Animal Drawn Multi-Purpose Tool Carriers

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Abstract

Animal-drawn, multi-purpose tool carriers have been in existence for at least 25 years. Tool carriers are designed to provide the advantages of improved implements to animal-power-based farming. They operate like tractors whose implements can be changed easily to suit the operational requirements.

Although successful adoption of tool carriers has been limited to only a few countries of West Africa, renewed work aimed at enlarging the area of usefulness has shown promising results. Timeliness, quality of operations, and efficiency in the utilization of animal power are the factors that make wheeled tool carriers economically and technically viable in dryland farming.

Introduction

Animal-drawn, multi-purpose tool carriers, frequently referred to as toolbars and tool frames, have been used in many countries for more than two decades now. The development of a number of tool carriers began in the 1950s and early 1960s. The objective of the present review was to introduce some form of acceptable farm mechanization in developing countries where governments have recognized the need to promote agriculture as an enterprise capable of providing food and employment for the increasing population, and also for generating exportable surpluses of cash crops such as groundnut and cotton. In order to increase the productivity of land, it became evident that research was needed on the improved use of agricultural inputs such as seeds, fertilizer, irrigation, and better cultivation practices. The role of mechanization is to complement other components in agriculture by improving tillage, seeding practices, and timeliness of operations. A great deal of work has been done in the past 25 years in the direction of mechanizing small farms in various ways, with varying success. However, some basic questions relating to the level and type of mechanization can still be posed in the context of the overall objectives of increasing productivity and maximizing the use of available resources. These questions are:

a) What should be the optimum level of available power/ha to obtain desirable yields?
b) What are the alternative sources of farm power and in what combinations should they be employed to ensure socio-economic acceptability and technical feasibility?
c) What are the choices of implements, the likelihood of their improvement in the near future, and the consequent effects on (a) and (b)?

In most countries of Africa, Latin America, and Asia it is widely recognized that no single mode of mechanization can solve all the problems associated with agricultural modernization. In Africa tractors have often been profitably utilized by large farmers on reclaimed lands, whereas small farmers have continued to depend on manual labor (Johnston 1980). In India, although the number of tractors used has increased to 300 000, about 170 000 (56%) are being used in the three states of Punjab, Haryana, and Uttar Pradesh, which account for only 16% of the total sown area in the entire country (Jain 1978). According to the National Commission on Agriculture (NCA 1976), "about 47% of India's cropped area which is under holdings of less than 5 ha will continue to depend heavily on animal power. The middle group of 5-20 ha holdings can afford to use mechanical and electrical power in an increasing manner and their dependence on animal power could be substantially reduced. The operational holdings of greater than 20 ha will hardly depend on bullock power. This means that about 50% of the cropped area in India will depend largely on bullock power".

In West Africa animal draft cultivation was introduced about 50 years ago. At that time it was not a question of introducing new

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methods of cultivation but of using more power by employing draft animals for certain cultivation operations (FAO 1972). As a result, the use of draft animals remained confined to areas where high-value crops such as groundnut and cotton are grown. It was only recently that several governments in West Africa have undertaken programs to train farmers in the wider utilization of draft animals (Shulman 1979).

The development and impact of animal-drawn tool carriers is discussed in this paper. Attempt has been made to put together the currently available information on several designs of tool carriers developed in various countries, including the latest work done at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad, India. This is followed by a discussion of a specific soil and crop management situation where a multi-purpose tool carrier proved to be very useful in improving the timeliness and quality of operations. Some field performance results and economic aspects of the tool carriers are also discussed.

The Animal-Drawn Tool Carrier

An animal-drawn tool carrier is a multi-purpose frame that provides the link between the implement and the power source, i.e., draft animals. By implication the tool carrier does not directly convert energy into work but serves as a chassis to transmit energy and motion to the implement, keeping the latter in a definite orientation with respect to the soil. As a multi-purpose unit, tool carriers are designed to be used in conjunction with a wide range of implements. The unit works in a way similar to a tractor in that the implement can be quickly changed on the toolbar to meet operational requirements.

It is through implements and machinery that power can be best employed to do useful work. In several Asian countries where the use of draft animals is common, one can see a variety of locally developed implements. Although the traditional implements look crude at first sight, they have been evolved over centuries and have stood the test of working in a particular region endowed with specific agroclimatic and soil conditions. The size and shape of these implements often vary from region to region depending upon soil type, cultural practices, size of bullock, etc. But there are no radical differences among implements meant for similar operations.

Although research and development on animal-drawn implements began in India around 1905, coordinated R&D gained momentum only with the initiation of India's first Five Year Plan in 1951 (NCA 1976). During the intervening period the activities were often limited to improving or replacing a particular implement with a so-called "improved" one. Post independence R&D has led to the successful introduction of various new animal-drawn implements such as the moldboard plow, disc harrow, ridgers, tined cultivator, puddler, and bund former.

In the African countries where animal traction has been introduced in the past few decades, its success has depended to a considerable extent upon the suitability of the implements, and the adequacy of the training that farmers received. Development of a particular implement to meet a pressing need has accelerated the expansion of animal draft cultivation in West Africa. For example, introduction of a groundnut planter and later a groundnut lifter specially designed to meet the requirements of the groundnut growing areas in Senegal and Mali has resulted in their adoption on a large scale. These were followed by other implements such as moldboard plows, hoes, and multi-purpose toolbars (Uzureau 1974; Le Moigne 1979). Similarly, in several countries in East and Southern Africa where some governments have promoted ox-cultivation, different designs of moldboard plows, including the Indian type steel plow (Sabash plow), were tested and introduced to farmers (Kline et al. 1969).

Many widely used animal-drawn implements do not make the best use of available energy because of their low draft utilization (Goe and McDowell 1980). At the same time the work done is inefficient and involves considerable strain and drudgery for the operator and the animals. Another major drawback is that each implement has its own frame and beam in addition to its soil-engaging part. The cost of the beam and frame could be reduced by providing a single frame to which different tools comprising only the working portion can be attached. The NCA (1976) concludes that "in short, what is needed is a toolbar preferably mounted on wheels, and a beam fixed to it for hitching to the yoke. Different working parts like plow, harrow, blade, drill or intercultivation implements could be fixed as required".

Types of Multi-Purpose Tool Carriers

In order to understand tool carriers' functional performances, versatility and limitations it is useful to divide the various designs into two groups: (1) lightweight simple tool carriers, and (2) wheeled tool carriers.

Light-weight, simple tool carriers

The designs are extremely simple as they consist of a lightweight metallic frame to which the implements are clamped directly. Some models may have small wheels normally intended to work as gauge wheels and to assist in following the correct path while in operation. However, these tool carriers are often used without wheels or with skids. They are pulled through a chain or a solid beam either by a single animal or a pair of animals (usually a pair of oxen). Pulling through a chain, which is most common, is helpful for operation in a field that is not adequately cleared of such obstacles as stumps and stones. On the other hand, a rigid beam, such as those commonly used in India, helps to minimize the lateral shift of the implement, thus reducing strain on the operator. The tool carriers in this category have no provision for the operator to ride. The operator must walk behind, often having to guide the implement with handles to maintain the correct working position.

Simple tool carriers of this category first appeared in francophone West Africa in the early 1950s. These were designed by Mr. Jean Nolle and manufactured in France. Subsequently, the Societé Industrielle Sénégaliase de Construction Mecanique et de Materiels Agricoles (SISCOMA) in Senegal and the Societé Malienne d'Etude et de Construction de Materiels Agricoles (SMECMA) in Mali began manufacturing them (Le Moigne 1979). Presumably several components are still imported from France.

The Ariana (**Fig. 1**) and Hoe Sine (**Fig. 2**) have become successful in several African countries. They were designed to be used with oxen, donkeys, or horses. Their frames are constructed from 40 x 20 mm rectangular mild steel sections. They are used with gauge wheels or skids. The implements and clamps are interchangeable between the two tool carriers. The available attachments are moldboard plow, ridger, cultivator tines with different types and sizes of sweeps, seeder, reversible plow, spring-tooth harrow, and groundnut lifter.

Fig. 1 Ariana with a right-hand moldboard plow.

Fig. 2 Hoesine with a right-hand moldboard plow.

Later several other similar tool carriers were introduced in West and East Africa. The Occidental hoe, a lightweight simple tillage tool designed for use with donkeys for weeding and cultivation, was recommended by the Bambey Center for Agricultural Research for groundnut-growing areas in Senegal. The Unibar multi-purpose toolbar manufactured by Project Equipment Ltd, UK, was introduced in the early 1960s. The Unibar consists of a Y-shaped frame and an adjustable handle. The unit is available with ridger, 6-inch moldboard plow, cultivator, peg-tooth harrow, and seed-fertilizer attachments. The recently introduced Anglebar is claimed to be superior to the Unibar (Stokes 1981).

In Upper Volta, a multi-purpose triangular frame has been introduced to farmers on a large scale under a resettlement project. The implement package, sold as a Multiculteur, actually consists of two separate frames, one for plowing and ridging with changeable attachments, and the other a triangular frame to which cultivator tines and groundnut digger are mounted. The biggest shortcoming of the package is the lack of a suitable planter and fertilizer drill. Despite this drawback, about 6 000 units were locally manufactured in 1979 (Imboden 1980).

In India, the Junagarh Agricultural College developed a toolbar in 1973 (NCA 1976) for blade harrowing, plowing, ridging, shallow cultivation with sweeps, and bund forming. However, there is no evidence of farmers' acceptance of this toolbar. Some work has also been initiated at the Indian Agricultural Research Institute (IARI), New Delhi, to develop an integral toolbar suitable to work with a moldboard plow, a three-tine cultivator, and a bund former; the design is under evaluation (Wadhwa and Srivastava 1980).

At ICRISAT a simple T-bar type tool carrier has been modified for operations on broadbeds discussed later in this paper.

Wheeled tool carriers

Wheeled tool carriers consist of a rigid frame (chassis) supported by two wheels (often pneumatic tires), a provision for attaching implements behind the chassis, a lifting mechanism to raise or lower the implement, and a beam connecting the tool carrier with the yoke. The superior features of these machines include the possibility of converting them into a cart, precise lateral and vertical adjustments of the implements, wheel track adjustment, and a seat for the operator. It is also possible in most of the designs to adjust the lift angle (angle between the face of the tool and the horizontal plane).

Wheeled tool carriers have great potential in animal-power based farming systems. They work like a tractor in that the implement can be changed easily to suit the operational requirements.

The designs listed below constitute those currently known.

1. Mr. Jean Nolle designed the Polyculteur in the early 1950s. He developed an improved version called the Tropicultor in the early 1960s. The polyculteur was manufactured by SISCOMA in Senegal until recently. The Tropicultor is being manufactured by Mouzon SA, Mouy, France, and Vicon Ltd, Bangalore, India.

2. The National Institute of Agricultural Engineering (NIAE), U.K., developed an animal drawn toolbar (ADT) called APLOS. The tool carrier was manufactured by John Darbyshire & Co., U.K., and exported to West African countries in the early 1960s. A second model with higher ground clearance was later introduced to suit tall-growing crops.

3. Voltas Limited, Bombay, India developed and marketed a wheeled tool carrier called the Otto Frame until 1965. However, manufacturing was discontinued due to lack of market demand.

4. Escorts Ltd., India, introduced a low-clearance wheeled tool carrier with limited success. It had a three-point lifting linkage operated with the right hand and the foot simultaneously.

5. In Tanzania, a multi-purpose wheeled frame was developed in 1963 at the Agricultural Machinery Testing Unit. The design had many features similar to the APLOS (Constantinesco 1964).

6. In Botswana, the Dryland Farming Research Team, supported by the Overseas Development Administration (ODA), U.K., developed the Versatool on similar lines (Gibbon et al. 1974).

7. Also in Botswana the Mochudi Farmers Brigade developed a tool carrier in 1973 called the Makgonatsotlhe (meaning the machine which can do everything). The Tool Carrier Production Unit, Mochudi, took up its manufacture and still produces on order (Mochudi Farmers' Brigade 1975).

8. The Directorate of Agriculture, Madras, India, has recently introduced a multi-purpose wheeled implement for rainfed agriculture; it is claimed to be suitable for wetland cultivation also. All the attachments plows (Japanese type), cultivators, and seeders are permanently mounted on the chassis. The operator is required to make suitable adjustments for using a particular attachment (Ponnayya 1979).

9. Medak Agricultural Centre (MAC), Medak, A.P., India, is manufacturing a wheeled tool carrier called the Agricart. The design is similar to the Tropicultor. MAC is promoting the sale of Agricart through direct extension and the training of farmers.

10. Sulky Tropism Intensificateur, a multi-purpose tool carrier with steel wheels, has recently been introduced by Sulky France, Chateaubourg, France.

11. NIAE and ICRISAT have jointly developed a new design called the Nikart. It is available to farmers from Mekins Agro Industrial Enterprises, Hyderabad, India, and Geest Overseas Mechanization Ltd., Spalding, U.K.

Many of the above designs have failed to impress farmers for a variety of reasons -- mainly technical, economic, and agronomic and, often, the lack of sufficient extension and training.

The Versatool was abandoned during trials under the Evaluation of Farming Systems and Agricultural Implements Project (EFSAIP), Botswana, due to low ground clearance, a difficult lifting mechanism, and frequent breakdowns (EFSAIP 1977). Only 125 units of the Makgonatsotlhe tool carriers have so far been sold, and most have been purchased by the Botswana Government for evaluation. Horspool (1981) concluded that Makgonatsotlhe has not been a successful tool carrier. Similarly the Otto Frame, the Escorts tool carrier, and the tool frame developed in Tanzania were not accepted by farmers.

Design Considerations

The design of a wheeled tool carrier may vary considerably, depending upon its targeted environment. Soil type, cultural practices, type of animals, farmers' general attitudes toward improved implements, and cost are factors that help in determining the technical requirements. However, several designs of tool carrier have been used under varying conditions with reasonable success. It is therefore possible to outline certain features that a tool carrier should have.

a) *Frame* -- This should have sufficient clearance to permit inter-row cultivation in tall row crops, such as maize, sorghum and cotton. At the same time, the center of gravity of the tool carrier should not be so high that stability problems occur.

b) *Wheel track* - This should be adjustable to permit operation at different row spacings. However, depending upon the cultural practices followed in a particular region there may not be a need for wheel track adjustment. The wheel track should be wide enough to ensure good stability on undulating terrain.

c) *Lifting mechanism* -- This mechanism for raising or lowering the implement as desired should be easy to operate through a well-positioned handle.

d) *Shock loading* -- Tool carriers should be sufficiently robust to withstand high shock loads.

They should be capable of withstanding at least 450 kg pull without bending or breaking any part of the frame, toolbar, or implement (Constantinesco 1964).

e) *Implement adjustment* - The tool carrier should have an easy adjustment for the varying soil working depth and lateral spacing between the tools.

f) *Cost factor* - Construction should be simple in order to maintain low manufacturing costs. The weight of the tool carrier should also be as low as possible to minimize the draft requirement.

g) *Seat* - The seat is important because its arrangement on a wheeled tool carrier simulates it to a tractor. A practical advantage in having a seat is the ease with which the operator can control the animals. Provision of a seat also saves the operator from the drudgery of walking behind the implement.

As the effectiveness of a tool carrier is judged by the work accomplished through the implements attached to it, it is essential to describe the main design features of the implements that are expected to match a particular tool carrier.

a) The size of each implement must be matched with power available from the draft animals.
b) The implement should be light in weight for easy handling while attaching or detaching it from the toolbar.
c) The implement should be strong enough to withstand stresses that may arise due to improper use and/or impact loads encountered from hidden obstacles in the soil.
d) The means of attaching the implements to the toolbar should be simple and robust to facilitate changes of implements with a minimum loss of time.

It is often difficult to satisfy all the above criteria in a single design. The actual technical features of a particular machine, therefore, may have to be a good compromise depending on its intended application.

Most of the early designs of the wheeled tool carrier (Otto Frame, APLOS, Escorts, and Polyculteur) had fixed wheel tracks and, in some cases, a solid axle. As a result they suffered from two major drawbacks. First, the plow was attached in such a way that the center of resistance and pull were not in line. Secondly, with a solid axle or low ground clearance, interrow cultivation in row crops such as sorghum, maize, cotton, and pearl millet was possible only during the early stages of growth.

The plowing problem was solved in three ways. The high arch of the Tropicultor permitted the wheels to be placed either outside or inside the frame. When one of the wheels is placed inside the frame, it is possible to mount the plow almost directly behind the beam. On the Nikart, which has a fixed wheel track, the beam can be shifted to a second position on the right side of the frame. This shift is required only for the plowing operation, to bring the beam nearer to the right wheel, thus permitting the plow to be in line with the beam. On the Otto Frame, the side draft problem was alleviated by providing a furrow wheel on the disc plow attachment. The problem of interrow cultivation was minimized by using a high-arch chassis and independent axles for the wheels.

All the above-mentioned designs of wheeled tool carriers have a lifting mechanisms to raise or lower the implements. In most designs the implements are held rigidly in the raised as well as the lowered working positions. The Otto Frame and Escorts tool carriers had levers that could be locked in various positions by using a spring-loaded stopper sitting in notches. The lifting mechanism and the position of the lever vary considerably among various tool carriers. The Makgonatsotlhe has two levers operated from the rear for lifting the implements from the right and left sides independently. The Polyculteur and Versatool have a long lever placed in the center of the machine, also operated from the rear. Other designs have a lever operated by the seated operator.

There are several ways to vary the soil-working depth of the implements. These include locking the lifting lever in a desired position to obtain the correct depth, vertical adjustment of the toolbar on which the implements are clamped, varying the height of the chassis with respect to the wheels, and, by sliding the implement shank in the clamp. Some tool carriers have a combination of two or more of the above features to obtain the correct soil-working depth.

The lift angle may vary considerably due to variation in the height of animals. To maintain the proper lift angle for good penetration, most tool carriers have a provision for adjustment of the angle of the beam with respect to the ground.

Tool Carrier Development at ICRISAT

At ICRISAT, research on improved animal-drawn implements is an integral component of Farming Systems Research (FSR). In FSR the concept of watershed based resource development, utilization, and conservation is being investigated as a more effective approach towards the maximization of returns through better crop performance, given improved seed, fertilization, and implements. The system evolved is based on the construction of broadbeds, separated by furrows at a regular interval of 150 cm. Fig. 3 shows the cross-

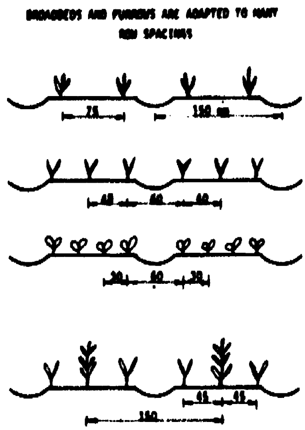

Fig. 3 Some possible cropping patterns on broadbeds (Source: Krantz et al. 1978).

section of such a broadbed with several possible cropping patterns at 75, 45, and 30 cm spacings (Krantz et al. 1978). The furrows serve as drainage channels for carrying excess water into grassed waterways, as a pathway for animals and the tool carrier wheels, and also as channels for supplementary irrigation.

Before the introduction of broadbeds-and-furrows (BBF), ridges were made after land preparation with traditional implements such as the wooden (desi) plow and the blade harrow. A bullock-drawn sugarcane ridger was subsequently used to make ridges at 75 cm spacing. A fluted-feed seed-cum-fertilizer drill was used for placing the basal dose of fertilizer before planting the seed in dry soil in a Vertisols (black clay soil).

However, in 1975, when the BBF system was tested on an operational scale, traditional implements were found unsuitable for maintaining uniformity in the tillage operations over the broadbeds. With the introduction in the Vertisols of dry seeding before the onset of the rains, and sequential cropping in the post-rainy season, timeliness and precision became important. Thus, a search was initiated for modified animal-drawn machinery which should be better suited to the requirements of new concepts of soil and crop management. Several multi-purpose wheeled tool carriers were tested to determine their functional and structural performance. Ultimately, the Tropicultor (**Fig. 4**) proved to be the most effective (Thierstein 1979). It has been successfully used since 1976 and, from 1979, its manufacture, along with several attachments, has been promoted in India.

The Tropicultor design and its use with various attachments has been explained in other publications (Bansal and Srivastava 1981). Several modifications were incorporated in the Tropicultor to avoid mechanical problems. Changes were also made on such implements as the moldboard plow standard, ridger, steerable toolbar, furrow opener, peg-tooth harrow, and cart. Some new attachments that have been developed at ICRISAT are an angle-blade scraper, seed-cum-fertilizer drill, blade harrow, and bed shaper.

Initial cost is perhaps a major constraint in the large-scale adoption of the Tropicultor-based machinery system. The possibilities of developing cheaper tool carriers are therefore being explored at ICRISAT, e.g., development of the Nikart and the Agribar.

The Nikart (**Fig. 5**) has most of the basic features of the Tropicultor except that the wheels are fixed at 150 cm track width. However, the design can be easily altered to permit manufacture with different wheel track widths, if necessary. This tool carrier has an over-center lifting mechanism which automatically locks the implement in the raised and lowered positions. The lever is operated by the operator sitting on the seat. The soil-working depth is varied by adjusting the height of the chassis with respect to the wheels by an individual screw jack system on both wheels. Ground clearance can be varied from 35 to 65 cm. The toolbar section is identical to that of the Tropicultor and allows interchangeability of the implements. In order to minimize the costs, front axles and wheels from an old passenger car can be used.

Fig. 6 shows a simple Agribar tool carrier. The present design has a detachable 170 cm long toolbar at right angles to the beam. The toolbar is supported on two 30 cm diameter wheels, each equipped with a lifting mechanism operated by individual lifting levers. A centrally-located handle is also provided for the operator to steer the tool carrier for correct working position of the implements. The design of the Agribar has not yet

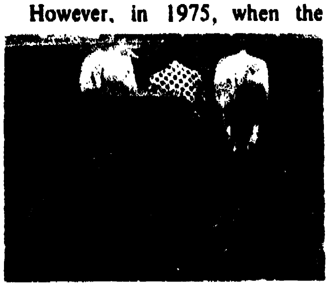

Fig. 4 Tropicultor being used for top dressing urea with an oscillating fertilizer drill.

Fig. 5 Plowing on flat land with the Nikart.

Fig. 6 Agribar with left- and right-hand moldboard plows.

been released to manufacturers as it is still under field-scale testing. The machine, however, has three limitations. First, it cannot be converted into a cart. Second, the operator has to walk behind the machine. And third, some stability problems have been encountered for heavier operations such as plowing and ridging because of its light weight.

Field Performance

At ICRISAT, the use of a wheeled tool carrier has been successfully integrated into an improved farming system. The performance of a tool carrier on flat-land cultivation and broadbeds-and-furrows, compared with the traditional system, is shown in **Table 1**.

The data presented here have been collected from Alfisols (red sandy loam soil) at Aurepalle village in Mahaboobnagar district, Andhra Pradesh, India, where ICRISAT has been involved in conducting on-farm studies on improved farming systems. The table shows two years' data for operating the wheeled tool carrier on broadbeds. In 1979/80 the broadbeds were made for the first time, and some additional operations were required to establish the system. These operations were not required in the successive years, as is clear from data for the second year.

It is apparent from **Table 1** and **Fig. 7** that bullock pair hours needed for operations on the broadbeds-and-furrows are 43% less for both cropping systems, as compared with traditional practicles. The use of broadbeds and furrows thus provides a more efficient utilization of available power. The most critical operation, where timeliness is important, is sowing. Under the traditional practice of planting behind the plow and metering seeds by hand, sowing takes a lot of time. By using a wheeled tool carrier and the proper planter attachment, the sowing time has been reduced to one-fifth. The table shows separate operations for applying a basal dose of fertilizer. With the development of a seed-cum-fertilizer drill, sowing time can be further minimized by combining the two operations. In addition, accuracy in seed metering and placement can make a substantial difference in yields, due to a more uniform and proper plant population.

In general, better quality operations can be expected with the use of a wheeled tool carrier, for two reasons. First, the precise adjustment of implements ensures proper depth and complete soil coverage, and, secondly, since the implements are held rigidly on the tool

Table 1 Comparison of Bullock Pair Hours input for Rainy Season (Kharif) Cropping by Traditional Implements and a Wheeled Tool Carrier (Tropicultor) at Aurepalle (Mahboobnagar District), A.P., India.

Unit: h/ha

Operation	Requirement of Bullock Pair Hours							
	Traditional system a) Average 1975/76 to 1977/78		Tropicultor on flat land (1979/80)		Tropicultor on BBF 1979/80 b)		Tropicultor on BBF 1980/81 c)	
	Castor	Cereal/ pigeonpea intercrop	Castor	Pearl millet/ pigeonpea intercrop	Castor	Pearl millet/ pigeonpea intercrop	Castor	Pearl millet/ pigeonpea intercrop
Plowing					3.7	3.8	9.5	8.1
Cultivation			11.7	11.7	15.7	13.5	11.9	12.2
Harrowing			34.9	35.0	9.3	8.2	-	-
Ridging			-	-	12.3	11.9	5.3	3.0
Bed forming			-	-	6.0	6.8	5.5	6.9
Sub-total	21.4	22.7	46.6	46.7	47.0	44.2	32.2	30.2
Manuring/fertilizer application	4.3	4.5	4.4	3.8	4.3	4.3	4.9	5.3
Sowing	24.0	22.6	5.0	3.6	3.5	3.8	4.1	3.9
Sub-total	28.3	27.1	9.4	7.4	7.8	8.1	9.0	9.2
Interrow cultivation I			8.4	4.3	3.6	4.2	4.5	2.8
Interrow cultivation II			11.1	-	3.0	4.2	4.4	3.9
Interrow cultivation III	57.9	30.5	16.8	-	3.2	3.4	4.0	
Interrow cultivation IV			8.7	-	4.2	-	4.0	
Interrow cultivation V			-	-	3.9	-	3.1	
Sub-total	57.9	30.5	45.0	4.3	17.9	11.8	20.0	6.7
Grand total	107.6	80.3	101.0	58.4	72.7	64.1	61.2	46.1

a) Traditional system includes use of traditional implements and traditional management.
b) The broadbed-and-furrow (BBF) system was developed in 1979/80 for the first time. Bullock pair hours for development of the watershed are included.
c) Second year of operation on BBF does not include any development.

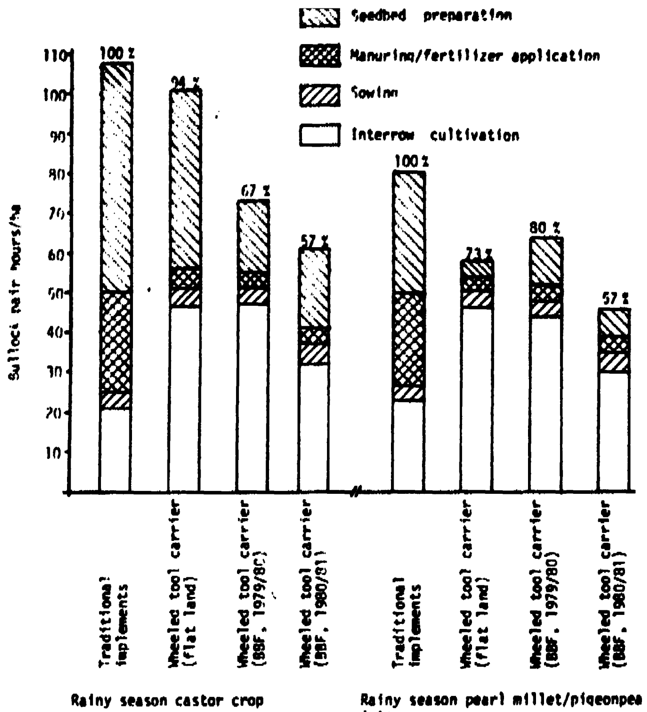

Fig. 7 Bullock pair-h/ha required for different soil management practices and implements in Aurepalle, A.P. India

carrier, there is no lateral shift with respect to the direction of travel. The operator's skill in maintaining the animals in a straight line ensures good results.

Economic Analysis

A direct comparison between an animal-drawn wheeled tool carrier and traditional implements would be quite misleading because improved implements in themselves make marginal contributions in increasing yields through better sowing, fertilizing, and weed management. In order to realize maximum benefit from the use of improved implements it is necessary to adopt other improved practices such as better soil and water management, and the use of fertilizers and improved seed. The high cost of an improved animal-drawn machine, therefore, will be compensated for by increased yields obtained through the combined effect of all improved inputs, similar to that achieved in tractorized farming. Timeliness of operations, possibilities of double cropping in Vertisols where rainy season fallowing is normally practiced, and better placement of seed and fertilizer can, however, directly affect profitability through the use of improved implements.

The second factor directly affecting the economic performance of the machine is its utilization throughout the year. The opportunities to maximize utilization of the machine depends upon such factors as cropping intensity, holding size, possibilities of doing custom hiring, and using the tool carrier as a cart. To ensure maximum efficiency of the machine, it would be desirable to use it for all agricultural operations.

Economic analysis for the Nikart manufactured in India is presented in **Table 2**. In the first case the capital costs for using the tool carrier only for agricultural operations have been calculated on the basis of a pearl millet/pigeonpea intercrop **(Table 1)** grown on broadbeds and furrows. ICRISAT studies have shown that an area of 14 ha can be managed with the tool carrier annually for all the operations under such a system (Farm Power and Equipment Report 1978). Thus an annual utilization of 587 h (about 98 days) has been assumed. Any change in management practices and cropping systems resulting in a different bullock pair hour requirement per hectare should make a corresponding difference in the command area. The life of the machine is assumed as 8 years with a 10% salvage value when used only for agricultural operations.

In the second case an additional use of the tool carrier as a 1-t capacity cart for 400 h (67 days) has been assumed. This utilization may be for transporting inputs and produce and/or for using the cart on hire.

It is apparent that the cost of using the machine is comparatively more for sowing and fertilizer application. This is because of the relatively higher cost of the attachment and its rather limited use. Nevertheless, this is one operation that has a high payoff if it is done with improved equipment. It can be argued that the tool carrier is an expensive unit for tillage and seedbed preparation. This is true if a direct comparison with traditional implements is made. However quality and timeliness are important factors, and farmers often do the plowing and other land preparing operation with the help of a hired tractor. The National Council of Applied Economic Research (NCAER 1980) has concluded that farmers hiring tractors use them mainly for plowing and tillage operations. With the

Table 2 Capital Cost of Nikart for Various Operations for Pearl Millet/Pigeonpea Intercrop on Broad-Bed and Furrow[a)].

Operation	Tool Carrier Used for Agricultural Operation only					Tool Carriers Used for Agricultural Operations and Transport				
	Utilization (h/hr)	Tool carrier cost (Rs/h[b)])	Implement cost (Rs/h[c)])	Total capital cost (Rs/h)	Cost (Rs/ha)	Utilization (h/yr)	Tool carrier cost (Rs/h)	Implement cost (Rs/h)	Total capital cost (Rs/h)	Cost (Rs/ha)
Tillage and seed-bed preparation	423	1.14	1.48	2.62	79.13	423	0.79	1.48	2.27	68.55
Sowing and fertilizer application	70	1.14	12.7	13.84	69.20	70	0.79	12.7	13.49	67.45
Interrow cultivation	94	1.14	1.48	2.62	17.55	94	0.79	1.48	2.27	15.21
Transport	--	--	--	--	--	400	0.79	0.74	1.53	--
Total	587				165.88	987				151.21

a) The calculations are based upon using the Nikart to cultivate 14 ha per year with the broadbed-and-furrow system.
b) The initial cost of the Nikart is Rs. 3000 and its life is assumed to be 8 years.
c) Initial cost of the implements: Tillage implements Rs. 3000, seeder and fertilization drill Rs. 3000, and cart frame Rs. 1000. (US$ 1 = Rs. 9 approx.)
d) Because of increased use, the life of the tool carrier is assumed to be 6 years.
Interest on investment is 12% and annual repair and maintenance cost at the rate of 5% on the tool carrier and 7% on the implements have been assumed.

use of an animal-drawn tool carrier and implements it is possible to improve the quality and efficiency of these operations.

The economics of the animal-drawn tool carrier should also be seen from the point of view of power availability. It has been observed that farmers who own tractors also employ bullock power for some of the operations (NCAER 1980). In other words most farmers, whether they own or hire a tractor, tend to maintain draft animals. Thus, by making use of a tool carrier with suitable attachments, one gets a better quality of operation at no extra cost for energy. In order to minimize the cost per unit area cultivated with the tool carrier, a farmer can loan it to other farmers whenever opportunity exists.

Drawbacks of the Multi-Purpose Tool Carriers

Any good machine is likely to have some special requirements and limitations. It is, therefore, necessary to understand the limitations associated with the tool carrier, so that we can search for appropriate answers to the special problems that may arise.

1) *Cost* – Traditional implements are generally inexpensive because they are made from relatively inexpensive materials. The initial investment for tool carriers, on the other hand, is high. They are, therefore, economical only if used over a long period in a year and if yields are increased through timely and improved-quality operations.
2) *Training* – Training of farmers and bullocks is important to ensure that the machine is properly used. The problems of breakdown can also be minimized by imparting proper know-how to the users.
3) *After-sales service* – The need for after-sales service varies from place to place, depending on the facilities available in the neighborhood. However, at least in the beginning, it is essential that sponsors of the improved technology should provide good after-sales service and ensure the availability of spare parts, if they wish to develop the confidence of the farmers.
4) *Utilization* – The tool carrier can be most profitably utilized by integrating it into an improved system of soil, water, and crop management with the use of fertilizers and improved seeds.

Conclusions

Animals are probably the most reliable source of power for farmers in South Asia. In Africa and Latin America there are increasing efforts to further promote the use of animal power on small farms to reduce human drudgery. Animal-drawn multi-purpose tool carriers have been successfully introduced in some parts of West Africa. Tool carriers have enhanced human productivity where there was scope for expansion in cultivable areas and in their working rate, and in other situations they have improved the quality and precision of operations.

In India there is scope for expanding the use of tool carriers. For this purpose it is necessary to ensure that there are machines with good design features, proper training and extension, and adequate after-sales service. The use of tool carriers must be integrated into an improved farming systems wherever possible, in order to bring about substantial returns to justify the additional investment.

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