Tractors, Tubewells and Cropping Intensity in the Indian Punjab

*by Bina Agarwal**

This paper quantifies the cropping intensity effects of tractors and tubewells in the Indian Punjab. In addition to the conventional measure of cropping intensity, a new index, which takes account of the time duration of crops grown, is specified. The advantage of tractor ownership vs. hiring the machine is also assessed as are the effects of farm size and agro-climatic zones. Relative to bullocks and canal irrigation, tractors and tubewells are respectively found to be associated with higher cropping intensities, as measured by both indices. Owned tractors have an advantage over hired ones and the effect of tubewells is substantially greater than of tractors.

I. INTRODUCTION

The effect of tractors and tubewells on cropping intensity can have a crucial bearing on what impact they have on the farm's annual output and employment per hectare. Any crop-specific positive effects on output, for instance, could be enhanced, or detrimental employment effects neutralised, through the cropping intensity factor [see *Agarwal, 1980*]. It is in this context that arguments in support of tractorisation often draw heavily on the fact that tractors could help to increase cropping intensity, by enabling the farmer to save time and hence grow an extra new crop, or to devote more area to existing crops. Likewise, an important advantage of tubewell irrigation over canals is seen to lie in its ability to promote more intensive cropping by making available an assured water supply throughout the year, and by enabling closer supervision over the quantum and timing of irrigation. These would be important factors influencing the farmer's decision regarding both what to grow and how much land to plant in a season.

While there is a fair amount of support in the literature for the contention that tubewells add to cropping intensity [*Billings and Singh, 1969; Kaneda, 1969; McInerney and Donaldson, 1975; NCAER, 1973; Rao, 1975; Vashishtha, 1975*], the evidence for tractors varies: in some previous studies, tractors have been found to add to cropping intensity [*Chopra, 1972; Johl, 1970; Grewal and Kahlon, 1972; Motilal, 1973*], and in others to have a neutral effect [*Rao, 1975; Vashishtha, 1975; Billings and Singh, 1969*]. Reservations may, however, be expressed with respect to the accuracy of both sets of studies dealing with the tractor effect.[1]

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Firstly, many of them do not take account of factors such as the source of irrigation, the level of irrigation, farm size and agro-climatic zones, which could also significantly affect cropping intensity. Hence some of the effects attributed to a tractor may in fact be unrelated to it.

Secondly, most studies use the ownership of a tractor as a proxy for usage: farms where tractors are hired in are counted as bullock farms. This is likely not merely to bias the results but also to obscure any differences in the impact of owned tractors relative to hired ones. For instance, a tractor owner would have greater flexibility in its use and hence be able to better reap any advantages than would a tractor hirer, especially where tractors are hired from other farmers (as is usual in the Punjab, where many of the Indian studies are based) rather than through an outside agency. Normally the owner will hire out his machine only after fulfilling his own requirements. The farmer hiring in the tractor would have to adjust the timings of his operations accordingly, thus losing some of the 'timeliness' advantage. This, plus the uncertainty regarding the availability of the tractor as and when he requires it over the year, can affect his cropping decisions.

In the studies mentioned, one or more of these aspects have been neglected. Johl, for instance, does not separate out the effect of any of the specified factors. Chopra and Motilal take account only of farm size. Grewal and Kahlon adjust for farm size and their farms are uniform in their source of irrigation, but as in other studies, so in theirs, tractor hiring is not explicitly taken into account. This last point also constitutes my main reservation as regards Rao's and Vashishtha's results. In both these studies, adjustment has been made for farm size, per cent area irrigated and the source of irrigation, but the computation of the tractor effect is based on a comparison of tractor owners with non-owners (irrespective of hiring in).

Thirdly, in all the noted studies, cropping intensity is defined conventionally as the ratio (expressed as a percentage) of gross cropped area to net sown area.[2] While this index is straightforward to interpret, it suffers from one major weakness: it takes no account of the differences between farmers in their ability to intensify cultivation further. If the farms compared have the same crop rotations over the year, the index presents no problem. Even when they have differing rotations the comparison is valid as long as no differences exist in the time taken by the alternative crops to mature. A wheat-paddy rotation would thus be comparable to a wheat-groundnut rotation since both paddy and groundnut take roughly four and a half months. However, when farmers are growing crops with different maturing periods, erroneous conclusions may be drawn from this index. Consider, for instance, two farmers both with five hectares of net sown area, one having a wheat-paddy rotation and growing five hectares of wheat in *rabi* (broadly mid-October to end of April) and three hectares of paddy in *kharif* (broadly May to mid-October), and the other growing only sugarcane (a 10-12 month crop) on all five hectares. By the conventional index, the first farmer will have a cropping intensity of 160 per cent and the second of 100 per cent. This is despite the first having two hectares idle for half the year and the second having the entire area occupied throughout the year. That the first farmer has some discretion in intensifying cultivation and the second has little, is obscured by the index. In fact, from the above results, we would conclude just the opposite.

In short, the main lacunae in previous studies may be traced to:

(i) their failure to separate the effects of tractors or tubewells from the impact of other variables; *and/or*

(ii) their basing their conclusions about the tractor effect on a comparison of bullock farms with tractor-owning farms, without taking account of tractor hiring on bullock farms; *and*

(iii) their basing their analysis only on the conventional index of cropping intensity.

The present study attempts to take care of all three aspects and so seeks to capture the cropping intensity effects of tractors and tubewells more accurately. Regarding the third aspect, an alternative to the conventional index is specified here, taking account of the differences in the time-duration of crops grown on different farms over the year. Both the conventional and the alternative indices have been used in the present analysis.

In the following sections of the paper, Section II gives the specification of the alternative cropping intensity index; Section III provides details of the data, the hypotheses and the methodology used for the empirical analysis; Section IV presents the results; and Section V contains a summary of the main findings and some concluding comments.

II. SPECIFICATION OF AN ALTERNATIVE CROPPING INTENSITY INDEX

The alternative index has been specified as follows:

$$\frac{\sum_{i=1}^{n} a_i t_i}{12 A_s} \times 100$$

Here a_i = area under crop 'i'; t_i = average duration (in months) of crop 'i'; A_s = net sown area. The maximum value for this index is 100, that is, when every cultivated hectare of the farm is occupied for all months of the year. This index thus helps to compute the 'hectare-months' for which farm land is unoccupied and hence to determine the scope that exists for further increasing cropping intensity, given the farmer's choice of cropping pattern.

Crops grown under 'mixed cropping', that is, more than one crop being grown on the same plot of land at the same time (as, for instance, wheat-gram), have been counted as a single crop, with the total time for which a plot of land is occupied in this way being taken as the time duration of the 'mixed crop'. (In the present sample such cases were very few.) I shall henceforth be referring to the cropping intensity index computed by the conventional method as the 'conventional index' (I_c) and the one specified here as the 'crop-duration index' (I_d).

III. DATA, HYPOTHESES AND METHODOLOGY

Data

The data used relate to a sample of 237 farms[3] taken from the principal wheat-growing areas of the Indian Punjab, and covering 20 *tehsils* spread across all the districts of the state. The data are for the crop-year 1971–72, and were collected under the 'Comprehensive Scheme for Studying the Cost of Cultivation of Principal Crops' by the Punjab Agricultural University, for the Directorate of Economics and Statistics, New Delhi. A three-stage stratified random sampling was undertaken, with the *tehsil* as the primary unit, a cluster of three villages in each *tehsil* as the secondary unit, and the farms in each cluster as the final unit. Information was obtained on the basis of day-to-day observation of selected cultivators by full-time researchers residing in the villages. This method is more accurate than the commonly used 'recall method' which relies on the memory of the respondent.

All the sample farmers own at least a part of the land they operate. The farms are of differing sizes ranging from 0.8 hectares to 33.7 hectares with the bulk (78.5 per cent) being over four hectares in size; and are spread over three agro-climatic zones. Each zone is broadly homogeneous with respect to cropping pattern, climate and level of rainfall, but differs from each of the other zones on these counts.[4]

Hypotheses

On *a priori* grounds (for reasons already stated) we would expect cropping intensity to be positively related to the following factors: the use of tractors in comparison with bullocks; irrigating with a tubewell rather than relying on canals alone; ownership of a tractor rather than relying on a hired one; and the percentage of gross cropped area irrigated. Further, *ceteris paribus*, we would expect cropping intensity to be negatively related to farm size. This is an important relationship and needs elaboration. Among reasons for expecting this inverse relationship are the following:

(i) A managerial constraint: The greater the area cultivated, the more would be the requirements of labour supervision and management, particularly under labour-intensive irrigated farming. This would set a limit on the amount of land the farmer decides to plant in a season. Also, land available between the main crop seasons is less likely to be planted with minor crops the larger the farm, since additional supervision would be needed both for the minor crops and for ensuring the timely preparation of land for the subsequent main crop. At what level a managerial constraint is encountered would depend on the availability of reliable persons (usually family members and/or permanent labourers) for supervision;

(ii) A power constraint: The larger the farm the greater is the likelihood of the farmer having to face this constraint. Even a farmer owning a tractor or a tubewell can encounter this problem if the farm exceeds the size for which a single tractor and/or tubewell would suffice, and yet is not large enough to make the purchase of an extra one worthwhile. This limit could again vary, depending on the availability of supplementary means (such as bullocks for tillage and canal water for irrigation) and/or the ability of the farmer to hire in such supplementary services;

(iii) Specific circumstances such as poor quality, inadequately levelled or temporarily water-logged land: the larger the farmer the more likely is he to leave such land fallow, at least for a part of the year, while the smaller farmer might put in the extra effort needed to cultivate it.

Finally, we would expect differences in soil and climatic conditions (for which the agro-climatic zones are a proxy) to affect cropping intensity through their impact on cropping patterns.

Methodology

The sample farms have been divided broadly into the following technique categories:

(i) Bullock farms: those ploughed exclusively with bullocks;

(ii) Tractor farms: those ploughed[5] with tractors (owned or hired in). Here, in addition to tractors, bullocks might also be used for ploughing on a part of the cultivated area. The tractor-using farms are divided further into (a) tractor-owning farms, i.e. those where owned tractors are used (although, additionally, tractor services may be hired in), and (b) tractor-hiring farms, i.e. those where no tractor is owned but tractor services are hired in for ploughing;

(iii) Canal farms: those exclusively canal irrigated;

(iv) Tubewell farms: those irrigated by tubewells (this category includes pumpsets). Here canals may be used to supplement tubewells. In 97 per cent of the tubewell farms, the tubewells used are owned. The average cropping intensities of farms classified by combinations of the above technique categories have been tabulated.

The relative effect on cropping intensity of each of the factors mentioned in the hypotheses has been measured through multiple regression. The variables entering the regression equations are as follows:

Equation number	*Dependent variable*	*Explanatory variables*
1.1	I_c	$A_s, I_r, D_w, D_p, D_{z1}, D_{z2}$
1.2	I_d	$A_s, I_r, D_w, D_p, D_{z1}, D_{z2}$
2.1	I_c	$A_s, I_r, D_w, D_{p1}, D_{p2}, D_{z1}, D_{z2}$
2.2	I_d	$A_s, I_r, D_w, D_{p1}, D_{p2}, D_{z1}, D_{z2}$

where:

I_c = conventional index of cropping intensity

I_d = crop-duration index of cropping intensity

D_w = tubewell-use dummy = 1 for tubewell use
0 for canal use

D_p	= tractor-use dummy	=	1 for tractor use 0 for bullock use
D_{p1}	= tractor-ownership dummy	=	1 when tractor is owned 0 otherwise
D_{p2}	= tractor-hire dummy	=	1 when tractor is hired 0 otherwise
D_{z1}	= zone I dummy	=	1 for zone I 0 for other zones
D_{z2}	= zone II dummy	=	1 for zone II 0 for other zones
A_s	= farm size (net sown area) in hectares		

$$I_r = \frac{\text{Gross irrigated area}}{\text{Gross cropped area}} \times 100$$

The equations presented have been computed by the method of ordinary least squares, and specified in the linear form since this gives not merely the direction of the cropping intensity effects but also their absolute magnitudes which are of interest here. (Log-linear specifications were also attempted, but the results were similar to those obtained from the linear specifications. Hence only the latter have been presented here.)

Equations 1.1 and 1.2 help to estimate the effects of tractor and tubewell use in comparison with the use of bullocks and canal respectively. In equations 2.1 and 2.2 the attempt is to disaggregate the overall tractor effect by the criteria of ownership and hire. We can thus compare exclusively bullock farms, tractor-hiring farms and tractor-owning farms. Dummy variables have been specified to separate the effects of the three agro-climatic zones, as well as to mark the differences between tractor-using (owned and hired) and bullock-using farms, and between tubewell-irrigated and canal-irrigated farms.

To identify the tractor and tubewell effects, there were two main reasons for using discrete (dummy) rather than continuous variables as, for instance, taking the percentage of farm area ploughed with tractors and the percentage of farm area irrigated with tubewells: (a) the effect of tractor or tubewell availability (through ownership or hire) on the decision of whether or not to grow an extra new crop or to plant more area with existing crops, is likely to be once-for-all during the year. We would thus expect the impact on cropping intensity to be in the nature of a jump. The more intensive use of a tractor or a tubewell may affect the output produced on the area planted, but it is unlikely to make much difference to the amount of area planted; and (b) in practice, it is not always possible to specify what percentage of farm area is operated with any single technique, because sometimes the same plot of land is given a few ploughings with a tractor and a few with a bullock; and similarly given a few irrigations with a tubewell and a few with a canal.

To compute the crop-duration index, the formula presented earlier has been used. For each farmer, the area under each crop (identified by variety) cultivated by him has been multiplied by the average time-duration of that crop, thus obtaining the total hectare-months for which his land is occupied.

IV. RESULTS AND INTERPRETATION

Tabulation Results

Table 1 gives the number and average size of farms using different combinations of ploughing and irrigation techniques; it also indicates, in the case of tractors, whether they are owned or hired. We note that 54.8 per cent of the farmers use tractors. Of these 40.8 per cent own the machine and 59.2 per cent rely exclusively on hired tractors. If tractor ownership alone had been taken as the criterion for separating bullock and tractor farms, these tractor-hiring farms would have been misclassified as bullock farms. The majority – 90.8 per cent – of the tractor-using farms are irrigated by tubewells. Among these, those owning tractors are almost all tubewell irrigated. Of the bullock-ploughed farms, 29.0 per cent are exclusively canal irrigated, and the remaining 71.0 per cent are tubewell irrigated. The average farm size for the sample comes to approximately eight hectares. Tractor farms, particularly tractor-owning ones, not unexpectedly, are larger than bullock farms. The latter have an average size of 6.06 hectares compared with the 9.54 hectares of all tractor-using farms. Among tractor-users, owners again are larger (12.85 hectares) than hirers (7.27 hectares).

TABLE 1

NUMBER OF FARMS AND AVERAGE FARM SIZE BY FARM TECHNIQUE CATEGORIES

Farm Technique Categories	No. of Farms	Average Farm Size (in Hectares)
1. All Bullock Farms	107	6.06
(i) Bullock-Canal	31	7.33
(ii) Bullock-Tubewell	76	5.54
2. All Tractor Farms	130	9.54
(i) Tractor owners	53	12.85
(a) Tractor owned-Canal	2	15.91
(b) Tractor owned-Tubewell	51	12.73
(ii) Tractor hirers	77	7.27
(a) Tractor hired-Canal	10	8.68
(b) Tractor hired-Tubewell	67	7.06
3. All Farms	237	7.97

Table 2 gives a cross-tabulation of the mean cropping intensities by combinations of ploughing and irrigation techniques. All the farms in the sample are cultivated in both the *rabi* and the *kharif* seasons. For all farms taken together, the average cropping intensity by the conventional index comes to 168.4 per cent. The mean value of the crop-duration index comes to 69.5, that is, the average utilisation of land over the year is approximately 70 per cent by I_d. Expressed in hectare-months, this would mean that out of the maximum of 12 months for which a hectare could be occupied, it is occupied on average for 8.3 months. The coefficients of variation for both I_c and I_d are low, being 0.18 and 0.16 respectively.

TABLE 2

CROPPING INTENSITY BY FARM TECHNIQUE CATEGORIES
(Mean Values)

Farm Technique Categories	Conventional Index			Crop-duration Index		
	Canal	Tubewell	All	Canal	Tubewell	All
Bullock	127.8	175.3	161.5 (0.20)	62.6	70.2	68.0 (0.14)
Tractor	134.2	178.1	174.0 (0.15)	65.6	71.4	70.8 (0.16)
Tractor owned	136.2	177.7	176.2 (0.13)	72.8	70.8	70.9 (0.17)
Tractor hired	133.8	178.3	172.6 (0.17)	64.1	71.8	70.8 (0.16)
All	129.6 (0.13)	177.0 (0.14)	168.4 (0.18)	63.4 (0.13)	70.9 (0.16)	69.5 (0.16)

Notes: Figures in brackets give the coefficients of variation of the respective values.
For number of farms in each technique category see Table 1.

On comparing farms of different technique categories we find that by both indices, bullock-canal farms have the lowest cropping intensity, and tractor-tubewell farms have the highest. In between come tractor-canal farms and bullock-tubewell farms in ascending order. However, the difference between bullock-tubewell and tractor-tubewell farms is small. The additional effect of farm size emerges from the regression equations.

Regression Results

The regression results (see Tables 3a and 3b) help to bring out the effects of the specified variables as below:

(i) *The use of tractors and tubewells*: Equations 1.1 and 1.2 confirm that farms using tubewells have a significantly higher mean cropping intensity than those relying on canal water alone: the difference comes to 34.51 percentage points by the conventional index and 13.30 by the crop-duration index. Again, by the conventional index, tractor-using farms are associated with a significantly higher cropping intensity than bullock farms, the difference coming to 6.77 percentage points. By the crop-duration index, however, the differences between bullock and tractor farms are not significant;

(ii) *Ownership of a tractor*: From equations 2.1 and 2.2, we obtain the effect not merely of the use of tractors but also of their being owned or hired. Tractor-owning farms are found to have a significantly higher cropping intensity, by both indices, than bullock farms: the difference comes to 12.06 as measured by I_c and 4.68 as measured by I_d. Tractor hirers too have a higher cropping intensity than bullock farms but here the differences are not statistically significant by either index. Relative to tractor hirers, tractor owners have a significant advantage by the conventional index. Also, the tubewell-irrigated farms

TABLE 3a

CROPPING INTENSITY REGRESSION RESULTS

(Linear)

Equation number	1.1	1.2	2.1	2.2
Dependent variable	I_c	I_d	I_c	I_d
Number of observations	237	237	237	237
$\bar{R}^2$	0.56	0.32	0.56	0.32
Constant	99.97	47.08	102.79	48.26
Explanatory variables		*Regression Coefficients*		
Farm Size (A_s)	–1.29**	–0.57**	–1.52**	–0.66**
	(4.93)	(4.76)	(5.26)	(5.04)
Percent Area Irrigated (I_r)	0.39**	0.22**	0.38**	0.22**
	(4.73)	(5.82)	(4.65)	(5.75)
Tubewell-use dummy (D_w)	34.51**	13.30**	34.07**	13.11**
	(6.73)	(5.69)	(6.67)	(5.62)
Tractor-use dummy (D_p)	6.77*	2.46	–	–
	(2.35)	(1.88)		
Tractor-ownership dummy (D_{p1})	–	–	12.06**	4.68*
			(2.97)	(2.53)
Tractor-hire dummy (D_{p2})	–	–	4.86	1.67
			(1.60)	(1.20)
Zone I dummy (D_{z1})	23.40**	–4.49*	22.31**	–4.95*
	(4.76)	(2.00)	(4.53)	(2.20)
Zone II dummy (D_{z2})	12.19*	–6.85**	11.76*	–7.03**
	(2.47)	(3.05)	(2.39)	(3.14)

Notes: Figures in brackets give the 't' values of the respective coefficients.
** Denotes significance at the 1% level.
* Denotes significance at the 5% level.
The rest are insignificant at the 5% level.
Significance has been tested in accordance with the two-tailed test.

TABLE 3b

DIFFERENCES IN REGRESSION COEFFICIENTS OF DUMMY-PAIRS

(Linear Results)

Equations number	Dummies compared	Difference in the coefficients of the dummies compared *	't' values of the differences
1.1	D_{z1}, D_{z2}	11.21**	3.54
1.2	D_{z1}, D_{z2}	2.36	1.63
2.1	D_{p1}, D_{p2}	7.20**	2.83
2.1	D_{z1}, D_{z2}	10.55**	3.32
2.2	D_{p1}, D_{p2}	3.01	1.68
2.2	D_{z1}, D_{z2}	2.08	1.44

Notes: * The coefficient of the dummy mentioned second has been subtracted from the coefficient of the dummy mentioned first.
** Denotes significance at the 1% level.
The rest are insignificant at the 5% level.
Significance is in accordance with the two-tailed test.

are again (among this second set of equations) found to have a significantly higher mean cropping intensity than canal-irrigated farms, by both indices;

(iii) *Other factors: per cent area irrigated, farm size, agro-climatic zones*: The index of irrigation is positively related to cropping intensity in all four equations. However, the coefficients of the irrigation variable, though significant, are small. This would be because, in the majority of farms, over 85 per cent of the gross cropped area is already irrigated and subsequent increases at the margin would thus lead to only small additions to cropping intensity.

Farm size is consistently significant and inversely related to cropping intensity in all the equations, as hypothesised.

Finally, both the zonal dummies emerge as significant variables in all the equations. It is interesting to note that the results for the conventional index have a sign opposite to those for the crop-duration index. In equations pertaining to the conventional index, Zones I and II have a significantly higher cropping intensity than Zone III; Zone I has the highest value, followed by Zones II and III. In equations pertaining to the crop-duration index, however, Zone III emerges as the one with the highest cropping intensity. This difference in the results obtained with the two indices may be attributed to the difference in the time-duration of the crops grown in the three zones in the *kharif* season. The main *rabi* crop, namely HYV wheat, is the same in all the zones, but the main *kharif* crop differs: in Zone III it is American cotton, which takes seven to eight months to mature, while in Zones I and II the main *kharif* crops are maize, paddy and groundnut which have an average duration of four to four and a half months. Hence Zone III, which has the lowest cropping intensity by the conventional index, has the highest by the crop-duration index.

Using the regression results, I also calculated the additional land that would be made available to the farmer over the crop year, due to the observed increase in cropping intensity through tractor and tubewell use. For an eight-hectare farm (which, as noted, is the average farm size in the sample), the land made available through increases in cropping intensity as measured by I_c, came to 0.96 hectares for the owned tractor relative to bullocks, and to 2.72 hectares for the tubewell relative to canal.[6]

V. SUMMARY AND CONCLUDING COMMENTS

This paper set out to identify the factors which could explain the observed differences between farms in their cropping intensities. In particular, I wanted to quantify the effect of tractors and tubewells, and to see whether the ownership of a tractor gave the user any special advantage over one who merely hired the machine. To take account of the differences in the duration of different crops, I specified, in addition to the conventional index, the crop-duration index of cropping intensity which could also give an idea of the degree to which a farmer under-utilised the land over the crop-year.

Both tractors (in particular owned tractors) and tubewells were found to be associated with a higher cropping intensity, as measured by each of the indices, in comparison with bullocks and canals respectively. However, the advantage of tubewells over canals was much greater (34.1 percentage points as measured by I_c) than that of tractors over bullocks (which came to 12.1

percentage points). That irrigation, in particular, tubewell irrigation, is a more important factor in increasing cropping intensity, than the use of tractors in lieu of bullocks, has been emphasised in other studies as well [see *Billings and Singh* on the Indian Punjab; *Kaneda, McInerney and Donaldson* for Pakistan].

Likewise, the association of zones with differences in cropping intensity noted here, agrees with the findings of Vashishtha who also took this factor into account (although, unlike here, he did not spell out why one zone may have an advantage over another). In this zone-wise comparison, the alternative crop-duration index helped to highlight the importance of taking account of cropping pattern differences, especially where farmers grow crops with substantially differing maturing periods.

The negative relationship that we observed between farm size and cropping intensity, for all farms taken together, again is in keeping with the results of others such as Vashishtha, Motilal, Rao, Grewal and Kahlon, and McInerney and Donaldson. Also, it is noteworthy, although the detailed results are not presented in this paper, that in my sample even when farms were separated into bullock, tractor-owning and tractor-hiring categories, the inverse relationship held for all three categories. This would caution against the contention of some scholars that tractors help in *preventing* a fall in cropping intensity on large farms [see, for example, *Vashishtha, 1975: 41*]. The most that could be said is that given the observed advantage of tractors over bullocks, cropping intensity would not fall to the same *level* on large tractor farms as on large bullock ones.

In this context, it is also necessary to view with caution the popular notion that tractors are likely to release large amounts of fodder land for crop cultivation. Although no precise estimates on this could be made from my data, the differences between bullock and tractor (owned or hired) farms in the average percentage of gross cropped area (GCA) devoted to fodder, was not found to be substantial: bullock farms devoted 16 per cent, tractor-hiring farms 15.6 per cent, and tractor owning farms 11.6 per cent of GCA to fodder.

On *a priori* grounds too, we would not expect much saving from fodder land with tractors because: (a) only a part of the bullock feed usually comes from fodder grown on the farm; much of it often consists of wheat and rice straw which are by-products [*Bose and Clark, 1969*]. Hence, even on bullock farms the amount of land needed for fodder would be small; (b) on tractor-hiring farms, bullocks are often retained to guard against the risk of tractors not being available for hire when needed; and even on tractor-owning farms, bullocks are often kept for some agricultural operations, and to counter the risk of a tractor breakdown especially during periods of peak requirements; (c) farms may 'fit in' a short duration fodder variety between the main crop seasons, in effect using land which would otherwise lie idle for that period; (d) fodder may be grown for sale, depending on the profitability of fodder relative to other crops.

On individual farms, therefore, tractors need not lead to a diversion of land under fodder to other crops; and at the macro-level, say, for Punjab as a whole, whether or not tractorisation significantly reduces the area under fodder would depend on how substantial a reduction in bullock requirements and hence in the bullock population it helps to bring about.

On the whole, the cropping intensity advantages of tractorisation in the Punjab appear to have been overstated.

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NOTES

1. The studies mentioned here are for purposes of illustration. For a more extensive coverage of research on the cropping intensity effect of tractorisation, see Binswanger's review [*1978*]. Binswanger does not, however, highlight the particular shortcomings of this literature that are emphasised here.
2. Gross cropped area is the total area under all crops grown over the crop-year. Net sown area is that part of the farm area that is cultivated at least once over the crop-year; it is given by: owned area plus net leased-in area minus area uncultivated throughout the year minus area under orchards or gardens.
3. The main sample had 240 farms; three were dropped due to incomplete data.
4. The original classification of zones adopted by the data-collecting unit did not strictly correspond to its stated criteria. Hence, for the present analysis, some *tehsils* were reclassified so that those falling within a zone were broadly homogeneous in these terms.
5. The principal agricultural operation for which tractors were used by the sample farmers was ploughing (including subsidiary functions associated with seed-bed preparation). Hence the separation of farms into tractor-using and bullock (non-tractor) using is based on the use or non-use of tractors in this operation. Some farms, however, sometimes did use tractors for additional operations as well.
6. This is given by multiplying the average farm size (in this case approximately eight hectares) with the regression coefficients obtained in equation 2.1 and dividing by 100.

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