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Utilization of draught animal power source for sustainable agriculture- A review

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Abstract
Despite rapid increase in tractors and power-operated machinery, the use of mechanical power in agriculture has increased but draught animal power (DAP) continues to be used on Indian farms due to small holdings and hill agriculture. In India, more than 35% of net or gross sown area is still being managed by using draught animals. Study reveals that the command area with per animal pair per season ranges from 1.5-2.0 ha to ensure timeliness in field operations. The present study shows that the improved implement system gave 32% more field capacity, 25% saving in labour and 60% cost of operations over conventional implement system. Bullock drawn air mist canopy sprayer saves 82.2 per cent cost and 88.4 per cent time for spraying of cotton and pigeon pea over the manual knapsack sprayer. The cost of operation with improved animal drawn implement was found to be Rs 714 per ha as compared to Rs 893 per ha in case of conventional method of manual broadcasting. The average grain yield and B:C ratio for mechanized rice with improved animal drawn implement were found to be 4.8 t/ha and 1.42 as compared to 4.2 t/ha and 1.24, respectively for conventional method. For small farmers having farm area of 1.5-2.0 ha, the animal based cultivation system has been found to be cost-effective and energy efficient. Animal based farming system get best fit to the size of the farms for practicing conservation farming, integrated farming and organic farming with management of appropriate technology practices on-farm.

Keywords: Animal energy, draught animal power, animal drawn implements

Introduction

Status of Draught Animal Power and its relevance

Draught animal power has traditionally been the main source of power in Indian Agriculture. Draught animals are mainly used for tillage, inter-culture, threshing, haulage, water lifting, transportation and other purposes. India is endowed with the best bovine fauna in the world. India possesses the finest breeds of draught animals in the world. There are about 24 cattle breeds along with a large number of non-descript breeds. These are Nagori, Khilari, Helicar, Amrit-mahal, Kangeyam, Malvi, Haryana, Red Khandhari, Gir, Ongole, Tharparkar, Sahiwal, Dhangi and Gaulao. Bullocks and he- buffaloes over two years of age are the main sources of draught animals for field operations. Camels (both male and female) by and large are also used for tractive power in a few states such as Rajasthan, Gujrat, Haryana, Punjab and Uttar Pradesh. They are also used in transport in cart and as pack animal. Donkey, mule, horse & pony, yak and mithun are used as pack animals and in carts for transportation. They are very versatile and dependable source of power for use under various climatic conditions and undulating terrain. They are born and reared in the village system and maintained on the feed and fodder available locally. They are ideal for rural transport where proper roads are not available. They reduce dependence on mechanical sources of power and save scarce petroleum products. Their dung and urine are also used as indirect source of energy—farmyard manure and biogas. The basic users of draught animal power are generally small, marginal and medium farmers which depend fully on animal power for farm operations. The land holdings are less than 2 ha. This area is within the command area of one pair of bullocks. Draught animals are used for seed bed preparation, sowing, inter-culture, spraying, threshing and transport. Draught animal system is in perfect harmony with the village ecosystem. Draught animals, besides being a source of power also are a major source of by-products such as manure and urine, which enhance the productivity of soil. Animal energy is environmental friendly which saves about Rs.60, 000 crores worth of fossil fuel annually. They are fed by crop-residue and also produce manure. Draught animals produce about 40 billion tonnes of dung which is used to make farm yard manure. Thus, draught animal system is more oriented towards organic farming. Organic farming is coming up in a big way in the country. At present about 90% of the registered farmers adopting organic farming has been from small and marginal farmers having up to 2 ha holdings. For small farms, the animal human system is the

best fit for practicing resource conservation, organic and integrated farming system. It gives higher economic value to the farmers by means of quality green/organic produce without damaging the soil and environment. Similarly, non-motorized transport using animal carts and pack load transport still constitute a significant portion of total transport sector. There are at present more than 12 million animal carts. Population of carts is on increase. It is expected that draught animals would continue to play an important role in Indian agriculture for the next two decades, especially in the backward and remote parts of the country, where fuel availability and tractorization are likely to be behind. Therefore, it is imperative to utilize the draught animals properly economically and enhance their productivity.

Improved Animal drawn Implements for Tillage, Seedbed Preparation, Farm-yard Manure Application, Sowing and Planting, inter-culture and harvesting.

Equipment package have been developed for tillage, sowing, weeding, spraying and harvesting which gave higher area coverage and lower cost of operation in comparison to existing size of implements. The increase in output ranged from 30-70%.

Iron Plough

A steel shovel is fixed at the lower end of plough and can be replaced when worn out. The power required to operate *tendua* plough is 0.38 kW, which is significantly less than the power requirement of 0.60 kW in case of traditional plough. An iron plough is suitable for deep tillage in irrigated fields. Pant hill plough has a width of 150 mm and weighs 5 kg. Due to its light weight, farmers in the hills can easily carry it. Cost of unit is Rs 500/-. This implement has also become popular with the farmers. The draught requirement is 400 N. It has a field capacity of 0.022 ha/h. It is lighter than the traditional plough and the field capacity is 53% higher.

Mouldboard plough

Animal drawn mould board plough is used extensively for primary tillage in many parts of the country. It inverts soil and tills weed unlike traditional plough and also contribute to increase yield. MB plough size 100 mm is found suitable for small bullocks. Field capacity is 0.016 ha/h and draught requirement is 430 N. Cost of operation was found Rs. 1200-1500/ha.

Blade harrow

The developed improved blade harrow with V shaped blades using 600 mm blade is suitable for primary tillage and 900 mm blade, V shaped blades for secondary tillage. The blade harrow gave 25% saving in cost of operation per hectare over the traditional method. The field capacity of the 600 mm and 900 mm blade harrow is 0.073 and 0.10 ha/h, respectively.

Disc harrow

The disc harrow consists of a frame, two gangs having, 6 discs and an operator's seat and its weight is 35 kg. The field capacity of disc harrow was 0.15-0.3 ha/h, 5-10 times of traditional plough and gave 75% saving in cost of operation per hectare. The draught requirement of disc harrow was 400 N.

Cultivator

The width of three tyne cultivator is 420 mm. The field capacity of the modified cultivator is 0.052 ha/h, 3-5 times of that traditional plough and inter-culture tool. It saves 50-75% in cost of operation per hectare. The draught required is 350 N, which corresponds to 8.4% of body weight and is within the draught capacity of local bullocks.

Patela harrow

Patela harrow is used for breaking clods and trash collection. It consists of sal wood plank, trash collection hooks, cogwheel and lever for lifting device. The width of the harrow is 2 m for large bullocks and 1.5 m for small and medium size bullocks. The field capacity ranges from 0.30 to 0.40 ha/h with cost of operation of Rs. 200-250/ha. It saves 60% cost of operation per hectare as compared to planking and manual picking of trash.

Animal operated clod crusher cum puddler

A developed bullock operated clod crusher cum puddler can be used for clod breaking and puddling. Field capacity was 0.26 ha/h. It can also be used for puddling operations in wet soil.

Bullock drawn stubble collector

The developed animal operated stubble collector is used for collection of stubbles of cotton in the field. It takes 2.5 h per ha for stubble collection. The cleaning efficiency and output power was 87.93% and 0.80 kW, respectively. It has become popular in Maharashtra region.

Implements for puddling

A lug wheel puddler having two passes of the puddler is adequate to prepare the puddle bed. The field capacity of the implement is 0.10 ha/h. It saves 50% time and 60% cost of puddling per hectare as compared to traditional spike tooth harrow.

Farmyard manure spreader

The farmyard manure spreader can be used both for transport of manure as well as spreading. The average draft requirement during spreading operation varies between 520-640 N. Manure application rate varies from 4.62 t/ha to 18.53 t/ha. Field capacity of the spreader for manure spreading was 0.18 ha/h.

Implements for Sowing and planting

Three row seed cum fertilizer drill

Three row seed cum fertilizer drill for line sowing of paddy has been developed by IGKV, Raipur. The draught requirement of the implement is 554 N with field capacity of 0.10 ha/h. Line sowing of paddy results in 10-15% increase in yield.

Zero till drill

An animal drawn zero till drill with one, two and three rows is suitable for sowing of wheat after rice. One row unit is ideal for narrow terraces of hills. This opens a narrow slit with minimum soil disturbance. The weight of unit varies from 4.5 to 25 kg depending on the size. Draught requirements vary from 400-600 N. The field capacity of the implement varies from 0.02 to 0.06 ha/h.

Multi-crop seed cum fertilizer drill

Animal drawn multi-crop seed cum fertilizer drill has been developed for sowing of seed spices. Two pneumatic wheels are provided for transportation on either side of main frame. A clutch is provided to engage or disengage the power

transmission to seed metering device. Five nos. shoe type furrow openers are provided. The draught was 250 N and field capacity was 0.23 ha/h.

Bullock drawn earthing-up cum inter-culturing
An earthing-up cum inter-culturing implement has been developed to remove weed as well as placement of fertilizer at a time in the crop. Field capacity of for inter-culturing, light earthing-up and final earthing-up operation were 0.151, 0.146, 0.117 ha/h, respectively for sugarcane and 0.196 ha/hr, 0.177 ha/h and 0.128 ha/h, respectively for turmeric.

Development of bullock drawn 8-row drum seeder
It has been developed for sowing of pre-germinated paddy. The seed rate was observed to be 30.0 kg/ha. Field capacity of drum seeder was 0.18 ha/h with field efficiency of 68.25%. The cost of seeding with this drum seeder was found to be Rs. 118 per hectare.

Implements for Weeding and Inter-culture operations
The developed improved animal drawn blade hoe is suitable of weeding in two rows, having working width of 200 mm. Its field capacity is 0.10 ha/h and weeding efficiency, 62-79% and draught requirement 550 N.

Animal drawn 3 Tyne ferti-hoe
Three tyne cultivator type hoe with fertilizer application attachment has been developed by MAU, Parbhani. Draft requirement for the ferti-hoe is 510 N at operating speed of 2.2 km/h. The time required to cover 1 hectare was 5 hour and observed weeding efficiency was 84%. It saves 50-60 % cost of operation over traditional method.

Sprayers
Bullock drawn traction sprayer
An animal operated traction sprayer suitable for medium and heavy pair of bullock. The maximum height of sprayer's nozzles from ground is 1.2 m. The sprayer uses stub axles and can therefore also be used as a high clearance sprayer for cotton and pigeon pea crops. Fourteen hollow cone nozzles of discharge 720 ml/min are used to produce fine droplets. Average discharge of nozzles varies from 712.0 to 715.0 ml/min with average boom discharge varies from 9.96 to 9.97 l/min at nozzle height of 450 mm from plant canopy. The field capacity of the sprayer is 1.33 ha/h with field efficiency of 84% whereas the draught requirement varies from 654 to 709 N. The cost of operation is reduced by 50-60% as compared to manual knapsack spraying.

Bullock drawn solar powered high clearance sprayer
In order to utilize available solar energy and labour saving, a solar powered bullock drawn high clearance sprayer has been devepoed for spraying in cotton and pigeon pea crop. The area covered by the solar powered sprayer was about 0.95 to 1.0 ha/h. The cost of operation of bullock drawn solar powered high clearance sprayer was Rs. 128.10/ha for cotton and Rs. 119.60/ha for red gram crop. The percentage of financial saving over the manual knapsack sprayer was 56 per cent for cotton and 67.1 per cent for red gram crop. The percentage of labour saving over the manual knapsack sprayer was 56.6 per cent for cotton and 59.48 per cent for red gram crop.

Bullock drawn air mist canopy sprayer
Bullock drawn air mist canopy sprayer is used for control of pests and diseases on top and underneath side of leaves, plant stem and other canopy surface of crop. It comprised of bullock cart, spray boom, air blower, HTP pump, diesel engine, spray tank, control valves, power transmission system, battery (12-volt), self-starter and pressure gauge. A pair of bullock is used for pulling the cart which acts as a traction device and the diesel engine has been selected as power source for operating canopy sprayer. The average field capacity of canopy sprayer was worked out as 0.70 ha/h for cotton crop and 0.60 ha/h for red gram crop, respectively. The financial saving for spraying operation on cotton and pigeon pea were 82.24 and 82.01 per cent. The time saving for spraying operation on cotton and pigeon pea over the manual knapsack sprayer was 88.43 per cent and 88.46 per cent, respectively. The energy requirement for spraying operation on cotton and pigeon pea crops was 65 and 85 MJ/ha, respectively.

Multipurpose tool carrier
It has been attachment of tools for tillage, seeding and inter-culture. The unit consists of main frame, tool bar and wheel (Pneumatic/Iron wheels) with provisions for attachment of tools and lifting of tools on turns. The wheeled tools carrier showed advantage in terms higher command area (1.5-2.5 times) than the conventional implements. Its field capacity is 0.032 ha/h at the forward speed of 2.95 km/h during the ploughing operation. For harrowing operation, its field capacity is 0.23 ha/h at the forward speed of 3.47 km/h. The average draft and power output is found 600 N and 0.66 kW.

Pneumatic Wheeled type multipurpose tool carrier
Tool carrier consists of a rectangular frame made of MS pipe. Power to the seed and fertilizer metering mechanism is given through a pneumatic transport wheel by a set of bevel gear and telescopic shaft. The size of the plough in light soil is 225 mm and in heavy soil it is 150 mm. The average field capacity observed in light and heavy soil is 0.05 and 0.035 ha/h, respectively. The draught requirement for operating the plough is 518 N in light soil and 700 N in heavy soil. For secondary tillage with 3 tyne cultivator, using sweep or shovel, the average field capacity is 0.176 ha/h, which is nearly a 300% increase as compared for indigenous plough. Draught requirement was found 700 N. For raised bed formation and sowing with raised bed planter, the draught requirement and field capacity is 635 N and 0.18 ha/h, respectively.

Light weight non-wheeled type tool frame
This tool frame is very light, weighing about 2 kg. Even with an attachment fitted, it weighs only about 4 kg. The tool frame was evaluated with different attachments, namely cultivator with shovel, ridger, MB plough and reversible plough. Farmer can easily lift the tool frame with implement. During operation, the tool frame remained very stable without giving any mechanical problems.

Garlic Digger
An animal drawn garlic digger with curved type blade having size 550 mm is popular among the farmers. The average draft and power output were found to be 683.5 N and 0.55 kW, respectively at average 12% (db) moisture content and 550 kPa soil cone index. The field capacity of developed digger was found to be in the range of 0.08 to 0.1 ha/h with 86% digging efficiency. By using animal drawn garlic digger, and 175.70 MJ/ha energy as compared to manual digging. The newly developed animal drawn garlic digger saved 75% cost and 45% energy as compared to traditional method.

Animal Drawn Single Row Improved Potato Digger
It is used for digging of potato tubers grown on raised beds. It consists of mild steel plate, shank, L Shape clamps (02 no.), main frame, clevis, beam and handle. The light weight digger can work up to 100 mm depth. The working width of digger is 200 mm and its required draught of 350N.

Pneumatic wheeled Multi-purpose Tool Carriers
It has been developed for use in light soils. Ploughing, secondary tillage with cultivator, sowing, bed forming, and bund making can be carried out with the tool carrier. MB. plough, 3tyne/5 tyne cultivator, 3/5 row seed cum fertilizer drill, bund former, bed former, trailer and water tanker are available as attachments. The tool carrier can be satisfactorily used with MB Plough both in light and heavy soil. The average field capacity observed in light and heavy soil is 0.05 and 0.035 ha/h, respectively. The draught requirement for operating the plough was 518 N in light soil and 700 N in heavy soil.

Animal drawn inter-culture cum fertilizer applicator
It has been developed for widely spaced crop, viz., cotton, sugarcane, maize etc. for topdressing of granular urea. It consists of fluted roller metering mechanism, triggering mechanism to detect plant and deliver fertilizer to target plant and *Bakhar* blade provided for weeding operation. The field capacity observed was 0.12 ha/h with fertilizer application efficiency 91%, weeding efficiency 84.5% and field efficiency 74.93%. The draught requirement for operating the implement was found 450-600 N.

Bullock carts
The transportation cost by tractor is about 7.14 times more than bullock cart. The animal transport is most economical for distance up to 10 km.

Steel Carts
A steel cart suitable for a pair of bullocks of was developed for convenient transportation of agricultural produce. It consists of 1860x980 mm size steel platform as well as steel axle and wheels. Steel wheel of 1270 mm diameter and 180 mm width provided. The outer drive is provided with a channel to accept thick rubber pads made from discarded truck tyres. It was found that even after 4 h continuous operations, the animals were not fatigued. The fatigue parameters were evaluated based on fatigue score card for bullocks based on physiological observations and visual symptoms. Draught for pulling the cart at 700 kg pay load varies from 463-480 N and output power varies from 0.29-0.35 kW. Studies have shown that it can be operated for a maximum of 6h with one hour rest after 3h work without fatigue.

Pneumatic Wheeled Carts
A pneumatic wheel cart was developed for use of one pair of bullock. On tar road the pneumatic cart could be operated for 3 hours with 2.5 t payload without animal getting fatigued. The draught requirement was 1062 N and power output 0.58 kW. The contact area between neck and yoke of bullocks ranged from 260-263 sq cm. The refined single animal cart could be operated with payload of 1000 kg and 750 kg on tar and earthen roads respectively. Due to the improved yoke there was an increase of 30% and 25% in payload capacity on tar and earthen roads, respectively. The draught requirement of developed cart was found 430 N in tar road and 540 N for earthen road.

Donkey cart
Donkey drawn cart is made completely of steel. Weight of the steel cart is 40-45% less as compared to traditional wooden carts. Traditional, donkeys are used for pack load transport. The load carrying capacity is 40-50 Kg whereas donkey cart has a capacity of 4-6 q per trip. Draught for pulling the cart at 700 kg pay load varies from 463-480 N and output power varies from 0.29-0.35 kW. Carts are eco-friendly as steel is used in place of wood. It has been popularized through front live demonstration.

Economics of animal based farming system
Economics of animal based farming system with improved package of implement and practices have been studied for different cropping systems. Bullock-operated rice (direct seeded) - wheat (Zero tillage) system the annual productivity was 7.4 t/ha (Rice=3.6 t/ha and wheat=3.8 t/ha) giving over all benefit cost ratio of 2.04:1.00**.** Besides, the specific operational energy and specific cost of production were 1.26 MJ/kg and 2.55 Rs/-kg of grain produced, respectively.

Constraints and Limitations
Though animal based farming has many advantages, it also has some constraints and limitations. These are given below.

Lack of timeliness: One of the concepts of commercial farming is timeliness of agricultural operations. To make the farming a profitable business, the farmers have to take up 2-3 crops in a year where assured irrigation is available. In this case, between two crops, the farmers get less time for the land preparation. As the animal operated implements have less field capacity, it is not possible to complete the land preparation in time to take up the next crop. Research results have showed that delayed transplanting beyond the optimum duration reduces the rice yield to a considerable amount.

Involves animal and human drudgery: In animal based farming, the animals have to work in trashy as well as muddy land and also in a field full of clods. The farmer has to walk behind the animals and at the same time operate the implement. Both the animal and the man have to perform the task in adverse weather conditions. This causes serious health hazards and reduces the work efficiency. Research studies showed that a man has to travel a distance of 66 kilometers to cultivate one hectare of land. Animal and human drudgery can be reduced considerably by adopting suitable work-rest cycles in different seasons.

Unavailability of matching tools and implements: The animals vary in type, breed height and weight from region to region. They also vary with respect to their draft load carrying capacity. So, a particular tool may not be suitable for all the animals. Moreover, the matching tools and implements are not available for all the agricultural operations.

Lack of interest of commercial manufacturers: The cost of the animal operated implements is comparatively less than tractor and power tiller operated implements. So, the profit margin is less. As there is large variation among the animals with respect to size and type, the demand for a particular design is less. Therefore, commercial agricultural implement

manufacturers are not coming up for large-scale production of these tools and implements.

Lack of awareness among the farmers: The farmers are not well aware of improved animal operated implements. So, the line departments of the Government, NGOs and the Agricultural Universities should arrange demonstrations in farmer's field at each block/panchayat levels. Besides demonstrations, farmer's fair should be organized regularly by involving the commercial manufacturers and local artisans. This will certainly create awareness among the farmers and beneficiaries.

Conclusion

Studies on use of improved animal drawn implements reveal that the improved implement system (improved blade harrow and improved Nagpuri type yoke) gave 32% more field capacity and 25% saving in labour over conventional implement system. Bullock drawn patella harrow saves 60% cost of operations as compared to planking and manual picking of trash. Bullock drawn air mist canopy sprayer saves 82.2 per cent cost and 88.4 per cent time for spraying of cotton and pigeon pea over the manual knapsack sprayer

From the above discussion it is concluded that improved animal drawn implements are well suited for cultivation of small and marginal farmers and found advantageous in terms of time and cost saving for tillage, sowing, weeding, spraying and digging operations. Adoption of these technologies reduced the cost of operation and increased the profitability of small and marginal farmers**.** Although several animal based equipment and technology have been developed those may need to be reoriented more focussing on system approach. Animal based farming system may be slow but stable with locally available inputs giving quality and green output with organic base without damaging the soil and polluting the environment.

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