Animal traction in improved farming systems for the semi-arid tropics: the ICRISAT experience in India and West Africa

by

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Abstract

In the semi-arid tropics (SAT), power availability is an important constraint to crop production. Limited available power coupled with the seasonal nature of crop production can lead to severe labour bottlenecks. Uncertain rainfall and high evaporative demand dictate the timing of cultural operations. The capability for timely weeding is considered to be the principal factor limiting the area cultivated.

Improved technologies combine biological and chemical elements (such as improved varieties, crop rotations, fertilizers, plant protection and improved residue management) with elements of mechanization such as the use of animal traction (AT). The use of AT without other intensified production practices will not have an appreciable impact on productivity. Yield-increasing synergistic effects are greatest when other improved management techniques are used with a high-yield-potential variety and adequate fertility. If cropping patterns cannot be intensified, increasing population pressures will result in the use of more marginal lands.

The use of AT in the SAT is largely confined to tillage, weeding, planting and land-levelling operations. Single purpose implements are common. Multipurpose toolbars are not well known. A distinction is made between toolbars with depth gauge wheels or skids and wheeled toolcarriers (WTC). With a WTC the working depth, weight transfer, and rake angle can be precisely regulated.

AT is commonly used in India. Current AT research at the ICRISAT Centre focuses on improving the quality and timeliness of farm operations. A "technological package" for Vertisols has been developed based upon an improved soil and water management. AT and the WTC play an important role. WTCs reduced the total oxen-pair hours per hectare by 18-54%. The greatest savings occurred in tillage and sowing operations.

ICRISAT's experience in West Africa is limited to on-station research using simple AT equipment. A multidisciplinary team is evaluating AT in operational-scale on-station experiments. WTCs have been integrated into the research farm operations.

Research on AT needs to be conducted at several levels of technological sophistication relevant to the diverse enterprises and ecologies within the region. AT is relatively inexpensive, not too complicated, and can help increase productivity. The information base necessary to fully exploit AT use needs to be developed and disseminated.

Introduction

In the semi-arid tropics (SAT) the power available at the farm level is an important factor limiting crop production. Giles (1975) estimates that in India there is 0.16 kW of available power per hectare. Of this, 67% is provided by human labour and 26% by draft animals. In Africa the available power is 0.08 kW

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per hectare. The figure is probably lower in much of the West African SAT where farmers working with simple hand tools carry out all farming operations. Giles (1975) suggests that a minimum of 0.37 kW per hectare is required for high yields.

The limited power available to SAT farmers coupled with the highly seasonal nature of crop production often leads to severe labour bottlenecks. Unpredictable and uncertain rainfall dictates the timing of land preparation, planting, and weeding. High evaporative demand shortens the time available to perform those operations. As conditions become less favourable the quality of the operations is reduced. This may negatively affect plant stands, early growth, and yield. The farmers' inability to effectively use the limited available time increases the instability of rainfed agricultural production in the SAT. Although there are traditional strategies to increase the efficiency of tasks accomplished in the limited time that is available, such as mixed cropping and delayed planting of cash crops, the capability to weed in a timely fashion is generally considered to be the principal factor limiting the area farmers cultivate. Timely land preparation and planting are serious constraints (Norman *et al.*, 1981).

Improved technologies generally combine land-intensive biological and chemical elements such as improved varieties, crop rotations that include a legume, chemical fertilizer, plant protection, seed treatment, and improved residue management with elements of mechanization such as the use of animal traction (AT) and equipment. The improved labour efficiency that results from the use of AT can lead to a more land-extensive cropping strategy (McIntire, 1982). None the less Norman *et al.* (1981) concluded that intensifying land use patterns may be desirable and indeed necessary for many regions in West Africa. It is felt that, if cropping patterns cannot be intensified, increasing population pressures will result in the use of more marginal lands.

The approach of ICRISAT's Farming Systems Research Program in India has been to choose a balanced mixture of improved cropping techniques to intensify crop production on land presently under production. As a result, the animal traction component emphasizes the adaptation, improvement, and effective use of AT equipment and techniques in improved, intensified, soil and crop management systems.

In West Africa there is scope for cropping strategies that are more intensive and/or extensive; both aspects will receive attention. Whether extensive or intensive the ultimate goal is improving the productivity of farmers in the SAT. This paper will examine the use of AT for soil and crop management operations, its possible impact on farming systems, and ICRISAT's Indian and West African experiences.

Animal traction equipment

Historically, a wide range of AT implements and techniques have been used to mechanize many facets of crop production. The on-farm use of AT in developing countries is largely confined to tillage operations, weeding, planting and land levelling. Single-purpose implements such as mouldboard plows, tined cultivators, harrows, and carts are common. In West Africa, it is principally used for primary tillage and transportation. The use of carts and mouldboard plows is more widespread than other kinds of equipment. Single-row precision seeders are used for cash crops. This is sometimes combined with fertilizer application. Groundnut-lifting blades are often used to facilitate harvesting.

Multipurpose frames to which a variety of implements can be attached are less well known. There are two basic types. A distinction is made between multiple toolbars that have one or more depth gauge wheels or skids and may be used for most tillage and weeding operations, and the bigger, more sophisticated and versatile, wheeled toolcarrier (WTC). It can be used for the full range of cropping activities. It

Table 1. Average grain yield of pearl millet and sorghum crops from steps-in-technology experiments, ICRISAT Centre 1976-79

Treatments	Seed variety	Fertilizer	Management	Pearl millet (kg ha^{-1})	Yield increase over treatment No. 1 (%)	Sorghum (kg ha^{-1})	Yield increase over treatment No. 1 (%)
1.	Local	FYM	Traditional	590		410	-
2.	HYV	FYM	Traditional	980	166	880	215
3.	Local	Recommended	Traditional	990	168	1000	244
4.	HYV	Recommended	Traditional	1420	241	2360	576
5.	Local	FYM	Improved	570		520	127
6.	HYV	Recommended	Improved	2010	341	3470	846
S.E.				+/-35		+/-120	

Notes:

FYM: Farmyard manure 10 tonnes ha^{-1} applied in alternate years.

HYV: High yielding variety.

Recommended Fertilizer applied at 80 kg of N and 34 kg P2O5 ha^{-1}.

Traditional: Use of traditional methods of soil management, agronomy and implements.

Improved: Cultivation on broad bed and furrows, use of a WTC and recommended agronomic practices.

Source: Gilliver (1981)

is possible to adjust the working depth, weight transfer, and rake angle very precisely. As much as 1.5 m can be covered in one pass. As a result, it is capable of delivering timely and high quality work. In addition, most WTCs can be converted into a cart. This is an important option because it increases the opportunities for non-crop-related work and income-earning activities (Binswanger *et al.*, 1979).

On-station farming systems research

ICRISAT's mandate is to develop farming systems that will help increase and stabilize agricultural production through the more effective use of natural and human resources in the seasonally dry SAT. Research activities are carried out in two phases: disciplinary research on production factors, and interdisciplinary operational-scale research. The latter integrates promising techniques into improved systems that are applied to large enough areas to "simulate" their on-farm use.

AT has been an important feature of improved systems at both the ICRISAT Centre in India and the ICRISAT Sahelian Centre in Niger. Data is taken on water use, crop growth and yield, pest incidence, labour use, runoff and erosion. The economic implications of this data are thoroughly evaluated. Finally the best combinations are tested on farm. Information from this stage is fed back into the factor and operational-scale research activities for appropriate refinement.

The importance of a balanced and complete set of crop materials and techniques in an improved production system should be stressed. This point is well illustrated in the "steps in technology" experiments conducted on Alfisols and Vertisols at ICRISAT Centre from 1976 to 1979 (ICRISAT Annual Report 1981, pages 218-219; Gilliver, 1981). In these experiments variety, fertilizer, soil and crop management options were compared in different combinations (see Table 1). The use of local varieties with the application of about 10 tonnes ha^{-1} of farmyard manure every second year was considered to be a reasonable approximation of farmer practices. Average grain yields for pearl millet of 590 kg ha^{-1} and for sorghum of 410 kg ha^{-1} from an Alfisol were obtained. Changing a single factor such as the use of a high-yielding variety (HYV) or chemical fertilizers increased pearl millet grain yield by 166-168% and sorghum by 215-244%. The use of both an improved variety and chemical fertilizer increased pearl millet yields by 341% to 1420 kg ha^{-1} and sorghum yield by 576% to 2360 kg ha^{-1}.

The synergistic effects of the combined treatments were greatest when improved management techniques were used. In this case the improved management techniques included: minimal land shaping and tillage to ensure drainage and minimize erosion, the use of an animal-drawn WTC, sowing and fertilizing early in the rainy season, and timely inter-row cultivation to ensure adequate weed control. Pearl millet yielded 2010 kg ha^{-1}, an increase of 341% from the low input farmers' system, and sorghum yielded 3470 kg ha^{-1}, an increase of 846%. Improved management without a HYV or fertilizer use had virtually no effect on crop yields.

The Indian experience

In India draft animals are widely used in agriculture and for transport. At present over 80 million draft animals (Ramaswamy, 1982) and 0.7 million tractors are used to cultivate approximately 143 million hectares. Farmers primarily use oxen with a wide variety of traditional equipment for land preparation, sowing and inter-row cultivation. Oxen are commonly used for land-development activities such as field levelling, constructing anti-erosion bunds, and field drains. Traditional equipment is varied and effective (ICAR, 1960).

Most crop residues are harvested for animal feed. The transport and sale of crop residues are an important source of income for farmers. Veterinary services are reasonably good in India. This is not the case in much of SAT West Africa where livestock health problems, such as trypanosomiasis, are more serious.

Current research on animal-traction equipment at the ICRISAT Centre is focused on improving the quality and timeliness of farm operations. This involves adapting equipment, a need that became evident from experiences in the soil and water management research activities, related agronomic and other disciplinary research, constraints observed in the operational scale research program, on-farm testing, and collaborative research activities carried out with other institutions. Local, private sector manufacturers have also been involved in prototype design, manufacturing, and testing.

In the past decade, a successful "technological package" for Vertisols has been developed based upon an improved soil and water management system. It employs the use of a zonal minimum-tillage system to construct and maintain a broad bed and furrows (BBF), with 150 cm spacing. The WTC has been used to overcome the problems of working these soils that are sticky when wet and hard when dry. The package permitted the use of these soils in the rainy season and, in certain cases, for double cropping. Traditionally only a dry season crop was grown on residual moisture. There are large areas of Vertisols in SAT India, Sudan, Ethiopia and to a smaller extent in sub-Saharan Africa, where this technology has potential (Swindale, 1981).

The WTC concept originated in Britain and France almost simultaneously in the early 1960s. A multipurpose WTC developed by the National Institute of Agricultural Engineering, U.K., was tested in Nigeria and Tanzania (Kline *et al.*, 1969). Mr. Jean Nolle, working at Bambey, Senegal, designed the "Polyculteur" and "Tropiculteur" that were tested and extended to farmers in Senegal. They were not widely adopted due to their relatively high cost and, in the case of the Polyculteur, design flaws in the toolbar lift mechanism. With some minor modifications both of these WTCs proved to be extremely versatile at the ICRISAT Centre. When other relevant agronomic and varietal factors were improved they effectively accomplished all cropping operations improving both yields and worker efficiency.

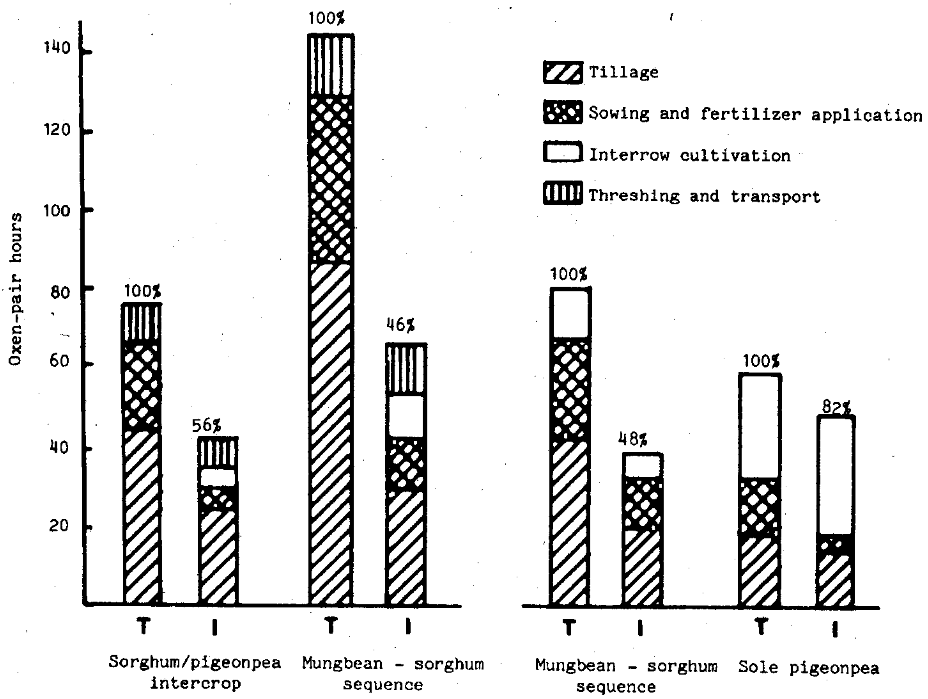

Figure 1. Oxen pair hours required using traditional (T) and improved (I) management

Early emphasis was put on the Tropicultor. It provided adequate versatility, flexibility, and stability for the mechanization of a variety of multiple cropping systems. It was particularly effective as a crop management tool on 150 cm raised beds. Sowing and fertilizer application equipment was developed for faster and more precise seed and fertilizer placement. Metering of seed and fertilizer was also improved.

After the successful experiences at the ICRISAT Centre with the Tropicultor, another WTC and equipment package using the "Nikart" WTC was developed in collaboration with the National Institute of Agricultural Engineering, U.K. The Nikart is lighter, easier to fabricate, and less expensive than the Tropicultor. It features superior weight transfer characteristics, as well as better toolbar lifting and working depth adjustment mechanisms, and it is suited to manufacture by small industries in developing countries.

At the ICRISAT Centre animal-drawn WTCs have been successfully integrated in improved farming systems developed for the management of Vertisols. In the Indian SAT on-farm verification has been carried out in different regions. Data from two villages, Taddanpally in Andhra Pradesh state and Farhatabad in Karnataka state, illustrates the role of improved farm equipment in a new system of farming. Taddanpally is located about 40 km northwest of the ICRISAT Centre and has an annual mean rainfall of 750 mm. It is representative of areas with relatively reliable rainfall. Farhatabad is about 250 km southwest of the ICRISAT Centre and has a mean annual rainfall of 727 mm. There is a higher risk of mid-season drought and crop damage or loss during the rainy season at this site. In both villages farming depends entirely on draft oxen and human labour. The improved farming systems tested at these locations combined the use of HYVs for sorghum, pigeon pea, and mung bean with fertilizers, BBF cultivation, and the use of WTCs.

The oxen-pair hours required per hectare are summarized in Fig. 1. To facilitate comparison between the traditional and improved management systems, primary tillage and seedbed preparation are grouped under "tillage". In the traditional management system, manure application, sowing, and seed covering are grouped under sowing and fertilizer application.

The WTC reduced the total oxen-pair hours required per hectare by 18-54% depending on cropping system and location. The greatest time savings occurred in the tillage and sowing operations. The WTC covers an effective width of 1.5 m with each pass whereas a country plow covers only 15 cm and most other traditional implements cover 60-75 cm. The 50-75% savings in the time required for sowing operations are particularly important. The availability of good planting conditions is often limited in the SAT due to the erratic nature of early season rainfall. The WTC can be fitted to sow and fertilize simultaneously. Traditionally sowing involves two operations, one for placing the seed and the other for covering it and firming the seedbed. Accurate and timely seed and fertilizer placement with the WTC substantially contributes to improved crop stands, early growth and yields.

It has been shown at the ICRISAT Centre that with one pair of oxen and traditional equipment it is possible to double-crop only 4-7 ha while a WTC has been used to effectively farm 12-15 ha (Ryan and Sarin, 1981). It is not the source of power, but rather the use of improved soil management systems and equipment that is important for the intensification of AT based farming systems.

Work patterns and productivity were also affected by the use of the WTC-based improved management system (Ghodake and Kshirsagar, 1983), but the total labour requirements were not (Table 2). In Taddanpally, where double cropping is practised, the use of a WTC led to substantial labour savings for field operations, but higher yields increased the labour requirements for harvesting and threshing. In Farhatabad, tillage and weeding operations with the improved system required slightly more labour than the traditional system. The additional labour was largely provided by women who removed the pigeon pea stubble from the fields to facilitate sowing. The women's labour contribution increased by 12% at Taddanpally and by 22% at Farhatabad. Labour productivity was defined as the grain yield per person-hour. The use of improved animal-drawn equipment, high yielding varieties, and fertilizer increased labour productivity from 1.71 to 2.97 kg person-hr^{-1} ha^{-1} at Taddanpally

Table 2. Average human labour utilization for farm operations in selected cropping systems at two locations of on-farm testing in India during 1982-83

	Taddanpally		Farhatabad	
	Traditional hour ha^{-1}	Improved hour ha^{-1}	Traditional hour ha^{-1}	Improved hour ha^{-1}
Tillage and seedbed preparation	80	46	64 (42)	72 (76)
Sowing and fertilizer application	55	14	34 (37)	16 (33)
Inter-row cultivation	240 (86)	196 (90)	179 (80)	219 (91)
Plant protection		22	28	29
Harvesting and threshing	315 (59)	405 (77)	276 (62)	270 (92)
	690 (60)	683 (72)	571 (61)	606 (83)

Figures in brackets show female labour expressed as a percentage of the total.

Table 3. Grain yield (kg ha^{-1}) for selected cropping systems and labour productivity in two villages in India, 1982-83

	Taddanpally		Farhatabad	
	Traditional	Improved	Traditional	Improved
Sorghum	980	1953		
Pigeon pea (intercrop)	189	696		
Mung bean	786	802	341	541
Sorghum (seq. crop)	409	612	1248	1456
Pigeon pea (sole crop)		729	1350	
Average grain yield	1182	2031	1159	1673
Yield man-hour^{-1}	1.7	2.97	2.03	2.76

and from 2.03 to 2.76 kg person-hr^{-1} ha^{-1} at Farhatabad.

Although ICRISAT is not actively doing so, the quality of the power source, the oxen, could be improved through appropriate breeding. It is possible that the number of animals necessary for AT activities could be reduced if higher quality cattle were available.

Table 4. Labour and animal traction utilization for cropping operations during operational-scale research experiment, ICRISAT Sahelian Centre, rainy season 1986

Operation	Hand cultivation (person-hr ha^{-1})	Animal traction* (person-hrs ha-^{1})	SE
RIDGING	-	12.8	+/- 1.2
PLANTING: Traditional			
Millet/cowpea	33.3	28.7	0
PLANTING: *Improved*			
Millet	21.5	21.5	0
Cowpea	64	64	0
Millet/cowpea	26	26	0
WEEDING (1st)**			
Millet/cowpea	103.0	26.7	+/- 6.38
Millet	106.0	28.9	+/- 5.04
Cowpea	158.2	75.4	+/- 4.32
WEEDING (2nd)**			
Millet/cowpea	54.8	33.8	+/- 4.36
Millet	45.0	34.4	+/- 5.62
Cowpea	35.8	39.6	+/- 4.47

Notes

* Weeding data are the sum of the time for inter-row cultivation using one operator working with one pair of oxen (time requirement range 3.5-4 person-hours ha^{-1}) and hand weeding within the row.

** Weeding with spring-tined cultivator

The West African experience

ICRISAT's experience in West Africa is limited to on-station research, operational and training activities in Mali (1978-1983) and more recently at the ICRISAT Sahelian Centre (ISC), 42 km southeast of Niamey, Niger.

A resource management research programme is now fully established at the ISC. Staff participating in this research area include an agroclimatologist, a soil chemist, a soil and water management engineer, a cowpea breeder/agronomist, a millet agronomist, a farming systems agronomist, an animal nutritionist and an economist. Most research is still addressing the performance and interactions of various production factors although an operational-scale experiment based on the synthesis of promising results from the more basic research activities was started in 1986. The treatment combinations were based on the use of phosphate fertilizer, rotations of improved millet and cowpea varieties, and animal traction for pre-planting cultivation and inter-row weeding. The plots were large enough for measuring material and labour inputs.

The AT component involved pre-planting ridging using a single-mouldboard plow pulled by a pair of oxen. Ridges were spaced 1.5 m apart. Preliminary results indicate that ridging took

13 h ha^{-1}. Hand planting traditional millet and cowpea required 33 person-hr ha^{-1}. The more densely planted improved millet required 21.5 person-hr ha^{-1} and sole cowpea 64 person-hr ha^{-1}.

The first weeding of AT-cultivated plots required less than 25% to 50% of the time spent weeding by hand depending on the cropping system. A tined cultivator was used for the AT weeding. Ridging reduced weed populations and the AT tine-cultivator was much faster than hand cultivation. The second AT weeding required 46% of the time spent in hand weeding because inter-row weeding still had to be done by hand (Table 4).

While the simplest and most widespread AT equipment has been used for experimental purposes, the "Nikart" WTC is used for regular general operations of the research farm at the ICRISAT Sahelian Centre. Trees and shrubs outside designated windbreaks were pulled by hand and removed with horses. Primary tillage, fertilization, seeding, and weeding were accomplished with three "Nikarts". Two pairs of oxen or cows were used per AT equipment unit during the day to develop and crop a total of 25 hectares. Ridging and weeding operations were carried out on another 120 ha. Each equipment unit effectively accomplished a quarter of the work of a 40 kW tractor. The quality of the operations carried out was equivalent or superior to the same operations accomplished with a tractor. The experience on the research station at Cinzana in Mali with the Nikart is similar.

Research needs and networking

Any agricultural research institution in the SAT must conduct research and farm operations at several levels of technological sophistication relevant to the diverse farm enterprises and ecologies within the region. Although a significant part of our programme is carried out with hand labour or tractors, AT offers an intermediate alternative that is relatively affordable, not too sophisticated, and, if properly applied, can effectively help farmers to increase their agricultural productivity.

ICRISAT has demonstrated that a properly conceived, AT-based crop management strategy can have significant impact on productivity. It has also been shown that the BBF system is applicable primarily on Vertisols with relatively reliable rainfall.

India has a long and sophisticated tradition of AT use. In West Africa, efforts to introduce and intensify the use of AT began in this century. ICRISAT should exploit the Indian-African contrast while exploring the possibilities for AT in the future.

In Africa, it is important that the information base necessary to fully exploit AT use be developed and disseminated. Appropriate techniques exist but are often unknown to those who could best benefit from their use. In some cases existing techniques need to be adapted through appropriate research to become most effective. Whatever be the case, it is only by working with animal traction techniques and equipment on both the production and research level that the potential of AT will be realized.

Conclusion

The use of AT and equipment is commonplace in India. In West Africa it was almost unknown as recently as 50 years ago, and it is still not widely practised. Increasing population pressure makes the intensification of crop production inevitable although in Africa, population densities are generally lower than in South Asia. The technical characteristics and adoption patterns of the animal traction component will necessarily reflect these and other differences.

As an isolated technique the introduction or intensification of AT use has not had a substantial effect on farmer efficiency. However, when it has been coupled with improved biological and chemical technology, appropriate soil management techniques, and adapted equipment there have been substantial and sustainable increases in production. Furthermore, significant synergistic interactions exist between AT use and other crop production techniques.

AT has an important role to play in strengthening agriculture. The exchange of information among cooperating institutes on implements and tools, agricultural mechanization programmes and relevant technological developments will accelerate this process.

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Title photograph (opposite)
Demonstrating an adapted Super Eco seeder at Yundum, The Gambia
(Photo: Paul Starkey)