The Cost of Draft Animal Power in West Pakistan

by

SWADESH R. BOSE & EDWIN H. Clark II*

INTRODUCTION

Most of the writings on the benefits of agricultural mechanization begin with an analysis of the savings in cost which will be achieved if mechanical rather than animal power is used for certain agricultural operations. There have been some studies, mostly in India[1], which have tried to measure these savings. The mechanization issue cannot, however, be judged solely on this criterion. In addition to bullock displacement, mechanization is likely to involve farm-labour displacement. As we have argued in a recent paper [2], the extent of such labour displacement and its social costs are among the basic issues which should be considered before going from bullocks to tractors. But leaving aside these other issues, before one can measure the cost advantage of mechanical power over animal power, one must define what the costs are and how they should be measured. For mechanical power, such measurement of costs is not difficult. We know the cost of importing the tractor and its implements. We know the costs of fuel which we have to pour into the machine every time we want it to do something. The first is clearly a fixed cost and the second, after adding repairs, maintenance, the driver's pay, *etc.*, is clearly a variable cost.

But it is not so clear with animals. Often, nothing is paid for the animal because it is born on the farm, and nothing is paid for most of the food because the farmer grows that himself or the animal forages. Furthermore if the animal is there, it eats whether it is to work or not, the amount of food consumed does not vary much in proportion to the amount of work done. All this complicates the analysis; for if no money is paid, then what are the costs?

In most of the literature, this problem has been dealt with mainly in two ways. The first is to assume that nobody owns anything. Thus, every time a

*The authors are respectively Senior Research Economist at the Pakistan Institute of Development Economics and Assistant Professor at Williams College, USA (formerly Research Associate at the Institute).

[1]For example, Mathur and William [12].

farmer uses a bullock he has to rent it. One measures the rental price of bullocks in the rather small bullock rental market, assumes that conditions of perfect competition roughly exist to make this rental price equal to the marginal cost of producing a bullock, and takes this as the cost to the farmers of using bullocks. This approach is also supported by the economist's concept of "opportunity" costs, by which it is argued that if the farmer did not use the bullocks himself he could rent them out, and therefore, by using them himself he is giving up the opportunity to earn the rental income. Thus, the cost to the farmer is the income he foregoes by not renting out the bullocks.

The second approach, which also requires some implicit assumptions about perfect competition, is to determine the price at which animals are being sold and, again because the farmer is foregoing that income by not selling the bullock to take that as the capital cost of the bullock. In this approach the value of food will typically be computed by multiplying the animal's consumption by the price of fodder. From here on, the second approach is quite similar to the approach used for machinery. The food, along with maintenance, repairs, *etc.*, is usually considered a variable cost apparently on the reasoning that if fuel, which is food for the tractor, is a variable cost, then food, which is fuel for the animal, must also be a variable cost. There is the difficulty that this variable cost does not vary much in proportion to the amount of work done, but by treating it the same way as the fixed cost — *i.e.*, by dividing the total annual cost by the number of hours the bullock works per year, one can calculate a hourly variable cost.

It is our contention that neither of these cost calculations is appropriate. There are, of course, various doubts about the extent to which the fodder, animal rental, and animal purchase markets actually satisfy the implied conditions of perfect competition. The fallacies become more obvious, however, in the estimation of the savings resulting from partial mechanization. In such an estimation one typically compares the cost of doing various activities by mechanical power and animal power (using the hourly rates computed as described above) and concludes that the farmer will "save" so many rupees by using mechanical power for certain operations. But there is no actual saving. Partial mechanization does not reduce the number of bullocks the farmer has. Besides, should he hire a tractor to perform these various operations, he will only add to his cost the cost of renting the tractor. The apparent savings only occur because of a faulty costing methodology.

This, we believe, is the famous fuzzy thought on fodder feeding. There are no, or at least only quite minor, variable costs associated with the use of animal power. The only way to save the supposed costs is to get rid of the animals.

But if we agree that almost the entire cost of animal power is an economic fixed cost, we ought to go back to determine what that cost is. The purpose of this paper is to identify and estimate that cost under West Pakistan conditions. The methodology used for the cost estimate should be applicable in the case of other countries as well. In our analysis in this paper we are concerned primarily with the cost to the nation — or, as it is often called, the social cost — and not with the costs to the farmer. For this reason, we must investigate the question of whether the market prices truly represented the social costs. This first requires agreement on how the social cost can be measured.

II. AN APPROPRIATE CONCEPT OF SOCIAL COST OF DRAFT ANIMAL POWER

Let us consider first the conceptual problem involved in an appropriate measurement of the social cost of draft animal power. To start at the beginning, a male calf is born. Directly the calf cost nothing. Furthermore, since in Pakistan the female animal does not usually do any heavy work anyway, there has been no production foregone. However, she has been eating, and the calf can be charged with the value of the food she (the mother) has consumed between her last calving and this one. There is also an associated benefit from milk obtained as a by-product. The calf is then raised for a certain number of years before it is put to work. By this time the farmer has made an investment in the animal which is equivalent to the present value of all the foodstuffs it has consumed since being born plus that consumed by its mother plus any other costs associated with keeping it alive. For the rest of its life the animal works. All the time it is working, it is consuming food and being maintained.

So the cost of an animal is the cost of raising it and keeping it alive, which cost is predominantly made up of the cost or value of the food it has consumed. To determine the investment in an animal one must, following the above analysis, compute the present worth of all past consumption less the total output of such products — meat, hide, manure, milk, *etc.*, — as are obtained in the process. Allocating this cost to the different working years of a bullock's life would be quite difficult — both conceptually and practically. It would be easier and as accurate to consider the annual cost of animal power to be equal to the annual cost of maintaining the entire animal population needed to perpetuate the required number of working bullocks in all future years, less the value of the associated animal products obtained from this population.

Such a population, P, would be composed of a certain number of working bullocks, B_W, a certain number of young males who will become working bullocks, B_Y, a certain number of females in the reproductive ages, F_r, and a certain number of young females, F_y. Assuming that only male animals work, F_r will be the number of females required to produce enough male calves to replace the adult males who die or are killed off every year. All excess female calves, and all unproductive adults will be killed off. The size of the entire animal population would be defined by the number of adult working animals required. Thus, the cost of animal power would be the cost of maintaining this entire animal population.

III. THE STRUCTURE OF THE REQUIRED ANIMAL POPULATION AND ITS FODDER REQUIREMENT: THE MODEL

The structure of the animal population required to sustain one working animal (*i.e.*, to provide replacement in perpetuity) can be estimated using techniques similar to those used by demographers in their theory of "stable population"[2]. However, we will be able to use a considerably simplified form. The basic equations can be derived with the help of Figure 1 which shows the generalized life history of all the animals born in year 0. Of X_0 births, only a certain proportion will be males. All these will be kept, along with enough females to reproduce the female population. The total of these two groups is X_1, and $X_0 - X_1$ animals are killed or raised for meat. What happens to these animals does not concern us since we are only interested in the population required for the working force. Those animals that are kept are raised for a certain number of years, until T_I, before they are put to work. Some of them also die during this period so that at the start of working period, Period II, there are only X_2 animals left. The survival rate for Period I, S_I, is X_2/X_1. Similarly, some die off during the working period, and the survival rate for Period II, S_{II}, is X_3/X_2. At the end of this period, *i.e.*, on completion of T_{II} years, all the remaining animals are killed off.

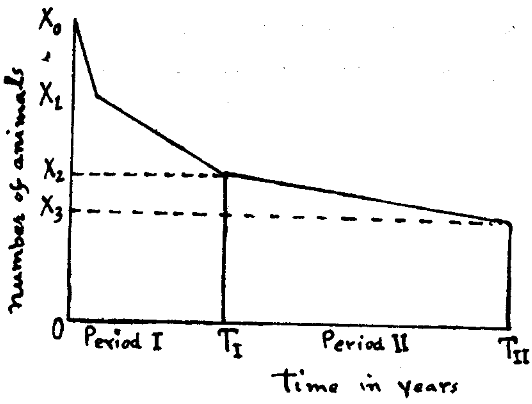

Figure 1

[2]The "stable population" is the foremost theoretical model of population processes. It is an extention of the stationary-population model, and represents the permanent structure that a hypothetical population would ultimately have, if the assumed age-specific birth rates and death rates persisted without change. It is derived completely from these birth rates and death rates, is closed against migration, and is not dependent on the composition any of concrete population, *see* [1, p. 133].

Let us first construct a model in which the population is stationary. The required total population will vary under different conditions in regard to birth rate, young age, working age, reproductive age, survival rates, *etc.* In our simplified but general model different values for these parameters can be incorporated to obtain estimates under different sets of conditions. The model is restrictive insofar as the assumed growth rate is zero.

Let

P = total cattle population required

B_y = young bullocks

B_w = working bullocks

F_y = young females

F_r = reproductive females

b = number of births per reproductive female per year

n = probability of a male calf being born

B_b = number of males born in a year

0 to $T_I - 1$ (in completed years) = young age of males and females

T_I to $T_{II} - 1$ (in completed years) = working age of bullocks and reproductive age of females

T_{II} (in completed years) = age of being killed off

S_I = survival rate of males and females from age 0 to age T_I years

S_{II} = survival rate of males and females from age T_I to age T_{II} years.

Then

$$B_b = F_r nb \quad \text{(A1)}$$

$$B_y = B_b \sum_{t=0}^{T_I-1} S_I^{(t/T_I)} \quad \text{(A2)}$$

$$B_w = B_b S_I \sum_{t=T_I}^{T_{II}-1} S_{II}^{(t-T_I)/(T_{II}-T_I)} \quad \text{(A3)}$$

$$F_r = \frac{B_b}{nb} \quad \text{(A4)}$$

Since under our identical assumptions about survival rates, and young and working ages of males and females

$$\frac{F_y}{F_r} = \frac{B_y}{B_w}$$

$$F_y = \frac{B_b}{nb} \cdot \frac{B_y}{B_w} \qquad \text{(A5)}$$

$$= \frac{B_b}{nb} \cdot \frac{B_b \sum_{t=0}^{T_I - 1} S_I^{(t/T_I)}}{B_b \cdot S_I \sum_{t=T_I}^{T_{II}-1} S_{II}^{(t-T_I)/(T_{II}-T_I)}}$$

$$P = B_w + B_y + F_r + F_y \qquad \text{(A6)}$$

Dividing both sides by B_w, we get

$$\frac{P}{B_w} = 1 + \frac{B_y}{B_w} + \frac{F_r}{B_w} + \frac{F_y}{B_w} \qquad \text{(A7)}$$

Let $Z_I = \sum_{t=0}^{T_I - 1} S_I^{(t/T_I)}$

and $Z_{II} = \sum_{t=T_I}^{T_{II}-1} S_{II}^{(t-T_I)/(T_{II}-T_I)}$

Then

$$\frac{P}{B_w} = 1 + \frac{B_b Z_I}{B_b S_I Z_{II}} + \frac{B_b}{nbB_b S_I Z_{II}} + \frac{B_b}{nb} \cdot \frac{B_b Z_I}{B_b S_I Z_{II}} \cdot \frac{1}{B_b S_I Z_{II}}$$

$$= 1 + \frac{Z_I}{S_I Z_{II}} + \frac{1}{nbS_I Z_{II}} + \frac{1}{nbS_I Z_{II}} \cdot \frac{Z_I}{S_I Z_{II}} \qquad \text{(A7)}$$

This expression gives the total population required per working animal if the bullock population remains stationary.

When S_I and S_{II} are both less than 1, as is likely, it can be shown that

$$Z_I = \sum_{t=0}^{T_I - 1} S_I^{(t/T_I)} = \frac{1 - S_I}{1 - S_I^{(1/T_I)}} \qquad \text{(A8)}$$

Similarly,

$$Z_{II} = \sum_{t=T_I}^{T_{II}-1} S_{II}^{(t - T_I)/(T_{II} - T_I)} = \frac{1 - S_{II}}{1 - S_{II}^{1/(T_{II} - T_I)}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (A9)$$

When a bullock population is growing at an annual compound rate g, the effect of this growth rate on each age interval of the stationary population is expressed as e^{-ga} where e is the base in the system of natural logarithms, and a is the mid-point of each age interval (adopted as the approximate average age of the age group) [1, p. 218]. The mid-point is $(x + \frac{n}{2})$ that is, age x plus one-half of the number of years, n, included in the interval. For example, when the age interval is 0 to 1 year, the mid-point is 0.5 year, for 1 to 2 years it is 1.5 years and so on.

The effect of the growth rate g is calculated by multiplying each single-year age group in the stationary population by the corresponding value of $e^{-(x \times n/2)g}$. When this is done, we can construct a more general model of cattle population. It can be shown that in this general case also the expression for $\frac{P}{B_w}$ is the same as shown in (A7) above, but in this case if S_I and S_{II} are both less than 1, as is likely,

$$Z_I = \sum_{t=0}^{T_I - 1} S_I^{(t/T_I)} e^{-(t+0.5)g}$$

$$= \frac{e^{-0.5} - S_I e^{-(T_I + 0.5)g}}{1 - S_I^{(1/T_I)} e^{-g}}$$

and

$$Z_{II} = \sum_{t=T_I}^{T_{II}-1} S_{II}^{(t - T_I)/(T_{II} - T_I)} e^{-(t+0.5)g}$$

$$= \frac{e^{-(T_I + 0.5)g} - S_{II} e^{-(T_{II} + 0.5)g}}{1 - S_{II}^{1/(T_{II} - T_I))} e^{-g}}$$

The total fodder consumption by the animal population required to maintain one working bullock can be estimated by multiplying the population of each group per bullock by its relative consumption. If db_w, df_r, df_y and db_y are respectively the fodder consumption (in "livestock units") of the working bullock, the fertile female, the young female and the young male then we can have the following general expression for $\bar{d}$ — the total fodder consumption by the animal population to maintain one working bullock:

$$\bar{d} = 1 \,.\, db_w + \frac{Z_I}{S_I Z_{II}} \,.\, db_y + \frac{1}{nbS_I Z_{II}} \,.\, df_r + \frac{1}{nbS_I Z_{II}} \,.\, \frac{Z_I}{S_I Z_{II}} \,.\, df_y \qquad \text{(A10)}$$

We made it clear earlier that given the values of other parameters, the values of Z_I and Z_{II} will depend on the growth rate g, whether it is zero or more than zero.

IV. ESTIMATES OF FODDER REQUIREMENT PER BULLOCK BASED ON THE MODEL

Although there is very little known about the livestock sector in Pakistan, there have been couple of recent studies which will help us to attach numbers to our constants. The Indus Special Study found that under the present conditions, bullocks do not begin to work until they are 3 or 4 years old and then continue to work for about 8 years [9, p. 282]. Therefore, we will take T_I as 3 years and T_{II} as 11 years, and alternatively T_I as 4 years and T_{II} as 12 years. They also found the average inter-calving period of reproductive females to be between 12 and 18 months [8, p. 111]. If we take 15 months as the average, this is equivalent to a general fertility rate of 800 per 1000 adult females or $b = .8$ per F_r. The probability (n) of a male calf being born is taken as .5. On the basis of information gathered from farmers, we assume that the survival rate (S_I) from birth to age T_I is .8 and the survival rate from age T_I to age T_{II} is 0.9. Values of db_w, db_y, df_r, and df_y in "likestock units" are given as follows:

TABLE I

FODDER CONSUMPTION (IN LIVESTOCK UNITS) BY BULLOCKS AND SUPPORTING ANIMALS

	Livestock units
Adult males (db_w)	1.00
Young males (db_y)	0.77
Adult females (df_r)	0.77
Young females (df_y)	0.74

Source: [9, p. 303].

The growth rate of the bullock population is unknown. Official estimates of the growth rate of the entire livestock sector are about 1.9 per cent, and another estimate by the Planning Commission was 2.7 per cent; but a more recent study has come up with a value of 4.5 per cent [4, p. 490]. We might expect the growth rate for the population of draft animals to be similar to that for cropped acreage, although there is reported to be substantial underemployment of these animals [8, p. 110; 9, p. 278]. Cropped acreage from 1958/59 to 1966/67 has been growing at a rate of about 2.5 per cent per year. Production has been increasing faster, but some of this increase has been (and more will continue to be) a result of increased yields. It is unlikely that total cropped acreage would grow any faster than 2 per cent over any extended period of time. Therefore, we might take this as a reasonable growth rate for the bullock population, although we will carry out computations for 2.5 per cent as well.

Using these parameters, the solutions for our several stable population models are as given in Table II. It shows that to maintain each working bullock (*i.e.*, to provide a continuous stream of replacement for each working bullock), the fodder requirements are around 2 livestock units per year.

TABLE II

TOTAL FODDER CONSUMPTION (IN LIVESTOCK UNITS) PER WORKING BULLOCK FOR ALTERNATIVE POPULATION PARAMETERS

($b = .8$ *and* $n = .5$ *in all cases*)

g	S_I	S_{II}	T_I	T_{II}	Z_I	Z_{II}	$\frac{B_y}{B_w}$	$\frac{F_r}{B_w}$	$\frac{F_y}{B_w}$	$\bar{d}$
0	.8	.9	3	11	2.789	7.692	.453	.406	.184	1.80
0	.8	.9	4	12	3.704	7.692	.602	.406	.245	1.96
2%	.8	.9	3	11	2.709	6.666	.508	.469	.238	1.93
2%	.8	.9	4	12	3.561	6.534	.681	.478	.326	2.13
2.5%	.8	.9	3	11	2.691	6.432	.523	.486	.254	1.97
2.5%	.8	.9	4	12	3.523	6.275	.702	.498	.350	2.18

Note: $\bar{d}$ is the number of livestock units per working bullock. Computed values of Z_I and Z_{II} are shown for convenient reference.

In comparison to these computed results, we can look at the actual result of livestock censuses. Probably the most recent survey was done on 20 watercourses spread through the Punjab and Sind [9, Chapter 12]. The average ratio of F_r/B_w (assuming their definitions correspond to ours) was 0.30, the average ratio B_y/B_w was also 0.30 and the average ratio F_y/B_w was 0.08.

Their computed $\bar{d}$ was about 1.52 [9, Pp. 304-305]. These ratios are lower than any given in Table II. However, they also report that "only about 30 per cent of the draft animals were bred and raised on the farms they were at present working" [9, p. 282]. Unfortunately, they have given no details on the distribution of the sources from which the other 70 per cent are purchased. If they are usually purchased from other farms in the same area, it should not affect our calculations since we are taking averages over an area. Apparently there is at least some interfarm exchange [8, p. 111]. On the other hand, if the animals are raised elsewhere and imported into the farming areas, then the total population per working bullock is higher than indicated by the survey figures. This may be the case. Since we cannot be sure that the survey data present the information we require, we will use the estimates from our stable population models in further computations.

V. COMPOSITION OF FEED PER LIVESTOCK UNIT AND ITS SOCIAL COST

After computing the number of livestock units per working bullock required to maintain the working animal population, we have to estimate the value of the resources consumed per year by these livestock units. A common measure of livestock feed is the number of total digestible nutrients (TDN) it contains. The survey referred to above covering 20 watercourses found an average of about 3,800 pounds of TDN fed per year per livestock unit [9, p. 308] although variations from this average were quite high. The composition of this total amount is shown in Table III. The organization making this survey computed the cost of these foodstuffs by using market prices as 834 rupees per pair of bullocks [9, p. 287]. However, this does not necessarily represent the social cost of these foodstuffs. To determine this cost, we have to consider what the opportunity cost is of the resources which go into their production. Here we have the immediate problem of deciding whether we should consider their opportunity cost only outside the livestock sector, or also consider their value when fed to other animals. The Indus Special Study found that the average value per pound of TDN fed to milch cattle was about 0.13 rupee. However, the marginal value was probably much below this. This conclusion is supported by the fact that the market price of fodder was found to be only about 0.09 rupees per pound of TDN.

It would be inappropriate to use the 0.13 rupee per pound figure as the value of animal foodstuffs transferred from draft animals to other animals. Nor should we use the 0.09 rupee per pound figure even assuming that it does represent the true present marginal value of animal foodstuffs, unless it was demonstrated that the marginal revenue product curve is horizontal which is quite unlikely. Transportation problems combined with presently limited markets make it unlikely that any amount of additional productions of milk

TABLE III

COMPOSITION OF LIVESTOCK FEED

Foodstuff	Lbs. TDN per lb. foodstuff	Percentage of total TDN supplied by foodstuff	Gross weight of foodstuff consumed per livestock unit (lbs.)
	(1)	(2)	(3)
Rabi fodder	.11 }	70.3%[a]	19,800
Kharif fodder	.16 }		
Sugarcane tops	.13	1.2%(8.2)[b]	350(2400)[b]
Wheat *bhusa*	.48	17.3%	1,370
Rice *bhusa*	.38	6.7%	670
Concentrates	.75	0.6%	30
Plant residues	.05	1.9%	1,440
Cash crops	.20	2.0%	380

Sources: Column (1) is from [7, p. 309];
Column (2) is from [7, p. 311].
Column (3) has been calculated from other two columns.

[a] 68.9 per cent of this was fed as green fodder and the remaining 1.4 per cent as grams fodder.

[b] Survey was not underway during sugarcane harvesting season so the figure in parentheses was computed from the amount of tops available.

and meat could be absorbed at the present price. For this reason, we think that the appropriate social cost of those foodstuffs which are largely by-products in the production of other crops is best measured by their value in alternative uses outside the livestock sector, and that of fodder crops by the value of the required resources when used in the production of alternative crops.

V.1 Social Cost of Fodder Crops

The primary resources which presently go into the production of fodder are land, water, manual labour, and bullock power. Of these resources, water is the only resource that has any real social cost. Labour inputs can be scheduled to occur at times when there is little alternative employment. The work the bullocks do in raising their own feed is an intrasectoral intermediate good, and is appropriately neglected in our computations. In most of West Pakistan, land as such has almost no economic value unless water is available for irrigation [7, p. 14; 11, Pp. 27 and 42].

However, fodder crops do require substantial irrigation. A study of water requirements of various crops indicates that in the *kharif* season a farmer could plant about 1.12 acres of cotton, 1.50 acres of vegetables, or 0.88 acres of rice with the water consumed by one acre of fodder, and in the *rabi* season, he could plant 1.60 acres of wheat, 2.19 acres of vegetables, or about 2.0 acres of oilseeds for every acre of *rabi* fodder eliminated [14, Appendix D].

To simplify our further calculations, let us assume that 50 per cent of the eliminated *kharif* fodder would be switched to cotton and 50 per cent to rice, and that all the *rabi* fodder would be replaced by wheat. The value of these alternative crops depends on their yields, prices, and the costs of input. In our calculations we shall use the world market prices adjusted for transportation costs, and assume that the social cost of labour input is nil.

Cotton is competitive with the world market price and has a farm-gate value of about 32 rupees per maund of seed cotton [9, p. 328]. The average yield is about 5.6 maunds per acre [9, p. 153]. Assuming that about 5 rupee worth of fertilizer is applied per acre, the net value of cotton acreage then is about 175 rupees.

The average yield of rice is about 21 maunds of paddy per acre [9, p. 156]. Taking the average value of paddy as 15 rupees per maund and deducting 5 rupee per acre as the cost of fertilizer, we may take the net social value per acre of rice as 310 rupees.

Assuming that 50 per cent of the *kharif* fodder water was transferred to cotton and 50 per cent to rice, the average net soil value per acre transferred would be about 240 rupees.

Taking the average yield of wheat as 13 maunds per acre [9, p. 181], the world market price of about 13 rupees as the social value per maund, and deducting 5 rupees per acre for fertilizer, we will adopt a net value of 165 rupees per acre of wheat. Thus, for every acre of *rabi* fodder given up, about (165×1.6) *i.e.*, 265 rupees will be gained in wheat.

According to these rough calculations, the annual social cost of two acres of fodder (one *kharif* plus one *rabi*) is about 500 rupees at present yields and prices. Future conditions are difficult to predict. Crop yields, particularly of wheat and rice, are increasing in West Pakistan; other crops, including fodder, may follow suit. But assuming differential yield increases in future let us arbitrarily raise the social cost of fodder by about 20 per cent to as much as 600 rupees for two acres. Surveys of the Punjab farming areas indicate that there is an average of 0.6 acres of fodder per livestock unit, which is split approximately 50:50 between *kharif* and *rabi* [9, p. 65]. We may assume that this proportion would remain reasonably constant over time. Therefore, the annual social cost of fodder per livestock unit is about 180 rupees.

V.2 Social Cost of Other Feed Items

For such items as grazing (which was not included in the Indus Special Study computations) and plant residues the social cost is obviously very low. The only apparent alternative use of these items is green manure. Their economic contribution in such a use would be so slight that we can safely disregard it. Wheat and rice *bhusa*, the straw left-over after the grain is thrashed, also has little value outside the livestock sector. It could be used as a sort of "green manure", or probably more profitably as a raw material for paper-making. It is unlikely that in the near future paper plants could possibly use all of the *bhusa* production in West Pakistan. Also, there is most likely a certain distance from any factory beyond which it would be uneconomical to collect the *bhusa*. We know of no studies which has been undertaken on this subject although it is obviously of great importance if, in fact, mechanization is to be a major agricultural policy. Therefore, we will arbitrarily assume that the *bhusa* fed to the cattle on the farm has an economic cost of 1.00 rupee per maund. Similarly, sugarcane tops have minimal alternative use outside the livestock sector and we shall assume them no value.

Some concentrates may have real opportunity cost, others probably not. For instance, an important concentrate is oilseed cake for which there is an international market. Pakistan already exports oilseed cakes at an average value of 10 rupee per maund. But the cost of transportation from the Punjab to Karachi is high, so that the farm-gate price is much lower. Therefore, we might value the total concentrates at an arbitrary 5 rupees per maund. Cash crops, of course, do have some value. Pakistan has particularly been faced with a shortage over the past several years. However, this situation is rapidly changing and it appears as if any additional foodgrains will have to be exported. In this case the farm-gate value would probably drop to below 9 rupee per maund. We will take 10 rupee a maund for our purposes.

V. 3 Gross Social Cost Per Livestock Unit

Adding together the fodder cost of 180 rupees per livestock unit and the cost of the other foodstuffs and including 50 rupees for other expenses, we have a total cost of about 304 rupees per livestock unit as shown in Table IV.

TABLE IV

TOTAL GROSS SOCIAL COST PER LIVESTOCK UNIT

Item	Amount consumed	Value
	(maunds)	*(rupees)*
Fodder	242[a]	180
Bhusa	25	25
Concentrates	0.4	2
Plant residues	17.6	0
Sugarcane tops	4.4	0
Cash crops	4.7	47
Other expenses	—	50
		304

[a]or 0.6 acres.

Source: Quantity of feed items from Table III.

VI. SOCIAL BENEFIT AND NET SOCIAL COST PER WORKING ANIMAL

Assuming that our estimates of livestock units required per working animal are correct, we can now compute the total gross social cost of the foodstuffs required to maintain one working bullock as shown in Table V.

On the other hand, there are certain benefits of raising work animals, and these should be deducted from the cost computed above to determine the net cost of draft animals. These benefits include the value of the hides, meat, bones, horns and hooves, manures, and the milk of the cows. Unfortunately, we do not have a great deal of information which can be used to evaluate the products. The selling price of the animals after they have finished their working life is reported to vary from 25 to 100 rupees with 50 rupees being about average

[8, p. 111; 9, p. 317]. Whether this actually represents the social value of these animals, or in fact exactly what happens to them after they are sold, is not clear. Hides, leather, and leather goods are important exports from West Pakistan as are bones, horns, and hooves. Much of the meat delivered to the cities probably comes from such animals. However having no way to estimate the contribution of the farmers' worn out bullocks and supporting cows to these purposes, one can only assume that 50 rupee per animal is a fair representation of their social value.

About 50 per cent of the adult females were found by the Indus Special Study to be in milk at any time, and the average annual production for a cow in milk is 248 pounds [9, p. 316]. Therefore, there are about 125 pounds of milk produced annually per adult female. This is mostly sold at the village for 0.50 rupee per *seer* to a vendor who transports it to a city [9, p. 340]. Thus, average value of milk production per adult female animal is about 30 rupee per year.

Each animal produces, according to one estimate, about 30 pounds of fresh dung a day [13, p. 128]. Approximately one-fourth is used as fuel, and the rest as manure [9, p. 318]. In addition, much of the urine is passed out in the fields and thus serves as fertilizer. The amount of fertilizer contained in one ton of manure is 9 pounds of nitrogen, 3 pounds of available P_2O_5 and 3 pounds of available K_2O [6, p. 127]. All these nutrients presently sell at a government subsidized rate of 0.50 rupee per pound in the form of chemical fertilizers. The rate of subsidy is supposed to be about 35 per cent. This indicates that the total value of these nutrients is about 10.00 rupee per ton of manure but we assume it to be as low as 2.50 rupee per ton (the value of the marginal physical product of these nutrients is clearly much greater than this). The organic matter in the manure and the urine also have some value, but we have no information by which to calculate these. Therefore, we will arbitrarily raise the value of the manure per ton to 3.00 rupee (This compares to a market price of 5 to 6 rupees per ton). Taking the output of 300 pounds per day to apply to a livestock unit, we get a minimum value of about 11.00 rupee per year per livestock unit for the 75 per cent of the manure used for fertilizing.

For the other 25 per cent used for fuel, one ton of dried dung has been found to be equivalent to 0.4 tons of coal or 0.06 tons of kerosene [6, p. 62]. About 70 per cent of fresh dung is water [13, p. 127], and in the drying process most of this is lost, leaving, let us say, 40 per cent of the original weight. This would mean that approximately one half-ton of dried dung, which is equivalent to 0.2 tons of coal or 0.03 tons of kerosene, is used for fuel per livestock unit per year. Kerosene, though it sells for more in the market, should actually cost somewhat less than light diesel fuel. The latter has been estimated to cost about 0.91 rupee per gallon after eliminating all taxes [3, p. 37]. Therefore, let us assume that kerosene costs about 0.85 rupee per gallon or 0.10 rupee per pound. By this measure the value of the dung burned as fuel per year would be about 6.60 rupees per livestock unit. Probably, not all of the old dung would be replaced by kerosene, so we might take a fuel value of 4 rupees per livestock unit per year.

Taking into account all of the above factors, and using the formula developed previously for the stable population parameters, we can express the benefit (in rupees) produced by the total animal population required to support one work animal as follows:

Value of dung: $15\bar{d}$

Value of milk: $30\dfrac{F_r}{B_w} = \dfrac{30}{nbS_I Z_{II}}$

Value of meat, hides, *etc:* $\dfrac{50S_{II}\, e^{-(T_{II}+0.5)g}}{Z_{II}} \cdot \left(1 + \dfrac{1}{nbS_I Z_{II}}\right)$

Combining our estimates of cost and benefit of the animal population with the results of our computations for the stable animal population, we can compute the net social cost per working bullock. The results are given in Table V.

Thus, it would appear as if the net social cost of maintaining an animal population is between 500 and 600 rupees per working animal per year.

CONCLUDING REMARKS

It might be said that we need not have bothered since the cost computed for a pair of bullocks using the more traditional type of calculation is about 970 rupees [9, p. 288] or 485 rupees per bullock per year, while our computations indicate a cost of 500-600 rupees per bullock per year, or 550 rupees as the average. However, one advantage this method does have beyond confirming the rationality of the West Pakistani farmer is that it allows the direct computation of the cost reductions which would result from such improvements as long life span, earlier working ages, *etc.*, as have been discussed earlier.

Several qualifications should be made about our computations of the social cost of animal power. First, as pointed out earlier, these computations assume that the animal population is raised entirely in the irrigated farming areas of the Punjab. The cost of raising animals in these areas would naturally be greater than the cost of raising them elsewhere because of the relative opportunity costs of the resources consumed. Obviously not all the animals are raised and used in these areas, and available survey data indicate that even those that

TABLE V

SOCIAL COST PER DRAFT ANIMAL FOR ALTERNATIVE POPULATION PARAMETERS

(b = .8 and n = .5 in all cases)

g	T_I = 3 and T_{II} = 11			T_I = 4 and T_{II} = 12		
	0	2%	2.5%	0	2%	2.5%
S_I	.8	.8	.8	.8	.8	.8
S_{II}	.9	.9	.9	.9	.9	.9
d	1.80	1.93	1.97	1.96	2.13	2.18
Gross cost (Rs./year)	547	586	598	595	648	663
Less benefit (Rs/year)						
Dung	27	29	30	29	32	33
Milk	12	14	15	12	14	15
Meat, *etc.*	8	10	10	8	10	10
Net cost (Rs/year)	500	543	543	546	592	605

Note: Computations are based on estimates shown in Tables II and IV, and formulas for estimating values of dung, milk and meat, *etc.*, stated earlier.

are used in these areas are not raised there. Therefore, the average cost of bullocks would be less than our computations indicate.

Second, these costs depend upon the existence of markets for the increased crop production. Pakistan is soon expected to attain self-sufficiency in food-grains whether there is mechanization or not. Therefore, any further increase in crop production will have to be exported. Although in our calculations we have implicitly assumed an unlimited export market for Pakistan's agricultural products at the present prices, it is unlikely to be so. Agricultural breakthrough in West Pakistan has been achieved primarily through the use of new seed varieties, fertilizer and water. The same development is rapidly taking place in other deficit countries. Wheat-surplus countries have already entered into agreement to restrict sale on the world market. The fairly strong rice market of the recent past is likely to weaken as new seed varieties (IRRI) rapidly increase output of rice. In cotton Pakistan's share of the world market is small enough that it should be relatively easy to increase exports. But it would be unwise for Pakistan to presume unlimited export markets for her major agricultural products.

Third, our computed cost of animal power indicates what direct benefit society will obtain if the bullocks are disposed off when the farm is mechanized. If some of the bullocks will be retained either as insurance against the risk of mechanical failure (a relatively high risk under present conditions), or because the tractor cannot perform all of the operations at present done by the bullocks, the benefits will be correspondingly lower.

A comparison of the cost of bullock power with that of mechanical power requires further information regarding the cost of mechanical power and the bullock-tractor 'conversion' ratio. This we have shown in a recent paper [2]. But it may be stated again that economic justification of a policy of agricultural mechanization must be based on the net social advantage and not on the direct cost advantage of mechanical over animal power. In particular, the social cost of displacing labour by tractors when the growth of alternative employment opportunities is inadequate should be very carefully assessed before going from bullocks to tractors.

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