Factors Affecting Current and Potential Cropping Intensity in the Southern Punjab of Pakistan

Khaleel A. Tetlay
Derek Byerlee
Zulfiqar Ahmad

PARC/CIMMYT Paper No. 88-1

Agricultural Economics Research Unit (PARC),
Ayub Agricultural Research Institute,
Faisalabad
PARC/CIMMYT Collaborative Program,
Islamabad

1988

Factors Affecting Current and Potential Cropping Intensity in the Southern Punjab of Pakistan*

Khaleel A. Tetlay[1]
Derek Byerlee[2]
Zulfiqar Ahmad[1]

PARC/CIMMYT Paper No. 88-1

*We appreciate valuable comments on an earlier draft by P. Hobbs, M. Morris and J. Wolf.

[1]Agricultural Economics Research Unit (PARC), Ayub Agricultural Research Institute, Faisalabad.

[2]PARC/CIMMYT Collaborative Program, Islamabad

1988

Research Reports in this Series

1. Derek Byerlee, A.D. Sheikh, M. Aslam and P. R. Hobbs. Wheat in the rice-based farming system of the Punjab: Implications for research and extension. PARC/CIMMYT Publication 1984.

2. S. Sajidin Hussain, D. Byerlee, B.R. Khan, B.M. Khan and P. R. Hobbs. Wheat in the irrigated farming systems of Mardan District: Implications for research and extension. NARC, AERU, CCRI and CIMMYT, Islamabad. PARC/CIMMYT Publication 1984.

3. Derek Byerlee, P.R. Hobbs, B. R. Khan, A. Majid, R. Akhtar and N. Hashmi. Increasing wheat productivity in the context of Pakistan's irrigated cropping systems: A view from the farmers' field. PARC/CIMMYT paper 86-7

4. M. Ramzan Akhtar, D. Byerlee, A. Qayyum, A. Majid and P. R. Hobbs. Wheat in the cotton-wheat farming systems of the Punjab: Implications for research and extension. NARC, AERU Faisalabad and CIMMYT, Islamabad. PARC/CIMMYT paper 86-8.

5. Peter R. Hobbs, B.R. Khan, A. Razzaq, B.M. Khan, M. Aslam, N.I. Hashmi and A Majid. Results from agronomic on-farm trials on barani wheat in the high and medium rainfall areas of northern Punjab for 1983 to 1985. Wheat Barley and Triticale Program, NARC/CIMMYT, Islamabad. PARC/CIMMYT paper 86-8a.

6. Report of wheat travelling seminar 1986. PARC/CIMMYT publication 86-10.

7. M. Ramzan Akhtar, K. A. Tetlay, Z. Ahmed, P. Heisey and A. Sattar. Wheat varietal verification in the irrigated Punjab: Farmers' and breeders' perceptions. AERU Faisalabad Staff Paper 86-13.

8. Report of wheat travelling seminar 1987. PARC/CIMMYT publication 1987.

9. Chris R. Dowswell. Wheat research and development in Pakistan: A national perspective, 1987. PARC/CIMMYT publication.

10. Paul W. Heisey, M. R. Akhtar, K. A. Tetlay, Z. Ahmad, M. Ahmad, A. Sattar, A. K. Khattak. Monitoring wheat varieties grown in Pakistan: Objectives, methods and results from three major cropping systems, 1985-86. PARC/CIMMYT Paper No. 87-3.

11. M. Ramzan Akhtar, Z. Ahmad and K. A. Tetlay. Monitoring wheat varietal diffusion in the irrigated Punjab: Results from 1986-87. AERU Faisalabad Staff Paper No. 87-3.

12. Melinda Smale. A note on multi-stage sampling with list frames: The PARC/CIMMYT survey of wheat harvest technology. PARC/CIMMYT Paper No. 87-9.

13. Melinda Smale. Wheat harvest technology in Punjab's rice wheat zone: Combines, laborers and the cost of harvest delay. PARC/CIMMYT Paper No. 87-23.

14. Khaleel A. Tetlay, P. W. Heisey and Z. Ahmad. Seed technology acquisition, Seed industry contact and on-farm seed management in the irrigated Punjab: Farmers' behaviour and perceptions. PARC/CIMMYT Paper No. 87-25.

Single copies of these reports may be obtained by writing to CIMMYT, P.O. Box 1237, Islamabad

Table of Contents

List of Tables

List of Appendix Tables

Table

List of Figures

FIGURE

Factors Affecting Current and Potential Cropping Intensity in the Southern Punjab of Pakistan

Summary

Cropping intensity in the cotton-wheat areas of Pakistan's Punjab is well below its potential and also significantly lower than in neighbouring areas of India's Punjab. Analysis of annual cropping intensity indicates that access to irrigation water is the major factor explaining differences in cropping intensity in a cross-section of farmers. Tractorization plays a very minor role although official policy has emphasised tractorization over investments in tubewells. Analysis of season-specific cropping intensity also indicates that inappropriate varieties for double cropping also constrain cropping intensity. It is estimated that cropping intensity could be increased by at least 30 percent through policies directed at improved water supplies and promoting research on earlier varieties of cotton, maize and oilseeds.

Factors Affecting Current and Potential Cropping Intensity in the Southern Punjab of Pakistan+

Introduction

Cropping intensity in irrigated areas of Asia has increased steadily over the past two decades, especially with the introduction of earlier maturing varieties and improved supplies of irrigation water. Nonetheless, a major source of future growth in agricultural production is expected to come from increased cropping intensity. For example FAO (1981) projects cropping intensity in irrigated Asia to increase from 118 in 1975 to 141 in 2000. In the Pakistan Punjab, the overall cropping intensity of 125 also suggests considerable scope for increasing production through higher cropping intensities. Despite this potential, the determinants of cropping intensity have received little attention in recent research in Pakistan.

It is the aim of this study to analyse major factors influencing cropping intensity in the cotton zone of the southern Punjab of Pakistan and to suggest policy directions that might facilitate further increases in cropping intensity. The potential impacts of tubewell and tractor mechanization on cropping intensity are well recognized and have been the subject of considerable analysis both in the Indian and Pakistan Punjab (Agarwal, 1984; Kaneda, 1969; McInerney and Donaldson, 1975; Lockwood, 1983). All of these studies show the expected positive effect of tubewell use on cropping intensity. However, the effect of tractor use on increasing cropping intensity is more controversial. Binswanger (1978) synthesized data from five studies of tractor mechanization in the Indian and Pakistan Punjab in the 1970s that suggest that tractor use increased cropping intensity by at most 10%, and this effect was usually not statistically significant. More recently (Jayasuriya et al., 1986) reviewed 15 studies in South and Southeast Asia and concluded that mechanized land preparation generally had no effect on cropping intensity, although a few studies showed an increase of around 10%. They attributed this to the fact that most farmers who mechanize land preparation use rented machinery and often have to wait for this service, since land preparation is the peak demand period for rental services.

Several studies in Pakistan, (Ahmad, 1972; WAPDA, 1982; McInerney and Donaldson, 1975; Kadri, et. al., 1982; Malik, 1983 and Khan et.al., 1986), however, indicate that tractor use increases cropping intensity by 10 to 20 points. This result should be treated cautiously since in many cases increased cropping intensity was associated only with tractor ownership (Malik, 1983; Khan, et.al., 1986) and not tractor hiring. Moreover, these studies have often analysed a sample dispersed over several different cropping systems and have not standardised for irrigation source which is strongly correlated with power source (e.g., Kadri, et. al., 1982; Malik, 1983 and Khan, et.al., 1986). Hence there is a need to jointly analyse the effect of tractorization and tubewell use and to disaggregate between ownership of these production factors and rental of their services.

Despite the ambiguity of these research findings, official credit policy in Pakistan has favoured lending for tractors over lending for tubewells. In the period 1982-85, loans for tubewells accounted for less than two percent of official lending of the Agricultural Development Bank of Pakistan compared to 63 percent for loans for tractors. Likewise the electrification of villages to facilitate use of electric tubewells has lagged well behind the Indian Punjab. The emphasis on tractors in official policy has been justified by the belief that draught power limits cropping intensity.

Beyond these questions of mechanization and irrigation, a major factor ignored by analyses of cropping intensity is the availability of suitable cropping patterns. Often there is a conflict between the harvesting of one crop and the planting of the next crop which leads to delayed planting and lower productivity. Hence farmers often prefer to leave land fallow than attempt double cropping. Research to develop short-duration varieties that fit into the cropping system or reduced tillage to speed up turnaround time between crops can potentially alleviate power constraints for policy is the role of varietal improvement versus mechanization in increasing cropping intensity.

This paper focuses on a major agro-ecological zone - the cotton areas of the Southern Punjab. Cropping intensity in the zone is relatively low at about 130, with substantial areas left fallow in both the Rabi (winter) and Kharif (summer) seasons. This fallow land has been targeted as a major area for the expansion of non-traditional oilseeds, especially sunflowers and soyabeans, in order to reduce Pakistan's chronic dependence on imported vegetable oil. Cropping intensity in the zone has increased rapidly relative to other zones in recent years; the index of cropping intensity rose from 112 in the early 1970s to over 130 in the early 1980s. Traditionally two major rotations were practiced - wheat-fallow and fallow-cotton. The introduction of semi-dwarf wheat varieties and earlier maturing varieties of cotton have, however, enabled double cropping of wheat after cotton (Byerlee, Akhtar and Hobbs, 1987). By 1985, about half of the wheat was sown after cotton (Akhtar et al., 1986). Nonetheless, wheat after cotton is generally planted late, increasing the risks of yield loss and decreasing the profitability of this rotation. Many farmers also leave land fallow because of a shortage of canal irrigation water. Hence the cotton zone of the southern Punjab is ideally suited to exploring the relative role of irrigation, mechanization and research on improved varieties in increasing cropping intensity.

Data Sources

Data used for this analysis were collected in 1985 and 1986 from two samples in the Multan area. In 1986, a sample of 71 farms was selected to obtain information on cropping patterns and cropping intensity. Fifteen villages were randomly selected with probability proportional to size as the first stage sample, and five farmers selected in each village.

Additional evidence on cropping intensity was obtained by analysing a larger sample of 150 farmers interviewed in 1985 during the wheat harvest season in the same area. This sample collected data only on cropping intensity in the rabi cycle. However, it provided more detailed information on irrigation sources and management and a larger sample size with which to explore these relationships. Major differences between the characteristics of farmers in each sample are given in Appendix A.

The characteristics of the sample farmers are summarized in Tables 1 and 2. Average farm size is 6.2 ha but quite variable. A range of irrigation and power sources are represented in the sample (Table 1). In general, there is an association between the source of irrigation water and the source of power. That is, farmers who own tractors also own tubewells. Another group of farmers tends to hire both services, while there is a further group who use only animal power and have no access to tubewell water. As expected, the largest farm size is associated with ownership of tractors and/or tubewells (Table 1).

Table 1: Distribution of Farmers and Farm Size by Power Source and Irrigation Source, 1986 Sample.

	Canal only	Canal + hired tubewell	Canal + tubewell	All
		Percent Farmers		
Power Source				
Animal only	15.5	7.0	0	22.5
Hire tractor[a]	8.5	39.4	4.2	52.1
Own tractor	9.9	4.2	11.3	25.4
All	33.9	50.6	15.5	100.0
		Farm Size (ha)		
Power Source				
Animal only	5.0	3.7	na	4.6
Hire tractor[a]	4.1	4.6	6.6	4.7
Own tractor	9.9	na	12.6	10.7
All	6.2	4.7	11.0	6.2

[a] Includes farms who use both hired tractor and own animals.

na Not calculated because cell size less than five observations

The canal system of the area was originally designed for a cropping intensity of only 66%, so clearly the major factor in increasing cropping intensity has been the installation of tubewells. In the 1985 survey, seventy five percent of the irrigations given to wheat were provided from tubewells, and even in the perennial canal areas, tubewells accounted for about half the water applied (Table 2). The use of tubewell water is, however, restricted by the quality of groundwater, and when farmers in the survey were asked to rate groundwater on their farms as "good" or "saline", 17 percent of the farmers rated their ground water as saline. In addition, nearly all farmers without access to a tubewell were located in areas of saline groundwater. Hence about

Table 2: Distribution of Farmers by Irrigation Source and Irrigation Practices in Wheat, 1985 Survey.

	None	Tubewell Use		All
		Good Water	Saline Water	
Percent of farmers				
- Seasonal canal	0	46.7	10.7	57.4
- Perennial canal	6.7	30.0	6.0	42.7
- All	6.7	76.7	16.7	100.0
Number of Irrigations to Wheat				
- Seasonal canal	na	4.9	4.7	4.9
- Perennial canal	4.4	5.4	4.9	5.2
- All	4.4	5.1	4.8	5.0
Percent of Wheat Irrigations from Tubewell				
- Seasonal canal	na	93	99	94
- Perennial canal	0	64	45	53
- All	0	80	79	76

na = not applicable

one quarter of farmers had to depend largely on canal water. Note also that farmers who had access to both perennial canals and good tubewell water also applied the most water to their wheat crop.[1]

Cropping Patterns and Cropping Intensity

The cropping pattern is almost completely dominated by wheat in the Rabi season and cotton in the Kharif season, (see Table 3). Fodder is the only other significant crop and occupies 13 to 15 percent of the cropped area in both seasons. Despite a slightly more diverse crop mix in the Kharif season, the cropping intensity in this season is lower than in Rabi season.

Table 3: Cropping Patterns, Kharif and Rabi Seasons, 1986 Survey.

		Kharif, 1986	Rabi, 1985/86
Percent cropped area	- wheat	-	85.8
	- cotton	77.7	-
	- fodder	14.5	13.2
	- mustard	-	1.0
	- sugarcane	4.5	-
	- other[a]	7.7	-
Total		100.0	100.0
Index of cropping intensity (%)		65	69

[a] Vegetables, maize, rice, etc.

1 This relationship is significant at the one percent level in an analysis of variance.

There are some differences in cropping pattern and cropping intensity by farm size (Table 4). As expected, the proportion of area devoted to fodder decreases as farm size decreases, since the number of livestock per farm do not increase in proportion to farm size[2]. There is also evidence that the area devoted to fodder crops is reduced by tractor ownership but not by tractor hiring[3]. Over seventy percent of farmers hiring tractors retained bullocks for some farm operations.

Table 4: Cropping Pattern and Cropping Intensity by Farm Size, 1986 Survey.

	Farm Size			
	<2.5 ha	2.5-5.0 ha	>5.0 ha	All
Percent cropped area				
- food crops	42.7	46.3	47.0	45.8
- fodder crops	23.4	17.7	15.6	18.0
- cash crops	33.9	36.0	37.4	36.2
Total	100.0	100.0	100.0	100.0
Cropping intensity index (%)[a]	152	124	134	134

[a] The difference between very small farmers (<2.5 ha) and other farmers is significant at the 5 percent level.

2 Small farmers substituted fodder crops equally for both food and cash crops.

3 From the 1985 survey, the following regression was fitted:

$$PFOD = 10.6 - .101\ FARMSZ - 3.21\ OWNTR$$
$$\qquad\qquad (2.12)^{**} \qquad (2.21)^{**}$$

$n = 150$, $R^2 = .12$, t-value in brackets, ** significant at 5% level and PFOD is percent area fodder, FARMSZ is farm area(ha) and OWNTR is a dummy variable = 1 if the farmer owns a tractor.

Cropping intensity, CI, was conventionally measured by the ratio of total cropped area to cultivated area. That is:

$$CI = (\Sigma CA_i)*100/TAREA,$$

where CA_i is cropped area in season i (i = 1,2), and TAREA is total cultivated area. In order to analyze the effect of a cropping pattern on cropping intensity we also calculated season-specific cropping intensity as:

$$CI_i = 2*CA_i*100/TAREA.$$

The inclusion of the conversion factor, 2, in this measure facilitated comparison of season-specific and annual cropping intensities and of regression coefficients analysing each measure of cropping intensity.

Cropping intensity in the area showed surprisingly large variation from 60 to 200, with a mean of 134 and a coefficient of variation (C.V.)of 25% (Figure 1). These figures compare with an average cropping intensity for the Indian Punjab of 168 with a C.V. of 18%, achieved as early as 1971-72 (Agarwal, 1983).

Cropping intensity is closely related to tubewell use, regardless of the type of power source (Table 5). Cropping intensity is also associated with tractor use and ownership. However, tractor ownership is positively related to tubewell use, and when cropping intensity is standardized for irrigation source, the effect of power source disappears.

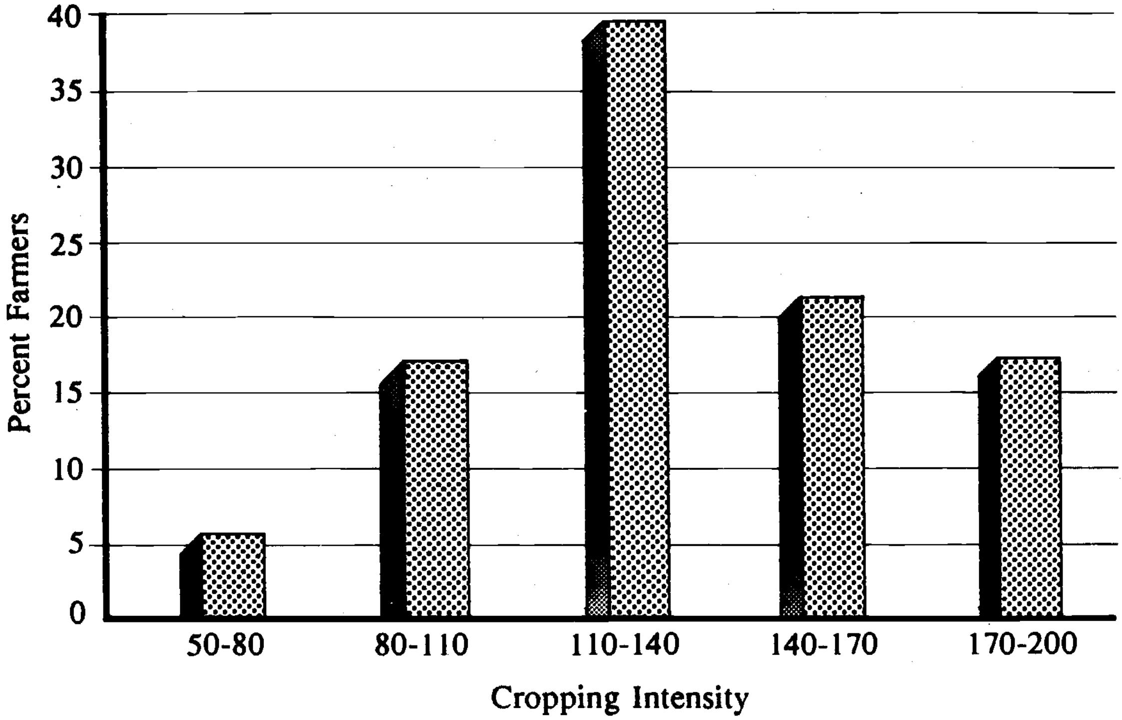

Figure 1. Distribution of farmers by cropping intensity, Southern Punjab.

Table 5: **Cropping Intensity by Irrigation and Power Source, Southern Punjab.**

	Irrigation Source			
	Canal only	Canal + hired tubewell	Canal + tubewell	All
	Annual Cropping Intensity (1986 Survey)			
Power Source				
Bullock only	107	156	b	123
Hired tractor[a]	121	137	b	136
Own tractor	111	b	171	146
All	112	142	158	134

[a] Includes farms who use both hired tractor and their own animals.

[b] Not calculated because less than five observations in the cell

Farmers who own both a tractor and a tubewell have the highest cropping intensity while the lowest cropping intensity occurs on farms that have no access to a tubewell and that use only bullock power.

Regression Analysis of Cropping Intensity

The relationship between cropping intensity, irrigation and power source were further examined in a regression analysis of annual and season-specific cropping intensity. A number of hypotheses governed the selection of the model:

1. The following irrigation variables were included in the analysis:

OWNTW = Dummy variable = 1 for ownership of a tubewell, zero otherwise.
HIRETW = Dummy variable = 1 for hiring of tubewell, zero otherwise
WATQU = Dummy variable = 1 for saline groundwater, zero otherwise
CANCLOSE Number of weeks of canal closure (usually 25-30 weeks for seasonal canals but also often 4-8 weeks for perennial canals).

In an alternative specification, USETW (dummy variable = 1 if a farmer uses a tubewell whether hired or owned) was substituted for OWNTW and HIRETW to test tubewell use against dependence only on canal water.

2. Three variables were used to represent farm power; USETR, OWNTR and HIRETR are dummy variables for tractor use, tractor ownership and tractor hiring analogous to the variables USETW, OWNTW and HIRETW defined above for tubewells. Again USETR was included as an alternative to OWNTR and HIRETR.

3. *Ceteris paribus,* cropping intensity is expected to be negatively related to farm size reflecting expected managerial constraint on supervision of mechanical and labour operations. Two variables were used to represent farm size:

TAREA = total farm area (ha)

LNAREA = Log_e(TAREA)

LNAREA allows for possible nonlinear effects of farm size. It consistently gave better explanatory power than TAREA and is reported here.

4. Finally, cropping intensity for individual seasons was expected to be negatively related to the proportion of area devoted to the dominant crop, wheat or cotton, in the previous season. Because of the conflicts between cotton harvesting and planting of wheat on time and, to some extent, the conflict between wheat harvesting and land preparation for cotton, some farmers were expected to specialize in one of these crops at the expense of the other. Hence, the variables, PCOT (percent area in cotton in Kharif season) and PWHEAT (percent area in wheat in Rabi season) were also included in the analysis of season-specific cropping intensity.

Regression analysis of the 1986 survey with annual cropping intensity as the dependent variable is given in Table 6. Because tractor ownership and tubewell ownership are positively and significantly correlated, the equation was specified in a number of ways. In equation 1, tubewell use and tractor use are analysed according to whether they are owned or hired. Tubewell use has the expected positive and highly significant effect on cropping intensity. Ownership of a tubewell is estimated to lead to an increase in the index of cropping intensity of 45 points. Hiring of a tubewell also has a highly significant effect compared to not having access to a tubewell. Although this effect is smaller than for tubewell ownership, a two-tailed t-test

Table 6: Regression Analysis of Index of Cropping Intensity, 1986 Survey, Southern Punjab.

	Equation[a]			
Independent Variable	1	2	3	4
LNAREA	-11.5 (2.04)**	-10.38 (1.90)*	-8.05 (1.44)	-10.38 (2.07)**
OWNTW	44.9 (3.79)***		49.9 (4.16)***	42.5 (3.71)***
HIRETW	34.3 (3.87)***		27.8 (3.20)***	31.1 (3.91)***
USETW		37.3 (4.58)***		
OWNTR	15.8 (1.37)	18.8 (1.71)*		20.9 (2.17)**
HIRETR	-8.1 (.83)	-8.8 (.91)		
USETR			-.38 (.04)	
Constant	128.0	125.5	125.2	124.5
n	71	71	71	71
R^2	.32	.32	.27	.32

[a] Dependent variable is index of cropping intensity (% on annual basis). t-values in brackets ***, **, * indicate significance at the 1, 5 and 10% levels, respectively.

indicates no difference between the coefficients of OWNTW and HIRETW.

In contrast, the tractor use variables have no significant effect on cropping intensity, and the coefficient for HIRETR is negative. Because the effect of OWNTW and HIRETW are not significantly different, and because of problems of multi-collinearity between OWNTW and OWRTR ($r = .47$) and between HIRETW and HIRETR ($r = .52$), equation 2 includes only the variable, USETW. The coefficient for tractor ownership, OWNTR, is now significant at the 10% level, but HIRETR still has a negative sign. In equation 3, the use of a tractor (USETR) is compared to bullock power and shows no significant or positive effect. In the final equation (Equation 4), ownership of a tractor is tested against other power sources (hired tractor and bullock) and found to be significant at the 5% level. Nonetheless the effect of tractor ownership on cropping intensity (21 points) is much less than for tubewell use (37 points).

The variable for farm size, LNAREA, has the hypothesized negative sign and is significant in most of the specifications given above. The size of the coefficient of LNAREA in Equation 4 indicates that a doubling of farm area decreases the index of cropping intensity by 8 points

(-11.6*ln2) after standardizing for power source and irrigation type.

For some of these variables a direct comparison with results from the Indian Punjab at a much earlier date, 1971/72, is possible (Table 7). Sample characteristics are quite similar, except that the use of hired tractors in our sample is much higher and bullock use correspondingly lower. The index of cropping intensity for the Indian Punjab is much higher even when it is adjusted to the cotton zone to make it comparable to our survey area. The effects of power source and irrigation source on cropping intensity are very similar,except for the effect of tractor hiring. However, in neither sample is the effect of tractor hiring significant.

We next used the same regression model to analyse season-specific cropping intensities. In the 1986 survey, the correlation between Rabi and Kharif cropping intensity for individual farmers was 0.48. This is highly significant but not as high as might be expected for farmers whose power source and irrigation source is unchanged between seasons. Tubewell use has the expected large and significant effect in both seasons (Table 8). However, LNAREA and OWNTR are significant only in the Kharif cycle. This is somewhat contrary to our a priori expectations. The turnaround time between cotton and wheat is quite short (on average 7 to 10 days) (Byerlee, Akhtar and Hobbs, 1987) compared to the

Table 7: Comparison of Factors Affecting Cropping Itensity, Indian Punjab, 1971/72 and Southern Punjab, Pakistan, 1986.

	Indian Punjab[a]	Pakistan Southern Punjab
<u>Sample Characteristics</u>		
Average farm size (ha)	8.0	6.2
Percent own tractor	22	25
Percent hire tractors	32	52
Percent access to tubewell	82	60
Index of cropping intensity	157[b]	134
<u>Effect on Cropping Intensity</u>		
- USETW	34.0***	37.3***
- OWNTR	12.1***	15.8**
- HIRETR	4.9	-8.1
- USETR	6.8*	.4

[a] Source: Agarwal, 1984.
[b] Adjusted for cotton zone only.
***,**,* denote significance at the 1%, 5% and 10% level, respectively.

turnaround time from wheat to cotton (average 20 to 30 days), so that power might be more constraining in the rabi cycle. On the other hand, land preparation is usually much more intensive for cotton and this seems to outweigh the longer turn-around time available between wheat and cotton.

Equation 5b and 6b in Table 8 test the effect of cropping pattern in the opposite season on cropping intensity in the current season. As expected, a higher proportion of area in cotton in Kharif season reduces the cropping intensity in Rabi season (Equation 5b). Similarly and even more pronounced

Table 8: Regression Analysis of Index of Cropping Intensity, Rabi and Kharif Seasons, 1986 Survey, Southern Punjab.

	Equation			
	Rabi Season[a]		Kharif Season[a]	
	5a	5b	6a	6b
Independent Variables				
LNAREA	- 8.68 (1.36)	- 6.37 (1.01)	-14.4 (1.98)*	-9.24 (1.53)
OWNTW	44.0 (3.37)***	46.7 (3.66)***	41.0 (2.74)***	52.8 (4.26)***
HIRETW	26.5 (2.93)***	33.0 (3.54)***	35.6 (3.43)***	36.4 (4.28)***
OWNTR	13.5 (1.23)	17.3 (1.59)	28.4 (2.25)**	16.1 (1.53)
PCOT		- .705 (2.16)***		
PWHEAT				-2.38 (5.80)***
Constant	127.7	143.7	121.6	216.8
n	71	71	71	71
R^2	.22	.28	.25	.51

a Dependent variable = $2*CA_i*100/TAREA$ where CA_i is cropped area in season i. t-values in brackets ***, **, * denote significance at the 1%, 5% and 10% level, respectively.

farmers who plant more wheat in Rabi leave more land fallow in Kharif (Equation 6b). To a large extent these results reflect the fact that the major alternative crops to cotton and wheat are fodders which are more easily grown in double-cropping patterns. In fact, farmers generally prefer to grow cotton after berseem (Trifolium alexandrinum) because of its nitrogen-fixing and soil-cleansing properties. This also explains in part the higher cropping intensity of small farmers, since they keep a larger proportion of area in fodder.[4]

The analysis of cropping intensity for the Rabi season for the larger 1985 sample is given in Table 9. Use of tubewell has a large effect, as in the 1986 survey. Again, the coefficient for OWNTW is larger than for HIRETW, but the difference is not significant. Other irrigation variables, i.e., duration of canal closure (CANCLOSE) and groundwater quality (WATQU), also have large and significant effects.

The variable for OWNTR has a small but insignificant effect on rabi cropping intensity, again as in the 1985 survey. HIRETR has a positive but insignificant effect. Overall, the use of a tractor (USETR) has a positive effect on rabi cropping intensity, significant at the 10 percent level (Equation 9). Finally, in the 1985 sample which represents a wider cross-section of farm sizes (see Appendix

4 Note that the inclusion of PCOT and PWHEAT in the equations reduces the size and statistical significance of the coefficient for LNAREA.

Table 9: Regression Analysis of Rabi Cropping Intensity, 1985 Survey, Southern Punjab.

	Equation[a]		
	7	8	9
LNAREA	-23.3 (5.87)***	-22.8 (5.84)***	-23.3 (6.62)***
CANCLOSE	- 1.26 (3.81)***	- 1.29 (3.74)***	-1.29 (3.82)***
HIRETW	30.1 (2.26)***		30.2 (2.27)***
USETW		31.3 (2.36)**	
WATQU	-18.4 (2.30)**	-19.9 (2.55)**	-18.3 (2.33)**
OWNTR	11.15 (1.18)	13.4 (1.46)	
HIRETR	10.36 (1.50)	10.6 (1.53)	
USETR			10.6 (1.70)*
Constant	176.0	175.7	175.7
N	150	150	150
R^2	.32	.32	.32

[a] Dependent variable = $2*CA_i*100/TAREA$ where CA_i is cropped area in season i. t-values in brackets. ***, **, * denote significance at the 1%, 5% and 10% level, respectively.

A), farm size has a large and highly significant negative effect on cropping intensity. A doubling of farm size decreases the index of cropping intensity for rabi season by 16 points.

Combining the two surveys, we can make the following general observations:

1. Irrigation source and quality are the major factors influencing cropping intensity. Owners of tubewells consistently have a higher cropping intensity than hirers of tubewell services, but the difference between ownership and rental is relatively small and insignificant. In addition to tubewell use, year-round canal supplies and good quality groundwater also have important positive effects on cropping intensity.

2. Farm size has the expected negative impact on cropping intensity, an effect that has been widely observed in the literature. Nonetheless, some of the effect of farm size seems to be due to the fact that small farmers have a larger proportion of area under fodder crops which are more conducive to double-cropping.

3. Tractor use has somewhat ambiguous effects on cropping intensity. Tractor ownership seems generally to have a positive effect, but this effect

is only weakly significant. Tractor hiring has an even smaller effect. This result, and the magnitude of the effect of tractor ownership on cropping intensity (about 10 percent), is in line with other studies from South Asia (Binswanger, 1978; Jayasuriya et al., 1986).

The Potential to Increase Cropping Intensity

In light of the above results, we now estimate the potential for further increases in cropping intensity and consider strategies needed to realize that potential. Clearly, without a substantial change in canal water supplies a significant area of land will always remain fallow, because saline groundwater limits the use of tubewells. The 1986 survey does not provide a measure of the quality of groundwater, but it is likely that in villages where <u>no</u> farmers in the sample used tubewells, groundwater is of poor quality. The average weighted index of cropping intensity in these villages (which accounted for 23% of the sample) was 108 compared to 141 in villages where at least one tubewell was installed.

Using these figures, we estimated that 69% of the fallow land could be brought under production with installation of further tubewells and with appropriate cropping patterns[5]. This would provide a potential increase

5 Quantity of tubewell water is not an issue in this zone.

in cropped area of 34%. In the 1985 survey where we asked about groundwater quality, the weighted average index of rabi cropping intensity on farms with saline water was 106, compared to 135 in areas with good groundwater. Given the sample size in each area, the estimated proportion of fallow land that could potentially be brought under production is again 69% (Table 10).

Table 10: Estimated Potential to Increase Cropping Intensity with Increased Tubewell Water Supplies and Appropriate Cropping Pattern, Southern Punjab.

	Index of cropping intensity		Percent total fallow area	
	1985 Survey	1986 Survey	1985 Survey	1986 Survey
Groundwater quality				
Good water	135	141	69	69
Saline water	106	108	31	31

Hence, for two thirds of the area, groundwater quality should allow a theoretical potential cropping intensity of around 200 with sufficient tubewell capacity and farm power. However, Table 5 and the estimated equations of Tables 8 and 9 suggest that even average size farms owning their own tubewell and tractor and located in areas of perennial canal and good groundwater are only able to achieve a maximum cropping intensity of around 165-170.

In our experience, the failure of these farmers with a good resource base to achieve a higher cropping intensity is due to lack of appropriate cropping patterns. In the 1985 survey, the lowest quartile (based on yield) of wheat fields yielded an average of 1.5t/ha. Two thirds of these fields were planted after cotton, and their average profitability was negative, largely due to late planting (Akhtar et al., 1985). Farmers are well aware of the risks of late planting of wheat and often prefer to leave land fallow rather than double crop. Many are seeking alternative crops for the rabi season, especially those farmers with over 2 ha of wheat who on average generate a marketable surplus (Byerlee, Akhtar and Hobbs, 1987) Most farmer interest centers on spring maize and the non-traditional oilseeds, sunflowers and soyabeans. Unfortunately, while these crops are appropriately planted in February after the cotton harvest in November/December, currently available varieties planted at this time mature in late May or early June and delay cotton planting (or at best, reduce the quality of seed bed preparation for cotton). Hence, while government strategy is to target oilseeds to grow on fallow lands, our own informal interviews indicate that farmers are unlikely to use oilseeds to increase cropping intensity.

Research that would allow spring maize or oilseeds to be planted in late January and harvested by mid-May is required before these crops can be widely double cropped with cotton. Such research would focus on varieties that mature 7 to 10 days earlier than current varieties and in the case of maize would also screen for cold tolerance in early seedling growth (Eagles, 1986). At present, major emphasis in oilseed breeding seems to focus on yield at the expense of earliness. Reduced and even zero tillage for these crops, as well as for cotton, also merits consideration as a way of reducing turnaround time and power constraints.

Conclusions

In a fairly homogeneous cotton-wheat cropping zone of the southern Punjab, we have identified several factors which limit cropping intensity. At a present cropping intensity of about 134, one third of the land is left fallow. The potential to utilize this fallow land is constrained roughly equally by three sets of factors:

1. Poor quality groundwater in some areas.

2. Water shortages even in areas of good groundwater due to insufficient canal flow and tubewell capacity. To a much lesser degree, draught power shortages may play a role.

3. Inappropriate cropping patterns, and in particular lack of early maturing and cold tolerant varieties

of maize and oilseeds that could be double cropped with cotton.

The first of these constraints cannot readily be alleviated without drastic increases in canal water supplies or improved efficiency of irrigation water use; hence nearly one third of fallow land is unavailable for increasing cropping intensity.

The second constraint underscores the importance of policy incentives for tubewell investment and suggests some reorientation of current credit programs. The bulk of official bank lending for farmers has been for tractor purchase, in part in the belief that this will increase cropping intensity. Likewise village electrification will substantially reduce the cost of tubewell use since electric tubewells can provide water at only half tne cost of diesel tubewells (Akhtar et. al., 1986). The evidence from this study strongly suggests that the payoffs to tubewell investment is much higher and that tractor use will have only a marginal impact on cropping intensity.

Finally, agricultural research can potentially play an important role in developing appropriate cropping patterns. Investment in the development of early maturing varieties may be a more efficient alternative from the national viewpoint than further investment in mechanization. The coupling of policy incentives to invest in tubewells with carefully focused varietal improvement research offers the potential for rapid increases in cropping intensity in this zone in the future.

The results of this study should be regarded as exploratory and a guide to further research on this important topic. An integrated approach that considers the natural resource base, farmers' resources, seasonal crop water budgets, and timing of critical planting and harvesting operations is needed to formulate appropriate policy measures to facilitate increases in cropping intensity.

Appendix A. Differences Between the 1985 and 1987 Surveys

Because of a different sampling methodology and slight differences in the sample area some caution is needed in directly comparing the 1985 and 1986 samples. Differences between the two surveys are shown in Table A.1. The major differences are as follows:

1) The 1985 survey included a wider cross-section of farm sizes.

2) The 1985 survey included approximately equal numbers of farmers from the perennial and seasonal canal system, while the 1986 survey was drawn largely from farmers on the perennial canal system. Consequently tubewell use was higher in the 1985 survey.

3) The 1985 survey asked about use of a hired tractor in a selected field of wheat, while the 1986 survey included hired tractor use for all operations and crops during the year.

Table A.1: Comparison of Farmer Characteristics of 1985 and 1986 Surveys, Southern Punjab.

	1985 Sample	1986 Sample
Number of farmers	150	71
Average farm size (ha)	8.2	6.2
Percent farms < 2.5 ha	23	15
> 10 ha	24	17
Irrigation		
- percent on a perennial canal	43	83
- percent own a tubewell	44	16
- percent hire a tubewell	49	50
Power		
- percent own a tractor	23	25
- percent hire a tractor	34	52
Cropping Intensity[a]		
- rabi cycle	64	70
- annual	na	134

[a] Weighted by farm size.

na = not available

In other respect the two surveys gave similar results. Both on an annual basis and for the rabi cycle, the index of cropping intensity indicates that about one third of land is left fallow. Hence, our estimate is almost identical to the official estimate of cropping intensity of 134 for Multan District.

References

Agarwal, B. 1984. Tractors, Tubewells and Cropping Intensity in the Indian Punjab. Journal of Development Studies 20:290-302.

Ahmad, B. 1972. Farm Mechanization and Agricultural Development. A Case Study of the Pakistan Punjab. Unpublished Ph.D. Thesis. Michigan State University, East Lansing, Michigan, U.S.A.

Akhtar, M.R. et al. 1986. Wheat in the Cotton-Based Farming System of the Punjab: Implications for Research and Extension. PARC/CIMMYT Paper No. 86/8.

Binswanger, H. 1978. The Economics of Tractors in South Asia: An Analytical Review. New York: Agricultural Development Council; Hyderabad, ICRISAT.

Byerlee, D., M.R. Akhtar and P. Hobbs. 1987. Reconciling Conflicts in Sequential Double Cropping Patterns through Plant Breeding: The Example of Cotton and Wheat in Pakistan's Punjab. Agric. Systems 24:291-304.

Eagles, H. A. 1986. Maize Breeding Strategies for Improved Productivity from Cool Season Environments in Pakistan. PARC/CIMMYT Paper No. 86-21.

FAO. 1981. Agriculture Toward 2000. Rome, Italy.

Jayasuriya, S.K., A.Te and R.W. Herdt. 1986. Mechanization and Cropping Intensification: Economics of Machinery Use in Low Wage Economies". Journal of Development Studies 22:326-35.

Kadri, A. et al. 1982. Impacts of Tractors on Agricultural Production in Pakistan. Research Report. Applied Economics Research Centre, University of Karachi, Pakistan.

Kaneda, H. 1969. Economic Implications of the Green Revolution and the Strategy of Agricultural Development in West Pakistan. Pakistan Development Review, 9.

Khan, M.A., M.J. Khan and M. Sarwar. 1986. Socio-Economic Impact of Tractorization in Pakistan. Publication No. 226, Lahore, Punjab Economic Research Institute.

Lockwood, B. 1983. Farm Mechanization in Pakistan: Policy and Practice". In Consequences of Small Farm Mechanization. IRRI, Los Banos, Philippines.

Malik, M.H. 1983. An Economic Analysis of Tractor Hire Market in Punjab: A Case Study. Publication No. 203, Lahore, Punjab Economic Research Institute.

McInerney, J.P. and G.F. Donaldson. 1975. The Consequences of Farm Tractors in Pakistan. Staff Working Paper No. 210. World Bank, Washington.

WAPDA. 1982. Use and Impact of Tractor Mechanization. Planning Division, Water and Power Development Authority, Lahore, Pakistan.