal traction, but it requires more skill in harnessing than does a head yoke. It is simpler in design, cheaper, and easier to manufacture locally.

However, the neck yokes used are sometimes crude and poorly designed, preventing animals from generating their full tractive power. A well designed yoke allows an animal to work longer at a sustained rate without repercussions on health. In India it was found that well designed yokes and harnesses can lead to performance gains ranging from 22 to 60% in relation to local

yokes, according to the type used (Goe and McDowell, 1980). Unfortunately, improved yokes are not always acceptable to farmers, who often take into account factors other than animal performance

The constraints imposed by cultivation implements are more difficult to identify because of the variety of ecological conditions in sub-Saharan Africa. A wide range of implements designed to suit different environmental conditions is needed. In many regions the implements used are not only ill-adapted to animal traction (mould-board and ridging ploughs), but also to ecological requirements. Using ploughs in the semi-arid zones of eastern and southern Africa is considered potentially damaging to the environment (Muchiri and Johnston, 1975). Also, few weeding implements are found in most of these areas. Yet mechanized weeding is a prerequisite if animal traction is to be fully successful, yields are to increase and cultivated areas are to be expanded.

Similar problems are found in areas of traditional ridge cultivation, where implements are unsuitable for weeding, so that farmers usually revert to manual weeding (Boyd and Ayok, 1974). An interesting example is provided by northern Togo, where attempts are now being made to spread animal traction by encouraging peasants to plough flat, reconstructing their ridges at a later date while recultivating after sowing. These ridges lie too close to one another, however, obstructing the passage of weeding implements, with the result that weeding is once again carried out manually (Domingo, personal communication).

Implements available to farmers seem far better adapted to needs in most West and central African countries, where efforts to develop light implements more in line with the traction capabilities of local stock have long been made. Here again, Senegal has led the way, largely through CRA attempts to develop implements matching local conditions. Technical constraints associated with unsuitable implements may therefore be considered of little importance in these regions. Unfortunately the same cannot be said for the farmer’s use of these implements.

Generally speaking the African peasant using animal traction finds himself confronted with unfamiliar implements that he has not been trained to operate, adjust or maintain. This unfamiliarity, together with problems in procuring spare parts, leads him to pay little attention to adjustable fittings. When a plough is poorly adjusted, control over the length and depth of furrows lies entirely in the hands of the driver, while the animals become needlessly exhausted. Even adjustments as simple as harnessing chains, where increasing the length can vastly improve plough penetration, cause problems. According to Alexander (1975), the plough in eastern Africa today is little more effective than was the ard in primitive societies. Literature on cultivation in West Africa abounds with examples illustrating the peasant's inability to handle the implements he is supposed to use. Cassé et al (1965) observed that the number of maladjusted ploughs in Africa is extremely high, and that very often implements remain unused simply because their owners have never learned how to use them. Boyd and Ayok (1974) noted that peasants rarely use the various hoeing implements that can be hitched to multi-purpose toolbars.

Multi-purpose equipment adaptable for most, if not all, cultivation operations, is obviously more demanding for farmers in terms of hitching or disengaging different tools and making the adjustments required, adding further risks of improper use or underutilization. Cassé et al (1965) reported that it had been hoped to change the attitude of farmers by providing them with equipment they could easily learn to adjust for themselves, but that the farmers had reacted by discarding it. The psychological barrier is apparently less great when farmers are supplied with

larger numbers of implements, each of which fulfils only one purpose and is therefore easier to use. In contrast to multi-purpose toolbars, which can only be used for one job at a time, separate implements can sometimes improve the division of labour and ease bottlenecks during peak periods. Several authors have pointed out that reducing the drudgery of labour is a crucial factor in getting innovations accepted. The peasant tends to reject tools that do not significantly ease his chores, even if these tools would spectacularly increase labour productivity per unit time (Boshoff and Minto, 1975). Here again it may be noted that productivity is not always the most decisive factor.

The poor adaptation of animal traction equipment to the needs of farmers emerges clearly in the case of weeding, and constitutes a major factor limiting yield and. cultivated area increases. Designing or upgrading simple weeding implements for lightness, suitability to local soil conditions and sufficiently reduced labour inputs to make them attractive to peasants, should therefore become a major priority. At the same time efforts to encourage their use should be controlled by a well organized extension service that would make peasants familiar with their tools so that they can maintain them better.

Feed resources

Cropping operations entail high daily rates of energy expenditure by the animals, so that supplementary feeding becomes necessary. The extra needs are difficult to quantify because they vary according to factors such as the animals' age and weight and the work required of them. Adult oxen's needs differ from those of young cattle and pregnant or lactating cows. Feed requirements for maintenance— i.e. the minimum below which the animal begins to lose weight—must be distinguished from those required for growth (milk, meat), work and reproduction.

The daily maintenance needs of oxen weighing 450 kg have been estimated at about 3.3 TDN[5] or 4.5 FU in temperate countries (Europe and USA) and in India, but only 3.6 FU in sub-Saharan Africa, while those for growth lie between 1.5 and 1.8 FU for a weight gain of 450/g per day, according to Goe and McDowell (1980). These authors conclude that animals at work expend three to eight times the energy required for basal metabolism. However, in practice relative metabolic rates are affected by the level and frequency of the work required. In addition, the animals become more tired when in poor physical condition or when external temperatures rise. Their energy needs undoubtedly increase at such times, but relationships here are little understood.

5. The unit TDN (total digestible nutrients) = carbohydrate + protein + 2.25 (fat). One kg of TDN equals about 1.37 FU (feed units) (Goe and McDowell, 1980)

Goe and McDowell (1980) estimated the feed requirements of horses and oxen of varying sizes providing different tractive power over short and long periods. The FU requirements of 450-kg draught oxen developing 0.67 Hp were estimated at 7 FU for a 4-hour work period, 8 FU for 6 hours and 9 FU for 8 hours. If work intensity and duration are considered together, feed requirements for draught oxen may vary between 7.1 FU for relatively light work during a short period to 10.5 FU for more intense efforts over a longer period (Table 8). The total feed requirements of a draught ox can thus be calculated at 1.5 to 2.3 times higher than maintenance needs.

Table 8. *FU requirements of draught oxen as a function of power output*[a].

			– in kg/day–
Power (Hp)	Duration of work (hours)		
	4	6	8
0.67[b]	7.1	8.1	9.2
0.70[c]	7.4	8.6	9.9
0.75[d]	7.7	9.2	10.5

Source: Goe and McDowell (1980).
For an ox weighing 450 kg, including maintenance requirements.
45 kg (10 % of body weight) at a speed of 4 km/hour.
54 kg (12 % of body weight) at a speed of 3.5 km/hour.
63 kg (14 % of body weight) at a speed of 3.2 km/hour.

Similar ratios were found by the French Ministére de la Coopération (1974), which estimated the total energy needs of ploughing oxen at 1.5 to 2.5 times higher than maintenance needs, depending on the scale of work, with maintenance needs estimated at 3.5 FU for an animal weighing 450 kg.

The supplementary protein required for draught animals to provide specific amounts of power is not accurately known. Some authors believe protein supplementation to be unnecessary since it may reduce work performance by increasing heart and respiration rates and sweating. Goe and McDowell (1980), for example, conclude that extra protein is not required if maintenance rations are properly balanced. The Ministére de la Coopération (1974), on the other hand, found that the protein requirements of draught animals are about 30% higher than maintenance needs, in other words 0.8 instead of 0.6 g of DCP[6]/ kg of liveweight. Although there are differences in approach, these two sources both agree that the energy component is the most important one for work performance, and that energy requirements may be up to twice as high as maintenance needs, or even higher if a strenuous effort is required.

6. Digestible crude protein.

Under sub-Saharan African conditions, grazing alone is unable to meet these feed requirements. In fact, it can barely meet maintenance requirements: the digestible energy and nitrogen contents of natural forage reach a maximum during the growing season but fall away rapidly during the dry season, reaching low levels when the latter is at its height. Moreover, ligneous content increases at the same time, curbing digestibility and thus voluntary feed intake (Dicko et al, 1981).

Draught animals relying on natural pasture for energy requirements will therefore lose weight and become weak during the dry season, reaching a poor physical condition for work by the time ploughing begins during the early rains. In addition, lack of opportunity for alternative uses, such as transport, means that the animals are usually left inactive during the dry season. This leads to reduced efficiency when cropping operations are resumed, because the animals are out of condition. Dronne (1969) noted in southern Chad that tethering oxen during the rains to protect crops further inhibits their feed intake, because the farmers leave them for long periods

where there is insufficient grass. As a result, draught animals' intake may be inadequate even during work periods.

The cumulative effects of undernourishment and overwork on oxen can be serious, especially if the animals are not yet mature. Not only is working efficiency diminished but also their state of health, making them more susceptible to disease. Many peasants do not understand the real reasons for the poor health of their draught animals, attributing what is the result of undernourishment and overwork to specific infections (Dronne, 1969). Animal feeding can only improve as farmers better understand their animals' feed requirements and begin to implement better herding practices.

Even then, supplementation will still probably be necessary, especially while major cropping operations are being carried out. Supplements may occasionally be provided from locally available agro-industrial byproducts: for instance, the CMDT (Compagnie Malienne de Développement du Textile) has encouraged farmers in southern Mali to supplement their draught oxen with cottonseed. However, initiatives of this kind rapidly reach their limits: byproducts available at smallholder level are few or even nonexistent and, where they are found, are usually too expensive. In Mali, cottonseed was sold in bulk to farmers in 1976/77 at a subsidized price of Malian francs (MF) 4/kg, whereas the true factory gate price for oil mills and export was MF 30/kg. Improved animal nutrition will therefore have to rely on the cultivation of forage crops, although their introduction often implies radical changes in traditional management methods.

Social constraints

Although the degree of integration between crop and livestock production in sub-Saharan Africa is gradually increasing, there are still many areas in which the two activities are carried out separately. This separation has given rise to considerable constraints to the development of animal traction.

Smallholders often leave their animals largely to their own devices, under the assumption that animal production is primarily the business of herdsmen, even if carried out on their own farms. Hence the common practice by sedentary farmers in West Africa of entrusting their animals to Fulani herdsmen. Alternatively, the farmer may attach great value to his cattle as a source of prestige and a form of investment in which case he may purchase animals but resist the idea of setting them to work. Finally, even if he accepts the idea of animal traction, he may subsequently become discouraged by the difficulty of training his animals.

The introduction of animal traction thus requires fundamental changes in farmers' attitudes as well as in cropping operations. In Senegal, Cassé et al (1965) observed that training horses to draw a seed drill or cart was relatively easy because the animal was already familiar to the Senegalese peasant and this step implied no radical changes in his habits. Introducing cattle for ploughing, on the other hand, would have meant moving the herd closer to the village and entrusting the animals to someone who could train them, harness them correctly, drive them and feed them properly. As a result extension work would have had to play a fundamental part, increasing peasant awareness of the advantages of animal traction and overcoming the social constraints to its use.

Dronne (1969) noted that in southern Chad the motive for purchase of oxen and ploughs by village elders was sometimes as much a desire for prestige as for production increases. Owner

farmers were not using their animals and equipment primarily to plough their own fields, but rather to lend them to other farmers so that most of their own cultivating was carried out late[7]. Commenting on the results of an experiment in the Republic of Central Africa, Morel (1966) indicates that, apparently for reasons of prestige, peasants were usually unwilling to buy communally owned animals and equipment, despite the fact that the smallness of their farms more or less dictated such a strategy to make animal traction a viable proposition.

7. The problem of loaning equipment is a complex one. Often it provides additional income for farmers and a better means of offsetting depreciation. Most authors have found that renting out carts throughout the year provides a substantial income to their owners.

The traditional attitudes of the farmer or herdsman towards his livestock thus constitute a serious constraint to the adoption of animal traction in sub-Saharan Africa. Similar attitudes restrict the adoption of new implements in agricultural systems still based mainly on hand tools that are usually well suited to the tasks for which they are designed and for which they have been used since time immemorial. These attitudes often account for peasants' difficulties in making proper use of their new equipment. Alexander (1975) notes that young people resist adopting animal traction just as their elders do, but that their reasons are quite different: they are unwilling to use methods that are, in their opinion, old fashioned, and instead pursue more attractive, up-to-date technology.

Animal traction equipment should theoretically be all the more acceptable for being easy to produce and repair by local craftsmen. But these craftsmen are often under-trained and have access to limited plant and raw materials. They may be able to produce simple tools useful to farmers, but they are seldom equipped to design new and improved models. Neither are they accustomed to working to demanding standards, or in line with modern ideas of management. As Boulanger (1972) pointed out, even distributors and extension agents are often unable to explain exactly how the tools they sell work. Lack of training at all levels, combined with financial and institutional constraints such as high costs and local shortages of materials or spare parts, thus effectively prevents the adoption of animal traction equipment.

Management and financial constraints

A team of oxen and the equipment to harness and use it for cultivation represents a substantial investment for the African peasant, whose cash income is usually low. A set of draught equipment, including a multi-purpose toolbar with plough, harrow and weeder as well as a cart and seed drill, costs at present around US$ 600–700, or over US$ 1000 if a pair of oxen are added. African farms are usually no more than 4 or 5 ha in size, about the area that can yearly be cultivated by a pair of oxen. In wealthier areas they tend to be even smaller: in Kenya, for example, smallholdings seldom average more than 1 ha. A typical enterprise devotes 70 to 80% of its land to food crops, consisting of cereals or tubers, pulses and a few vegetables, while the rest is given over to cash crops: cotton, oilseeds, coffee, cocoa or others, depending on the potential of the land. On the basis of current tropical African producer prices, a typical farm probably has a gross income of about US$ 600 to 700 per year. In other words, a set of draught equipment costs 1 to 1.5 times annual farm income and an even higher proportion of net income. As most agricultural output is home consumed and not marketed for cash, the cost may even be more than four to five times from cash income, which probably is little more than US$ 200/year on most smallholdings.

Cassé et al (1965) observed that in West Africa ratios between draught equipment costs and farm income were fairly close[8]. They estimated that in 1960–65 the cost of implements for cultivating groundnuts and cereals in Senegal was between CFA francs 53,000, for a seed drill, a hoe and a horse-drawn cart, and CFA F 92,000 for a multi-purpose toolbar with a lifter for harvesting. Over the same period, gross farm income for farms less than 4 ha not using animal traction was around CFA F 60,000 to 80,000 (Table 9). In Upper Volta the price of a hoe alone, estimated at almost CFA F 10,000 in 1960–65 (Table 10) represented approximately twice the cash income of traditional farms.

8. The few available data on the costs and benefits of introducing animal traction in sub-Saharan Africa are not recent. It would be useful to update information in this field

Table 9. *Size and annual incomes of surveyed farms not using animal traction in West Africa (1960–65).*

				– in CFA francs –
Country/Region	Area (ha)	Income		
		Gross	Net	Cash
Upper Volta				
Bobo-Dioulasso area[a]	7.1	50 960	46 430	4 570
Senegal: Laghem Oriental				
Darou village[b]	3.5	76 070	55 380	–
Darou village[c]	5.9	127 660	119 800	–
Dierry village[d o]	3.9	60 700	42 780	–
Hanene village[e]	3.5	84 220	69 950	–
Mali				
Ségou, Sikasso and Haute Vallée[f]	8.3	58 500	57 000	–

a. Survey results on 21 farms mostly producing food crops.
b. Survey results on 8 farms, producing groundnuts and millet.
c. Survey results on 5 farms, producing groundnuts and millet.
d. Survey results on 10 farms, producing groundnuts and millet.
e. Survey results on 20 farms, producing groundnuts and millet.
f. Estimates.
Source: Cassé et al (1965).

Table 10. *Capital expenditure and running costs incurred by the introduction of animal traction in West Africa (1960–65).*

				–in CFA francs–
Implements Used	Capital expenditure[a]		Annual running costs[b]	Total annual costs
	Total	Depreciation		
Hoe[c]	9 000	1 000	2 000	3 000
Hoe and seed drill[d]	18 600	2 800	8 150	10 950
Hoe, seed drill and cart[d]	53 600	5 400	12 500	17 900
West African UCA[e]	54 200	6 800	11 400	18 400
Multi-purpose toolbar[f]	92 600	11 600	11 400	23 000
Barjac B2 ploughs[g]	19 500	2 500	4 000	6 500

a. Excluding purchase of draught animals; depreciation over 10 years, 5 % interest.
b. Including additional costs of feeding concentrates to draught animals.
c. Donkey-drawn hoe (Upper Volta).
d. Horse traction (Senegal).
e. Unité de culture attelée (animal traction unit), comprising seed drill, hoe, lifter and ox-drawn cart (Senegal).
f. With plough, using oxen (Senegal).
g. traction (Mali).
Source: Compiled from Cassé et al (1965).

Estimates by Morel (1966) in the Central African Republic are even higher, with the cost of a pair of oxen and the equipment for mechanizing the production of cotton, groundnuts and cereals calculated at almost CFA F 90,000 in 1965, while cash income on traditional smallholdings of less than 1 ha was probably no more than CFA F 5,000 per year.

The farmer who decides to mechanize must also face heavy depreciation on his equipment and maintenance costs on both his animals and his equipment. In Senegal, where animal traction was already fairly well advanced in the early 1960s, introduction costs were at that time estimated at around CFA F 11,000 to 12,000 per year in running costs (maintaining equipment and feeding animals) and at between CFA F 6,500 and 11,500 per year for depreciation, depending on the equipment, in other words around CFA F 20,000 per year in all, corresponding to approximately one third of gross income on traditional farms. A similar ratio emerges from recent estimates in northern Togo, where the incremental costs of introducing animal traction (repaying credit over a 5-year period covering all capital investment costs—multi-purpose toolbar with ox-team, tools and harnessing equipment—plus running costs) were evaluated at over CFA F 85,000 per year, whereas gross annual income on traditional farms was estimated at some CFA F 250,000 (Domingo, personal communication).

Such high costs mean that incomes must improve sharply on farms deciding to mechanize. These improvements are clearly possible, since the aims of mechanization in the first place are to increase labour and land productivity, expand the area cultivated, and improve the profitability of the crops grown. Farmers devoting less labour to the basic food crops are in a position to spend the time saved on production alternatives that are not crucial to subsistence but instead provide higher cash incomes. For instance, in Togo, where the government is currently

promoting animal traction, it is estimated that by acquiring a multi-purpose toolbar and a cart farmers can grow an extra 2 ha of cotton and earn an additional CFA F 120,000 per year (on the basis of a yield of 1 tonne per ha at CFA F 60,000). This extra income is enough to cover the cost of buying the equipment and a pair of oxen (Domingo, personal communication).

According to Le Moigne (1980), the productivity gains from ploughing vary enormously according to the crop, amounting to 20 to 25% for millet and groundnuts in the arid zone, but reaching 50 to 100% in humid areas where rainfed rice and maize are grown. Manpower savings were estimated by Cassé et al (1965) at between 20 and 50%, depending on crop, soil conditions and other factors (Table 11). Because the savings come at times of intense activity, the farmer is able to spend the time saved on increasing the area under cultivation—by up to 50% for groundnuts in Senegal—or on improving cultivation by adopting new practices or repeating old ones, such as weeding.

Table 11. *Increase in agricultural productivity due to animal traction.*

–in %–				
	By type of implement used		By type of crop grown[f]	
	Yields	Area cultivated	Crop	Yields
Ox-drawn hoe (Upper Volta)	10–15	50	Millet	19
Seed drill (Senegal)	10–15[b]	–	Sorghum	24
Seed drill and hoe (Senegal)	20–25	20–50[c]	Maize	50
Lifter (Senegal)	20–30[d]	–	Rainfed rice	103
Plough (Mali)	–	30	Groundnuts	24

a. Shallow cultivation before sowing and weeding.
b. Groundnut cropping with good sowing density.
c. Groundnut cropping.
d. With a mature crop, avoiding losses.
e. Millet and groundnut cropping.
f. In Senegal.
Source: Cassé et al (1965) and Le Moigne (1980).

The high introduction costs mean that the anticipated net increase in earnings is highly sensitive to the rise in gross farm income and the costs of the equipment used. Table 12 shows that only the simplest kinds of equipment turn out to be profitable when the rise in gross income is only moderate (20%), and they do so only if the farmer already possesses draught animals. It also indicates that gross farm income has to rise by almost 40% before the more expensive kinds of equipment become justifiable.

Table 12. *Impact of animal traction on net farm incomes (1960–65)*[a].

–in CFA francs–				
Implements purchased	Increase in running costs	Effect on net income[b]		
		Case 1[c]	Case 2[d]	Case 3[e]
Hoes (Upper Volta)	3 000	7 000	12 000	17 000

Hoes and seed drills[f]	11 000	3 000	10 000	17 000
Hoes, seed drills and carts[f]	18 000	– 4 000	+ 3 000	10 000
West African UCAs[f]	18 500	– 4 500	+ 2 500	9 500
Multi-purpose toolbars[f]	23 000	– 9 000	– 2 000	5 000
Barjac B2 ploughs[g]	6 500	5 500	10 900	16 700

a. Assuming that farmers already own draught animals.
b. Gross incomes adopted as follows: Upper Volta: CFA F 50 000
Mali: CFA F 58 000
Senegal: CFA F 70 000
c. Farm income rises by 20 %.
d. Farm income rises by 30 %.
e. Farm income rises by 40%.
f. Senegal.
g. Mali
Source: Compiled from Tables 9 and 10.

These costs provide a strong incentive to accompany the introduction of animal traction with other innovations. In view of the new opportunities it brings to the farmer for transporting dung, burying green manure or growing forage crops, animal traction should indeed be accompanied by other improvements at low marginal cost to enhance the operation and its financial viability. However, these innovations require changes in the cropping practices of the traditional farmer. They also require not only a substantial improvement in management methods on family farms but also the development of national support services such as extension and credit facilities.

Two additional constraints will hamper animal traction development on many African smallholdings. First, their low cash incomes will mean that subsistence-oriented enterprises will experience difficulties in making repayments on mechanization. Their problems will be magnified by their previous isolation from outside influences and lower exposure to innovations. Second, in high-potential areas with greater existing links with the outside world, where land is scarce and there are other production alternatives such as milk, keeping animals for draught may not prove viable owing to the relatively high opportunity cost of land and of forage production (Adelheim and Shcmidt,1975). Admittedly, in these areas other approaches can be considered, for example using draught cows instead of oxen and so keeping animals for two or even three purposes—milk, meat and traction. However these development paths are more demanding in terms of the innovations introduced and, as a result, in terms of management.

The lessons of development experience

Development efforts

Animal traction has developed appreciably in some areas. Between 1965 and 1975–79 the number of ploughs tripled in nine West African countries and in Chad while the number of seed drills increased 2.5 times, mostly in Senegal. The fleet of multi-purpose toolbars, negligible in 1965, now outnumbers both ploughs and seed drills (Table 13). Although Senegal and Mali are the two countries in which animal traction has really expanded, it has recently been adopted in several others on a fairly large scale, notably in Upper Volta, Benin and Togo. In Senegal animal traction is most widespread in areas producing groundnuts, which take up more than half

of the area under cultivation in the country. Seed drills were the first kind of implement to be disseminated, numbering 85,000 units in 1965, and they continued to increase as the multi-purpose toolbar later came in. Since using a groundnut lifter requires considerable tractive force, adoption of this implement was also one of the main factors behind the introduction of cattle traction in Senegal (Uzureau, 1974).

Table 13.*Trends in numbers of traction implements in West African countries and Chad.*

Implements	Senegal	Mali	Upper Volta	Ivory Coast	Benin	Togo	Chad	Total
Ploughs								
1965	3 500	45 000	3 500	100	60	105	7 500	59 765
1975–79	8 000	100 700	20 000	–	7 500	–	60 000	196 200
Multi-purpose toolbars								
1965	1 000	–	350	very few	very few	–	very few	1 350
1975–79	210 000	95 300	26 000	6 000	7 500	2 000	5 700	352 500
Seed drills								
1965	86 100	–	100	–	–	–	–	86 200
1975–79	220 000	9 800	n.d.	–	–	–	–	229 800
Groundnut lifters								
1965	1 000	–	–	–	–	–	–	1 000
1975–79	90 000	–	–	–	–	–	–	90000
Carts								
1965	33 000	5 000	1 000	very few	very few	–	n.d.	39 000
1976–79	90 000	52 300	n.d.	2 600	very few	–	14 600	159 500

Source: Adapted from Casséetal (1965) and miscellaneous sources.

In Senegal the active rural population is estimated at under 1.5 million (FAO, 1978), with the number of farms no more than 400,000. Probably about 50% of farmers have taken up animal traction, and around 25% are using groundnut lifters and carts. A Senegalese parastatal known as SISCOMA (Societe industrielle senegalaise de commercialisation du materiel agricole) has been responsible for meeting the domestic demand for this equipment since 1965. The company produces lightweight implements suited to local production, for both export and domestic markets. It has a fairly limited range, geared to all-purpose use and including a seed drill for groundnut, millet and sorghum, and various types of multi-purpose toolbar, both light and heavy. SISCOMA also manufactures lightweight hoes for donkey traction.

The adoption of animal traction has been considerable in Mali, where there are now some 100,000 ploughs and almost as many multi-purpose toolbars. With nearly 500,000 farms in the country, the level of uptake is around 40%. But this average masks considerable regional disparities: adoption has been virtually nil in the more arid zones where only millet is grown and,

in contrast to Senegal, has met with little success in groundnut production areas, being confined mostly to the cotton and rice cropping regions instead. A good example is the Office du Niger area, where 40,000 ha of irrigated rice are grown under a settlement system. Here it was the many difficulties encountered by *colon*s (settlers) in using tractors that led to the adoption of animal traction. Draught animals are also widespread in southern Mali, where CMDT has for many years been instrumental in stimulating cotton cropping with a package of innovations covering not only animal traction for ploughing and weeding, but also crop rotations, fertilizers and insecticides.

Attempts to develop animal traction among the miscellaneous Mossi in Upper Volta, mostly under a project implemented by SATEC (Sociéte d'Aide Technique et de Coopération), have been only moderately successful. Implements in Upper Volta are estimated to number 26,000 multi-purpose toolbars and 20,000 ploughs, only a quarter of the Malian fleet, although the agricultural population is roughly the same and the area cultivated is much higher. Nevertheless, the Government of Upper Volta is anxious to develop animal traction, and two small-scale production plants have been started. Because the soils are light and fragile, the tools used for a long time consisted only of a simple donkey-drawn hoe to scarify the soil before drilling and weeding. The implements now produced are heavier all-purpose types suitable for cattle traction.

After somewhat fruitless trials during the colonial era a programme to promote animal traction was implemented in Benin, with FAO and UNDP assistance. Intended to boost cotton production, it began in the Borgou Subregion in 1963 and was extended to the Atakora from 1969 onwards under an integrated programme for crop diversification. The fleet now numbers some 7,500 ploughs and multi-purpose toolbars of the Arara design marketed by SISCOMA in Senegal, as well as a smaller supply of implements for crop spraying, sowing, spreading and harvesting (cutters and threshers). A domestic manufacturing plant was operated in 1975. The launching of animal traction in Togo, where several small development projects have promoted its use in cotton cropping, took place only recently, but was apparently made easier by earlier difficulties with tractors. The fleet numbers around 2000 Arara multi-purpose toolbars imported from Upper Volta or Benin.

Two southern African countries have also tried to develop animal traction. In Botswana, where draught animals are used by almost all farmers, efforts have focused on developing a multi-purpose toolbar better adapted than the traditional plough to local conditions. In northern Malawi centres have been set up where animals are trained while farmers are taught to use draught equipment. There is a training centre within a radius of 10 miles (16 km) of most farms and 15,000 ox teams have been trained each year (Jellema, 1975).

Impact on farm productivity

Despite this interest in animal traction in several sub-Saharan African countries over the last 10 to 20 years, no recent studies appear to have assessed its impact on farms and overall output. In this section an attempt is made to draw a few conclusions from available information, although much of it is far from up-to-date.

As has been seen, by improving land and labour productivity the introduction of animal traction should in theory lead to increases in the area cultivated and in farm income. The latter should occur in total gross income as well as in cash earnings from greater involvement in cash crops.

West African studies during the 1960's, notably by Cassé et al (1965), give some information about these factors. Surveys of enterprises with and without animal traction showed that the area cultivated is appreciably higher on the former: on average it was twice as high in Senegal and Mali. Results from Upper Volta give a less clear picture, but again the areas cultivated are probably higher (Table 14). However, these surveys do not indicate whether this difference is the direct effect of introducing animal traction, or merely stems from the fact that it is mostly the larger farms that practise traction in any case, either because they feel a greater need or because they have more cash available. In Senegal the percentage of farms using animal traction increased considerably with size of the enterprise, from 17% on farms under 3 ha to 66% on those over 8 ha (Table 15).

Table 14. *Average size of area cultivated on farms with and without animal traction.*

	–in ha.–	
Country/Region	With traction	Without traction
Senegal		
Thies	3.40	1.65
Sine Saloum	8.69	3.40
Boal	7.40	2.85
Average[a]	5.97	2.92
Laghem Oriental[b]		
Darou village:		
Ouolof farmers	14.02	3.54
Bambara farmers	3.95	5.91
Dierry village	6.11	3.93
Hanene village	9.42	3.46
Average	8.88	4.23
Mali		
Haute Vallée	16.80	5.57
Ségou	9.10	5.95
Sikasso	7.85	3.05
Average	11.85	5.41
Upper Volta		
Bobo-Dioulasso area[d]	4.17	6.47
Ouagadougou area[e]	4.68	2.26
Average	4.42	4.37

a. According to an agricultural survey of 1960–61; N = 1517 (1018 without traction, 499 with traction).
b. 1962–63 survey by IRHO (Institut de Recherches pour les Huiles et Oléagineux), using samples in which N = 17, 13, 27 and 39.
c. According to an agricultural survey of 1960–61; N = 417.
d. According to a 1963 agricultural services survey; N = 24 (including 3 farms with ploughs)

e. Gaskay village; N = 12.
Source: Cassé et al (1965).

Table 15. *Use of animal traction according to farm size in three areas of Senegal (1960–65).*

Farm area (ha)	Farms with equipment(%)
0–3	17
3–8	44
8	66

Source: Adapted from Cassé et al (1965).

The impact of animal traction on labour productivity, i.e. on the area cultivated per worker, appears somewhat uneven. From surveys on farms with and without traction it emerged that labour productivity was usually higher on the former. The number of hectares cultivated per worker was 30 to 50% higher on mechanized farms in Senegal and 65% higher in Mali, but emerged as about the same in Upper Volta. In some cases labour productivity was actually lower on mechanized enterprises (Table 16). The figures for Senegal appear open to question: while analysing these data in relation to farm size in three regions of Senegal, Cassé et al (1965) noted that labour productivity on farms with animal traction was only higher than on those without when the area cultivated lay between 3 and 8 ha (Figure 1). On other enterprises, whether under 3 ha or over 8 ha, the area cultivated per worker was roughly the same whether or not the farm possessed animal traction.

Table 16. *Labour productivity on farms with and without animal traction.*

			–in ha/employee–
Country/Region	With traction	Without traction	Ratio with/without%
Senegal			
Thiés	0.91	0.57	160
Sine Saloum	1.37	1.00	137
Boal	1.30	0.94	138
Weighted average	1.34	0.87	154
Laghem Oriental			
Darou village:			
Ouolof farmers	1.77	1.18	150
Bambara farmers	1.80	1.97	91
Dierry village	3.22	3.00	107
Hanene village	1.72	1.15	150
Weighted average	2.24	1.74	129
Mali			
Haute Vallée	1.35	0.80	169

Ségou	1.90	1.26	151
Sikasso	1.12	0.81	138
Weighted average	1.38	0.84	164
Upper Volta			
Bobo-Dioulasso area	0.82	0.92	89
Ouagadougou area	1.09	0.84	130
Weighted average	0.95	0.88	108

Source: Cassé et al (1965).

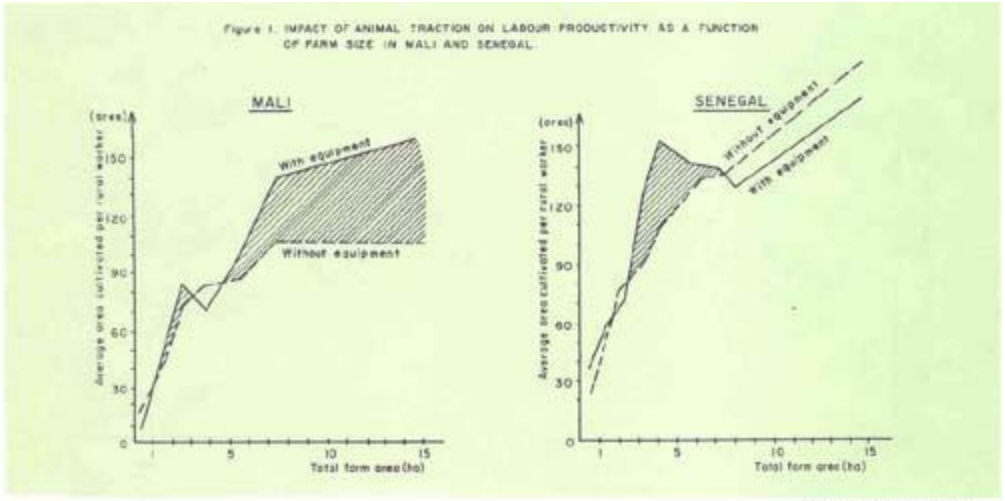
These results are only partially confirmed by those of four surveys during the same period in villages of the Laghem Oriental. On small farms (under 3 ha) in this region of Senegal, the area cultivated per rural worker was substantially higher on enterprises with traction than on those without, although it was about the same on the larger farms (especially those between 3 and 8 ha). Labour productivity in the Laghem Oriental appeared generally higher than in the three regions analysed above (Table 17).

Table 17. *Hectares cultivated per farm worker and net income of farms in Senegal and Upper Volta as a function of their size and equipment.*

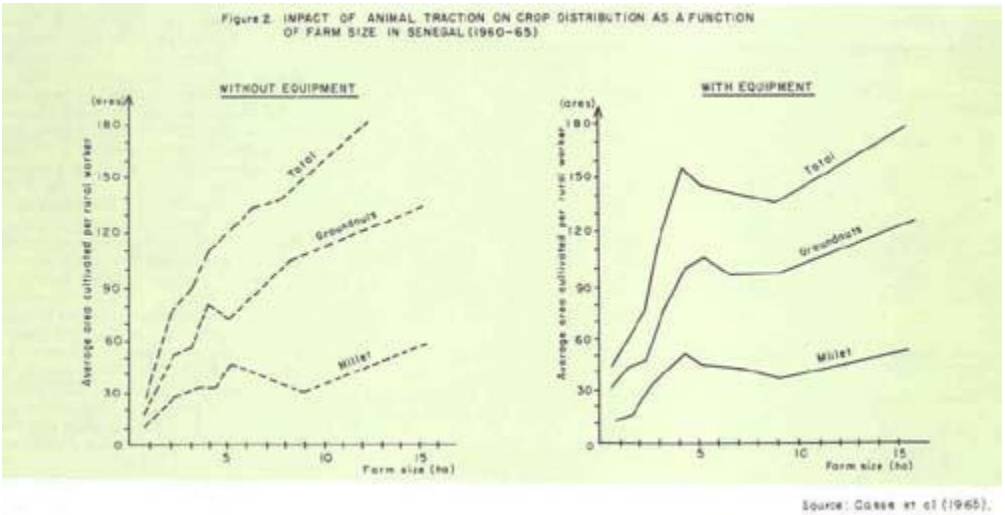
	Senegal (Laghem Oriental)				Upper Volta
	< 3 ha	3–8 ha	> 8 ha	Average	
Size (*ha*)					
With equipment	2.20	5.10	14.87	10.85	7.1
Without equipment	2.03	4.52	10.29	4.05	5.3
Ha cultivated worker					
With equipment	1.38	1.80	2.07	1.95	0.82
Without equipment	0.91	1.78	2.06	1.35	0.92
Net income (*CFA francs*) per ha					
With equipment	19 593	20 699	20 101	20 210	6 806
Without equipment	19 067	17 990	13 6185[a]	17 640	7 177
Per employee					
With equipment	26 940	37 228	41 572	39 570	7 095
Without equipment	17 357	32 015	28 164[a]	27 636	6 633

a. Results not significant, 2 farms only.
Source: Cassé et al (1965).

A different picture emerges in Mali. According to surveys of the early 1960s in three regions (Haute Vallée, Sikasso and Segou) the use of animals for ploughing, unlike in Senegal, boosted labour productivity appreciably when farm area was over 5 ha. The difference increased with size of enterprise, such that when the area cultivated was over 8 ha labour productivity continued to rise on farms with traction, but fell on those without (Figure 1).



The differences in labour productivity are partly explained by differences in the distribution of the area cultivated to subsistence and cash crops. In Senegal the share of land given over to groundnuts averaged 64% on farms without traction and 69% on those with it. However, this difference, found in all the country's regions, is not significant: whether farms have traction or not, the share of land devoted to groundnuts does not seem to vary with the size of the enterprise (Figure 2).



In Mali, on the other hand, where the proportion of land assigned to cash crops in the early 1960s was under 10% on non-mechanized farms and around one third on those with traction, mechanization has had a marked impact on crop distribution. This impact has three components (Figure 3): increased labour productivity affects first food crops (from 4 up to 7 ha), then cash and food crops together (from 7 to 8 ha), and finally cash crops alone (over 8 ha), with the share of food crops in overall area cultivated tending to fall.

This brief comparison thus suggests that the impact of traction on labour productivity differs radically .according to the environment where it is introduced, and that the anticipated sequence of events—improved labour productivity followed by increased area cultivated and altered crop

distribution—may not unfold as expected. However, these piecemeal results should be seen in their proper context and the impact of traction on farm profits should be analysed before their true significance can be assessed.

Impact on farm income

On the basis of estimates by Cassé et al an attempt has been made to analyse and compare the financial results (per hectare or per worker) achieved by enterprises with and without traction in the Laghem Oriental and Upper Volta. The farms were grouped in three categories (under 3 ha, 3 to 8 ha and over 8 ha) so as to avoid any bias arising from the possibility that farm size itself might influence per capita earnings and labour productivity.

In Laghem Oriental net income per hectare on enterprises with traction was 15% higher than on those without, whereas net earnings per rural worker were higher by 43% (Table 17). On farms under 3 ha, however, there was no difference between average incomes per hectare on the two categories of enterprise, suggesting that in this group land productivity does not improve when animal traction is introduced. On the other hand, in the same group earnings per rural worker on farms with traction were 50% higher than on those without. A tentative conclusion might be that, although it did not improve yields, the introduction of better designed implements led farmers either to increase the area cultivated or reduce the number of farm workers to cultivate the same area.

On farms over 3 ha, income per hectare and per worker both appear fairly high for enterprises with traction. They were 15% higher in the 3 to 8 ha farm group and much higher still on farms over 8 ha. There are several reasons for these increased incomes. First, in addition to improving labour productivity, farmers using traction were able to increase their area cultivated, and this resulted in a higher number of hectares cultivated per worker. Secondly, they were able to improve yields by using their land more intensively, reflected in simultaneous increases in profits per hectare and per worker, while power inputs rose owing to the use of better equipment. Thirdly, they may have been able to improve yields by combining more intensive land use with an expansion of the area cultivated.

Assuming that the conclusions reached above can be extrapolated, a substantial rise in earnings caused by animal traction must also have occurred on the farms surveyed in Mali. As has been seen, in this country the area cultivated per rural worker tends to be higher on enterprises using ploughs. The data from Senegal show a correlation between earnings per worker and labour productivity, and a rise in earnings per worker triggered by improved labour productivity which is significantly higher on enterprises with traction than on those without. Given equal size, mechanized enterprises in Mali must therefore also have experienced higher earnings per rural worker than nonmechanized.

The results from Upper Volta are less favourable, since income per hectare appeared lower on farms using donkey-drawn hoes, while earnings per worker were only very slightly higher. Similar results were observed by Morel (1966) in the Central African Republic, but in a region where the area cultivated per family was only about 1 ha. According to this survey, the increase in gross farm earnings on partially mechanized enterprises was just enough to cover the extra costs, so that family income did not improve.

The information gathered by Cassé et al in Laghem Oriental also distinguished farms using only a seed drill from those using a UCA[9] or a seed drill plus hoe, so that the effects of degree of

mechanization on farms could be studied in greater detail. Generally speaking income lay closely in line with the previously observed pattern on farms using only a seed drill (Table 18). On the other hand, earnings per worker and even per hectare on the more highly mechanized enterprises (UCA or seed drill plus hoe) were lower than on farms using only a seed drill[10]. It would seem that intensive mechanization does not improve farm income since it allows neither labour productivity nor yields per hectare to improve: the number of hectares cultivated per worker falls, while profits per hectare stagnate. In other words, the available evidence suggests that farmers only know how to take real advantage of implements that relieve their major cultivation bottlenecks—for example, sowing the groundnut crop in Senegal. When farmers own more sophisticated and expensive implements they underuse them and fail to allow for depreciation. The surveys indicate that hoes and other UCA-adapted components, apart from seed drills and ploughs[11], were frequently underused: either they were not used at all because of inadequate know-how on the part of the farmer or disrepair, or else the areas covered were inadequate to make such expensive implements economically viable (Cassé et al, 1965).

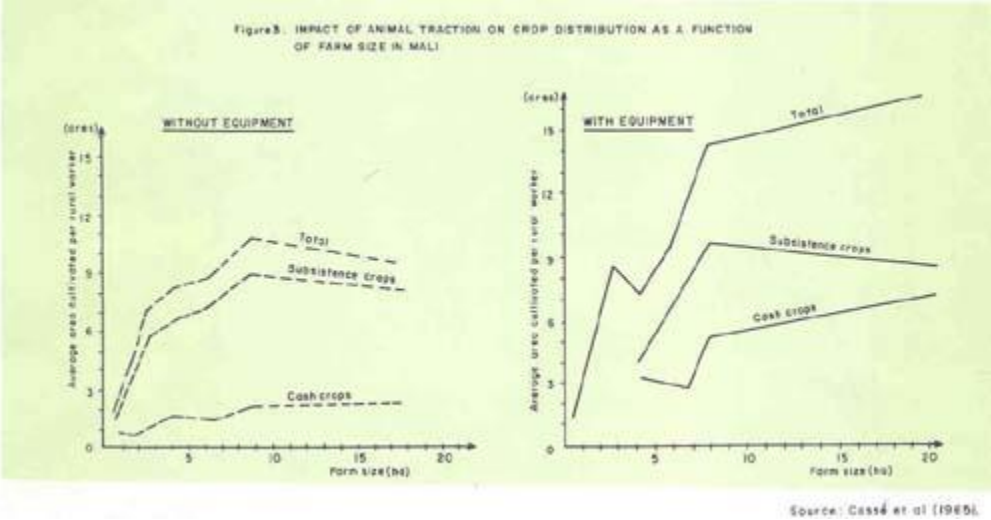
9. Unité de culture attelée: a West African cattle traction unit comprising seed drill, hoe, lifter and cart.
10. Similar results were observed during a survey at about the same time on farms managed by SEMA (Secteur Experimental de Modernisation Agricole) in Boulel, also using various kinds of animal traction equipment.
11. Mostly groundnut diggers and muck spreaders.

Table 18. *Impact of degree of mechanization on farm income in Laghem Oriental, Senegal (1960–65).*

			–in CFA francs–
	Without equipment	With seed drill	With UCA[c] or seed drill and hoe
Farms under 3 ha			
Ha cultivated/worker	0.91	1.34	1.00
Income/ha	19 067	18 750	21 776
Income/worker	17 357	25 032	21 776
Farms of 3–8 ha			
Ha cultivated/worker	1.78	1.66	2.12[b]
Income/ha	17 990	22 100	11 234[b]
Income/worker	32 015	35 400	24 220[b]
Farm over 8 ha			
Ha cultivated/worker	2.06	2.19	1.87
Income/ha	13 685[a]	20 235	19 835
Income/worker	28 164[a]	44 343	37 134

a. Not significant.
b. Results probably insignificant; data on farm profits are few and far between, and appear incompatible with the other estimates of income per ha and per employee.
c. Unité de culture attelée: a West African cattle traction unit comprising seed drill, hoe, lifter and

cart.
Source: Adapted from Cassé et al (1965).



These findings are not an isolated occurrence. Rather, they are confirmed by much of the information collected on the use of draught equipment. As noted while reviewing the constraints on the development of animal traction, weeding in both West and eastern Africa, which is the second most troublesome bottleneck for most enterprises, is still normally carried out by hand even on farms with draught. In many cases this is because the available equipment is not suited to weeding. But the Senegalese surveys clearly demonstrate that even when proper implements are made available through distribution and credit services, the farmers themselves still have to be taught how to use them properly.

However, the long-term aim of animal traction is not merely to remove labour bottlenecks but rather to promote a much-needed transformation of traditional production systems by harnessing local resources. In line with past experience in today's developed countries, where mixed agricultural systems were gradually intensified by the phased introduction of innovations, crop and livestock production on mixed smallholdings in Africa should in future become more closely integrated in a process of mutual improvement, whereby the development of each component benefits the other as well as raising farmers' incomes and the overall output of food products. The severe socio economic constraints impinging on the adoption and use of animal traction demonstrate that this task will be a long and arduous one, involving a profound change in farmers' attitudes.

Macro-economic impact

A further lesson to be drawn from African experience concerns the focus of development strategies. As has been seen, animal traction in West and central Africa has been geared to cash crops. This approach is vindicated by economic analysis. It finds further confirmation in the failure of attempts by SATEC in Upper Volta to use animal traction in traditional food crop development in a poor area with relatively low and erratic rainfall. As de Wilde (1967) noted, the experience demonstrates the risks of launching an expensive large-scale animal traction

programme with extension services in areas where it has not been proved that higher incomes will offset the incremental cash costs while still leaving farmers with enough profit to serve as an incentive.

Cash crops nevertheless have their limitations, in that in sub-Saharan Africa they are usually for export and must therefore find outlets on external markets. Senegal, where groundnut monoculture is well established, provides a typical example of the problems of developing animal traction under such conditions. Although from the farmer's point of view the advantages of animal traction rapidly became evident, leading to increases in net income per worker and per hectare, the Senegalese agricultural sector today seems one of the most vulnerable in Africa. Admittedly its two traditional crops, millet and groundnuts, fluctuated sharply with rainfall over the period 1967–79, but even discounting these incidental variations output rose very little, with zero growth recorded for millet over the period under review (Table 19). Despite the high potential for rice production in the south (Casamance), Senegal is at present one of the largest cereal importers in Africa. In 1976–78, food imports were equivalent to 58% of foreign exchange earnings from agricultural exports—mostly groundnuts and groundnut oil. Fifteen years earlier, in the early 1960s, the situation was approximately the same (Table 20).

Table 19. *Agricultural output growth in Senegal and Mali (1967–79).*

	Average annual growth rate
Senegal	
Millet	0.0
Groundnuts	0.02
Mali	
Millet	0.0
Rice	0.049
Cotton	0.102

a. Estimated by semi-logarithmic regression.
Source: FAO (1971–79b).

Table 20. *Trends of external trade in agricultural products in Senegal and Mali (1963–1976).*

	Food imports[a]	Agricultural exports[b]	I:E ratio (%)
Senegal			
1963	58	100	58
1976	177	307	58
1976/63 (%)	305	307	–
Mali			
1963	9.5	10.2[b]	93
1976	38.0	81.0°	47
1976/63 (%)	400	794	–

a. In millions of US$.
b. In millions of US$; excluding unofficial exports of livestock on the hoof.
Source: FAO (1965) and FAO (1978).

Two factors lie behind this unfavourable trend. First, the decline of a major outlet for groundnuts meant that the Senegalese farmer suffered severe competition on the international market—mostly from the USA, which entered the soya market. Secondly, as the income elasticity of demand for millet and sorghum is almost zero in African countries, any increase in output is difficult to dispose of on the market. The food deficit urban areas prefer the more refined types of cereal, such as rice and wheat. A further factor might be the fragile ecosystems of the semi-arid zones, where over-intensive land use at the expense of soil recovery through fallow periods and manure application leads to its impoverishment more quickly than elsewhere. Animal traction promotion in these environments must therefore take special account of ecological imperatives. Against this background the pace of change in Senegal was probably too fast, given the additional social constraints on the transformation of production systems.

In contrast, the Malian example appears much more encouraging. As in Senegal, the traditional crops, millet and sorghum, seem to have progressed very little over the last few years and Mali, lying mostly in the semi-arid Sahel zone, experienced serious trade deficits in food products during the drought. Nevertheless, Mali has a considerable potential for increasing agricultural output, possessing important assets in the inner Niger Delta and the southernmost part of the country, which lies in the subhumid zone. Animal traction has been geared to two crops, cotton in the south and rice in the delta area, while efforts devoted to groundnuts have been much more modest.

These two crops are the ones for which output seems to have increased most rapidly. The development of cotton production has been spectacular: it has risen nearly six-fold in about 15 years as a result of increases in the area cultivated (up 200%) and in yields, which have moved from 610 kg/ha in the early 1960s to 1180 kg/ha in 1977/78. Progress of this kind illustrates the advantages of introducing animal traction in a package of innovations to modernize a whole production system. Despite a policy of pegging cereal prices at levels that discourage the Malian peasant and curb investment, the promotion of animal traction in this case may be considered a successful means of improving the efficiency of a production system tied to a crop for which demand is continually rising. Partly as a result of success in these two fields the food balance of Mali has improved. In 1976–78, the cost of food imports accounted for 47% of export earnings from agricultural and food products, whereas in the early 1960s almost all export earnings from agricultural products were used for food imports (Table 20).

Although animal traction has great potential in ecologically suitable areas with sufficient animals, the opportunities for development depend on eliminating many interconnected constraints linked with the traditional nature of the agricultural smallholding. These constraints, frequently accompanied by a marked prejudice against a technology labeled old-fashioned, have undoubtedly curbed its development in the past.

The true extent of its progress is masked by inadequate information, but many indicators nevertheless show that animal traction is gradually making inroads into a number of areas of Africa. Enough has already been learned to indicate that the practice could bring real benefits to African crop and livestock production.

References

Adelheim, R. and Schmidt, H. 1975. Economic aspects of ox-cultivation. In *Proceedings of a workshop on farm equipment innovations for agricultural development and rural industrialization.*Occasional Paper 16, Nairobi, Institute for Development Studies, pp. 104–168.

Alexander, E. 1975. Increasing the efficiency of the traditional system of ox-cultivation. In *Proceedings of a workshop on farm equipment innovations for agricultural development and rural industrialization.* Occasional Paper 16, Nairobi, Institute for Development Studies, pp. 169–176.

Boshoff, W.H. and Minto, S.D. 1975. Energy requirements and labour bottlenecks and their influence on the choice of improved equipment. In *Proceedings of a workshop on farm equipment innovations for agricultural development and rural industrialization. Oc*casional Paper 16, Nairobi, Institute for Development Studies, pp. 195–199.

Boulanger, C. 1972. La fabrication du matériel de culture attelée en Afrique tropicale. *Mach. Agric. Trop.* 39: pp. 43–49

Boyd, J.E.L. and Ayok, E.A. 1974. *Report on farm equipment development project, Daudawa, N.C.S. Nigeria, November 1971–December 1973.* London, Intermediate Technology Development Group.

Cassé, M., Dumas and Garin, 1965. *Bilan des expériences de culture en Afrique occidentale d'*expression f*rançaise, Guniée exeeptée.* Vols 1, 2 and 3. Paris, Ministere de la Coopération.

CEEMAT (Centre d'Etudes et d'Experiméntation du Machinisme Agricole Tropical) 1975. *Manuel de culture avec traction animale.* Paris, Ministére de la Coopération.

De Montgolfier-Kouévi, C. and Vlavonou, A. 1981. Trends and prospects for livestock and crop production in tropical Africa. Working document 5, Addis Ababa, ILCA.

De Wilde, J.C. 1967. *Experiences with agricultural development in tropical Africa.* Vols 1 and 2. Baltimore (Maryland), John Hopkins Press.

Dicko, M.S., Lambourne, L.J., De Leeuw, P.N. and De Haan, C. 1981. Voluntary intake and livestock productivity. Paper presented at the 32nd annual meeting of the European Association for Animal Production, Zagreb, 31 August–3 September 1981.

Dronne, M. 1969. Problémes humains du développement de 1'elevage en zone sud du Tchad. In *Colloque sur l'élevage,* Fort Lamy (Chad), 13–18 December 1969. Maisons-Alfort, IEMVT (Institut d'Elevage et de Médecine Vetérinaire des pays Tropicaux).

FAO (Food and Agriculture Organization) 1965, 1978. *Trade yearbooks.* Rome.

FAO (Food and Agriculture Organization) 1971–79b. *Production yearbooks.* Rome.

FAO (Food and Agriculture Organization) 1979a. Preliminary papers for *Agriculture: Towards 2000* Rome.

Goe, M.R. and McDowell, R.E. 1980.

Animal traction: Guidelines for utilization. Cornell International Agriculture Mimeograph 81, Ithaca (New York), Cornell University.

Hamon, R. 1971. Quelques résultats obtenus en matiére d'intégration élevage agriculture par le CNRA – Bambey. *Mach. Agric. Trop.* 36: pp. 34–43.

Heyer, J. 1975. A preliminary report on farm surveys: Tractor and ox-cultivation in Makueni and Bungoma. In *Proceedings of a workshop on farm equipment innovations for agricultural development and rural industrialisation.* Occasional Paper 16, Nairobi, Institute for Development Studies, pp. 68–89.

ILCA 1980. *ILCA***:** *The first years.* Addis Ababa.

Jahnke, H. 1980. An analysis of development prospects within the livestock production systems of tropical Africa. Draft working paper, Addis Ababa, ILCA.

Jellema, K. 1975. Report on cultivation practices in Malawi. In *Proceedings of a workshop on farm equipment innovations for agricultural development and rural industrialisation.* Occasional Paper 16, Nairobi, Institute for Development Studies, p. 22.

Kline, C.K., Green, D.A.G. and Donahue, R.L. 1969. *Agricultural mechanization in equatorial Africa.* Research Report 6, Institute of International Agriculture, East Lansing, Michigan State University.

Le Moigne, J. 1980. Culture attelée en Afrique francophone. In *Proceedings of the international workshop on socio-economic constraints to the development of semi-arid tropical agriculture,*Hyderabad, 19–23 February 1979. ICRISAT (International Crops Research Institute for the Semi-Arid Tropics).

McCown, R., Haaland, G. and de Haan, C. 1979. The interaction between cultivation and livestock production in semi-arid Africa. In *agriculture in semi-arid environments.* Ecological Studies 34, Berlin, Springer-Verlag.

Ministére de la Coopération. 1974. *Memento de 1'agronome: Techniques rurales en Afrique.* Paris.

Monnier, J. 1965. Contribution á l'etude de la traction animale au Sénégal. *Mach. Agric. Trop.* 10: pp. 3–25; 11: pp. 15–27.

Morel, R. 1966. Une methode de developpement rural: La traction animale dans la prefecture de Ouaka (République Centrafricaine). *Mach. Agrie. Trop.* 13: pp. 3–27.

Muchiri, G. and Johnston, *B.F.* 1975. Equipment and tillage innovations for Kenya's medium potential (semi-arid) farming region. In *Proceedings of a workshop on farm equipment innovations for agricultural development and rural industrialisation. Occasional Paper* 16, Nairobi, Institute *for* Development Studies, pp. 200–214.

Uzureau, C. 1974. Animal draught in West Africa. Offprint from *World crops* (May/June, 1974): pp. 112–114.

Von Rotenham, D. 1968. Cotton farming in Sukumaland. In *Smallholder farming and smallholder development in Tanzania,* ed. Ruthenberg, H. Afrika-Studien 24, Munich, Ifo-Institut für Wirtschaftsforschung.

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