Empowering farmers through animal traction in India

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Abstract

The majority of the Indian farmers continue to use draught animals in agriculture. Bullocks, he-buffalos and camels are the main draught sources for field operations in agriculture. Although total population of bovine has increased, the population of working animals has been reduced from 77.81 to 77.69 million during 1961-62 to 1991-92. The study also revealed that male and female ratio in cattle declined from 1.22 to 1.02 and in buffaloes from 0.39 to 0.29. Matrix of size distribution of draught animals revealed that as per their body weight, 41% draught cattle were small and 44% medium in size. Large and heavy draught cattle comprised of only 15% of the total draught cattle surveyed. Computed on the basis of weight, speed and draught matrix distribution, the weighted average draught power developed by the Indian breeds of animals was 0.24 kW. The analysis further revealed that, on All India basis, DAP use, during 1972-91, declined from 159 to 109 animal-pair-hour per hectare (aph/ha).

Introduction

The Indian agriculture is characterized by the small fragmented land, hill farming, shifting (*Jhum*) cultivation, *Tal* and *Diara* land (waterlogged land): all suitable for cultivation by animate (human and animal) power only. There are about 106 million operational holdings possessing 165 million ha land. The average size of farm holdings in India is 1.57 ha with 79 per cent farm holders having farm size of 1.34 ha. These are further divided into 2-6 parcels (Table 1). Intensive cultivation as a result of introduction of high yielding varieties in mid 1960s after *'Green Revolution'*, and increased area (142 million hectare) and cropping intensity (1.3%) required higher energy inputs and better management practices. This required additional energy to ensure timeliness in field operations, for agro-processing and farm transport.

Draught animals are the major source of motive power (tractive and rotary) for the majority of the farmers. Bullocks, buffaloes, camels, horses, mules and donkeys are the major draught animals. Tillage, irrigation and threshing operations are arduous to perform, these are gradually performed by mechanical power (Singh, 1992 and 1996). But other field operations continued to be performed by animate power. An analysis has been made in this paper to investigate the population dynamics and trends in use of draught animal power in Indian agriculture vis-a-vis mechanical power.

Indian agriculture

Out of the total 329 million hectare geographical area, 165.6 million hectare is available for cultivation. During the last thirty years the net sown area has remained around 138 to 142 million hectares. The gross cropped area has, however, increased to 185.5 million hectare in 1997-98. The land is divided amongst 106 million farm holders (1991) with average farm size of 1.57 ha (Table 1). The farms are further divided in 2-6 parcels and small plot sizes. The sub-division of land in India is due to Laws of 'Inheritance' and the 'Hindu Succession Act', where children have equal share in the property of their parent. Animal power has been the chief source of farm power, used extensively for irrigation, threshing and transport besides tillage, sowing and interculture.

During 1947 to 1965, the increase in production was achieved mainly due to increase in cultivated area (Table 2). The farming was on a subsistence level and there was almost no role of mechanical energy. Since green revolution era of 1965-1975, net sown area remained at 142 million hectare and productivity increased due to introduction of high yielding varieties and modern agricultural practices. The increase in land productivity has been achieved through corresponding increased use of indirect sources of energy - improved seed, fertilizer and agro-chemicals (Table 3). The consumption of fertilizer increased many-fold and the demand of electricity and diesel in agriculture, increased steadily. Compared to 51 million tonnes of food grains production in 1950-51, the country achieved production of 199 million tonnes in 1997-98.

Table 1:Trends in distribution of land holdings

Year	*Marginal < 1 ha*	*Small 1-2 ha*	*Semi-medium 2-4 ha*	*Medium 4-10 ha*	*Large > 10*	*All India*
Farm holdings, million numbers						
1970-71	36.20	13.43	10.78	7.93	2.67	71.01
1976-77	44.52	14.73	11.67	8.21	2.44	81.57
1980-81	5.12	16.07	12.45	8.07	2.17	88.88
1985-86	56.15	17.92	13.25	7.92	1.92	97.16
1990-91	62.11	19.97	13.91	7.63	1.67	105.29
Operated area, million hectare						
1970-71	14.56	19.28	29.98	48.23	50.09	162.14
1976-77	17.51	20.90	32.43	49.63	42.87	163.34
1980-81	19.73	23.17	34.65	48.54	37.71	163.80
1985-86	22.04	25.71	36.62	47.14	33.00	164.56
1990-91	24.62	28.71	38.35	45.05	28.89	165.60
Average size of holdings						
1970-71	0.40	1.44	2.78	6.08	18.76	2.28
1976-77	0.39	1.42	2.98	6.05	17.56	2.00
1980-81	0.39	1.44	2.78	6.01	17.38	1.84
1985-86	0.39	1.43	2.77	5.95	17.19	1.60
1990-91	0.40	1.44	2.76	5.90	17.33	1.57

Source : Agriculture Statistics at a Glance, Government of India.

The traditional farm tools and implement mainly relied on use of animate power. Improved farm tools, implement and machinery are used by animal and mechanical power. The traditional animal operated country plough although having low output (30-40 h/ha) and requiring higher number of tillage operations are still being used by farmers on small farms and in regions where economic status of the farmers is not sound. Bullock drawn cultivator and disc harrow has gained popularity due to higher output (2-3 times more area coverage) and better quality of work.

The use of mechanical power for traction and stationary operations is increased considerably since the green revolution era. Developmental support in the form of a subsidy on electricity, prime movers and farm equipment enhanced the pace of mechanization. Farmers are encouraged to adopt mechanical power sources to supplement animate power. Custom hiring of tractor drawn tillage equipment has become an accepted practice and is expected to be more common on economic considerations.

Irrigation is one of the major energy-intensive operations. The number of irrigation pumps have swelled from 0.109 million to about 14.3 million during 1951-52 to 1996-97 as a result gross irrigated area increased from 22.56 to 70.64 millions. About 950 000 irrigation pumps are being introduced every year. Electric pumps are preferred over diesel engine operated pumps due to lower recurring cost, which also provide higher energy-use efficiency. Prime movers for irrigation are also used by the farmers for operating thresher, chaff cutters and cane crushers.

Farm power in India

Human power has been predominantly used in Indian agriculture for crop production. Sowing, transplanting, fertilizer application, interculture, earthing, harvesting and digging are performed by human power. Use of human power is expected to continue at present rate in hilly regions, drier lands, small land holdings and in areas where mechanization has not been adopted. As per Census reports, the population of agricultural workers was 97.2 million in 1951 and steadily grew to 186.5 million in 1991 (Table 4). The growth pattern of agricultural workers since 1971 indicate that about 206 million agricultural workers would be available for agriculture by 2000 AD. This is equivalent to 10.5 MkW.

Table 2: Agricultural development since independence

Year	Area, million hectare				Cropping intensity, %	Grain production million tonne	Remarks
	Net cropped area	Grossed cropped area	Net irrigated area	Gross irrigated area			
1950-51 1960-61	118.75 133.20	131.89 152.77	20.85 24.66	22.56 27.98	111 113	50.8 82.0	Pre-green revolution era, land area increased
1965-66 1975--76	136.20 141.64	155.28 171.29	26.34 34.59	30.90 43.36	114 121	72.35 121.0	Green revolution era, adoption of better inputs
1980-81 1990-91	140.00 143.00	172.63 185.91	38.72 47.78	49.73 62.47	123 131	129.6 176.4	Post green revolution era, management and mechanization adoption
1996-97	142.8	188.15	53.00	70.64	132	199.3	

Source : Agricultural Statistics at a Glance (1998), Ministry of Agriculture, Govt of India.

Table 3: Trends in use of agricultural inputs

Inputs	1950	1960	1970	1980	1990	1995	1996
Seed, 10^3 T	-	-	200	240	570	688	700
Fertilizer, 10^5 T							
Nitrogenous, N	0.55	2.10	14.87	36.78	79.97	98.23	103.00
Phosphatic, P_2O_5	0.08	0.53	4.62	12.14	32.21	28.97	29.77
Potassic, K_2O	0.06	0.29	2.28	6.24	13.28	11.56	10.30
Agro-chemicals, 10^3T	2.35	8.62	24.32	45.00	75.00	61.26	56.11
Diesel, 10^3 T	-	-	153.5	1034.5	2113.9	3230.0	3352.0
Electricity, GWh	-	-	4460	14489	50321	85736	-

Source: Agricultural Statistics at Glance, 1998, Teddy, 1997-98
T = tonne; GWh = giga watt-hour (10^9 Wh)

Table 4: Population dynamics of agricultural workers (millions)

Type of workers	1951	1961	1971	1981	1991	Growth, %
1. Total population, million	361.1	439.2	548.9	685.2	846.3	2.15
Annual growth rate, %	1.25	1.96	2.20	2.22	2.11	
2. Agricultural workers	97.2	131.1	125.8	151.70	186.54	1.64
(% to total worker)	(69.43)	(69.48)	(69.69)	(66.46)	(64.85)	
Agricultural workers power, MkW	4.86	6.56	6.29	7.59	9.33	1.64

Source : Agricultural Statistics at a glance, 1995.
Note: Figures in brackets give percentage to total main workers. Capacity: 0.05kW/person

Draught animal power has been extensively used for crop production and transportation. India possessed the most famous draught breeds in the world. These are Nagori, Khilari, Helikar, Amrit Mahal, Kangayam, Malvi, Hariana, Gir, Angol, Tharparkar and Gaulao. Bullock and he- buffalo over three years of age are the main sources of draught animals for field operations. A small percentage of less than 2% of the total cows are also used in few eastern and southern states. Adult male and female camels are used for field operations, besides for transport. Their population is estimated to be less than 1%. The population of draught animals has declined to about 77.69 million in 1991-92 from 80.75 million in 1971-72 and is estimated as 77.13 million in 1996-97 contributing 19.12 MkW (Table 5). This is 14.5 % of the total farm power. The average DAP availability was estimated as 3.68 ha per pair which is considered far below the normal command area of 1.5 - 2.5 ha per pair.

Table 5: Population of draught animals for field operations (in millions)

Animal	1961-62	1971-72	1981-82	1986-87	1991-92	Growth, %
Cattle	70.67	73.14	61.05	63.58	70.33	-0.20
Buffalo	7.14	7.61	7.32	6.78	7.36	0.09
Total	**77.81**	**80.75**	**68.37**	**70.36**	**77.69**	**-0.19**
DAP power, MkW	19.45	20.19	17.09	17.56	19.42	-

Source : Livestock Census 1972,1982, 1987 and 1992. Capacity bovine - 0.25 kW/animal.

Table 6: Population growth trends in mechanical tractive power

Tractive power	1961-62	1971-72	1981-82	1991-92	1996-97*	Growth rate (%) Base year 1980
Tractor	0.031	0.148	0.518	1.233	1.82	8.2
Power tiller	-	0.017	0.08	0.095	0.110	7.76
Total power, MkW	**0.70**	**3.44**	**12.18**	**28.36**	**41.67**	**12.02**

Source: Livestock Census Reports. Automobile Association of India * estimated
Capacity, Tractor-22.5 kW, power tiller-6.5kW

Table 7: Population growth trends in irrigation pumps (in million)

Mechanical power	1951-52	1961-62	1971-72	1981-82	1991-92	1996-97	Growth rate since 1980, %
Electric pump	0.02	0.10	1.629	4.33	8.91	9.73	5.50
Diesel pump	0.08	0.23	1.55	3.10	4.66	5.58	4.00
Power, MkW	**0.47**	**1.57**	**14.14**	**32.27**	**56.53**	**65.31**	**10.91**

Source: Livestock Census Reports, Automobile Association of India and Singh G. Data Book on Agricultural Mechanization and Agro-Processing in India, 1997
Capacity: Electric motor-3.73 kW, diesel engine-5.2 kW

Table 8: Farm power availability per unit net cropped area

Power	1961-62	1971-72	1981-82	1991-92	1996-97
Total farm power, MkW	28.28	44.05	69.13	113.64	136.33
Unit farm power kW/ha	0.22	0.32	64.3	0.80	0.97
Draught over total power, %	**68.78**	**45.83**	**24.72**	**17.09**	**14.11**

Table 9: Share of farm power sources

Power source, MkW	1971-72	1996-97
Human power	6.29 (14.2)	10.12 (7.4)
Animal power	20.19 (45.8)	19.23 (14.1)
Mechanical and electrical	17.57 (40.0)	107 (78.5)
Total farm power	44.05	136.35

Note : The values in brackets indicate percentage of the total power.

Table 10: Share of coverage of net cropped area by different power sources (1996-97)

Power source	Population, million	Unit command area, ha	% area coverage
Draught animals	77.13	2	54.3
Tractor	1.82	15	19.2
Power tiller	0.11	5	0.4

The tractors in India were introduced through importation. There were only 8635 imported tractors in use in 1951. The local tractor production started in 1961-62 with 880 numbers. Today, India is manufacturing more than 257,449 tractors per year (1997-98) with total estimated population of more than 1.82 million (1996-97) contributing 41.67 MkW (Table 6). Custom hiring of tractors has become popular for tillage, transport and threshing. Different sizes of tractors are manufactured in India ranging from less than 15 kW to more than 37.5 kW, but most popular range is 15-30 kW.

Power tiller was introduced in the country in the sixties, but could not gain popularity as tractor due to their limitation in field and on-road use as well as ergonomic weaknesses. The use of power tillers is presently more in rice and sugarcane producing areas of Tamil Nadu, Andhra Pradesh, Kerala, Karnataka, West Bengal, Orissa, Bihar and Maharashtra. The yearly production is about 10,500 units The potential power availability is estimated to be 0.66 MkW (Table 6).

Diesel engines and electric motors are used for stationary operations especially for lifting water for irrigation and operating grain mills, oil ghanis, sugar cane crushers, power threshers and chaff cutters. The growth in irrigation pumps is indicated in Table 7. The government support through financial incentives for irrigation hard wares have played an important role in their popularization. The electric motor operated pumps are more preferred in electrified areas due to lower recurring cost. It is estimated that the population of electric motors for irrigation is 9.73 million with potential power availability of 36.29 MkW and that of diesel engines 5.94 million with potential power availability of 30.16 MkW in 1996-97.

Farm power per unit area is one of the parameters for expressing mechanization status of any country. The total farm power availability in 1951-52 was 0.20 kW/ha which increased to 1 kW/ha in 1996-97 (Table 8). The farm power input per unit cultivated land in India is still very low. It is evident that mechanical power contributed about 78% to the total farm power but for tractive power it is only less than 30% and thus major use of mechanical power has been for stationary farm operations only.

Animal power contributed 45.8% of the total farm power in 1971-72 and mechanical and electrical together contributed only 40%. In 1996-97 the contribution from animal power reduced to 14% while mechanical and electrical power increased to 79 % (Table 9). But in terms area coverage draught animals continue to dominate with more than 54.3% area cultivated them and only 19.6 by tractor and power tiller (Table 10). The remaining land is cultivated by human power especially in shifting cultivation, mainly done in hilly land and water-logged areas.

Dynamics of draught animals

The population dynamics analysis of draught animals is based on the secondary data of Livestock Census and Special Reports of Department of Animal Husbandry and Dairying, published by Department of Economics and Statistics, Ministry of Agriculture, Government of India. Crop wise use of animal energy (for cereals, pulses, oilseeds fruits, vegetables and commercial crops) and area cultivated under each crop, grown in different states was obtained from the reports of cost of cultivation of principal crops in India, Agricultural Statistics at a glance and Indian Agriculture in brief published by Ministry of Agriculture, Government of India.

Growth in bovine power

Zebu cattle (*Bos indicus*) and buffalo *(Bubalus bubalis)* are major sources of draught animals in India (Table 11). In most part of the country only male bovine are used for draught purposes. Cows are generally not used for draught work due to social and religious considerations. Only in few Eastern and Southern states, female bovine which are generally not calved (heifers), are used for draught work. The castrated male cattle over 3 years of age (2.5 years in crossbred) are used as draught animals-classified as 'animals for work'. Un-castrated bulls and buffaloes are also used for draught purpose (7.5% of the total working bullocks and 26.5% of the total working buffaloes). During 1961-62 to 1991-92, the population of working bovine has reduced from 77.81 to 77.69 million, registering a negative growth of 0.20% per annum (Table 5). It is observed that although, population of total bovine in the country has increased but ratio of male to female reduced, as a result population of draught animals reduced (Table 12). The male and female ratio in cattle was 1.22 and in buffaloes 0.39 in 1961 which, respectively reduced to less than 1 in cattle and 0.29 in buffaloes in 1992. This is indicative of the fact that cattle and buffaloes both are now reared more for milk than draught animals.

The camels (both male and female) are by and large, used in transport and as pack animal, but they are also used for tractive power in few states such as Rajasthan, Gujarat, Karnataka, Haryana and Punjab for field operations and for lifting of water from open wells. The total camels population has increased marginally from 0.9 to 1.03 million but adult population increased to 0,74 million during the period. About 60% of the adult male and female are usually used for tillage beside transport.

Pack animals

Camel, donkey, mule, horse, pony, yak and mithun are used mainly as pack animals and in carts for transportation. The growth dynamics in pack animals is given in Table 13. It is seen that total population of horses and donkeys reduced by 1.6% and 0.42% per annum during 1961-62 to 1991-92, respectively. Camels and mules have shown positive growth, but over all pack animal population declined from 3.38 to 3.01 million, registering a negative growth of 0.39%. The population of adult pack animals for work in 1961 was 3 million which reduced to 2.47 million in 1992, indicating a negative growth of 0.65% per annum. Farmers preference for faster mode of mechanical transport such as tractor, *Maruta* (local improvised four wheel transport) and mini-truck for haulage has increased and this may be one of the reasons for decreased used of pack animals.

Table 11: Draught animal population at a glance, 1992 (in million)

Cattle	Buffaloes	Camels	Horses& ponies	Mule	Donkey	Yak & Mithun
204.79 (70.06)	84.21 (28.84)	1.03 (0.54)	0.82 (0.43)	0.19 (0.10)	0.97 (0.51)	0.21 (0.11)

(Figures in brackets represent percentage to total livestock)

Table 12: Trends in male/female ratio distribution in bovine

Year	1961-62	1971-72	1981-82	1986-87	1991-92	Annual growth, %
Cattle	175.60	178.30	189.91	195.87	204.68	0..51
male/female ratio	1.22	1.21	1.08	1.02	0.986	-0.71
Buffalo	51.05	57.40	69.8	76.77	84.21	1.68
male/female ratio	0.39	0.36	0.26	0.28	0.259	-1.29

Table 13: Growth and distribution of pack animals (population in million)

Animal	1961-62	1971-72	1981-82	1986-87	1991-92	Annual growth, %
Horse	1.33	0.95	0.90	0.78	0.82	-1.6
Camel	0.90	1.11	1.10	1.09	1.03	0.45
Mule	0.05	0.08	0.13	0.17	0.19	4.6
Donkey	1.10	1.00	1.00	0.96	0.97	-0.42
Yak	0.02	0.04	0.12	0.04	0.06	3.7
Total	3.38	3.09	3.23	2.95	3.01	-0.39
For work	**3.00**	**2.49**	**2.32**	**2.15**	**2.47**	**-0.65**

Table 14: Distribution of draught animals as per size of farm holdings (1986-87)

Inputs	Farm holdings size ,ha					
	Marginal <1	Small 1-2	Semi-medium 2-4	Medium 4-10	Large >10	All sizes
Draught animals(million)	25.97	16.29	14.72	11.12	3.24	71.34
ha/animal pair	1.61	2.93	4.64	7.89	15.84	4.14
Form holders possessing a pair, %	23.13	45.45	55.55	70.2	84.38	36.71

Source: Input Survey 1987-88, Ministry of Agriculture

Adoption of draught animals by farm size

As a result of introduction of tractors, engines and electric motors, use of draught animals has reduced but these still are used by the farmers. Table 14 shows that draught animals are possessed by all groups of the farm holders, but in terms of intensity (area commanded by the animals), semi-medium, medium and large farm holders the are per animal pair is very large and these group of farmers may not be in a position to cultivate the area within a given time. Marginal and small farmers have sufficient pairs of animals but they are available with limited farm holders and therefore they may have to share with others.

Table 15: Acreage per draught animal pair in India (ha/animal-pair)

States	1987	1992
A. High draught animal power intensity states		
1. Himachal Pradesh	1.29	1.40
2. Manipur	1.65	0.8
3. Bihar	1.79	1.75
4. West Bengal	2.70	1.92
5. Assam	3.06	1.62
6. Jammu & Kashmir	3.16	1.50
B. Medium draught animal power intensity states		
7. Utter Pradesh	2.50	2.89
8. Orissa	2.51	2.22
9. Tamil Nadu	3.36	3.32
10. Madhya Pradesh	3.96	3.36
11. Andhra Pradesh	4.87	3.90
12. Karnataka	6.79	4.29
C. Low draught animal power intensity states		
13. Maharashtra	5.35	5.10
14. Gujarat	7.17	6.47
15. Haryana	8.62	9.30
16. Rajasthan	5.60	10.05
17. Punjab	6.07	10.66
18. Kerala	14.00	16.59
All India	**3.87**	**3.67**

Intensity of draught animals

Draught animals (DA) intensity, defined as inverse of draught animal pair per unit net area i.e. average area to be cultivated by a pair of animal (ha per animal-pair), has been expressed to assess the average availability of draught animals in different provinces (Table 15). To ensure timeliness in field operations, usually 1.5-2.5 ha per animal-pair is considered reasonable command area on net area basis. It revealed that Himachal Pradesh, Manipur, Bihar, West Bengal, Assam and Jammu and Kashmir have DA intensity less than 1.5 ha per animal-pair, Uttar Pradesh, Orissa, Madhya Pradesh, Andhra Pradesh, Tamil Nadu and Karnataka within 2.9-4.3 ha per animal-pair and the states of Maharashtra, Rajasthan, Punjab, Karnataka, Gujarat, Haryana and Kerala have DA intensity varying from 5-16.6 ha per animal-pair. On all India average basis, the estimated DAs intensity was computed as 3.67 ha per animal-pair.

Weight matrix of draught animals

The draught characteristics of animals is usually defined by the weight of the animals. Generally this is 8-10% of the body weight in cattle and buffaloes. Comprehensive data on draught animals as per their body weight was lacking at national level. Information was collected through quick surveys at micro-level (Table 16). It is evident that 41% of the draught cattle population were small in size (with body weight group of 200-300 kg) and 44% in the medium range (body weight 300-400 kg). Only an estimated 11% were large (body weight 400-500 kg) and 4% heavy with body weight over 500 kg. The weighted average body weight of the draught cattle at all India level was estimated at 325 kg.

Draughtability characteristics and animal fatigue

Animal fatigue parameters under load

The draughtability experiments are usually conducted by varying the draught loads on animals and studying their effect on speed and fatigue levels under continuous work. The 'fatigue levels' of the animals have been defined by quantifiable parameters (body temperature, respiration rate, pulse rate and speed) and qualitative symptoms such as frothing, unco-ordination of legs, excitement, inhibition of progressive movements and tongue protrusion (Upadhyay and Madan, 1985). For oxen and buffaloes the maximum points assigned were 40 and for camels and donkey 30 and 32 respectively. The animal is considered fatigued at 50% of the maximum score points. The safe response values without getting the animal fatigued as reported by Upadhyay and Madan (1985) were R_0+30, H_0+20 and T_0+1.0 in the case of oxen. The tolerance limits for different animals have been investigated and

reported by Srivastava and Ojha (1986), Srivastava (1987, 1993) and Upadhyay (1993). It is reported that camels can exert up to 18%, donkey 32%, horses 15% and bullocks 12% of their body weight respectively. The limiting physiological response values due to working load (respiration rate, heart beat rate and body temperature) are given in Table 17 for selected draught animals. The bullocks are stressed due to environment and scores up to almost 16 points and therefore, animal fatigue due to environment stress is more important (Table 18). The safe work load based on present score card as investigated by researchers thus, needs further investigation and refinement of fatigue score card.

Table 16: Matrix of spatial distribution of draught cattle by weight

State	Draught animal population (millions)	Weight distribution of animals, %			
		Small 200-300kg	Medium 300-400kg	Large 400-500kg	Heavy >500kg
1. Uttar Pradesh					
Jhansi	11.928	38.88	36.57	14.44	10.11
Faizabad		30.00	40.00	25.00	5.00
Allahabad		10.00	70.00	10.00	10.00
2. Bihar	7.182	45.00	40.00	10.00	5.00
3. Karnataka	2.091	45.39	34.04	14.18	6.39
4. West Bengal	3.543	75.00	15.00	10.00	-
5. Orissa	4.336	75.00	20.00	5.00	-
6. Madhya Pradesh	8.399	30.00	65.00	5.00	-
7. Haryana	0.702	10.00	70.00	10.00	10.00
Weighted average	**39.18**	**41.42**	**43.90**	**10.59**	**4.09**

Source: Srivastava and Ojha (1987).

Table 17: The range of fatigue parameters of draught animals due to load

Animal	Respiration rate *breath/min*	Heart beat rate *beats/min*	Body temperature ^oC
Oxen	R_o + (15 - 75)	H_o + (10 - 50)	T_o + (0.5 + 2.5)
Buffaloes	R_o + (40 - 50)	H_o + (10 - 33)	T_o + (1.8 - 3.2)
Camel	R_o + (04 - 08)	H_o + (12 - 18)	T_o + (0.7 - 1.7)
Donkey	R_o + (15 - 50)	H_o + (15 + 45)	T_o + (1.0 - 3.0)

Source : Annual Reports of AICRPs on Utilization of Animal Energy, Central Institute of Agricultural Engineering, Bhopal.

Table 18: Variation of physiological response of draught animals without load during the day

Animal	Respiration rate *breath/min*	Heart beat rate *beats/min*	Body temperature ^oC
Oxen			
Summer	16-30	44-62	37.3-38.6
Winter	16-28	40-58	36.5-38.3
Hot & humid	16-33	44-60	36.6-38.4
Buffaloes			
Summer	22-38	40-60	37.5-39.2
Winter	22-33	40-50	35.5-37.8
Hot & humid	22-35	40-60	35.5-37.7
Camels			
Summer	8-13	33-40	37.1-37.7
Winter	6-10	30-38	36.9-37.4
Hot & humid	7-10	32-42	37.0-37.6
Donkeys	35-44	56-62	36.6-38.1

Source : Annual Reports of AICRPs on Utilization of Animal Energy, CIAE, Bhopal.

Animal fatigue under environment stress

The animals are fatigued due to draught load and/or due to environmental stress (temperature and humidity). The resulting effect on animals is reduction in walking speed. The animals are subjected to environment stress under three conditions: (i) winter cold and dry (ii) summer (hot and dry) and (iii) rainy (hot and humid). Low temperature with high humidity intensifies cold stress due to presence of high moisture in the lungs during breathing. At high temperature, in combination with high humidity, animals loose their ability to cool through evaporative cooling which affects their feed in-take. Low temperature with dry air, dehydrates the mucous membrane. In temperate climate, the animals feel comfortable over wide range of humidity (30-90 %). Thus, it is the temperature-humidity index (THI) which has been found to be more effective for expressing comfort environment. The relation can be expressed as,

$$S_{(t)} = f(S_0, D, W, THI \text{ and } t) \quad \ldots\ldots\ldots\ldots \quad 1$$

Where,

$S_{(t)}$ = instantaneous speed of animal
S_0 = initial speed of animal
D = draught load
W = body weight of the animal
THI = temperature -humidity index
t = elapsed time

The temperature-humidity index, THI was defined by Premi and Singh, referred by Shrivastava and Ojha (1987):

$$THI = 0.99\, t_d + 0.36\, t_{dp} + 41.5 \quad \ldots\ldots\ldots \quad 2$$

Where,

t_d = dry bulb temperature, ^oC
t_{dp} = due point temperature, ^oC

The effect of environment on speed of draught animal was studied at Central Institute of Agricultural Engineering, Bhopal by conducting the experiment throughout the year on same pair of bullocks. The results are reported in Table 19. It is seen that walking speed of the animals without load is reduced on an average by about 30% from the initial speed. In general the average speed of the animals during hot and humid seasons was lower compared to the winter and summer season.

The effect of draught load on speed of the bullocks has been studied by many research workers. Table 20 gives an indication of the rate of reduction of speed of a pair of bullocks (body weight 800 kg/pair) observed during winter (temperature 11.5-27 ^oC) at different draught loads. Depending upon the draught load, which varied from 8 to 14% of the body weight, the speed was found to be reduced by 10.7-16.9% of the initial values after 4 hours of continuous work (Gaur and Jain, 1993). The study also revealed that as the draught load increased from 8% of the body weight to 14%, the speed reduced from 3.26 to 2.63 km/h (19.3%) during first hour of the work and 2.71 to 2.27 km/h (16.2%), after four hours of the work. Although, these two studies are not conclusive, it is evident that environment stress affects the walking speed of animals more than working draught load, and reduction in speed of the animal has a pronounced affect on work output. The relationship of instantaneous speed, draught and body weight was computed through regression analysis (Equation 3).

$$S_{(t)} = S_0\,[1 - 1.5\,(D/W) - 0.05t] \quad \ldots\ldots\ldots \quad 3$$

Table 19: Effect of environment on speed of draught animals under no load condition

Animal	Speed of animal km/h		Reduction in speed, %
	0800h	1600h	
Summer			
Crossbred	3.10	2.10	32
Malvi	3.35	2.30	31
Local	3.24	2.28	30
Winter			
Crossbred	3.22	2.15	33
Malvi	3.40	2.42	29
Local	3.28	2.32	29
Hot & humid Crossbred			
Malvi	2.98	2.52	15
Local	3.22	2.15	33
	3.12	2.15	31

Environment:

Summer : Temperature, 17-37 ^0C ; R.H., 15-57 %
Winter : Temperature, 7-24 ^0C ; R.H., 38-82 %
Hot & humid : Temperature, 15-35 ^0C ; R.H., 21-77 %

Table 20: Effect of draught load on walking speed of a pair of oxen (local breed)

Draught, kg (% of body weight)	Average speed of animals, km/h				Reduction in speed %
	1st hour	2nd hour	3rd hour	4th hour	
63 (8)	3.26	2.99	2.83	2.71	16.9
80 (10)	3.12	2.90	2.85	2.66	14.7
95 (12)	2.80	2.71	2.56	2.50	10.7
110 (14)	2.63	2.45	2.43	2.27	13.7

Source : Gaur and Jain (1993)

Table 21: Distribution of draught and speed in relation to body weight

Body weight of animal, kg	Average speed, km/h	Average draught, kg	Power kW
200-300	1.54±0.07	26.41±4.54	0.15
300-400	2.09±0.49	34.56±10.15	0.27
400-500	2.46±0.69	42.57±9.40	0.39
>500	2.37± 0.40	40.07±11.55	0.35

Table 22: Trends in growth of population of bullock drawn implements (in millions)

Implements	1971-72	1976-77	1981-82	1986-87	1991-92
Wooden plough	39.29	41.03	43.04	43.02	39.58
Steel plough	5.36	6.52	6.69	8.86	9.6
Disc harrow	--	--	3.36	1.18	2.26
Cultivator	--	--	4.26	4.96	5.33
Puddler	1.69	2.06	2.32	3.29	2.37
Sowing devices	4.09	4.86	5.62	6.47	6.74
Leveling karaha	0.37	8.89	10.47	8.70	9.6
Olpad thresher	--	--	0.36	0.37	0.32
Cane crusher	0.68	0.78	0.69	0.72	0.75
Persian wheel	0.64	0.57	0.53	0.34	0.16
Bullock cart	12.96	12.67	13.67	14.35	13.38
Sprayer & duster	0.44	1.55	1.55	1.67	2.61

Livestock Census, 1977, 1982, 1987 and 1992

Average speed and power developed by draught animals

The work output (draughtability) of the animal depends upon the breed, physical condition, harnessing device, loading characteristics, rate and duration of work output, environment, feed and feeding method. This is assessed by measuring the draught, speed and physiological responses of the animals. Draughtability studies have been reported by several authors. The data from a number of these studies was compiled and grouped to study the variability in draught, speed and power characteristics and weighted average power output. Range of draught and speed values as investigated by researchers are given in Table 21. The variability in speed values reported by the researchers may have been on account of breeds and environments. It is seen that speed and draught both increased as body weight increased. Heavy animals having a body weight more than 500 kg developed lower draught and walked at a lower speed. As a result, their draught power reduced. The average speed for draught animals having different body weight was estimated to be 1.5, 2, 2.5 and 2.4 km/h and draught 26, 35, 43, and 40 kg for small, medium, large and heavy bullocks respectively. The overall weighted average power developed from the bullock was 0.24 kW.

Draught animal energy use in crop production

Adoption of anima-drawn machinery

Traditional country plough, sowing devices, carts and water lifts made of wood and steel have been used in India up to independence in 1947. Concerted effort by the engineers and industries helped in development of improved machinery. Table 22 shows the trends in adoption of bullock-drawn implements by the farmers. The use of steel plough, disc harrow, cultivator and seed drill has increased considerably.

Table 23: Trends in animal energy utilization (pair-hour/hectare)

Crops	1971-72	1975-76	1981-82	1986-87	1990-91
Paddy	197	197	198	188	157
Wheat	187	213	128	91	71
Sorghum	121	90	90	100	103
Pearl millet	71	65	61	51	
Maize	146*	134	125	113	
Gram	138*	138	108	102	83
Pigeon pea	146*	146*	146	87	
Groundnut	122	131	135	123	93
Rapeseed & mustard	105*	105	88	75	
Soybean	145*	145	109	108*	
Sugarcane	135*	135	101	75	74
Cotton	113	101	90	101	62
Jute & mesta	241	235	203	203	229
Potato	162*	162*	162	120	n. a.#
Onion	173	173	191	127	n. a.#
All India average (E), aph/ha	**159**	**147**	**139**	**123**	**109**

* Previous or following years data used.; # Data of all the crops not available. Average values used.

Animal energy use in crop production

The animal energy use in crop production was computed from the Cost of Cultivation of Principal Crops in India, Ministry of Agriculture, Government of India. The weighted average use of animal energy (pair-hour/hectare; aph/ha) in crop production was computed taking into account energy use in growing various crops in different states.

Average animal energy used per hectare (E_i) (aph/ha) of i^{th} crop is calculated using equation 4.

$$\mathbf{Ej} = \frac{\sum_{1=1}^{n_j} \mathbf{E}_{ij}\,\mathbf{A}_{ij}}{\sum_{1=1}^{n_i} \mathbf{A}_{ij}} \quad \ldots\ldots\ldots 4$$

Average animal energy used per hectare combining all crops,

$$\mathbf{E} = \frac{\sum_{1=1}^{m} E_i\,A_i}{\sum_{1=1}^{m} A_i} \quad \ldots\ldots\ldots 5$$

Where,

- $\mathbf{E}_{ij}$ = average animal energy used per hectare by i^{th} crop in j^{th} state, aph/ha
- $\mathbf{E}_i$ = weighted energy per hectare used by i^{th} crop
- $\mathbf{E}$ = weighted energy per hectare at all India level
- $\mathbf{A}_{ij}$ = area under i^{th} crop in j^{th} state, m-ha
- $\mathbf{A}_i$ = area under i^{th} crop at all India level, m-ha
- $\mathbf{n}_i$ = number of states from where energy data collected for i^{th} crop
- $\mathbf{m}$ = number of crops for which energy data collected.

Use of DAP energy in crop production

Use of weighted animal energy per hectare for different crops at all India level (E_i) is shown in Table 23 for the period 1971-91. It revealed that there has been reduction in use of animal energy in all the crops. Maximum reduction of 5% per annum was recorded in case of wheat crop, 3% in sugarcane and 2.8% per annum in pulses. In wheat crop, use of DAP increased up to 1975-76 and then it decreased. In 1990-91, depending upon the level of mechanization and agronomic practices adopted by the farmers in different states, the DAP energy use varied in wheat, 9.5-100; paddy 7.5-213; coarse cereal 36-114; oil seeds 35-93; sugarcane 40-113; jute 197-239 and cotton, 11-98 aph/ha.

The coarse cereals and pulses are generally grown in rainfed areas, where resources are limited and vagaries of weather higher. The farmers are usually reluctant to invest higher inputs in field. The jute (241-229 aph/ha), potato (162-120 aph/ha), onion (173-127 aph/ha) and paddy (197-157 aph/ha) required higher energy. These crops are grown in less mechanized states and therefore, depend more upon DAP for field operations. The Table 23 also revealed that, at all India level, there has been gradual reduction in use of animal energy. It reduced from 159 to 109 aph/ha (all crop combined) during 1971 to 1991, registering a compound negative growth rate of 2% per annum.

Conclusions

Draught animal power continues to be major farm power source in India. Male cattle and buffaloes are the chief sources of DAP for field operations. In 1991-92, the total DAP population was estimated equivalent to 35.77 millions pairs for field operations. As a result of introduction of mechanical power in agriculture, use of DAP declined from 159 to 109 aph/ha during 1971-72 to 1990-91, registering a negative compound growth of 2% per annum. The analysis also revealed that not only use of DAP energy per hectare and total DAP energy in crop production declined but yearly use of draught animals also reduced from 655 to 567 hours during 1972-91, even though, grossed cropped area increased from 165.79 to 185.57m-ha.

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