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Environmental Value of Draught Animals: Saving of Fossil-fuel and Prevention of Greenhouse Gas Emission

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Abstract

Animal energy is a renewable and sustainable source of energy. It is renewable because the animals can be reproduced by breeding and rearing the required number of animals. It is sustainable because the animals derive their energy for work largely from agricultural by-products. In addition, there are other environmental contributions of the working animal stock — consider replacing it by agricultural machinery run on fossil-fuel. Animal energy saves natural resources, fossil fuel and prevents green house gases emission. The fossil-fuel equivalent of the animal energy used in the Indian agriculture has been found pretty large, as much as 19 million tonnes of diesel in 2003. If this much amount of fuel were to be burnt through combustion to run tractors in the absence of the working animal stock of over 60 million, it would have released about 6 million tonnes of carbon dioxide.

Introduction

Interdependence of livestock and crop production for energy is a distinguishing characteristic of the mixed crop-livestock systems. Crops supply feed and fodder to livestock — the source of their energy and they return that energy in the form of food (milk and meat), dung (manure and fuel) and draught power. In India, despite increasing mechanization of agricultural operations, animals remain an important source of energy for crop production. India has a stock of about 60 million working animals used for various agricultural operations, and thus saving fossil fuel worth Rs 60 billion, annually (GoI, 2007).

A number of studies have come out with the finding that farm mechanization by ensuring timeliness of operations and precision in the application of inputs, enhances agricultural production and productivity (Anonymous, 1977; 1980; Patil and Sirohi, 1987; Singh, 2001). The other side of this scenario, however, is that the mechanization is associated with emission of greenhouse gases like carbon dioxide and other trace gases due to burning of fossil fuels (Mishra and Dikshit, 2004).

Animal energy is a renewable and sustainable source of energy. It is renewable because the draught animals can be replaced by breeding and rearing in the required number. It is sustainable because the animals derive their energy for work from feed and fodder made available from agricultural production, indeed largely from agricultural by-products. In addition, there are other environmental contributions of the working animal stock — consider replacing it by agricultural machinery run on fossil-fuel. It saves natural resources, fossil fuels and prevents emission of greenhouse gases. Despite its benign effect on the environment, the stock of working animals in India has been declining, while the stock of agricultural machinery, particularly tractors has been increasing.

In this paper, we have examined the environmental contribution of working animals at the national level. A brief account of the changes in the stock of working animals and tractors alongwith their densities has been

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provided. The substitution rates of bullocks with tractors are estimated, and the contribution of the working animal stock to environment in terms of saving of fossil-fuels and prevention of emission of carbon dioxide has been discussed. Finally, concluding observations have been made in the last section.

Changes in the Stock of Working Animals and Tractors

According to the classification in the Livestock Census of India the stock of working animals includes cattle and buffalo males of more than three years of age, i.e. the males used only for work and used for work as well as breeding. The data on population of working males and tractors were extracted from the Livestock Censuses for the years 1972, 1987 and 2003.

There had been a continuous decline in the number of working animals at the national level during the periods 1972-87 and 1987-2003. If figures for 1987 are set aside, there is no mistaking the fact that between 1972 and 2003, there was a decline of more than 20 million in the number of working animals at all-India level (Table 1). It is also beyond doubt that much of this decline occurred during the 1980s. Across states, highest decline in the stock of working animals has been recorded in Uttar Pradesh, followed by Bihar, Madhya Pradesh, Tamil Nadu and Andhra Pradesh. The decline in the stock of working animals was engineered by the rapid mechanization of agricultural operations and the growing market for tractor-hire services. Small farmers, who dominate the Indian agriculture, find it more economical to hire tractor services for agricultural operations than to maintain a pair of bullocks.

While the stock of working animals got reduced over the past three decades, the number of tractors increased tremendously during this period. Their number increased from about 0.15 million in 1972 to more than 0.60 million in 1987 and further to 2.4 million in 2003. The state-wise changes in the number of tractors have shown highest increase in Uttar Pradesh, followed by Punjab, Madhya Pradesh, Haryana, Gurarat and Bihar. In other states also, the number of tractors has increased but not as much as in these states.

In the quest of attaining a faster growth in agricultural production, India started introducing mechanical draught power alongwith modern seed varieties, chemical fertilizers and pesticides during the late-1960s. The policy support came in the form of soft credit and subsidy for the purchase of tractors and other agricultural machinery. The success on the agricultural front galvanized, especially the large, so called "progressive" farmers into a formidable interest group, which through lobbying and pressure has seen to it that the policy support is not withdrawn. Indeed, the policy support has continued to-date, and is likely to continue in future (Mishra and Dikshit, 2004).

To examine these changes in detail, it was more important to consider them in relative terms, i.e. to a common base of area under cultivation. The number of working animals per 100 ha of net sown area, in other words, their density consistently declined from

Table 1. Trend in the population of working animals in India: 1972-2003

State	Stock of working animals (in thousands)			Change in working animal stock (in thousands)		
	1972	1987	2003	1987 over 1972	2003 over 1987	2003 over 1972
Uttar Pradesh	15152	13703	6857	-1449	-6846	-8295
Bihar	7920	1634	2472	-6286	838	-5448
Madhya Pradesh	10585	11493	6432	908	-5061	-4153
Tamil Nadu	4716	3146	1127	-1570	-2019	-3589
Andhra Pradesh	6504	5910	4099	-594	-1811	-2404
Punjab	1654	1435	436	-219	-999	-1218
Karnataka	3750	3690	3010	-60	-680	-740
Kerala	603	234	27	-369	-207	-576
Gujarat	3072	2817	2619	-255	-198	-453
Haryana	394	782	466	388	-316	73
West Bengal	5055	5346	5676	291	330	621
India	**80220**	**72012**	**60154**	**-8208**	**-11858**	**-20066**

Source: Livestock Census 1972, 1987, 2003

Table 2. Trend in the number of tractors in India: 1972-2003

State	Number of tractors (in thousands)			Change in number of tractors (in thousands)		
	1972	1987	2003	1987 over 1972	2003 over 1987	2003 over 1972
Uttar Pradesh	28	230	676	202	446	648
Bihar	6	39	91	33	52	85
Madhya Pradesh	6	44	235	38	191	229
Tamil Nadu	5	22	50	17	28	45
Andhra Pradesh	7	33	87	26	54	80
Punjab	41	222	299	181	77	258
Karnataka	8	31	61	23	30	53
Kerala	2	6	8	4	2	6
Gujarat	8	70	148	62	78	140
Haryana	18	87	194	69	107	176
West Bengal	2	12	18	10	6.4	16.4
India	**148**	**604**	**2361**	**456**	**1757**	**2213**

Source: Livestock Census 1972, 1987, 2003

59 in 1972 to 54 in 1987 and further to 43 in 2003. In contrast to this, the density of tractors correspondingly increased, from 0.11 per 100 ha in 1972 to 0.5 per 100 ha in 1987 and further to 1.68 per 100 ha in 2003.

The density of working animals and changes therein vary across states; reflecting the differences in landholding size, labour supply, cropping pattern, etc. These differences have a bearing on the replacement rate between working animals and tractors. Keeping this in view, we have classified the states into three broad groups according to the density of working animals estimated as working animal population per unit of net sown area for 2003. These groups are: low density state (< 20 working animals per 100 ha), medium density state (20 - 40 working animals per 100 ha) and high density state (> 40 working animals per 100 ha). The results on the density of working animals for selected states are presented in Table 3. Among low working animal density states, the density of working animals has continuously declined in Punjab and Kerala, but Haryana has shown a marginal improvement in working animal population. All medium-density states, viz. Karnataka, Gujarat and Tamil Nadu have followed a trend similar to that of the low-density states, Punjab and Kerala. Contrarily, across high-density states, West Bengal has reflected an improvement in the density of working stock between 1972 and 2003. It has been due to high degree of sub-division of landholdings in the state. In other states in this category, viz. Uttar Pradesh, Madhya Pradesh and Andhra Pradesh, there has been a significant negative trend in the density of working animal stock.

During the period 1972-2003, the density of tractors per 100 ha of net sown area increased in all the states (Table 3). In 2003, Punjab had the highest density of tractors per 100 ha of net sown area (7.1), followed by Haryana (5.5). In other states, except Uttar Pradesh, density of tractors hardly ever exceeded 3 per 100 ha. In general, there is a negative relationship between the densities of the two sources of draught power — the correlation coefficient between the two has been estimated to be -0.39 for the pooled data. This is also confirmed by Figure 1 in which working animals density has been plotted against tractor density for the selected years.

Substitution Rate between Working Animals and Tractors

An effort was also made to work out the fossil-fuel (diesel) equivalent of energy associated with the working animal stock in 2003. To do so, we need to have a set of three parameters: (i) substitution or replacement rate between working animals and tractors, (ii) fossil-fuel (diesel) required per tractor per year to do the work of replaced animals, and (iii) conversion factors to estimate carbon dioxide emission from burning of required quantity of diesel.

Energy input to agriculture from various sources like human labour, animal labour and tractor is reported in terms of horse-power (HP) or kilowatt-hour (kWh). An average bullock is rated at 0.4 - 0.5 HP. A 35 HP tractor is, therefore, supposed to replace at least 70 bullocks. This is a pure engineering rate of substitution between working animals and tractors. Some farm

Table 3. Density of working animals and tractors in India: 1972-2003

State	Density of working animals (per 100 ha of Net Sown Area)			Density of tractor (per 100 ha of Net Sown Area)		
	1972	1987	2003	1972	1987	2003
			Low-work animal density			
Kerala	27.45	0.58	1.23	0.09	0.27	0.37
Punjab	0.48	4.52	0.28	1.00	5.34	7.05
Haryana	1.08	4.19	3.19	0.51	2.69	5.49
			Medium-work animal density			
Tamil Nadu	74.5	54.4	24.0	0.08	0.38	1.07
Gujarat	32.0	30.0	26.6	0.08	0.74	1.50
Karnataka	38.2	34.4	30.6	0.08	0.29	0.62
			High-work animal density			
Uttar Pradesh	87.6	79.6	40.9	0.16	1.34	4.04
Andhra Pradesh	58.7	56.4	40.5	0.06	0.32	0.86
Bihar	153.2	31.6	43.3	0.12	0.75	1.59
Madhya Pradesh	53.2	59.4	43.0	0.03	0.23	1.57
West Bengal	92.7	100.1	104.6	0.04	0.22	0.34
India	58.5	53.8	42.7	0.11	0.45	1.68

Source: Estimated by authors

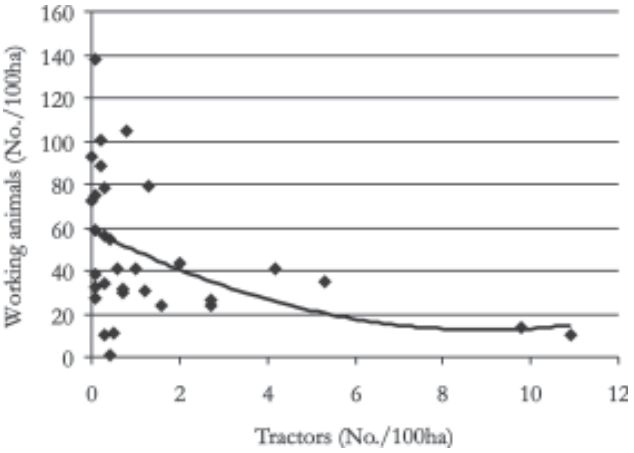

Figure 1. Relationship between density of animals and tractors

level studies carried out during 1970s and 1980s in the northwestern states of Punjab, Haryana and western Uttar Pradesh — the sheet of green revolution in India — reported the replacement rates of three to four bullocks per tractor (Binswanger, 1978; Sharma,1987; Mishra and Sharma, 1990). Based on the changes in the stock of working animals and tractors between 1972 and 1982, Mishra and Sharma (1990) also reported a replacement rate of four animals per tractor in Haryana and western Uttar Pradesh. These macro level results appear to be in congruence with the reported farm level observations. It is worthwhile to mention here that the tractor energy is used not only for agricultural purposes but also to perform off-farm activities.

The estimated replacement rates of bullocks with tractors for the major states and country as a whole are given in Table 4. India has considerable heterogeneity in agro-ecological, technological, socio-cultural, economic and institutional factors; hence the replacement rate is likely to vary across states. During 1972-1987, which was the high time of green revolution, the working animal population in Punjab marginally declined, while the net sown area in the state increased. As a result, density of working animals declined, which is reflected in a lower rate of substitution (-1.4) during this period. Contrary to this, Haryana registered an increase in the stock of working animals and a marginal decline in net sown area; consequently, the density of working animals increased in the state during this period. Nonetheless, it does indicate that the demand for draught power, irrespective of its source, has significantly increased to improve the cropping intensity in these states. The substitution rates between 1987 and 2003 were -3.9 and -14.2 for Haryana and Punjab, respectively. This may be due to sharp decline in the number of working animals during the same period. During 1972 to 2003, the substitution rate in Punjab remained negative (-5.0), while it was marginally positive (0.4) for Haryana.

Table 4. Rate of substitution between working animals and tractors: 1972- 2003

State	1972-1987	1987-2003	1972-2003
Low-work animal density			
Haryana	6.0	-3.9	0.4
Punjab	-1.4	-14.2	-5.0
Kerala	-93.5	-99.6	-95.6
Medium-work animal density			
Gujarat	-3.1	-4.5	-3.8
Karnataka	-18.6	-11.5	-14.2
Tamil Nadu	-66.4	-44.4	-51.1
High-work animal density			
Uttar Pradesh	-6.8	-14.3	-12.0
Andhra Pradesh	-9.1	-29.2	-22.8
Madhya Pradesh	-31.3	-12.1	-6.6
West Bengal	39.5	39.2	39.4
Bihar	-190.5	13.9	-74.4
India	**-13.8**	**-9.0**	**-10.2**

Source: Estimated by authors

The major states in the medium-work animal density group were Tamil Nadu, Karnataka and Gujarat. The stock of working animals in these states declined during 1972-1987, but the density of working animals in Karnataka and Gujarat declined marginally while in Tamil Nadu, there was a sharp decline — almost 20 animals per 100 ha of net sown area. The substitution rates in these states were -3.1 for Gujarat, -66.4 for Tamil Nadu and -18.6 for Karnataka during the period 1972-87. These rates declined further during the period 1987-2003. The rate of change in the density of working animals was found lower in Karnataka and Gujarat than in Tamil Nadu. This may be due to a majority of the districts in these states being rainfed and the demand for animal draught remaining high during the reference period.

Among high-work animal density states, there was no substitution effect in West Bengal (the substitution rate had remained positive) during the entire study period. In West Bengal, the stock of working animals increased substantially, and the net sown area declined marginally. The net effect was the increase in the density of work animals as well as of tractors. This may be due to change in the landholding pattern in favour of small and marginal farmers. Uttar Pradesh has presented a consistent pattern of substitution effect. The stock of working animals between the study periods (1972-1987, 1987-2003 and 1972-2003) declined; so was the density of working animals. A marginal decline in the net sown area was also recorded during the periods 1987-2003 and 1972-2003. As a result, the rate of substitution during 1987-2003 worked out to be 13.9 animals per tractor.

Across states, the substitution rate has been estimated very high in Kerala (-95.6), Bihar (-74.4), Tamil Nadu (-51.1) and Andhra Pradesh (-22.8) over the long period of 30 years, 1972- 2003. The substitution rate remained between 3.8 and 14.2 animals per tractor in most other states. For the country as a whole, the rate of replacement worked out to be 13.9 working animals per tractor during 1972-1987 and 9.0 working animals per tractor during 1987-2003. However, when we estimated it over a long time horizon, that is 1972-2003, we found one tractor to replace on an average 10.2 working animals. Considering it as a discontinuous input, we used a value of 10.0 animals per tractor. In other way, as per 2003 Livestock Census, India had 2.5 million tractors, each tractor with a command area of 16 ha. To cultivate 185-190 million ha we need a total 11.6 million tractors. That means additional 9.0 million tractors are required to cultivate 190 million ha of land. This is 1.5-times of our estimate of 6.0 million tractors. We take the latter figure as the one which incorporates the complexity of the whole lot of institutional and technological changes that may have occurred in Indian agriculture during the past three decades or so.

CO_2 Emission Prevented due to Animal Energy

In addition to the replacement rate of 10.2 (used 10.0 considering it as a discontinuous input) working animals per tractor, we have taken the diesel consumption rate per tractor per year at 3.25 tonnes (Mishra and Sharma, 1990) to estimate the environmental contribution of draught animals. The relevant assumptions and parameters for this exercise are given in Table 5.

Using these parameters, we have estimated that India would require 6.0 million tractors for the complete replacement of the working animals stock of over 60 million (Table 6). And, to run this much number of tractors for agricultural operations, we would require about 19.5 million tonnes of diesel each year. This is the order and value of the fossil-fuel saved annually due to animal energy use in the Indian agriculture.

Table 5. Values of the relevant parameters used in estimation of environmental contribution of draught animals

Parameters	Value
Consumption of diesel per tractor (tonnes/year)	3.25
Carbon fraction of diesel	0.8752
Fraction oxidized	0.99
Conversion factor from carbon released to carbon dioxide	0.3666

Source: Mishra and Dikshit (2004)

Table 6. Prevention of greenhouse gas emission due to use of draught animal power

Particulars	Values
No. of tractor required to replace the existing stock of working animals (million)	5.95
Consumption of diesel by the required number of tractors(million tonnes)	19.34
Estimated carbon release from burning of fossil fuel (million tonnes)	16.75
Estimated prevention of carbon dioxide emission (million tonnes)	6.14

Source: Estimated by authors

In the context of environmental contribution, using the carbon fraction of diesel (0.8752) and the fraction oxidized (0.99) from the Intergovernmental Panel on Climate Change (IPCC) (Anonymous, 1995), we estimated the amount of carbon dioxide emission from the burning of the above quantity of diesel at about 6.14 million tonnes of CO_2, which in fact got prevented because of the working animals' stock. Note that this does not include emission of CO_2 and trace gases that would occur from the burning of crop-residues currently used as feed for the working animals, if the stock were to be replaced by tractors. Incidentally, one ought to take credit for emissions thus prevented while preparing the national inventory of greenhouse gases.

Concluding Remarks

To conclude, animal energy is renewable as well as sustainable, and has immense significance in the Indian context. The fossil-fuel equivalent of the animal energy utilized in the Indian agriculture is pretty large, as much as 19.5 million tonnes of diesel in 2003. If this much amount of fuel were to be burnt through combustion to run the tractors in the absence of the working animal stock of over 60 million in India, it would have caused an emission of over 6.14 million tonnes of carbon dioxide. These effects are highly valuable from the perspective of both national energy budget as well as global warming. Indeed, these numbers do not present a complete scenario since they are point-estimates obtained in a static frame of comparison. For a closer, realistic picture one ought to compare the working animals and tractors over their respective working life.

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