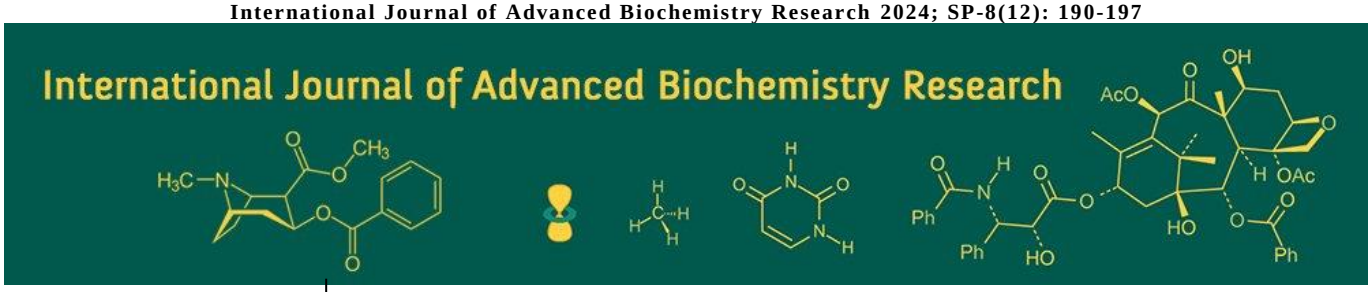

ISSN Print: 2617-4693
ISSN Online: 2617-4707
IJABR 2024; SP-8(12): 190-197
www.biochemjournal.com
Received: 11-09-2024
Accepted: 18-10-2024

Shubham Bhammerker
Research Scholar, Department of Farm Machinery and Power Engineering, Research Scholar College of Agricultural Engineering and Technology and Research Station Faculty of Agricultural Engineering, IGKV, Raipur, Chhattisgarh, India

VM Victor
Professor, Department of Farm Machinery and Power Engineering, Professor College of Agricultural Engineering and Technology and Research Station Faculty of Agricultural Engineering, IGKV, Raipur, Chhattisgarh, India

Shankar Lal
Research Scholar, Department of Farm Machinery and Power Engineering, Research Scholar College of Agricultural Engineering and Technology and Research Station Faculty of Agricultural Engineering, IGKV, Raipur, Chhattisgarh, India

Hirendra Kumar
Research Scholar, Department of Farm Machinery and Power Engineering, Research Scholar College of Agricultural Engineering and Technology and Research Station Faculty of Agricultural Engineering, IGKV, Raipur, Chhattisgarh, India

Sanjay Kumar Gilhare
Research Scholar, Department of Farm Machinery and Power Engineering, Research Scholar College of Agricultural Engineering and Technology and Research Station Faculty of Agricultural Engineering, IGKV, Raipur, Chhattisgarh, India

Corresponding Author:
Shubham Bhammerker
Research Scholar, Department of Farm Machinery and Power Engineering, Research Scholar College of Agricultural Engineering and Technology and Research Station Faculty of Agricultural Engineering, IGKV, Raipur, Chhattisgarh, India

Animal drawn multipurpose wheeled tool carriers: A review

Shubham Bhammerker, VM Victor, Shankar Lal, Hirendra Kumar and Sanjay Kumar Gilhare

DOI: https://doi.org/10.33545/26174693.2024.v8.i12Sc.3116

Abstract
Animal-drawn multipurpose wheeled tool carriers (MPTCs) are multipurpose machines designed to perform various agricultural operations, as well as provide transportation. Developed to reduce machinery costs for small and medium-sized farmers, these carriers serve as a versatile alternative to traditional single-purpose systems. Initially, MPTCs did not achieve widespread adoption due to their limited time-saving advantages compared to traditional methods, which discouraged significant investments. However, recent advancements and successful implementations, such as those at ICRISAT in India and CPATSA in Brazil, have demonstrated their potential to enhance crop production and efficiency in smallholder farming. Despite their growing utility, adoption has been uneven. Studies show that many farmers, particularly in dryland areas, remain skeptical of MPTCs, often relying on subsidies to afford them. Market penetration has been more successful in irrigated regions, though the full potential for MPTCs in such environments is yet to be fully realized. Overall, these carriers offer a promising alternative for small landholders, enabling them to bypass the high costs of tractors and year-round maintenance of draught animals, provided that economic and perception barriers are addressed. The present review article discusses about the modifications and advances in multipurpose tool frames or multipurpose wheeled tool carriers form 90s to present.

Keywords: Multipurpose wheeled tool carriers, small and medium-sized farmers, traditional methods, enhanced crop production

Introduction
Agricultural mechanization has played a crucial role in increasing productivity, particularly in regions where traditional manual methods or low-level mechanization using animal traction have been prevalent. One of the most innovative tools developed for smallholder farmers is the Animal-drawn multipurpose tool frame (also referred to as the wheeled tool carrier, MPTC), a versatile piece of equipment designed to reduce labor and enhance efficiency in farming operations. This tool allows farmers to perform various agricultural tasks such as plowing, seeding, weeding, and transportation by using one single frame with interchangeable attachments, thereby reducing the need for multiple single-purpose tools.
The concept of animal-drawn tool frames is not new; prototypes were used as far back as 25 years ago in regions such as East Africa, India, and Senegal. These early models had limitations in design and functionality, which limited their widespread adoption. However, recent advancements in design, particularly through research institutions like the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and other organizations, have addressed these shortcomings. The integration of MPTCs into improved farming systems has shown significant promise, especially in semi-arid regions, offering small and medium farmers a low-cost mechanization solution that does not require heavy investment in tractors.
Despite these improvements, the adoption of MPTCs has faced challenges. Research shows that many farmers are hesitant to invest in these tools without significant subsidies. Additionally, the full potential of MPTCs in both dryland and irrigated agricultural systems remains underexplored. Studies conducted in regions like India and Brazil have demonstrated that while MPTCs can improve farm efficiency, their time-saving advantages have not always been sufficient to outweigh the costs for many farmers, especially those with small landholdings.

This review evaluates the development, applications, and adoption patterns of animal-drawn multipurpose tool frames across different agricultural systems. It explores the technical, economic, and social factors influencing their use, and considers how these tools can be more effectively integrated into sustainable farming systems to benefit smallholder farmers. By analyzing case studies from various regions, the review will provide insights into the challenges and opportunities surrounding the adoption of M[PTCs.

Advances on animal drawn multipurpose wheel tool carriers

Hubbard *et al.* [1] developed a versatile multipurpose tool carrier, known as the "Versatool," under the Dryland Farming Research Scheme in Botswana. The tool carrier featured an adjustable main frame and tool-mounting frame, which could be positioned at different heights from the ground by sliding the main frame along the wheel axle. The main frame, constructed with a 50 x 50 mm box section, was mounted on 680 mm diameter pneumatic wheels, spaced 1.5 meters apart. Within this frame, a smaller angle-iron frame was suspended by four vertical arms. A hand lever, located at the back of the main frame, enabled users to raise or lower the tool-mounting frame with a lift of up to 350 mm. A beam, fitted at the front of the main frame, allowed for angle adjustment, making the tool adaptable for a variety of tasks such as chisel plowing, subsoiling, planting, weeding, and transporting.

Jean Nolle [2] developed the a multipurpose tool carrier naming 'Tropicultor' operated by a pair of bullocks, designed for performing on all kind of field operations and providing road transportation. Originally designed in France, the Tropicultor was adapted to local needs at ICRISAT in Hyderabad. Functioning similarly to a tractor, it could handle various field tasks and was also practical for transporting goods.

The Tropicultor featured a sturdy frame mounted on two pneumatic wheels, equipped with a beam to attach a bullock yoke. At the rear, the frame included a tool bar where a variety of implements could be attached using simple clamps. Its working depth was adjustable, and a mechanical lifting mechanism allowed the tool bar to be raised and lowered, with a locking device ensuring the implement remained securely in place. Below is a table summarizing its performance across different field operations:

Table 1: Field capacity and draft requirement of Tropicultor for various field operations

Field Operation	Field Capacity (ha/h)	Draft (kgf)
Ploughing (2 bottom, 250 mm)	0.11 to 0.22	230
Ridging	0.12 to 0.43	138
Cultivation	0.11 to 0.46	160
Bed Forming	0.11 to 0.37	185
Planting & Fertilizer Application	0.14 to 0.20	127
Inter-Row Cultivation	0.16 to 0.45	112
Transportation on Tar Road	800 to 1000	30

Mishra [2] reported that the *Samrat-Santi*, a bullock-drawn multipurpose implement, was widely used in Saurashtra for cultivating crops like groundnut, cotton, wheat, bajra, jowar, and pulses. The main component, the head piece, had dimensions that ranged from 5.0 to 7.5 cm in diameter and from 90 to 120 cm in length. It was constructed from galvanized iron pipe, with 18 square holes placed at specific locations to enhance its functionality for various field operations.

Bansal and Thierstein [4] studied the development and implementation of animal-drawn multipurpose tool carriers (MPTCs), particularly focusing on their contribution to agricultural mechanization in semi-arid regions. The study acknowledged that although MPTCs have been in existence for over 25 years, their adoption remained limited to a few West African countries. The renewed interest in these tools stemmed from their ability to improve timeliness, quality of operations, and efficiency in utilizing animal power for dryland farming.

They discussed the evolution of tool carriers, noting that they were designed to function like tractors, where implements could be easily changed to suit different operations. Despite early limitations, tool carriers were gradually refined, addressing issues such as low ground clearance and ineffective draft utilization. The research highlighted successful case studies in Senegal and Mali, where the adoption of MPTCs, particularly for groundnut cultivation, led to improved farming outcomes.

It was pointed out that the high initial cost and limited technical support had hindered widespread adoption. The study concluded that with appropriate training, design improvements, and better after-sales service, tool carriers had the potential to significantly enhance agricultural productivity, especially in regions dependent on animal power.

Garg and Devani [5] developed an economical multipurpose tool frame with attachments such as sweeps for tillage, a seed-cum-fertilizer drill, and a cart frame. The tool frame was tested at the Central Institute of Agricultural Engineering (CIAE) in Bhopal, specifically for cultivating soybean and wheat crops. Results showed the tool frame outperformed conventional tools, delivering nearly double the work output across various operations. Additionally, the cost of operation per unit was lower, yielding significant reductions in human and bullock labor hours. The estimated cost for the tool frame with basic attachments for tillage, sowing, seeding, and transportation was approximately 33% of that of commercial models.

Maurya and Devadattam [6] evaluated the performance of an animal-drawn multipurpose tool carrier through four treatments, including the *Tropicultor*, *Krishiratha*, a set of improved implements, and indigenous implements as a control. The study found that draft requirements were higher for the *Tropicultor* and *Krishiratha*, particularly during ploughing, which posed a challenge for an average pair of bullocks. Additionally, the results indicated no reduction in the overall cost of operation, attributed to the high initial cost of the improved implements tested.

Kshirsagar *et al.* 1984 [7] conducted a study on analysis of animal-drawn Wheeled Tool Carriers (WTCs) in India, particularly examining their role in agricultural operations and transportation. The focus is on their recent development, adoption, and the challenges faced in promoting their use. Key points from there report was as follows:

1. WTCs are designed to perform multiple agricultural tasks and provide transport. Although the concept is not new, WTCs have only been widely manufactured in India in the last five years.
2. **Subsidized Demand:** A large portion of WTCs sold has been through government programs, often with

significant subsidies (up to 80%). Private, unsubsidized purchases are rare, making up only 3% of sales.

3. **Utilization:** There is limited utilization of WTCs, with some farmers using them for traditional practices like plowing and harrowing, while others have adopted the Bed and Broad Furrow (BBF) system. However, most farmers have not adopted these newer systems, and many are not aware of the benefits of the Vertisol Technology package associated with WTCs.
4. **Challenges:** Farmers in dryland regions, where traditional methods are dominant, are reluctant to invest in WTCs because they don't perceive enough advantage over simpler, cheaper tools. In some cases, even government-purchased WTCs have not been widely used, with many sitting idle in large inventories.
5. **Future Demand:** There is skepticism about WTCs gaining widespread adoption, particularly in dryland areas, unless there are significant price reductions or clearer benefits in crop yields and timeliness of operations. Irrigated areas may present better market prospects.

The report concludes that while there is some promise for WTCs in Indian agriculture, particularly in irrigated areas, the current demand and utilization rates are not encouraging. It suggests a reassessment in the near future to evaluate long-term prospects and adoption trends.

Singh *et al.* [8] evaluated the feasibility of using an animal-drawn tool carrier for agricultural operations, including transport, with a focus on crop rotations in the Punjab region. Field trials demonstrated that the tool carrier offered a significant advantage in increasing the operational capacity for seeding and weeding in row crops. Results showed that the tool carrier improved the capacity of tillage, sowing, and weeding equipment compared to conventional tools, highlighting its potential to enhance efficiency in regions reliant on animal power.

Lal [9] Conducted study on the development, functionality, and adoption challenges of the animal-drawn wheeled tool carrier (WTC). The study revealed that, despite its potential advantages, the WTC did not gain widespread popularity among farmers. Early adoption was hindered by the tool's inability to provide significant time-saving advantages over traditional single-purpose implements. The WTC was tested in regions such as India and Brazil by institutions like ICRISAT and CPATSA. These trials demonstrated that the WTC, when integrated into improved farming systems, could increase crop production and save time, even for small landholders. However, the cost of the initial investment remained a significant barrier to widespread adoption.

The study emphasized that the WTC could offer superior precision and comfort for both operators and animals compared to traditional tools, but it also highlighted the challenge of convincing farmers to invest in this system, particularly in regions where low-cost traditional implements were more familiar.

Chavan *et al.* [10] developed a power-tiller-driven multipurpose tool carrier capable of supporting various implements, including a seed-cum-fertilizer drill, harrow, cultivator, and ridger, for effective seeding and tillage operations. The tool carrier was built with a 45 mm square tool bar, 1500 mm in length, and included a hitch bracket for rear-side attachment and a 48 mm diameter drawbar, 300 mm long, for front attachment to the power tiller. Transportation and field operations were facilitated by two 410 mm lugged ground wheels.

Implements were mounted on the tool bar using "U" clamps. For seeding, a seed-cum-fertilizer drill attachment with a trapezoidal hopper was fitted with separate seed and fertilizer compartments and a ground-wheel-driven metering mechanism operated via a chain and sprocket system. A 1500 mm harrow was also designed to attach to the tool bar using tines and clamps, while a cultivator with 240 mm sweeps was mounted for dry tilling. Additionally, a 500 mm ridger was available for creating ridges and furrows, capable of forming raised beds of up to 900 mm in width.

Guruswamy *et al.* [11] evaluated the field performance of a multipurpose wheeled tool carrier (MPW) at the College of Agricultural Engineering, Raichur, focusing on its efficiency in tillage and sowing for rabi sorghum. The study compared the MPW tool carrier with indigenous and improved implements. Results indicated only minor differences in effective field capacity between the MPW tool carrier and traditional implements for ploughing, harrowing, and tilling, with capacities ranging from 0.086 to 0.20 ha/h for both tool types. Field efficiency for the MPW tool carrier ranged between 88.6% and 92.47%, while that of the indigenous and improved implements ranged from 88.69% to 95.14%. This demonstrated that the MPW tool carrier performed comparably to conventional tools in both capacity and efficiency.

Chandegara [12] developed a multipurpose G.I. pipe frame implement designed for various agricultural operations such as tillage, sowing, interculturing, and digging in sandy loam deep soils. The implement consisted of a main frame, beam, and handle with different attachments including cultivator tines, a seed drill furrow opener, interculturing prongs, and digger tines. One of its key features was the ability to adjust the row-to-row distance based on crop requirements, offering flexibility in operations.

During field trials, the multipurpose implement demonstrated superior efficiency compared to traditional wooden implements. It reduced the cost of cultivation to Rs 3,883.49 per hectare, saving Rs 1,561.84 per hectare compared to local implements. Additionally, the investment cost was 52.19% lower than traditional implements. The hourly cost of operating a pair of bullocks was estimated at $1.24. The study also highlighted that the improved implement covered 7.28% more area in sowing operations, with a field efficiency of 89.69%. In groundnut digging, it reduced draft requirements by 33.3% and covered 37.6% more area than the local wooden implement.

The economic analysis revealed that the multipurpose implement provided a cost-effective solution for small-scale farmers, particularly when high initial investment in machinery was a barrier. Overall, the implement proved to be a durable, low-cost, and labor - saving alternative to traditional implements, suitable for various crop operations.

Mundeet *et al.* [13] Developed a groundnut digger suitable for the MAU multipurpose tool carrier, created by the Department of Farm Machinery and Power at Marathwada Agricultural University, Parbhani. The developed digger was tested on a plot to assess its performance in harvesting the TAG-24 groundnut variety. Its performance was compared with the CIAE Bhopal model and a locally available digger. The MAU digger demonstrated better results, with a field capacity of 0.126 ha/hr, a field efficiency of 80.25%, and an operating speed of 2.1 km/h.

The digger recorded a total pod loss of 8.01% and a digging efficiency of 92%. The cost of operation was found to be Rs.168.30 per hectare for groundnut harvesting.
The digger, featuring a V-shaped blade, was designed to minimize soil moisture loss and handle bunch-type groundnut varieties more efficiently. The tests were conducted on a 0.025 ha plot of black cotton soil, with a moisture content of 14.3% at harvest time. The performance was measured based on various factors, including the depth and width of cut, field capacity, efficiency, and pod losses. Soil moisture and bulk density were determined using the oven drying method, and operational speed was measured over a 25-meter distance. The digger's specifications included a 60 cm blade width and a ground clearance of 20 cm.
Roy and Tiwari [14] evaluated the work performance of 10 adult dromedary camels using a multipurpose tool carrier for tillage operations. The camels, weighing an average of 618 kg, were trained to perform tillage on farm plots, with each animal ploughing an average area of 2200 m² per hour. The draught force exerted was approximately 40 kg, and the endurance time of the camels ranged from 60 to 90 minutes before fatigue symptoms like frothing, frequent urination, and leg incoordination appeared.
Physiological and biochemical changes were recorded before and after the tilling work. Significant increases were noted in rectal temperature, pulse rate, respiration rate, glucose, and lactate levels, indicating heightened metabolic activity due to the work stress. Cholesterol levels decreased post-work, likely due to its metabolism into stress hormones. Other parameters, such as serum proteins and creatinine, showed moderate changes, reflecting the camel's capacity to endure work-related stress. The study concluded that camels remain valuable for agricultural tasks in arid regions, offering an affordable and sustainable alternative to mechanical tractors.
Veerangouda *et al.* [15] explored the development and evaluation of a power tiller-drawn multipurpose tool carrier at the College of Agricultural Engineering in Raichur, Karnataka.

Key findings include

- **Field Efficiency and Capacity:** The tool carrier achieved field efficiencies of 66.66% for tilling and 69.88% for harrowing, with theoretical and actual field capacities of 0.30 ha/h and 0.20 ha/h for tilling, and 0.33 ha/h and 0.23 ha/h for harrowing, respectively.
- **Fuel Consumption and Cost:** Fuel consumption was recorded at 1.05 liters per hour for tilling and 0.95 liters per hour for harrowing, with operational costs of Rs 231.86 per hectare for tilling and Rs 201.20 per hectare for harrowing.
- **Versatility and Year-Round Utility:** The tool carrier was found suitable for year-round use, capable of performing various tasks such as tilling, harrowing, and potentially, seed and fertilizer drilling with additional attachments.

This study concluded that a power tiller-drawn multipurpose tool carrier can efficiently reduce labor, increase operational timeliness, and be cost-effective for small and medium farms, providing an alternative to bullock maintenance and high tractor investment costs

Nayak and Verma [16] developed and conducted performance evaluation test of an animal-drawn multipurpose tool carrier (MPT) for tillage and Biasi operations. Conducted at IGKV, Raipur, the research aimed to provide a cost-effective and efficient solution for small-scale farmers by creating a versatile tool carrier that could be used for multiple agricultural tasks, such as ploughing and Biasi operations, in sandy loam soils.
The MPT was tested for its ability to carry different attachments and its ease of use in controlling the animal and adjusting the tool for various operations. The tool was evaluated using local bullocks, and the results showed that the MPT was efficient in both ploughing and Biasi operations, with average field capacities of 0.0958 ha/h and 0.112 ha/h, respectively. The power required for the MPT's ploughing and Biasi attachments was 0.47 and 0.45 kW, with speeds of 2.13 and 2.33 km/h.
The study found that the MPT attachments provided better field efficiency and coverage than traditional Tendua and indigenous ploughs. The MPT-plough attachment covered the largest area, saving significant time and costs compared to traditional tools. Economically, the MPT saved farmers Rs. 606.8/ha and Rs. 597.4/ha over *Tendua* and indigenous ploughs, respectively, while also reducing operation time by over 50%. Additionally, the MPT-Biasi plough attachment provided cost savings of Rs. 263.04/ha and Rs. 1263.2/ha over Tifal Biasi and indigenous ploughs.
Gautam, Jogdand, and Nayak [17] developed a multipurpose tool carrier (MPT) specifically tailored to the draught capacity of the local, non-descript bullocks in Chhattisgarh. The MPT was designed to perform essential agricultural operations like seedbed preparation, secondary tillage, sowing, and weeding.

Key findings from this research included

- **Enhanced Field Capacity:** The MPT equipped with a cultivator and seed drill attachments achieved field capacities of 0.1385 ha/h for the cultivator and 0.1558 ha/h for the seed drill, allowing a daily operational capacity of 1 ha, which is efficient for small-scale farming.
- **Cost Efficiency:** The operational costs were found to be significantly lower compared to traditional methods, with MPT costs for cultivation and sowing at Rs. 551.54 and Rs. 695.18 per hectare, respectively, versus higher costs with the traditional *Tendua* plough.
- **Affordability:** The fabrication cost of the MPT with essential attachments was approximately Rs. 7800, making it a feasible option for small and marginal farmers.

The study concluded that the MPT offers an economically viable and operationally efficient tool for small holder farmers, enabling them to perform a range of tasks with reduced labor and cost requirements.
Singh and Yadav [18] evaluated the performance of an animal-drawn multipurpose seed cum fertilizer drill (MPT) developed for direct sowing of paddy. The study was conducted at the research farm of the Faculty of Agricultural Engineering, IGKV, Raipur, during the *kharif* season. The performance of the MPT drill was compared with a conventional seed cum fertilizer drill.

Key findings included

- The recommended seed rate was 76.80 kg/ha, achieved at a 10 mm fluted roller exposure length and full hopper capacity.
- The MPT drill had an actual field capacity of 0.0853 ha/h and a field efficiency of 73.9%.
- The draft and power requirements for the MPT drill were 53.7 kgf and 0.4 hp, respectively.
- In terms of energy input-output ratio, the MPT drill showed a slightly lower energy output compared to the conventional drill, with ratios of 17.47 for MPT and 18.43 for the conventional drill.

The study concluded that although the conventional drill slightly outperformed the MPT in terms of yield and energy efficiency, the MPT drill offered versatility with its ability to attach various implements for different field operations, making it more cost-effective for farmers.

Tiwari *et al.* [19] performed and performance evaluation test on improved multi-purpose tool frame fitted with a planting attachment for maize cultivation in the terraced fields of Sikkim. The research aimed to address inefficiencies in traditional maize planting practices, which typically involved broadcasting seeds followed by planking using traditional wooden tools.

The results demonstrated notable improvements in planting efficiency compared to traditional methods. The tool frame, when attached with a planting unit, achieved a working width of 720 mm and an effective field capacity of 0.088 ha/h in terraces. Under zero-tillage conditions, the same tool frame offered an effective field capacity of 0.079 ha/h, with a field efficiency of 54%. The introduction of this system resulted in significant savings: 26.23% in labor and 17.85% in time compared to traditional practices. Additionally, cost savings were reported to be 33.95% in normal tillage and 26.35% in zero tillage.

Ramya *et al.* [20] Conducted performance evaluation test of the CIAE multipurpose tool carrier, which was tested at the University of Agricultural Sciences, Raichur,. The tool carrier, pulled by a pair of bullocks, was assessed for various agricultural tasks like ploughing, harrowing, and tilling. The results showed that the average draft requirement was 686.70 KN for ploughing, 490.50 KN for harrowing, and 539.55 KN for tilling. The corresponding energy requirements were 98.70 MJ/ha, 17.40 MJ/ha, and 37.23 MJ/ha, respectively.

The study also evaluated the tool carrier's field efficiency, which was found to be 70% for ploughing, 69.79% for harrowing, and 69.90% for tilling. The cost of operation was recorded at ₹60.12 per hour for ploughing, ₹59.47 per hour for harrowing, and ₹59.79 per hour for tilling. These results demonstrated that the CIAE multipurpose tool carrier is efficient and capable of reducing operational costs and labor while being suitable for year-round use in various agricultural operations.

This research concluded that the CIAE tool carrier can enhance the efficiency of farm operations by utilizing bullock power effectively and reducing the drudgery associated with traditional farming methods.

Waghmare and Annasaheb [21] developed A prototype multipurpose tool carrier (MPTC) designed for bullock-drawn operations was developed at Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. This research aimed to address the challenges faced by small and marginal farmers in Maharashtra who rely on draught animals for farm operations.

The MPTC was developed to perform various agricultural tasks, including seed planting, fertilizing, spraying, and intercultivation, with attachments designed for different functions. During testing, the average draft required for the planter cum sprayer and intercultivator was 62 and 58 kg, respectively. The MPTC achieved theoretical field capacities of 0.189 ha/h and 0.32 ha/h with field efficiencies of 88% and 65%. The average speed of operation for the planter cum sprayer was 2.10 km/h, while the three-tyne hoe with furrow opener operated at 1.8 km/h. Weeding efficiency was recorded at 84%. The average seed and fertilizer application rates were 63-67 kg/ha and 92-96 kg/ha, respectively. The implement required only one laborer for operation, and nozzle discharge rates ranged from 195.97 to 197.66 ml/min.

This research highlighted the potential of the bullock-drawn MPTC to improve efficiency, reduce labor costs, and provide a cost-effective solution for small-scale farmers.

Thajur and Jagadale [22] The research involved developing and evaluating a low-cost, multipurpose tillage tool carrier (MPTC) that could be used with a 5 hp (3.7 kW) power unit. The MPTC was designed to perform various farming operations such as ploughing, leveling, and other tillage tasks with easy adjustments for row spacing, depth, and width of cut.

Field experiments were conducted on different soil moisture levels (6.6%, 12%, and 20%) to assess the performance of the MPTC with a mouldboard plough and horizontal blade. The results showed that at 20% moisture content, the mouldboard plough performed efficiently, achieving a field capacity of 0.20 ha/h and a field efficiency of 86.6%. The power requirement was 0.8 kW, and the energy consumption was 3.3 kWh/ha. The tool carrier demonstrated good matching with the power unit, offering adjustable settings for various tillage tools. The MPTC provided a low-cost solution for small farmers by allowing the use of multiple tools with a single frame, reducing the need for separate implements.

James and Arya [23] developmed a Multipurpose Tool Carrier for Homestead Agriculture performing multiple farming operations with a single engine by incorporating a brush cutter engine as the power source, the tool carrier was designed to perform tasks such as weeding and earth auguring, which are critical for homestead agriculture.

Field tests demonstrated that the developed tools were highly effective, showing significant improvements in weeding efficiency and fuel consumption compared to manual methods. For instance, the vegetable weeder achieved an impressive 86.23%weeding efficiency, and the earth auger was able to dig 8 pits per minute. These findings were indicative of the tool's ability to reduce labor-intensive farming tasks and increase operational efficiency.

The cost analysis further validated the practicality of the tool carrier. With a 35%lower cost than similar market products, the multipurpose tool carrier offered an affordable alternative for small farmers who otherwise lacked access to such machinery. This made the tool carrier particularly suited to the economic constraints of Kerala's small landholders.

Shindkar [24] Designed and fabricated a manually operated, multi-purpose agricultural machine aimed at enhancing efficiency for small to medium farms by consolidating key

tasks like ploughing, sowing, and pesticide spraying into a single unit. Conducted at the Dnyanshree Institute of Engineering and Technology in Satara, India, the research sought to create a cost-effective, labor-saving tool that reduces reliance on external resources like fuel and electricity. Key components included a chassis with adjustable heights, seed and fertilizer trays, and a spraying mechanism. The machine operates bidirectionally, using a belt drive mechanism for the seed feeder and a pump for spraying, which activates when moving backward.

Key Findings

- The machine, with its multi-attachment design, can effectively perform operations traditionally requiring multiple tools, thereby saving time and reducing labor costs.
- The equipment was found to be easily assembled, dismantled, and maintained, making it accessible for small-scale farmers.
- The design promises economic benefits by reducing energy costs and improving productivity with a tool that can be managed manually on uneven terrain.

This multi-purpose agricultural machine provides a practical, low-cost solution aimed at supporting smallholder farmers in achieving better productivity through integrated functionality.

Advantages of MPTC

Animal-drawn multipurpose wheeled tool carriers (MPTCs) offer several advantages, especially for small and medium-scale farmers who rely on animal power for agricultural operations. Here are the key benefits:

1. **Cost-Effectiveness:** MPTCs are generally more affordable than mechanized equipment like tractors, both in terms of initial purchase and maintenance, making them ideal for smallholder farmers with limited budgets.
2. **Versatility:** MPTCs can perform multiple operations such as ploughing, harrowing, sowing, weeding, and even transportation by attaching different implements, reducing the need for multiple, single-purpose tools.
3. **Increased Efficiency:** By consolidating several tasks into one system, MPTCs save time and labor, improving the efficiency of field operations and allowing farmers to complete tasks in a timely manner, which can positively affect crop yields.
4. **Reduced Physical Labor:** Using animals to pull MPTCs reduces the physical strain on farmers compared to manual tools, especially in heavy tasks like ploughing and harrowing, thereby lowering human labor demands and enhancing comfort.
5. **Environmentally Friendly:** MPTCs use animal power instead of fuel, lowering emissions and avoiding the environmental impact associated with fossil fuels, making them a sustainable choice for eco-friendly agriculture.
6. **Adaptability to Various Terrains:** MPTCs are well-suited for different soil conditions and terrains, especially where tractors may not be feasible, such as in hilly, uneven, or small plots where maneuverability is limited.
7. **Low Maintenance Requirements:** With simpler mechanical components, MPTCs require minimal maintenance compared to engine-powered machinery, reducing downtime and ongoing costs for repairs and parts.
8. **Enhanced Control and Flexibility:** MPTCs offer better control over row spacing, depth, and angle adjustments, making them adaptable to different crop types and farming techniques, allowing for precision in operations like planting and weeding.
9. **Utilization of Existing Animal Resources:** In regions where draught animals are readily available, MPTCs maximize the use of these animals, ensuring they remain productive year-round and providing an economical power source for farming tasks.
10. **Employment Generation:** MPTCs support traditional agricultural practices, which can contribute to local employment by preserving skills related to animal care and operation of animal-powered equipment.

Overall, animal-drawn MPTCs provide a practical, affordable, and sustainable solution that aligns with the needs of smallholder and traditional farming systems, particularly in regions with limited access to mechanized farming.

Limitations and challenges

While animal-drawn multipurpose tool carriers (MPTCs) offer numerous benefits, they also have certain limitations and challenges:

1. **Limited Power Output:** Unlike tractors or mechanized tools, MPTCs rely on animal strength, which can limit their efficiency and effectiveness in tough soil conditions or larger fields, especially during intensive tasks like ploughing in compacted or clay soils.
2. **Slower Speed and Lower Field Capacity:** MPTCs operate at a slower pace than mechanized equipment, resulting in lower field capacity and extended time to complete farming tasks, which can be critical during peak planting or harvesting seasons.
3. **Animal Maintenance Costs:** Draught animals require year-round feeding, care, and housing, which can incur significant costs. These expenses are necessary even when animals are not in use, adding an ongoing financial burden.
4. **Physical Strain on Animals:** Using animals for heavy tasks can lead to fatigue, injury, and even long-term health issues, especially if adequate rest or breaks are not provided. This limits the duration and intensity of work that animals can perform safely.
5. **Seasonal Dependency:** In regions with extreme climates, animals may not be able to work year-round. For example, hot or humid weather can reduce animals' endurance and efficiency, limiting the utility of MPTCs during certain seasons.
6. **Limited Adaptability to Certain Crops:** MPTCs may not be suitable for all types of crops, particularly those that require precise planting, heavy lifting, or very specific planting techniques, as the attachments might lack the precision or strength needed for specialized crops.
7. **Reduced Efficiency on Large Farms:** MPTCs are better suited to small or medium plots, as they lack the power and efficiency required for larger-scale operations, where mechanized equipment provides a significant advantage.

8. **Dependence on Skilled Operators:** Operating MPTCs effectively requires skill and experience in managing both the tool and the animals, which can be a challenge in regions with declining knowledge of traditional animal-powered farming practices.
9. **Wear and Tear on Components:** Though generally low-maintenance, the components of MPTCs may suffer faster wear and tear under heavy use or in rugged conditions, requiring periodic replacements or repairs.
10. **Physical Effort for Operators:** While MPTCs reduce labor compared to manual tools, they still require physical effort to operate, especially when steering and handling the animals, which can lead to operator fatigue, particularly in long work sessions.
11. **Environmental Impact of Animal Waste:** In larger operations where several animals are used, managing animal waste can become an environmental concern, especially in terms of its disposal and potential contamination of water sources.

Overall, MPTCs are valuable for small-scale farming, but their limitations can make them less efficient or practical for large-scale, intensive, or highly specialized agricultural operations.

Conclusion

The research on animal-drawn multipurpose tool carriers (MPTCs) demonstrates their critical role in improving agricultural efficiency, particularly for smallholder and traditional farms in regions with limited mechanization. Studies across different models and regions highlight MPTCs' effectiveness in performing essential farming tasks such as ploughing, harrowing, sowing, and weeding through a single adaptable frame, which reduces the need for multiple, single-function tools and saves on labor and operational costs. For instance, research in Maharashtra showed that MPTCs can enhance field capacity and operational efficiency, with comparable field capacities and efficiencies to indigenous implements, while offering significant cost savings in operation and maintenance.

The studies underscore the advantages of MPTCs in increasing seeding and weeding capacity, as seen in Punjab, and in handling diverse soil types and terrains in regions like Uttarakhand and Raichur, Karnataka. Additionally, ergonomic improvements, such as operator seating and depth control, have been noted to reduce operator fatigue and improve the adaptability of MPTCs for various farming conditions.

Despite these advantages, certain limitations persist. Studies pointed out higher draft requirements in some models, notably during primary tillage, which may strain draught animals over extended use. Additionally, the initial costs of improved MPTCs may offset their operational savings for some farmers. Seasonal dependence and physical demands on both the animals and operators also limit the year-round utility and effectiveness of MPTCs, particularly in regions with challenging climates or heavy soil types.

Further investigations, such as those conducted on MPTCs integrated with battery support or powered attachments, reveal that these designs can augment the operational speed and reduce draft requirements, thereby improving overall productivity and field efficiency.

Overall, MPTCs provide a sustainable, low-cost alternative to mechanized tools, especially suited for small-scale agriculture. They increase efficiency, reduce reliance on manual labor, and offer a practical solution in low-resource settings. The future of MPTCs lies in refining designs to further decrease energy demands, improve durability, and incorporate ergonomic and technological enhancements, ensuring they continue to support the productivity and well-being of smallholder farmers worldwide.

References

1. Hubbard K, Harvey J, Gibbon D. An animal drawn tool carrier for crop production systems in semi-arid regions. Ministry of Agriculture, Division of Agricultural Research, Dryland Farming Research Scheme, Botswana. Tech Bull. 1974;6:28.
2. Nolle J. Development of bullock drawn multipurpose tool carrier (Tropicultutor). ICRISAT, Hyderabad. Annual Report 1978-79:207-9.
3. Mishra D, Savani J, Singh PM. Bullock operated improved agricultural implements in Saurashtra. J Inst Eng India. 1981;62(HI-2):119.
4. ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). The Animal-Drawn Wheeled Tool Carrier Revised Feb 1983. ICRISAT Information Bulletin 8, Patancheru, A.P. 502 324, India. 1983.
5. Garg BK, Devnani RS. Performance evaluation of multipurpose tool carrier. Annual Report 1983-84 of ICAR Coordinated Scheme on Farm Implements and Machinery, CIAE, Bhopal Centre and paper presented in XXI Annual Convention of ISAE at ICAR, New Delhi, April 5-7, 1984.
6. Maurya NL, Devadattam DSK. Evaluation of animal drawn multipurpose tool carrier. Proc ISAE SJC. 1985;1:1-4.
7. Kshirsagar KG, Fieldson RS, Mayande VM, Walker TS. Use of and prospective demand for wheeled tool carriers in India. Economics-RMP Progress Report-64. 1984:1-32.
8. Singh S, Sharma VK, Singh S, Gupta PK. Feasibility study on animal-drawn tool carrier for selected crop rotations. Agric Mechanization Asia Africa Latin America. 1987;18(3):33-35.
9. Lal H. Animal-drawn wheeled tool carrier: an appropriate mechanization for improved farming systems. Agric Mechanization Asia Africa Latin America. 1985;16(1):38-44.
10. Kankal US, Anantachar M, Chavan VK. Performance of self-propelled intercultivator. In: Emerging Technologies in Agricultural Engineering. Apple Academic Press; c2017. p. 165-205.
11. Guruswamy T, Mathew M, Veeranagouda M, Desai SR. Field performance of multi-purpose wheeled tool carrier A. College of Agricultural Engineering, Raichur. 1994.
12. Chandegara VK. Development of low cost, bullock drawn, multi-purpose implement for sandy loam soil. Ama Agric Mechanization Asia Africa Latin America. 2009;40(4):63.
13. Munde PA, Nadre RG, Sawant BP. Performance evaluation of bullock drawn groundnut digger suitable for MAU multi-purpose tool carrier. 2009.
14. Roy AK, Tiwari GS. Work performance of dromedary camels on multipurpose tool carrier. J Camel Pract Res. 2010;17(2):199-200.

15. Veerangouda M, Sushilendra ER, Anantachar M. Development and evaluation of multipurpose tool carrier for power tiller. Karnataka J Agric Sci. 2012;24(5).
16. Nayak VK, Verma AV. Performance evaluation of animal drawn multipurpose tool carrier for tillage and Biasi operations. 2012.
17. Gautam AG, Jogdand SV, Nayak VK. Design, development of animal drawn multipurpose tool carrier suitable for non-descript breed of bullocks of Chhattisgarh. 2013.
18. Singh J, Yadaw M. Testing and evaluation of animal drawn multi-purpose tool seed cum fertilizer drill. Int J Sci Eng Technol. 2014;3(5):463-6.
19. Tiwari RK, Chauhan SK, Singh YJ, Chaudhuri D. Evaluation of animal drawn improved multi-purpose tool frame with planting attachment for maize-A case study in Sikkim. Agric Eng Today. 2016;40(1):32-9.
20. Ramya V. Performance evaluation and energy estimation of multipurpose tool carriers for tillage operations. Doctoral dissertation, University of Agricultural Sciences, Raichur. 2014.
21. Waghmare AA. Design and development of bullock drawn multipurpose tool carrier. Doctoral dissertation, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. 2017.
22. Thakur N, Jagadale M. Development and performance evaluation of a low cost multi-purpose tool carrier with matching tillage tools. Int J Curr Microbiol Appl Sci. 2018;7(9):2151-219.
23. Arya KT, James PS. Design and development of a multipurpose tool carrier for homestead agriculture. Department of Farm Power Machinery and Energy. 2019.
24. Shindkar A, Shinde A, Ubale D. Design and fabrication of multi-purpose agriculture machine. Int Res J Eng Technol (IRJET). 2023;10(10):623-626.