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Factors Affecting Cropping Intensity in Barani Areas of Northern Punjab, Pakistan

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ABSTRACT: The major factors affecting cropping intensity in the barani farming systems of Northern Punjab are analysed. Area of lepara land, rainfall, mechanization and farm size are major determinants of overall cropping intensity. This is almost 120 percent, but on lepara land it is 175 (compared with 100 on mera land). Quite different factors explain cropping intensity of the two distinct land types. The research and policy needs for increasing cropping intensity are identified.

In the Punjab of Pakistan, new land is available to be brought under agriculture. Cropping intensity, therefore, will have to increase rapidly in the future to provide an important source of growth in its agricultural sector. The index of cropping intensity in the Pakistani Punjab is currently about 125 compared to 170 in the Indian Punjab, a difference which indicates considerable potential for improvement.

Factors determining cropping intensity at the farm level have been the subject of considerable study both in Pakistan (e.g., Ahmad, 1972; Malik, 1983; Khan *et al.,* 1986 and Tetlay *et al.,* 1988) and elsewhere in South and South-east Asia (e.g., Binswanger, 1978; Agarwal, 1984; Jayasuriya, Te and Herdt, 1986). These studies have generally emphasised the role of mechanization, irrigation water supply, and farm size as determinants of cropping intensity. Almost without exception, these studies have been conducted in irrigated areas where there has been substantial debate about the appropriate strategies for increasing cropping intensity, especially the role of mechanization.

Rainfed (barani) areas, which are the subject of the study reported here, account for about 20 percent of cropped area in Pakistan's Punjab. Current cropping intensity in rainfed areas at 112 is considerably below that in irrigated areas. Much of the land in the barani areas is left fallow for one year – that is, two complete crop seasons – even in relatively high rainfall

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areas such as Rawalpindi district. More intensive use of that fallow land offers considerable potential for improving cropping intensity in rainfed areas.

The determinants of cropping intensity in rainfed areas are likely to differ from those in irrigated areas. Rainfall and moisture conservation is one set of factors hypothesized to be an important determinant of cropping intensity in barani areas. Associated with moisture conservation is the need for timely land preparation and planting; hence mechanization and power supply are hypothesized to be more important factors in rainfed than in irrigated areas, where mechanization to reduce turn-around time in multiple cropping systems has only a weak influence on cropping intensity.[1] Finally, crop and livestock production are closely integrated in barani farming systems (Supple *et al.*, 1985; Byerlee *et al.*, 1988). Hence such factors as the use of land for grazing and the contribution of farm-yard manure (FYM) to the moisture holding capacity of the soil are hypothesized to be important variables determining cropping intensity.

This paper analyses factors influencing cropping intensity in the barani areas of northern Punjab. The analysis is based on data collected from a 1985 survey of 150 households in the Pothwar Plateau, located in Islamabad, Rawalpindi, Attock and Chakwal districts. First, a team of social scientists, and crop and livestock scientists made an informal survey of the area to become familiar with local farming systems and farmers' circumstances (Supple *et al.*, 1985). On the basis of that survey, a questionnaire was designed to elicit key information on cropping patterns, resource ownership, and factors influencing farmers' management decisions. The questionnaire was administered to a sample of 150 farmers. They were selected after stratifying the area into three rainfall zones (high rainfall, > 750 mm annual rainfall; medium rainfall, 500 to 750 mm; and low rainfall, < 500 mm). Seven villages were chosen randomly in each rainfall zone with probability of village selection proportional to population size. Seven to eight farmers were then selected in each of the sampled villages.

A brief summary of the characteristics of the sampled farmers is presented followed by a descriptive analysis of cropping intensity in the three rainfall zones. To test hypothesis on the determinants of cropping intensity in the area, a multiple regression model is used. Finally, future trends in cropping intensity are projected and research and policy needs for accelerating the trend toward increased cropping intensity discussed.

1. For an excellent review of studies in South Asia, see Binswanger, 1978.

Major Characteristics of Barani Farms and Farming Systems

The major agroclimatic features of barani agriculture are reviewed in Supple *et al.,* 1985. Rainfall is, of course, the most important agroclimatic variable affecting agriculture in the area. Even in the high rainfall zone, farmers are subject to substantial year-to-year variability. The severity of moisture stress in a given zone also interacts closely with land and soil type. Variability in both rainfall and crop yields is higher for rabi than for kharif crops (table 1).

Table 1. Average Seasonal Rainfall, Yields, and Variability, Rawalpindi and Attock, 1969-86

	Mean value		Coefficient of variation	
	Rawalpindi	Attock	Rawalpindi	Attock
Rabi season rainfall (mm)[a]	281	173	40	39
Kharif season rainfall (mm)[b]	585	363	31	40
Wheat yields (t/ha)	0.76	0.69	17.4[c]	13.7[c]
Groundnut yields (t/ha)	1.25	1.21	5.2[c]	6.2[c]

a October-March
b April-September
c Cuddy-Della Valle Index $I = CV\sqrt{1 - R^2}$. See Cuddy and Della Valle.

Barani areas are generally characterized by small farms which are owner operated. Average farm size in the sample was 4 ha, but in the medium and high rainfall areas, nearly half of the sampled farmers cultivated less than 2 ha. The higher average farm size in the dry zone reflects a more unequal distribution of land holdings, especially in Attock District, as well as the lower productivity of land in the drier areas. For example, in the sample of farmers, average yields for the major crop, wheat, vary from 0.9 t/ha in the dry zone to 1.4 t/ha in the high rainfall zone. In this study, farmers were divided into two groups according to farm size-smaller farmers operating less than 5 ha and larger farmers operating 5 ha or more.[2]

In recent years, agriculture in the study area has undergone substantial technological change (Hobbs *et al,* 1988). Land preparation is now to a

2. In the sample, there were few large farmers, as they are conventionally defined in Pakistan, with over 10 ha. In Attock District, however, the sample included three farmers who held over 25 ha each. Because these farmers were 'outliers' with respect to the rest of the sample, they were excluded from the analysis of cropping intensity.

large extent mechanized through use of hired tractors. Only 13 percent of farmers depend entirely on bullocks for land preparation although the majority owned at least one bullock to supplement tractor use in farm operations. Use of improved varieties and fertilizer is now also common, at least for the major crop, wheat, although a significant number of farmers in the dry zone have yet to adopt improved wheat varieties.

An important variable for any analysis of farming systems and cropping intensity in the barani tract is land type. Farmers recognize two major land types: *lepara* fields, which are located close to the village and regularly receive FYM, and *mera* fields, which are located at a distance from the village and do not receive FYM on a regular basis. Farm yard manure is important as a means of improving soil structure and enhancing the soil's capacity to retain moisture. Farmers follow a deliberate strategy of concentrating manure on lepara fields close to the village. Ninety-five percent of lepara fields received FYM annually compared to only 22 percent of mera fields located away from the village (table 2). Lepara land is, however, limited by the supply of FYM and accounted for only 27 percent of total farm area (table 3). The great majority of farmers (72 percent) had access to both lepara and mera land. A small group (about 6 percent) had access to only lepara land, whereas 22 percent of farmers, mostly in the dry zone, had access to only mera land.

Table 2. Frequency of Application of Farm Yard Manure by Land Type, Barani Areas, Punjab

Crop season	Land type	
	Lepara land	Mera land
	(Percent farmers applied FYM:)	
In rabi season	78	22
In kharif season	62	3
In both seasons	49	2
At least once annually	95	22

Wheat, the staple food, was by far the dominant crop in the cropping pattern. It was grown by all but one farmer in the sample and was dominant in both lepara and mera land types in all rainfall zones. Besides wheat, maize and sorghum/millet were the only other crops grown by the majority of farmers. The secondary food staple, pulses, as well as the main cash crop, groundnut, were grown by only a minority of farmers.

Table 3. Lepara Land as a Percentage of Farm Area by Farm Size and Rainfall Zone, Barani Areas, Punjab

Rainfall Zone	Percentage farm area lepara land: Farm size < 5 ha	> 5 ha	All
Low	32.6	11.9	23.6
Medium	26.6	18.0	25.0
High	32.6	26.0	31.4
All	30.4	16.6	26.8

Figure 1 is a calendar for major cropping patterns in the area. Wheat harvesting is usually completed in May, which allows ample time to prepare for kharif planting in early July. Traditionally, however, the harvest of kharif crops conflicts with land preparation for the main rabi crop, wheat. For maize and kharif pulses this conflict has been reduced by switching to earlier maturing semi-dwarf wheat which allow wheat planting to be changed from October, the traditional planting time, to November. However, the sorghum and groundnut harvests still conflict with wheat planting.

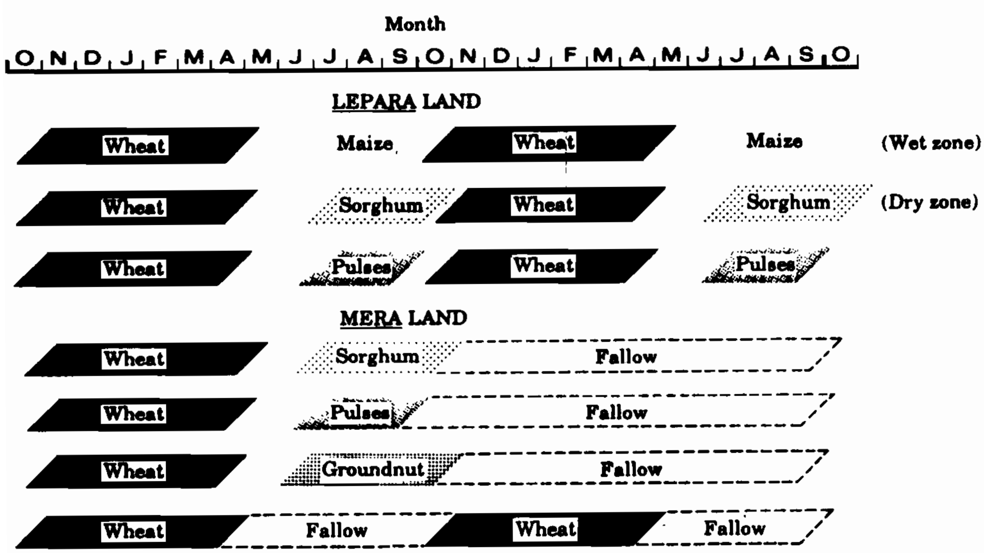

Figure 1. Some common rotations in *Barani* areas, Punjab, Pakistan.

Many of the crop rotations feature a fallow period which reduces that conflict, as is the case in the widespread crop rotation where wheat followed by a kharif crop is followed by a full year of fallow (locally called the "dofasla-dosala" system). That rotation is particularly common in the higher rainfall zones on mera land (table 4). In the dry zone, fallowing only in the kharif season is also common, a strategy that emphasizes food crop production and reduces risks, since rainfall is more variable in the kharif season in the dry zone (table 4). Continuous cropping of two crops per year is widely practised on lepara land, although in the dry zone fallowing of lepara land is common.

Any analysis of cropping patterns and cropping intensity must recognize the importance of livestock in barani farming systems. Animal unit equivalents[3] averaged 6.0 per farm but varied from 4.2 in the wet zone to 8.3 in the dry zone. Farmers with more land own more animals, but when livestock figures are converted to animal equivalents per hectare of cultivated land, the density of animals on small farms is over double that on larger farms.

Table 4. Distribution of Major Crop Rotations by Rainfall Zone and Land Type, Barani areas, Punjab, 1983-84.

Rotation: Year 1		Year 2		Rainfall zone			
Rabi	Kharif	Rabi	Kharif	Low	Medium	High	All
				(Percent fields in zone)[a]			
Lepara land							
Crop	Crop	Crop	Crop	53	79	95	72
Crop	Crop	Fallow	Fallow	17	10	0	10
Crop	Fallow	Crop	Fallow	14	6	5	9
Crop	Crop	Fallow	Crop	10	1	0	3
Mera land							
Crop	Crop	Crop	Crop	10	11	10	11
Crop	Crop	Fallow	Fallow	50	50	76	55
Crop	Fallow	Crop	Fallow	29	27	10	25
Crop	Crop	Fallow	Crop	7	10	3	7

a Percentages do not add to 100 because some minor rotations are not included.

3. Calculated by weighing buffaloes by 1.5, cows and draught animals by 1.0, young stock by 0.5, and sheep and goats by 0.25

Given the much higher density of animals on small farms, it is expected that the percentage of lepara land would be higher for small farms. This hypothesis is confirmed in table 2. For larger farmers, the percentage of farm area that is lepara land is also lower in the dry zone, where larger farms average over 10 ha.

The importance of the availability of FYM as a determinant of land type composition is shown by the following regressions of lepara area (LEPARA) on farm size (FSIZ) and weighted animal units (WANIM) and the number of buffaloes (BUF)

$$\text{LEPARA} = -.777 + \underset{(1.96)^{**}}{.087\ \text{WANIM}} + \underset{(4.37)^{***}}{1.204\ \text{FSIZ}}$$

$R^2 = .20; \quad N = 139$

$$\text{LEPARA} = -.509 + \underset{(2.88)^{***}}{.558\ \text{BUF}} + \underset{(4.06)^{***}}{1.104\ \text{FSIZ}}$$

$R^2 = .23, \quad N = 139$

Note: t-values are given in parentheses; **, denotes significance at the 5% level; *** denotes significance at the 1% level.

While the number of animal units has the expected positive and significant effect on lepara area, the effect of the number of buffaloes owned is particularly strong. Since buffaloes (as opposed to cattle, sheep, and goats) are almost exclusively stall fed, they are expected to be the major source of FYM.

Cropping Intensity and Fallowing

Average cropping intensity for the sample was 118 (weighted by farm size) with a C.V. of 25 percent (table 5). This figure compares favourably with a cropping intensity of 134 with a C.V. of 25 percent in the irrigated southern Punjab (Tetlay, Byerlee and Ahmed, 1988). Nonetheless, farmers followed a deliberate strategy of fallowing nearly half of their land at any one time.

Table 5. Seasonal and Annual Cropping Intensities, Barani Areas, Punjab

Rainfall zone	Index of cropping intensity[a]			Coefficient of variation of total
	Rabi season	Kharif season	Total	
Low	62	48	112	0.24
Medium	70	52	122	0.24
High	73	62	131	0.24
All	68	51	118	0.25

a Weighted by farm size

A number of factors potentially influence cropping intensity and fallowing in barani areas. They include:

(1) *Rainfall:* If moisture conservation is a rationale for fallowing, cropping intensity is expected to be lower in the dry zone.
(2) *Land type:* Lepara land with higher fertility and moisture retention capacity is expected to allow more intensive cropping.
(3) *Farm size:* Managerial constraints on larger farms, lower family labour input per land area and reduced pressure to meet subsistence needs are expected to result in lower cropping intensity on larger farms.

(4) *Power constraints:* Farmers who own tractors or who have ready access to one are expected to have fewer constraints to preparing land on time between rabi and kharif crops. This factor could be particularly important in rainfed areas where timely land preparation is often critical if crops are to benefit from available moisture.
(5) *Livestock ownership:* Farmers who specialize in livestock may leave land fallow for grazing.

The importance of the first three factors is clear from examining table 5 and figures 2 and 3. Cropping intensity increases significantly from 108 in the low rainfall zone to 129 in the high rainfall zone. Cropping intensity is also 50 percent higher on lepara land, especially in the higher rainfall zones. Note especially that the increase in cropping intensity with rainfall is due entirely to an increased intensity of use of lepara land. Lepara land is not only cropped more intensively but also provides considerably higher yields. Farmers estimate that wheat yields, for example, are about 50 percent higher on lepara land compared to mera land. Hence, although lepara land accounts for only about 25 percent of cultivated area, it produces an estimated 43 percent of total crop production, and over 50 percent of total production on small farms.

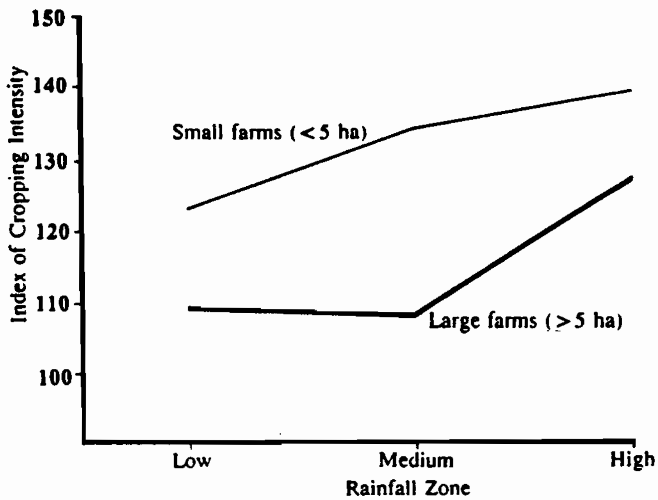

Figure 2. Index of Cropping Intensity over all land types by rainfall zone and farm size, barani areas, Punjab

Because small farmers have a higher proportion of lepara land they are expected to have a higher cropping intensity. However, small farmers also crop *both* lepara and mera land more intensively (figure 3). Overall the most important component of the higher cropping intensity of small farmers is their more intensive use of mera land.

Finally, there were significant differences in cropping intensity by season. Although kharif rainfall is higher and less variable, cropping intensity

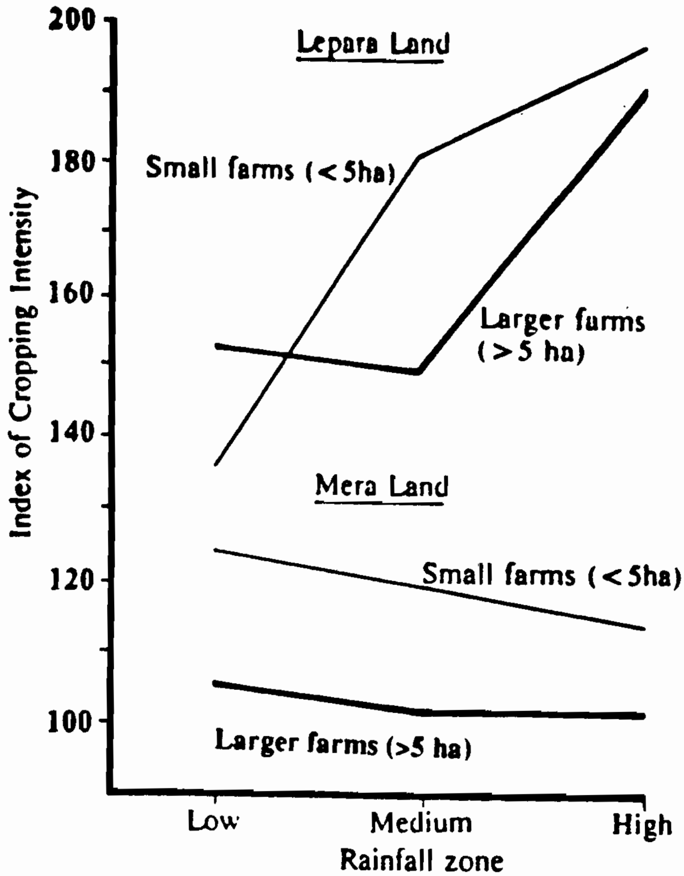

Figure 3. Index of Cropping Intensity by rainfall zone, land type, and farm size, barani areas, Punjab

in rabi season is significantly higher than in the kharif season in all rainfall zones (figure 4). Wheat, the main food crop, is produced in rabi season; by careful conservation of moisture, especially through fallowing in the kharif season, farmers are able to reduce the risk of rabi season cropping. Further evidence of this strategy to emphasize food crop production is shown by the fact that in the rabi season small farmers crop much more intensively than larger farmers.

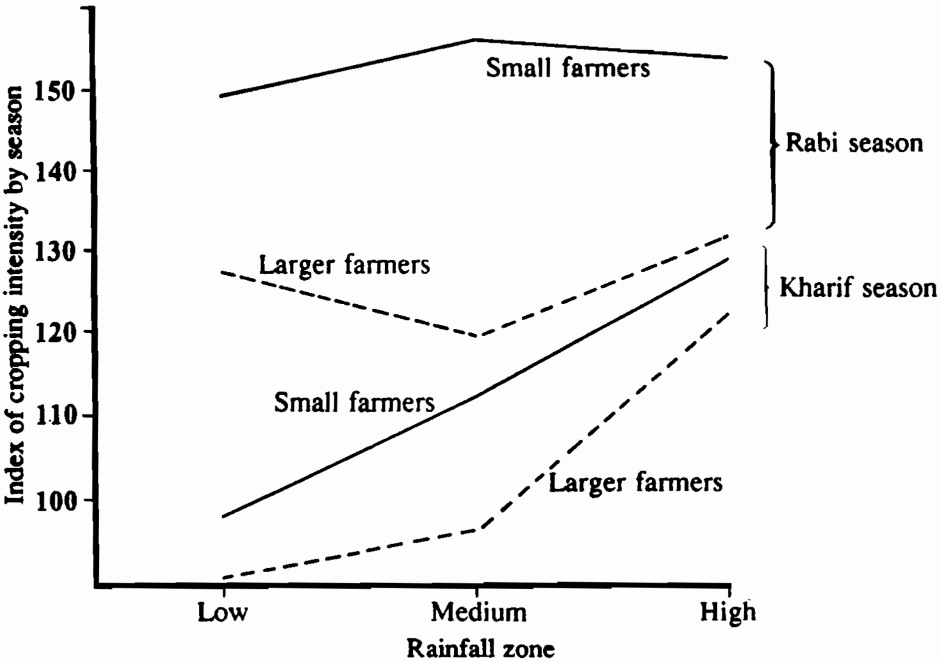

Figure 4. Index of cropping intensity by rainfall zone and farm size barani areas, Punjab.

Regression Analysis of Cropping Intensity

Multiple regression analysis was used to further analyse factors influencing cropping intensity. The variables included in the regressions followed the hypotheses outlined above. The independent variables were defined as:

PLEP = Percent farm size as lepara area
LNFSIZ = Logarithm of farm size (in ha)
TRUSE = Dummy variable for use of a tractor[4]
ANHA = Number of animal units (weighted) per ha of farm land
MEDIUM = Dummy variable for medium rainfall zone
DRY = Dummy variable for dry rainfall zone

4. In another specification, tractor ownership was compared with tractor use. This model failed to show any significant benefit of owning a tractor compared to hiring a tractor.

For simplicity, only linear models were fitted, except for the variable for farm size, which consistently gave better explanatory power in logarithmic form. An interaction term, PLEP*DRY, was included to test the hypothesis that lepara land is cropped less intensively in the dry zone.

The dependent variable used was average cropping intensity over the two-year period 1983-84, defined conventionally as 100 (RCA + KCA)/ FSIZE, where RCA is average rabi cropped area and KCA is average kharif cropped area over the two-year period, and FSIZE is farm size measured in terms of cultivated area. In addition, disaggregated measures of cropping intensity were analysed to better understand the factors influencing total cropping intensity. These measures were 1) cropping intensities on lepara and mera land and 2) cropping intensities in the rabi and kharif seasons.

Results of the analysis are presented in table 6. Clearly the major factor explaining total cropping intensity is the availability of lepara land. The conversion of 10 percent of farm area from mera to lepara land would lead to an increase in the index of cropping intensity of 5.2 points. Using a tractor, as opposed to relying only on animal power, also has a large and significant effect on cropping intensity of 20 points (over 20 percent). As hypothesized, farm size has a significant and negative effect on cropping intensity. The number of livestock per hectare has a negative effect, but for total cropping intensity this effect is only significant at the 10 percent level. Finally, the dummy variable for dry rainfall zone is significant, especially the interaction with lepara land type in the second equation. The negative sign of this interaction term confirms the earlier finding (figure 2) that lepara land is cropped much more intensively in the higher rainfall zones.

Disaggregating the regression analysis of cropping intensity shows that quite different variables influence cropping intensity in each land type in ways that would be expected from our knowledge of the system (see the third and fourth equations of table 6). As expected, rainfall is the major determinant of cropping intensity in lepara land. Farmers with more lepara land crop it less intensively. Livestock density, tractor use, and farm size do not influence cropping intensity in lepara land, but they are the most important variables explaining differences in cropping intensity in mera land. Mera land is likely to be given first priority for grazing, especially by larger farmers, since it has a lower opportunity cost in crops. Also, since mera land is more extensively cultivated and constitutes the bulk of farm area, power and managerial constraints are expected to be greater on cropping intensity than they are for lepara land, which constitutes only a small proportion of farm area.

Table 6. Regression Analysis of Cropping Intensity, Barani Areas, Punjab

Independent variables	Dependent variable[a]			
	Total cropping intensity	Total cropping intensity	Lepara cropping intensity	Mera cropping intensity
Percentage lepara	0.522 (4.95)***	0.752 (6.45)***	–0.281 (1.85)*	0.142 (.99)
Log (farm size)	–8.19 (2.16)**	–7.67 (2.13)**	–1.49 (.27)	–11.2 (2.25)**
Tractor user	18.9 (2.22)**	19.9 (2.46)**	5.60 (.38)	24.2 (2.39)***
No. animals/ha	–4.64 (1.75)*	–3.45 (1.36)	0.84 (.25)	–12.3 (1.93)*
Dummy dry zone	–1.82 (0.26)	16.31 (1.99)**	–43.4 (4.31)***	20.6 (2.45)**
Dummy medium zone	–3.43 (0.53)	–2.33 (0.38)	–18.5 (2.25)**	8.98 (1.17)
Interaction Dry zone* Lepara		–0.72 (3.86)***		
Constant	113.3	103.5	197.2	103.8
R-squared	0.29	0.36	0.23	0.12
N	136	136	108	128

Note: t-values are given in parentheses; * denotes significance at the 10% level, ** at 5%, and *** at 1%.

a Average of two years, 1983-84.

Farmers' stated reasons for leaving land fallow also confirm the hypotheses listed above (table 7). Restoring fertility and conserving moisture were the major reasons given by farmers for fallowing. These reasons are more important for farmers in lower rainfall areas. In higher rainfall areas, grazing of own livestock and the communal decision to leave land fallow for grazing are also important reasons for fallowing land. The latter reflects the widespread practice in which all farmers in a village change cropped land in alternate years from one side of the village to the other, leaving fallow land for communal grazing. Hence, the decision to fallow is outside the individual farmer's control.

Table 7. Farmers' Reasons for Leaving Land Fallow, Barani Areas, Punjab

	Rainfall zone			
	Low	Medium	High	All
Reason	(Percent farmers in zone)[a]			
Moisture conservation	34	29	15	26
Fertility restoration	50	46	21	38
Own livestock grazing	2	5	17	8
Communal livestock grazing	9	10	23	14
Lack of resources	5	10	25	14
Total	100	100	100	100

a Most important reason stated by farmer

We also analysed cropping intensity separately for the rabi and kharif seasons. Rabi cropping intensity at 68 (weighted by farm size) is significantly higher than kharif cropping intensity at 51. Perhaps more importantly, the correlation between rabi and kharif cropping intensity across farmers was negligible. By rainfall zone, this correlation varied from −0.14 in the dry zone to 0.01 in the medium rainfall zone and 0.37 (significant at the 5 percent level) in the wet zone. In the dry zone, farmers appear to specialize somewhat in either rabi or kharif crops but in the wet zone, some farmers crop more intensively in both seasons compared to other farmers in the same rainfall zone. Nonetheless, the low overall correlation between seasonal cropping intensities suggests substantial individual choice in cropping pattern.

In addition to the variables analysed above for annual cropping intensity, the regression analysis of seasonal cropping intensity (table 8) includes variables to represent cropping pattern in the previous season. We hypothesised that, since harvesting sorghum and groundnuts in November conflicts with wheat planting, a higher proportion of those crops in the kharif cropping pattern is expected to reduce rabi cropping intensity. Likewise, farmers who specialize in wheat in the rabi season may leave more land fallow in kharif to conserve moisture for the following rabi season. The regression analysis in table 8 confirms these hypothesized effects of cropping pattern on cropping intensity in the following season. Farm size and tractor use have similar effects in both seasons, but lepara land is much more important in determining cropping intensity in the kharif season than in rabi season, although it has a significant and positive effect in both cases. A further interesting finding is that kharif cropping intensity is significantly and negatively related to the number of animals owned, whereas the effect of animal ownership on rabi cropping intensity, while also negative, is much smaller and not statistically significant. This reflects the fact that kharif grazing offers more benefits than rabi grazing because of the vigorous growth of grasses in the monsoon period.

Table 8. Regression Analysis of Kharif and Rabi Cropping Intensity, Barani Areas, Punjab

Independent variables	Dependent variable[a]			
	Kharif cropping intensity	Kharif cropping intensity	Rabi cropping intensity	Rabi cropping intensity
Percent lepara	0.454 (5.47)***	0.462 (5.65)***	0.296 (3.79)***	0.293 (3.63)***
Log (farm size)	−5.14 (2.01)**	−5.34 (2.11)**	−4.98 (2.06)**	−3.79 (1.49)
Tractor user	9.92 (1.72)*	10.8 (1.90)*	11.0 (2.02)**	10.6 (1.90)*
No. of animals/ha	−4.05 (2.24)**	−4.45 (2.48)**	−1.56 (.92)	−0.89 (.35)
Dummy dry zone	2.60 (.45)	0.67 (.12)	14.8 (2.70)***	20.0 (3.13)***
Dummy medium zone	−6.24 (1.43)	−7.97 (1.83)*	3.56 (0.87)	4.17 (1.00)
Interaction Lepara* dry zone	−0.379 (2.86)***	−0.339 (2.57)**	−0.336 (2.69)***	−0.403 (2.82)***
Percentage sorghum or groundnuts				−0.096 (1.89)*
Percentage wheat		−0.251 (2.28)**		
Constant	51.3	74.8	55.0	56.0
R^2	0.32	0.34	0.19	0.24
N	136	136	136	128

Note: t-values are given in parentheses; * denotes significance at the 10% level, ** at 5%, and *** at 1%.

a Average of two years, 1983-84.

Finally, cropping intensity in rainfed areas is likely to vary from year to year, depending on seasonal availability of moisture. The data summarized in table 9 for two years (1983, a wet year, and 1984, a dry year), support this hypothesis. After a wet year, 1983, farmers increased their rabi area in 1983/84 to exploit available moisture. But after a very dry rabi season, the area planted to kharif crops was reduced. Overall, the annual cropping intensity in 1984 was only slightly below that in 1983. Correlations of cropping intensities over the two years for individual farmers show that year-to-year variation is quite high and is greater for mera land than lepara land (i.e. low correlation between years). This again supports the finding that lepara land, with its greater moisture holding capacity, offers more security in crop production in the face of rainfall variability. The lower year-to-year variability in rabi cropping intensity compared with kharif cropping intensity, despite the higher variability in rabi season rainfall, underlines the importance given to wheat production in farmers' cropping decisions.

Table 9. Cropping Intensity in a Wet Year, 1983 and a Dry Year 1984, Barani Areas, Punjab

	Index of cropping intensity		Correlation between years
	1983	1984	
Lepara land	175	175	0.64
Mera land	116	114	0.61
Rabi season	66	73	0.37
Kharif season	63	55	0.29
Total farm	130	128	0.67

Synthesis

The major influences on cropping intensity in the Barani farming systems revolve around the various interactions between crops and livestock production. The most important of those interactions is the use of farm yard manure (FYM) in crop production. Farm yard manure has traditionally been important as a means of maintaining soil fertility, but the vast majority of farmers now use chemical fertilizer, which reduces the need for FYM in maintaining fertility. However, the use of FYM to build soil structure and improve moisture holding capacity is still critical. In the high rainfall zone, the strategy of concentrating FYM on selected fields near the village – that is, lepara land – enables those fields to be cropped at double the intensity of fields away from the village, which receive little FYM. Thus lepara land, which constitutes only about one-quarter of farm area, has substantially higher productivity than mera land due to both higher cropping intensity and higher yields, and contributes half of the value of crop production for small farmers. However, the distinction between land types becomes less clear in the low rainfall zone, where even land that receives FYM regularly does not have sufficient moisture holding capacity to be double-cropped.

The amount of lepara land is obviously limited by the amount of FYM, which in turn is limited by the number and composition of animals and by competing uses of FYM. Farmers estimate that over the past decade the total number of animals in barani areas has declined as tractors have replaced bullocks. However, there is evidence, especially in th wet zone, that the composition of animals has shifted away from grazing animals (cattle, sheep, and goats) to stall-fed animals (buffaloes) (Byerlee *et al.*, 1988). Since FYM is largely produced by stall-fed animals, the shift in animal composition may have compensated for the effect of any decline in animal numbers on the availability of FYM.

A second influence of crop-livestock interactions on cropping intensity is the use of animals for draught power. Traditionally draught animals were the major source of farm power. Poor nutrition of draught animals in the dry season when land was prepared for wheat was often a major constraint on increasing cropping intensity (Rochin, 1987). That interaction has become less important with the widespread introduction of tractors in recent years and with the development of rental markets for tractors. Tractor power now constitutes the major source of farm power for land preparation, even among small farmers. Nonetheless, a significant minority of farmers still depends on animal power, and cropping intensity is much lower on their farms. The use of tractor power appears to be much more important in determining cropping intensity in this sample of barani farmers than has been observed in studies of cropping intensity in irrigated areas (e.g., Tetlay *et al.*, 1988; McInerny and Donaldson, 1975). The poor nutrition of draught animals, when land must be prepared for wheat, combined with the need for timely tillage operations to conserve moisture, are plausible reasons for this difference between irrigated and barani areas.

A third influence of livestock on cropping intensity in the barani tract is the use of fallow land for grazing, which seems to be most important for mera land away from the village and in the kharif season.

With respect to future trends in cropping intensity in the barani tract, the results of this study are ambiguous. The continued replacement of draught animals as a source of power should lead to further increases in cropping intensity. However, any decline in the number of animals, although reducing the need for fallow land for grazing, has potential implications for supply of FYM. In addition, an increasing amount of FYM is used as cooking fuel. In the survey, about 40 percent of farm households used FYM as a cooking fuel and farmers estimated that some 20-25 percent of FYM is used that way, with the greatest use occurring in the higher rainfall areas. As population density increases and the availability of fuel wood declines, this competition is likely to grow. Hence one strategy to preserve the productivity of lepara land and maintain cropping intensity will be to evaluate alternative means of providing cooking fuel, including increased emphasis on agroforestry.

Farmers are aware that increased cropping intensity offers an opportunity to increase productivity. Seventy-three percent of farmers stated that they were seeking ways to reduce the area of land left fallow. To date, very little research has been done to assess the potential long-term sustainability of more intensive cropping, especially of mera land where cropping intensity barely exceeds 100 percent . This issue needs to be tackled on both the technical as well as the socio-economic side. On the technical side, there is a dearth of long-term experiments exploring different crop rotations and intensities under representative moisture and fertility conditions. Crop modelling could help analyse some of these relationships over the long term. Recent research indicates that improved tillage techniques can substantially increase moisture conservation and potentially allow higher cropping intensity (Hobbs *et al,* 1987). On the socio-economic side, a better understanding of farmers' decisions criteria for fallowing is needed. Since such decisions are often communal, some analysis of group decision making and the potential for influencing those decisions is required. The role of risk aversion in the decision to crop or fallow land also needs further research.

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