Analytics of Barani Farming Systems of Northern Punjab: Cropping Intensity, Crop-Livestock Interactions and Food Self-Sufficiency

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Executive Summary

1. The rainfed areas of Pothwar plateau cover about one quarter of total cropped area of the Punjab. Farming in the area is characterised by a complex and diversified set of activities. Farm productivity in the region is relatively low and this contributes to the significant food deficit of the area. Livestock are an important part of the farming system and interactions with crops and implications for technology are not well understood.

2. This study is based on a survey conducted in barani areas of Pothwar plateau in 1984 to analyse the main determinants of farming systems (such as cropping intensity, crop livestock interactions and food self-sufficiency) and to assist researchers in designing appropriate technological interventions for farmers.

3. On the basis of rainfall distribution patterns, the barani Pothwar was stratified into three zones:

    - low rainfall zone - receiving < 500 mm rainfall
    - medium rainfall zone - receiving 500-750 mm rainfall
    - high rainfall zone - receiving > 750 mm rainfall.

4. Most farmers in the area sampled were small farmers. Average farm size in the sample was 4 ha and nearly half of the farmers cultivated less than 2 ha of land. Owner operation was the norm of the area, but share tenancy prevailed over the other tenancy systems. Almost 90% of the farmers depended on tractors for ploughing for land preparation and the remainder used bullocks.

5. Farmers recognized two major land types in the area. 'Lepara' fields are located close to the village and receive farm yard manure (FYM) regularly while 'Mera' fields are located away from the village and do not received FYM on a regular basis. Ninety five percent of lepara fields received FYM on an annual basis compared to 22% of mera fields.

6. Wheat, the staple food crop, was dominant in both lepara and mera lands, in all rainfall zones. Most other crops were specific to a particular land type or rainfall zone. Mustard, maize and kharif pulses were more important in the higher rainfall areas, and groundnut, sorghum/millet and rabi pulses in the lower rainfall areas. Maize was mainly grown on lepara lands while pulses, groundnuts and sorghum/millet crops were grown on mera lands. Thus farmers adopted very pertinent strategies in allocating land according to the fertility and moisture requirements of individual crops.

7. Crop rotations differed widely between lepara and mera lands. Two crops per year on a continuous basis was the most common rotation on lepara lands. On mera lands, the "dofasla dosala" rotation prevailed, typically wheat: kharif crop: full year's fallow.

8. Cropping intensities were greatly influenced by rainfall, land type, farm size, power constraints and livestock ownership. Overall cropping intensity was 118%, but it was 50% higher on lepara lands than mera. Cropping intensity increased from 108 to 129 in low and high rainfall areas respectively. It increased with rainfall mainly due to more intensive use of lepara lands, whereas mera cropping intensity was uniform across rainfall zones. Rabi season cropping intensity was significantly higher than that of the kharif season in all rainfall zones.

9. Across all rainfall zones, cattle were an important component of livestock systems. In the wet zone, the higher percentage of milk animals, particularly buffaloes, was mainly due to proximity of urban markets as well as an ensured availability of green fodder. In drier areas, draught animals, sheep and goats were more prevalent.

10. Farmers managed fodder requirements from two major sources: (1) intercropping of fodder with grain and (2) production of sole fodder crops. Fodder was managed from scarce land resources through intercropping mustard in wheat and maize fodder (from thinning) in maize grain crops. Sorghum and millet, and to some extent barley and oats, were the main sole fodder crops grown by the farmers. Farmers supplemented home-produced feed by purchasing concentrates in lean fodder periods.

11. Barani farmers produced a small surplus over subsistence requirements in grain. They were near to self-sufficiency in pulses but were in deficit with fodder. Small farmers, especially in the dry zone, were in deficit in all three subsistence products, with the largest deficit occurring for fodder.

12. The majority of farmers ranked livestock products as their main source of cash income from the farm in each zone. Generally, sales of cash crops exceeded cash sales of food crops. Off-farm income was very important for farmers in the survey area, especially small farmers.

13. The analysis conducted in the paper has emphasised that crop and livestock interact in important ways in barani farming. This suggests three major implications for research for the barani tract - the importance of land type, the importance of fodder production and the opportunity that exists for increasing productivity by higher cropping intensity.

14. Two distinct land types exist in the barani tract, lepara land and mera. These should be treated as different recommendation domains for research on crop management (fertility and tillage), as well as on crop rotations. Stratification by land type is equally as important as stratification by rainfall zone.

15. Because of the importance of fodder in barani areas, it should receive high priority for research in the future. This should include research on ways of more efficiently producing and conserving fodder. A high payoff is likely for research on specialty fodder crops. There is also a need to better understand the tradeoffs between fodder and grain in barani crop production.

16. Finally, research needs to be undertaken on the potential long-term sustainability of more intensive cropping, especially of mera land. There is a dearth of long-term experiments exploring different crop rotations and intensities, using representative moisture and fertility conditions. Socio-economic research needs to be undertaken on key criteria affecting barani cropping and fallowing practices, including risk and communal decisions on land use.

Analytics of Barani Farming Systems of Northern Punjab: Cropping Intensity, Crop-livestock Interactions and Food Self-sufficiency

Introduction

The rainfed areas, commonly known as the Barani tract, account for about one quarter of total cropped area of the Punjab. Until recently this Barani tract, centered on the Pothwar Plateau, was relatively neglected by agricultural research and development efforts. While the green revolution in wheat resulted in rapid technological change in irrigated areas, the effect on rainfed areas was small until recent years. Partly because of this neglect, the Barani tract is one, of the poorest areas of the Punjab and, unlike the irrigated areas, it is a significant food deficit area.

The Barani areas are characterized by a diverse and complex agriculture, reflecting the interaction of land and soil type, rainfall variability and socio-economic factors in farmers' management. Cropping intensity tends to be relatively low with large areas left fallow for a whole year. Livestock are a major component of the farming system and interact closely with crop production. Yet the nature of these complex interactions and their implications for the design of technological interventions for farmers of the area are not well understood.

The objective of this paper is to describe and analyse determinants of farming systems in the Barani areas and draw implications for researchers and planners. The major characteristics of Barani agriculture are first described. This leads to an analysis of cropping patterns, cropping intensities, and livestock composition and fodder management. Finally we examine how these characteristics relate to food and fodder self-sufficiency and cash income generation in the Barani household.

Data Sources

Data for this study were collected from a survey of 150 households in the Pothwar Plateau located in the Districts of Islamabad, Rawalpindi, Attock and Chakwal in 1985. First, a team of social scientists, crop scientists and livestock scientists made an informal survey of the area to become familiar with local farming systems and farmer circumstances. During this survey, different parts of the Barani tract were visited and informal but in-depth interviews were conducted with farmers. On the basis of this survey, a questionnaire was designed to elicit key information on cropping patterns, livestock ownership and factors influencing management decisions. This questionnaire was administered to a sample of 150 farmers. The sample was selected by first stratifying the area into three rainfall zones - high rainfall (> 750mm of annual rainfall), medium rainfall (500 to 750 mm) and low rainfall (< 500mm) (see Figure 1). Seven villages were chosen randomly in each

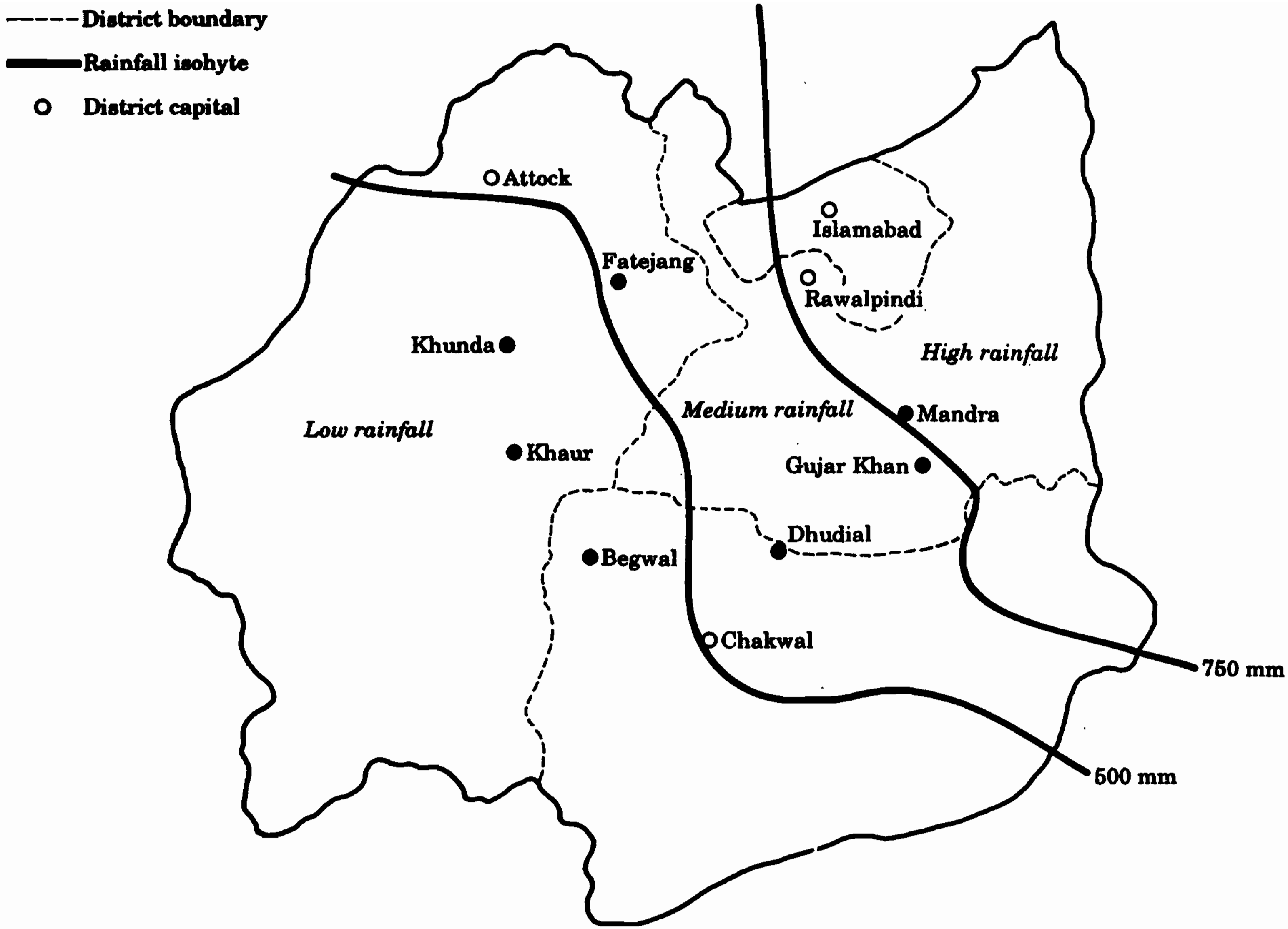

Figure 1. Survey area and three rainfall zones, barani areas, Punjab.

rainfall zone with probability proportional to population size and seven to eight farmers were then selected in each village.

Major Characteristics of Barani Farms

The major agro-climatic features of Barani agriculture are reviewed in Supple et al. (1985). Rainfall is, of course, the most important agro-climatic 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 type and soil type. Variability in both rainfall and crop yields is higher for Rabi than Kharif crops (Table 1). However, variability in Kharif rainfall and yields increases relative to variability in the Rabi season, in the drier zones.

The Barani areas are generally characterized by small farm size. Average farm size in the sample was 4 ha and in the medium and high rainfall areas, nearly half of the sampled farmers cultivated less than 2 ha. Figure 2 illustrates the dominance of small farmers except in the low rainfall areas where a bimodal distribution of farm sizes prevails. This is primarily due the presence of some very large farmers in Attock District. Consequently the Gini

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 (1978)

coefficients of farm size distribution are .33 and .39 for the medium and high rainfall areas and .57 for the low rainfall zone.[1] For Attock District, the Gini coefficient is 0.60. The higher average farm size in the dry zone reflects this unequal distribution of land holdings as well as the lower productivity of land. For example, 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.

1 The Gini coefficient is a measure of inequality varying from zero for equal distribution of land between farms to a maximum of close to one if one farmer controls all the land.

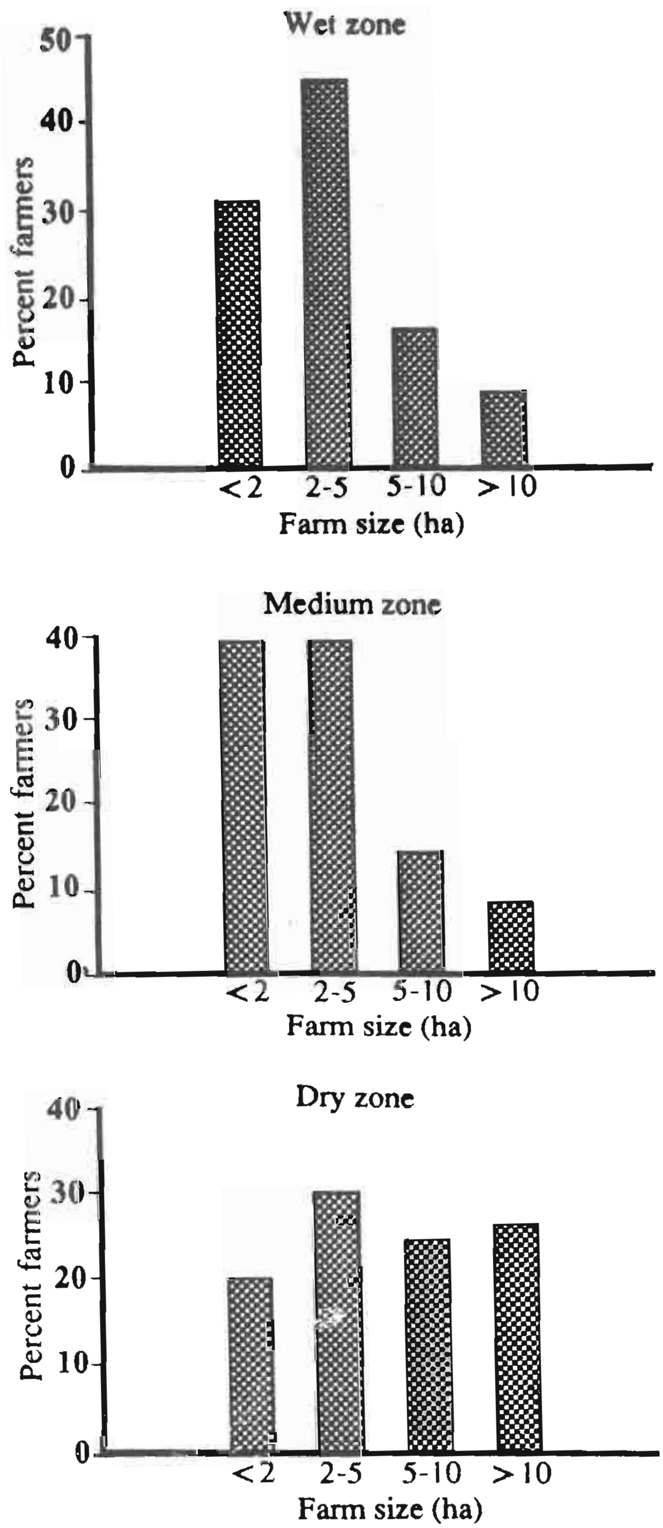

Figure 2. Distribution of farm size by rainfall zone, barani areas, Punjab.

In this study, farmers were divided into two farm size groups - smaller farmers operating less than 5 ha and larger farmers operating 5 ha or more. In most of the Barani tract (except Attock) there are very few farmers with more than 10 ha - the standard widely used in Pakistan to delineate large farmers.[2]

Owner operation is the norm in the area (Table 2) although in Attock District one-third of the farmers are tenants; share tenancy is the common form of tenancy as would be expected in a risky environment. Outputs and purchased inputs are generally shared equally between owners and tenants although in the drier areas sharing of input costs is not yet well established and the tenant usually pays all costs.

In recent years, agriculture has undergone substantial technological change (Hobbs et al., 1988). Land preparation is to a large extent mechanized through use of hired tractors. Almost two-thirds of farmers own bullocks but only 13% depend entirely on bullocks for land preparation. (Table 3). Not uncommonly a farmer will use a hired tractor for the first tillage operation but then use his own bullocks for subsequent operations.

2 Three very large farmers in Attock operating over 50 ha were excluded from the analysis of this paper, because of they represented extreme outliers in the sample.

Table 2. Distribution of tenancy forms by rainfall zone, Barani areas, Punjab

Rainfall zone	Owner	Type of tenancy: Owner/ tenant	Owner/ landlord	Tenant	All
		(% farmers)			
Low	80	6	4	10	100
Medium	48	33	15	4	100
High	38	30	14	18	100
All	56	23	11	11	100

Chi-squared test of differences by rainfall zone is significant at the 1% level.

Table 3. Farmers' power source by farm size, Barani areas, Punjab

Power source	Farm size: < 5 ha	> 5 ha	All
Percent farmers use	(Percent farmers)		
Own tractor	5	38	13
Hired tractor	26	14	22
Own bullock	14	8	12
Hired tractor + bullock	56	41	52
Percent farmers own bullock	64	59	62

The replacement of bullocks by tractors is a gradual process. Only a little over one-third of farmers owned a bullock pair. Another one-quarter of farmers maintained one bullock which can be used for miscellaneous tasks but is commonly exchanged with neighbours to provide a bullock pair. Only in the high rainfall area where tractor markets are well developed and farm size is very small do a majority of farmers not own any bullocks.

In addition, drills are also widely used and threshers have spread very rapidly in the past five years. Mechanization has occurred across all rainfall zones but adoption of deep tillage has been much more rapid in low rainfall areas where moisture conservation is more critical (Table 4). Conversely, use of a mechanical thresher is more widespread in high rainfall areas where cropping intensity and the risk of damage from rainfall at harvest are much higher.

Use of improved varieties and fertilizer is now also common practice, at least for the major crop, wheat. Significant numbers of farmers in the dry zone, however, have yet to adopt improved varieties (Table 4). There is little difference in adoption by farm size, except for the two mechanical innovations currently under rapid adoption, threshers and deep tillage, where large farmers lead.

Table 4. Percentage of farmers adopting various improved technologies, Barani areas, Punjab

Rainfall zone	Improved variety[a]	Chemical fertilizer	Tractor	Drill	Deep tillage	Thresher
	Type of technology					
	(% farmers adopted)					
Low	71	83	90	59	52	67
Medium	92	88	85	42	21	90
High	100	98	98	59	0	98
All	88	90	91	53	24	85

[a] For wheat only.

Overview of Farming Systems

Land Type

An important variable for any discussion of farming systems in the Barani tract is land type. Farmers recognize two major land types - 'lepara' fields located close to the village which regularly receive farm yard manure (FYM), and 'mera' fields located at a distance from the village which do not receive FYM on a regular bases. Farm yard manure is not only important in fertility maintenance but is even more important as a means of improving soil structure and enhancing the capacity to retain soil moisture. Farmers follow a deliberate strategy of concentrating FYM on fields close to the village - their lepara fields (Table 5). Ninety-five percent of lepara fields received farm yard manure on an annual basis compared to only 22% of mera fields located away from the village. Farm yard manure is also more frequently applied in the Rabi season when the priority crop, wheat, is grown. As discussed below, the amount of lepara land is limited by the supply of farm yard manure and, overall, it accounts for only 27% of total farm area (Table 6) and only 20% of total area (weighted by farm size).

The great majority of farmers (72%) have access to both lepara and mera land. A small minority of 6% of farmers have access to only lepara land, while 22% of farmers, mostly in the dry zone, have access to only mera land.

Cropping Patterns

Wheat, the staple food, is clearly dominant 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[3] are the only other crops grown by the majority of farmers. The secondary food staples, the pulses,

[3] Sorghum and millet are normally intercropped and are referred to as a single crop enterprise in this paper.

Table 5. Frequency of application of farm yard manure by land type, Barani areas, Punjab

Use of farm yard manure	Land type: Lepara land	Land type: Mera land
Percent farmers applied		
in Rabi season	78	22
in Kharif season	62	3
in both seasons	49	0
at least once annually	95	22

Table 6. Lepara land as a percentage of farm area by farm size and rainfall zone, Barani areas, Punjab

Rainfall zone	Percent 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

as well as the main cash crop, groundnuts, are grown by only a minority of farmers.

Except for wheat, most crops are specific to a particular land type or rainfall zone. In Figure 3 it is clear that mustard, maize and Kharif pulses are much more important in the higher rainfall areas, while groundnuts, sorghum/millet and Rabi pulses are favoured in lower rainfall areas. Maize is almost exclusively grown on lepara land while pulses, groundnuts and sorghum/millet tend to be confined to mera land (Figure 4). Clearly, farmers follow a strategy of allocating land according to fertility and moisture requirements of individual crops. Maize, for example, is a crop that responds well to fertility, but at the same time it is sensitive to moisture stress; hence it is best suited for lepara land and higher rainfall areas.

The crops traditionally grown in the Barani tract serve the needs of both subsistence food and fodder production. Wheat is the staple food crop but it is nearly always intercropped with mustard for fodder and its by-product, wheat straw, commands a high price in the Barani areas relative to the rest of the country (Byerlee and Iqbal, 1987a). Maize is also produced as a dual purpose food and fodder crop (Sheikh and Haq Nawaz, 1987). Sorghum and millet were also dual purpose crops but are now almost exclusively used for fodder. Partitioning maize by its relative value as

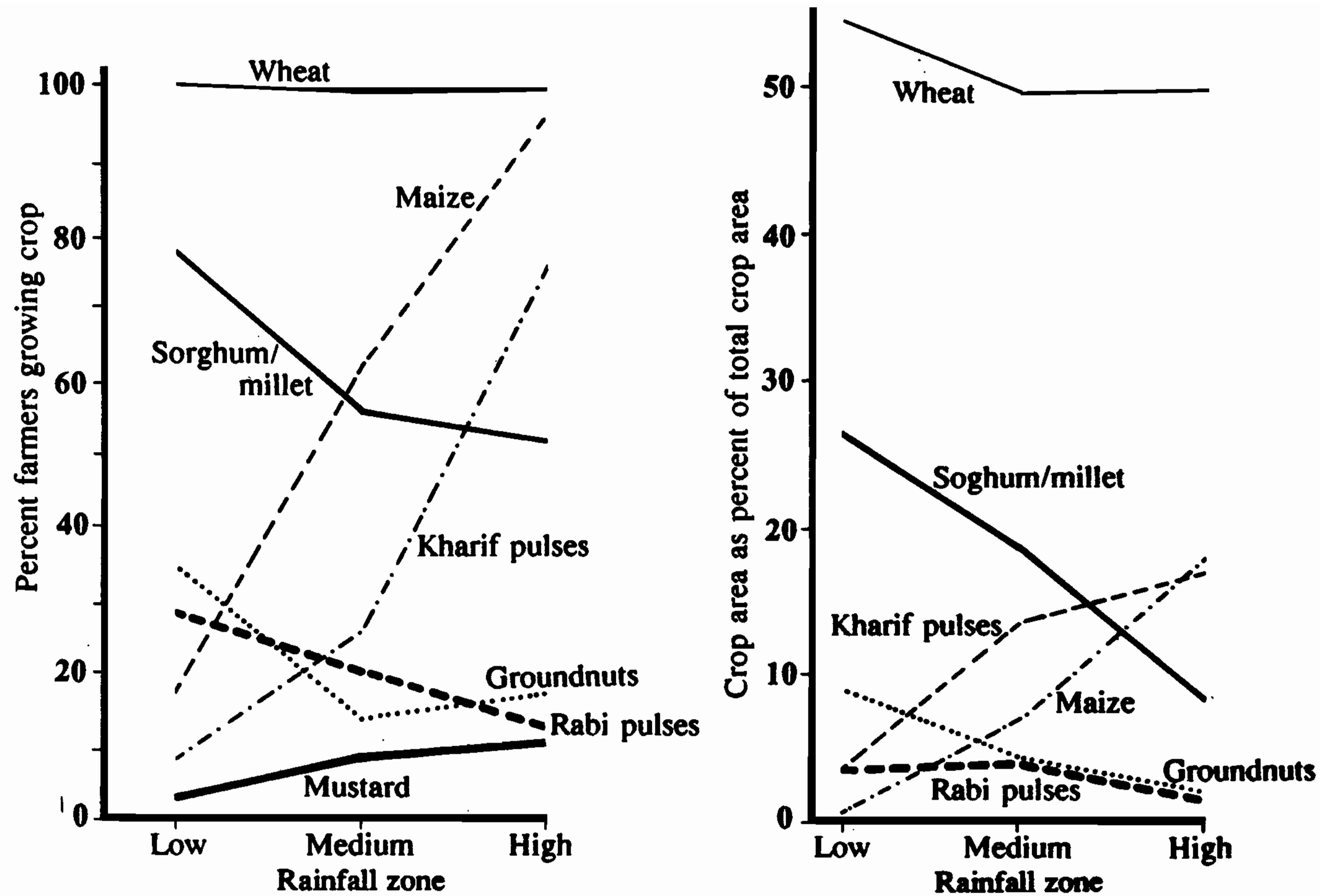

Figure 3. Relationship between cropping pattern and rainfall, barani areas, Punjab.

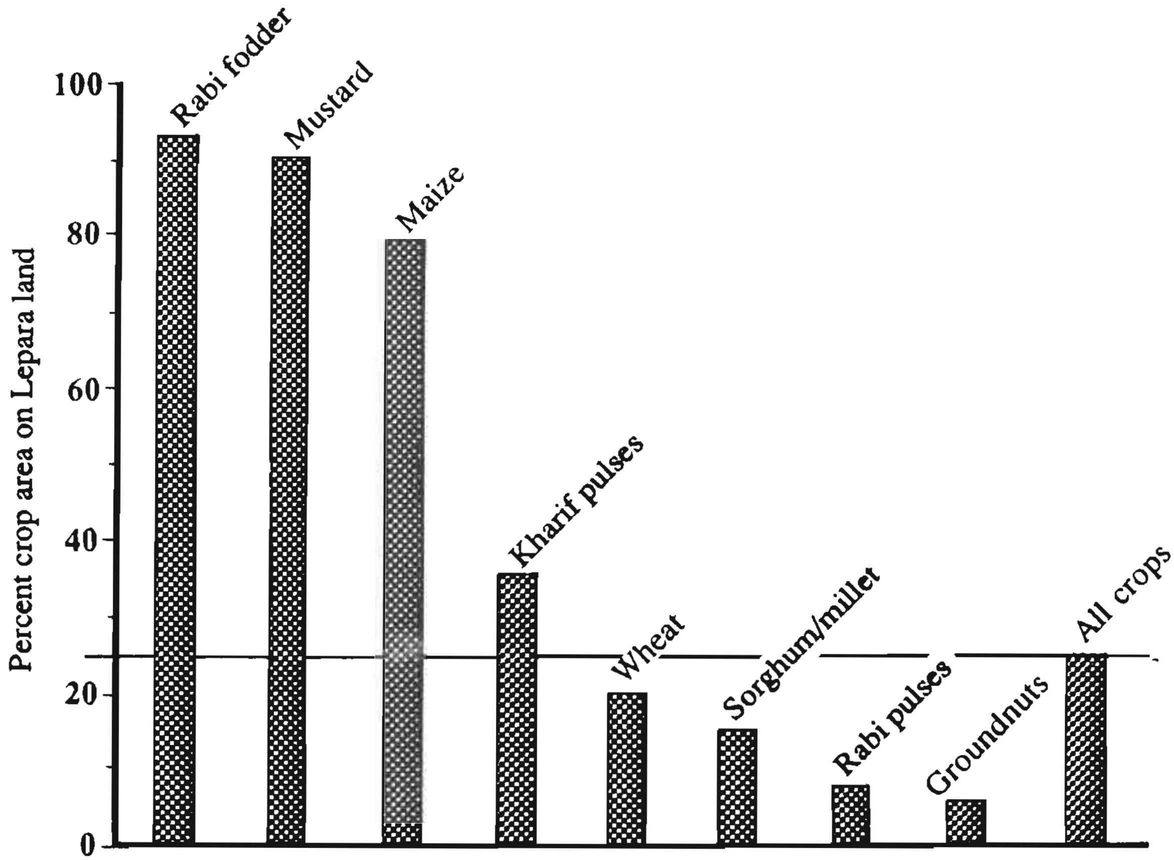

Figure 4. Percent of area planted on Lepara land for individual crops, barani areas, Punjab.

a food and fodder, and assigning groundnuts and miscellaneous Kharif crops, such as melons, as cash crops leads to the overall pattern of food, fodder and cash crop production shown in Table 7. Fodder and cash crop production are relatively more important in the drier areas, and small farmers in general devote a larger proportion of cultivated area to food crops. Overall, a significant proportion (23%) of area is devoted to fodder production, reflecting the importance of animals in the farming systems.

Table 7. Farmers' allocation of crop land between food, fodder and cash crops, Barani areas, Punjab

	Percent crop area			
	Food crops	Fodder crops	Cash crops	Total
Small farmers	71.2	22.9	5.9	100
Low rainfall	63.0	31.5	5.6	100
Medium rainfall	69.9	20.8	9.4	100
High rainfall	78.6	18.4	3.0	100
Large farmers	62.4	23.6	14.0	100
Low rainfall	55.0	23.0	22.0	100
Medium rainfall	60.0	35.6	4.4	100
High rainfall	79.1	16.2	4.7	100
All farmers	66.8	23.2	10.0	100

Figure 5 provides a crop 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 harvesting 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 the earlier semidwarf wheat varieties which allow wheat planting to be changed from the traditional planting time in October, to November. However, harvesting of sorghum and groundnuts into November still conflicts with wheat planting. Many of the crop rotations feature a fallow period which reduces

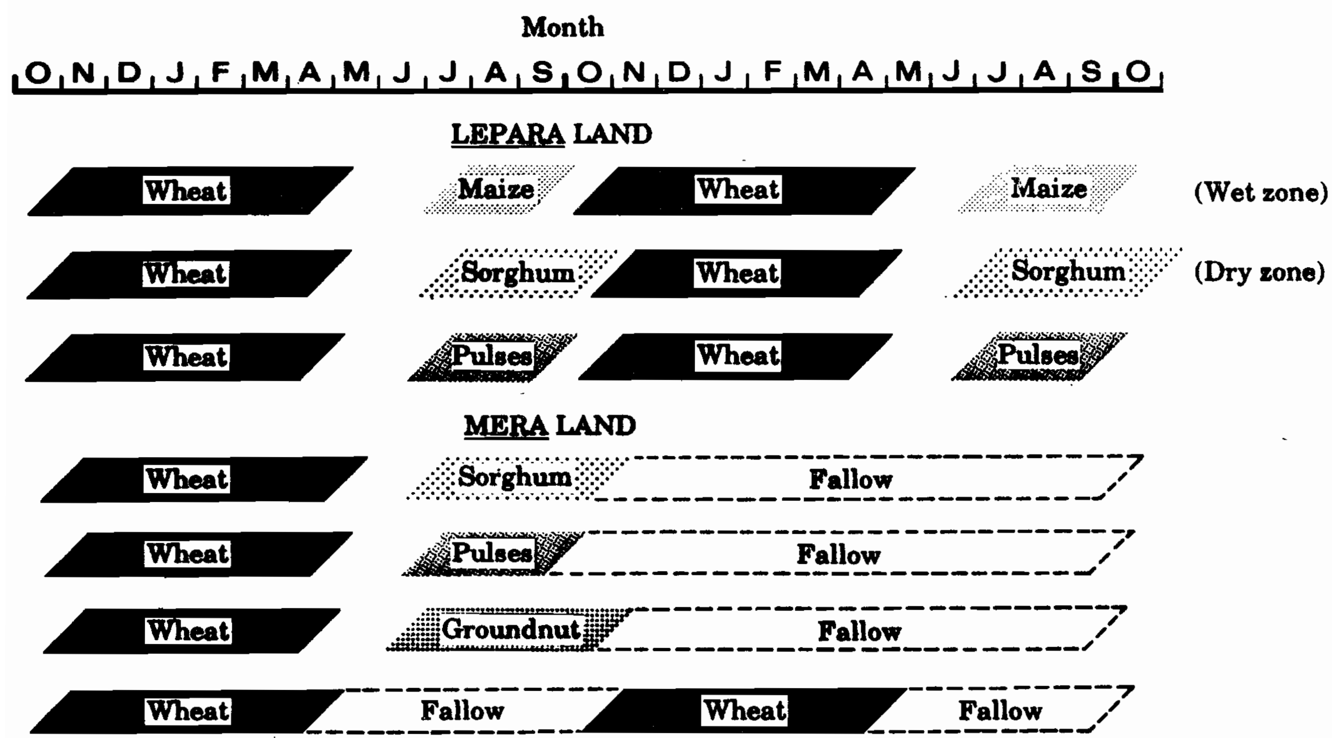

Figure 5. Some common rotations in barani areas, Punjab, Pakistan.

this conflict. This is especially the case in the widespread crop rotation of wheat followed by a Kharif crop followed by a full year's fallow - locally called the "dofasla-dosala" system. This crop rotation is particularly common in the higher rainfall zones on mera land (Table 8). In the dry zone, fallowing only in the Kharif season is also commonly practiced - a strategy that emphasizes food crop production and reduces risks since Kharif rainfall in the dry zone is

Table 8. Distribution of major crop rotations by rainfall zone and land type, Barani areas, Punjab.

Year 1		Year 2		Rainfall zone			
Rabi	Kharif	Rabi	Kharif	Low	Medium	High	All
Lepara land				(Percent fields in zone)[a]			
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

quite variable. Continuous cropping of two crops per year is widely practiced on lepara land, although in the dry zone fallowing of lepara land is also common. Farmers' rationale for fallowing will be discussed further below.

Importance of Livestock

Any analysis of cropping patterns and cropping intensity must be conducted with an awareness of the important role played by livestock in Barani farming systems. Animal unit equivalents, calculated by weighting buffaloes by 1.5, cows and draft animals by 1.0, young stock by 0.5, and sheep and goats by 0.25, averaged 6.0 per farm but varied from 4.2 in the wet zone to 8.3 in the dry zone. Larger farmers own more animals but, converted to animal equivalents per ha of cultivated land, the density of animals is less than half that on small farms (Table 9). This figure is particularly important given that most fodder is provided by speciality fodder crops and by crop residues. Note also that animals are relatively more important in the dry zone and that, even though the carrying capacity in this zone is lower, small farmers have a higher density of animals per hectare.

Livestock and Land Type

Given the much higher density of animals on small

Table 9. Number of animal units per farm and number of animal units per ha, by rainfall zone and farm size, Barani areas, Punjab

	Rainfall Zone			
	Low	Medium	High	All
Farm size	No. of animal units/farm[a]			
<5 ha	6.60	5.15	3.88	5.02
>5 ha	7.91	8.47	5.39	7.38
All	7.13	5.73	4.27	5.61
Farm size	No. of animal units/ha[a]			
<5 ha	2.37	2.29	1.73	2.11
>5 ha	0.87	1.21	0.74	.91
All	1.34	1.86	1.30	1.47

[a] Weighted number of animal units.

farms, it is expected that the percent of lepara land is higher for small farms. This was confirmed in Table 6. The percent of farm area as lepara land for larger farmers is also quite sensitive to rainfall zone. In the dry zone, where average size of larger farmers is over 10 ha the percent of farm area as lepara land type on larger farms was only 12%.

The importance of the availability of farm yard manure as a determinant of the land types available to farmers is shown by the following regressions of lepara area (LEPARA) on the log of farm size LN(FSIZ) and WANIM (weighted animal units) or the number of buffaloes (BUF)

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

$R^2 = .20$, $N = 139$

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

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

t-values are given in parenthesis and **, *** denote significance at the 5% and 1% levels, respectively.

While the weighted number of animal units has the expected positive and significant effect on lepara area, the effect of the number 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 farm yard manure. Furthermore, since buffaloes are relatively less important in the low rainfall zone where there is a less secure supply of green fodder, 40% of farmers in this zone had no lepara land compared to only 5% in the high rainfall areas.

Cropping Intensity and Fallowing

Average cropping intensity for the sample (weighted by farm size) was 118 with a C.V. of 25% (Table 10). This

Table 10. Seasonal and annual cropping intensities, Barani Areas, Punjab

Rainfall zone	Index of cropping intensity: Rabi season	Kharif season	Total	Coefficient of variation of 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

Weighted by farm size

compares favourably with a cropping intensity of 134 with a C.V. of 25% in the irrigated southern Punjab (Tetlay, Byerlee and Ahmed, 1988). Nonetheless farmers follow a deliberate strategy of fallowing nearly half of their land at any one time. An understanding of the rationale for fallowing land is clearly important to designing interventions that require an increase in cropping intensity.

A number of factors potentially influence cropping intensity and fallowing in Barani areas. These include:

(1) **Rainfall.** If moisture conservation is a rationale for fallowing, cropping intensity is expected to decrease with diminishing rainfall.

(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 as well as 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 tractor power are expected to have fewer constraints on preparing land on time between Rabi and Kharif crops. This could be particularly important in rainfed areas where timely land preparation in terms of moisture availability is often critical.

(5) **Livestock ownership.** Farmers who specialize in livestock may leave land fallow for grazing purposes.

The importance of the first three of these factors is clear from examining Figures 6 and 7. Cropping intensity increases significantly from 108 in the low rainfall zone to 129 in the high rainfall zone. Cropping intensity is also 50% 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 increase in intensity of use of lepara land. Cropping intensity on mera land is uniform across rainfall zones.

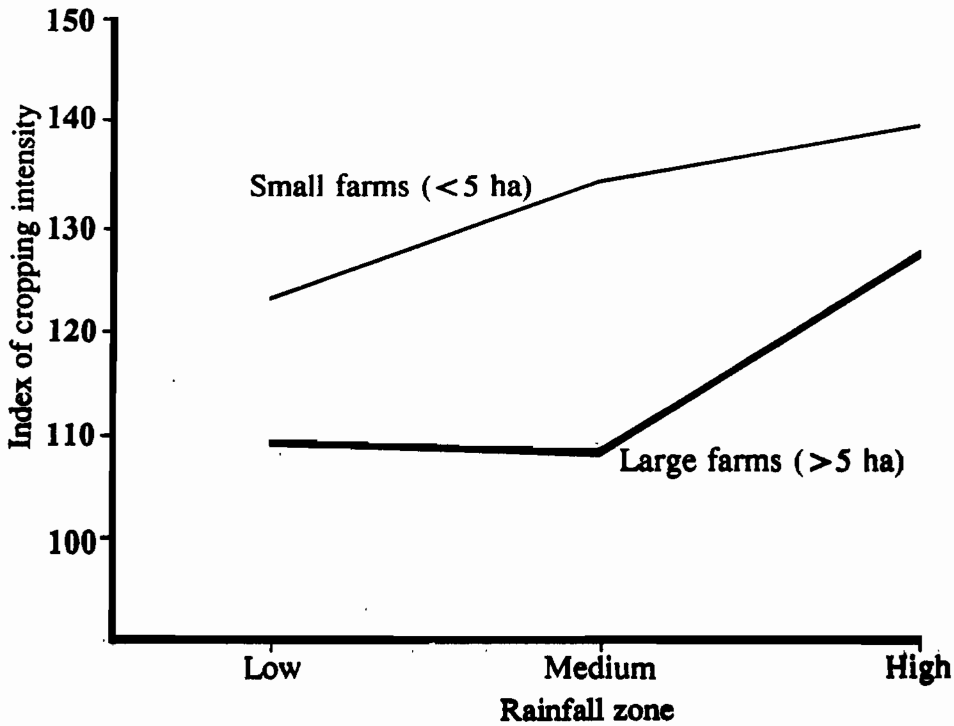

Figure 6. Index of cropping intensity overall land types by rainfall zone and farm size, barani areas, Punjab.

It should be noted that lepara land is not only cropped more intensively but also provides considerably higher yields. Farmers estimated that wheat yields are about 50% higher on lepara land compared to mera land (Table 11). Hence, although lepara land is only about one-quarter of cultivated area, it produces an estimated 43% of total crop production, and over half of production on small farms.

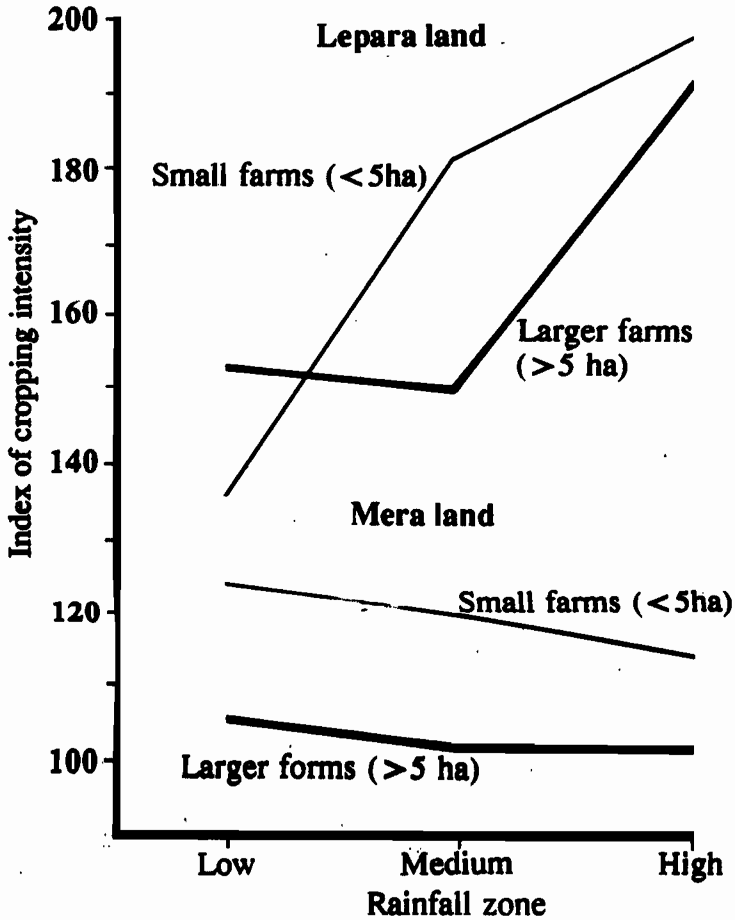

Figure 7. Index of cropping intensity by rainfall zone, land type, and farm size, barani areas, Punjab.

Table 11. Average wheat yields by rainfall zone and land type, Barani areas, Punjab

Rainfall zone	Average Wheat Yield Lepara land	Mera land	All
		(t/ha)	
Low	1.22	0.86	0.90
Medium	1.78	1.08	1.22
High	1.90	1.09	1.40
All	1.67	1.02	1.15

Source; Farmers' estimates over years

Because small farmers have a higher proportion of lepara land they are expected to have a higher cropping intensity. However, small farmers also crop <u>both</u> lepara and mera land more intensively (Figure 7). 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, Rabi season cropping intensity was significantly higher than for Kharif season in all rainfall zones (Figure 8). The main staple food crop, wheat, is produced in the Rabi season and by careful conservation of moisture especially through fallowing in the Kharif season farmers are able to reduce the risk of Rabi season cropping.

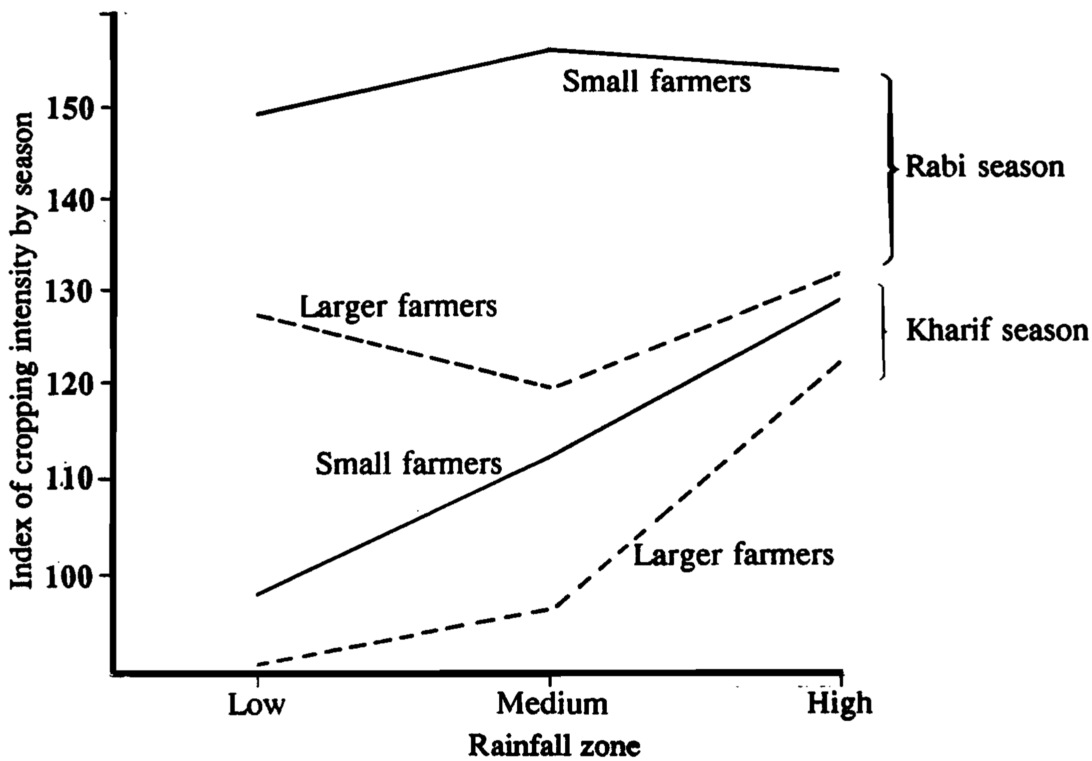

Figure 8. Index of cropping intensity by rainfall zone and farm size, barani areas, Punjab.

Nonetheless, variability in yields of Rabi crops appears to be much higher than for Kharif crops (see Table 1). Further evidence of this strategy to emphasise food crop production, despite the higher risks, is shown by the fact that small farmers crop much more intensively than large farmers in the Rabi season (Figure 8).

These relationships were further examined in the regression analysis of Table 12. The variables included in these regressions followed the hypotheses outlined above. That is:

PLEP	=	Percent farm size as lepara area
LNFSIZ	=	Logarithm of farm size (in ha)
TRUSE	=	Dummy for use of a tractor
ANHA	=	No. of animal units (weighted) per ha of farm land
MEDIUM	=	Dummy for medium rainfall zone
DRY	=	Dummy for dry rainfall zone

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.

Clearly the major factor explaining cropping intensity is the availability of lepara land. A 10% increase in the proportion of farm area in lepara land leads to a 12% increase in cropping intensity. The use of a tractor also

Table 12. 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 lepara*dry		-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 parenthesis; * denotes significance at the 10% level, ** at 5%, and *** at 1%.

[a] Average of two years, 1983-84.

has a large and significant effect on cropping intensity of 20 points (about 20%). As hypothesised, farm size has a significant and negative effect on cropping intensity. The number of livestock per ha has a negative effect as expected if land is left fallow for grazing purposes. Finally the dummy variable for the low rainfall zone is significant, especially the interaction with lepara land type. The negative sign of this interaction term confirms the earlier findings (see Figure 7) that lepara land is cropped much more intensively in the higher rainfall zones.

Disaggregation of the regression analysis of cropping intensity for each land type shows that quite different variables influence cropping intensity in each land type in ways that would be expected from our knowledge of the system. As expected, rainfall is the major determinant of cropping intensity in lepara land. Also, those 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. Large farmers especially are likely to give mera land first priority for grazing, since it has a lower opportunity cost in crops. Since mera land is more extensively cultivated and since it constitutes the bulk of farm area (80%), power and managerial constraints are expected to be greater constraints on cropping intensity than for lepara land which constitutes only a small proportion of farm area.

Farmers' stated reasons for leaving land fallow also confirm the above hypotheses (Table 13). Fertility restoration and moisture conservation were the major reasons given by farmers. These reasons were more important for farmers in lower rainfall areas. In higher rainfall areas, lack of resources, grazing of own livestock and the communal decision to leave land fallow were also important reasons for fallowing land. The latter reflects the widespread practice of changing cropped land from one side of the village in alternate years to the other side, leaving fallow land for communal grazing. Hence, the decision to fallow is outside of individual farmer's control. Both small and larger farmers gave similar reasons for fallowing land, although the use of fallow land for grazing was more frequently mentioned by small farmers.

We also analysed cropping intensity separately for the Rabi and Kharif seasons. Rabi cropping intensity at 68 (weighted by farm size) was 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

Table 13. Farmers' reasons for leaving land fallow, Barani areas, Punjab[a]

Farmers' reason for fallowing	Rainfall zone Low	Medium	High	All
	(Percent farmers in zone)			
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	15
Total	100	100	100	100

[a] Most important reason stated by farmer.

correlation varied from -0.14 in the dry zone, 0.01 in the medium rainfall zone to 0.37 (significant at the 5% level) in the wet zone. In the dry zone, farmers may choose to specialize in either Rabi or Kharif crops but in the wet zone some farmers crop more intensively in both seasons. Nonetheless, the low overall correlation across seasons suggests substantial individual choice in cropping pattern.

The regression analysis of seasonal cropping intensity (Table 14) includes variables to represent cropping pattern

Table 14. Regression analysis of Kharif and Rabi cropping intensity, Barani areas, Punjab

Independent variable	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. 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 and dry	-0.379 (2.86)***	-0.339 (2.57)**	-0.336 (2.69)***	-0.403 (2.82)***
% Sorghum or groundnuts				-0.096 (1.89)*
% Wheat		-0.251 (2.28)**		
Constant	51.3	74.8	55.0	56.0
R-squared	0.32	0.34	0.19	0.24
N	136	136	136	128

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

[a] Average of two years, 1983-84.

in the previous season, in addition to the variables included above for analysing annual cropping intensity. We hypothesised that since sorghum and groundnuts are harvested in November and conflict with wheat planting a higher proportion of these crops in the Kharif cropping pattern is expected to reduce Rabi cropping intensity. Likewise farmers who specialize in wheat in Rabi season may leave more land fallow in Kharif season to conserve moisture for wheat production. The regression analysis in Table 14 confirms these 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 Kharif than Rabi cropping intensity, although it has a significant and positive effect in both seasons. A further interesting finding is that Kharif cropping intensity, but not Rabi cropping intensity, was significantly and negatively related to the number of animals owned, reflecting the fact that grazing in the Kharif season offers more benefits than grazing in the Rabi season because of the vigorous growth of grasses in the monsoon period.

Finally, cropping intensity in a rainfed area is likely to vary from year to year, depending on available moisture. The data summarized in Table 15 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 for

Table 15. Comparison of 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

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 1983. Correlations of cropping intensities for individual farmers show that year-to-year variation is quite high and is greater for mera land and Kharif season (i.e., low correlation between years). Year-to-year variation is also highest for the medium rainfall zone where informal surveys indicate that farmers practice considerable "opportunity" cropping - that is, planting on what would normally be fallow land when rains are particularly favourable. At the extremes of rainfall, farmers seemed to be locked into more rigid cropping patterns across years.

Livestock

Livestock Composition

As already seen in Table 9, both the number of animals and the number of animals per hectare of crop land were highest in the Barani tract, especially in the drier areas. There were also important differences in livestock composition across rainfall zones and by farm size (Table 16). In all zones, cattle were the most important component of livestock. In the wet zone, however, buffaloes were nearly as important and ranked much higher than in other zones. Both the relatively high number of buffaloes as well as the higher percentage of milk animals in this zone (see Table 16) reflect the proximity to urban markets as well as the greater availability of green fodder. By contrast the number of draft animals and sheep and goats in the wet zone was less than in the drier zone. Almost all farmers in the wet zone now use tractors for all or part of their land preparation and only 40% own animal draft power. Rather than reducing animal numbers as tractors replace bullocks, farmers appear to have substituted buffaloes in order to generate cash income, especially from sales of milk by farmers close to urban areas. Hence while the number of cattle in Rawalpindi District declined slightly between the 1960 Agricultural Census and the 1980 Agricultural Census, the number of buffaloes increased by 25%.

Table 16. Composition of livestock herds, Barani areas, Punjab

	Rainfall zone Low	Medium	High
	Percent animal units[a]		
Buffaloes	20.9	21.4	35.7
Cows	43.2	44.2	40.8
Draft animals	23.4	22.7	15.6
Sheep and goats	12.5	11.7	7.9
Total	100.0	100.0	100.0

[a] Expressed in cow equivalents

Livestock composition also relates to farm size - only 46% of small farmers owned buffaloes compared to 70% of larger farmers - and to access to range land for grazing (locally termed Khudar, Shamlat or Porah). Farmers who had access to grazing land (usually privately owned) owned significantly more sheep and goats. Again nearly all larger farmers (86%) had access to grazing land compared to only 56% of small farmers.

Sale of young livestock are an important source of cash income, especially in the dry zone. Milk is also a major livestock product for home consumption and, in the wet zone, for cash sales. In the wet zone, with better supplies of green fodder and a more commercial orientation, average milk yields were highest for both buffaloes and cows (Table 17). For all zones, milk yields for cows were only 38% of yields for buffaloes and both were highly variable by season depending on fodder supplies and temperatures (Table 17).

Fodder Management

A major component of Barani farming systems is managing seasonal fodder supplies. Approximately 25% of crop area is

Table 17. Average annual milk yield by rainfall zone and season, Barani areas, Punjab

	Average milk yield (l/day)	
	Buffalo	Cow
By rainfall zone		
Low	7.1	2.7
Medium	6.4	2.7
High	8.7	3.3
By month		
Lowest month[a]	5.5	2.0
Highest month[b]	9.4	3.7
Annual average	7.5	2.9

[a] May-June [b] March-April
Source: Farmers' estimates

devoted to fodder production from two major sources: (1) intercropping of fodder with grain and (2) production of speciality fodder crops. In addition crop by-products are a major component of fodder supplies. The main crop by-products are wheat straw and maize stover. A recent analysis of fodder markets (Byerlee and Iqbal; 1987a) indicates that prices of dry fodder are substantially higher and more variable in the Barani areas compared to the irrigated areas.

Intercropping of grain and fodder is especially common for wheat and maize. Nearly 90% of farmers intercropped mustard in wheat, removing most of the mustard from January to March for green fodder. In the drier areas, where intercropping with mustard is less common, many farmers graze or cut the wheat crop early to provide green fodder. They particularly favour traditional wheat varieties which have a demonstrated ability to produce grain after forage cutting. Likewise, maize grain and maize fodder are "intercropped". Maize is planted at a high seed rate and the plant stand is reduced over the season to provide green fodder. The value of green and dry fodder from maize is nearly equivalent to the value of maize grain produced (Byerlee and Iqbal, 1987b). These intercropping practices represent a deliberate strategy by farmers to trade off grain for fodder production. For example, the seed rate used by farmers in maize was significantly correlated with the number of animals/ha owned (Sheikh and Haq Nawaz, 1987). While researchers have often questioned these intercropping strategies, there is growing evidence that they may be an efficient way of using scarce land resources and managing risk (Hobbs et al., 1985; Byerlee and Iqbal, 1987b).

Finally, most farmers also grow speciality fodder crops, mostly sorghum and millet, and to some extent barley and oats. The fact that farmers allocated about half of Kharif cropped area to fodder demonstrates the priority to fodder production, although many large farmers also sell part of this fodder (see below).

Nearly all farmers also purchase animal feed concentrates, especially oilseed cakes, to supplement home-produced green and dry fodders. The use of concentrates is largely for milk animals and is also partly seasonal; their use increases when there is no green fodder available (Figure 9). Clearly, the management of fodder from a number of different sources and with considerable year-to-year variation in availability due to rainfall is a complex task.

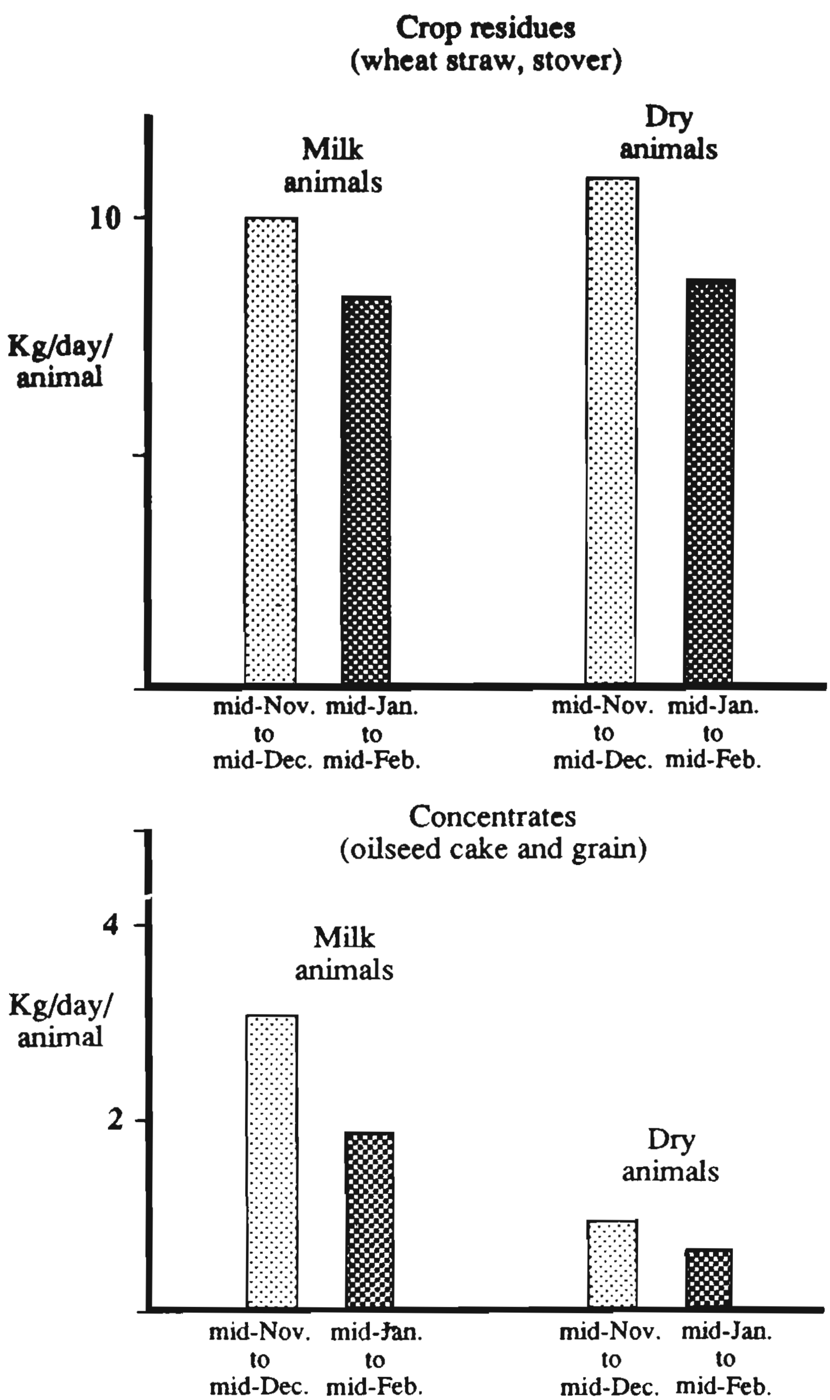

Figure 9. Average diet of crop residues and concentrates for buffaloes for two periods of the rabi season, barani areas, Punjab.

Meeting Subsistence and Cash Requirements

For the entire sample, Barani farmers produced a slight surplus over subsistence requirements in grains (wheat and maize), were close to self-sufficiency in pulses and were deficit in fodder (Table 18). However, these aggregate figures hide substantial diversity among farmers. Small farmers, and especially those in the dry zone, were on average deficit in all three subsistence products with the largest deficit occurring for fodder.

Table 18. Farmers' average level of self-sufficiency in food and fodder, Barani areas, Punjab

	Net surplus in rupees/year/farm			Percent self-sufficiency[a]	
	Grains crops	Pulses crops	Fodder crops	Grains crops	Pulses crops
Small farmers	-239	-68	-341	94	85
Low rainfall	-824	-229	-604	77	41
Medium rainfall	50	-23	-147	101	95
High rainfall	-167	-20	-362	96	96
Large farmers	1,728	197	617	128	127
Low rainfall	-55	-183	308	99	78
Medium rainfall	3,600	-253	650	155	64
High rainfall	3,232	1,273	1,172	152	206
All farmers	253	-1	-101	106	100

[a] (Total production/total consumption)*100

Small farmers are usually more willing to depend on the market for secondary staples than for basic staples. This is reflected in the fact that 71% of small farmers were net purchasers of pulses, a secondary staple in the diet (Figure 10). Nonetheless a surprisingly high number of farmers (nearly half) depended on the market for 10% or more of their grain requirements. In the dry zone, nearly two-thirds of farmers are deficit in grains. Fewer farmers depended on the market to meet fodder needs, no doubt because of high transport costs in relation to value for fodder. Interestingly, the farmers in the wet zone were most dependent on purchased fodder; the excellent road system in this zone and the proximity to well-developed fodder markets in Rawalpindi undoubtedly explain this difference.

Small farmers aiming to meet subsistence needs have little flexibility to substitute within the current cropping pattern, although to some extent they devote less area to cash crops than larger farmers (Table 7). Nearly half of larger farmers gave sale of food or cash crops as their main source of cash income compared to less than a quarter of small farmers (Table 19). Given this inflexibility, the main opportunities for meeting cash requirements are through sales of livestock products or sales of labour off farm. There are important differences by farm size and by rainfall zone in the role of these sources of cash income. In the dry zone sales of livestock products, especially sales of young

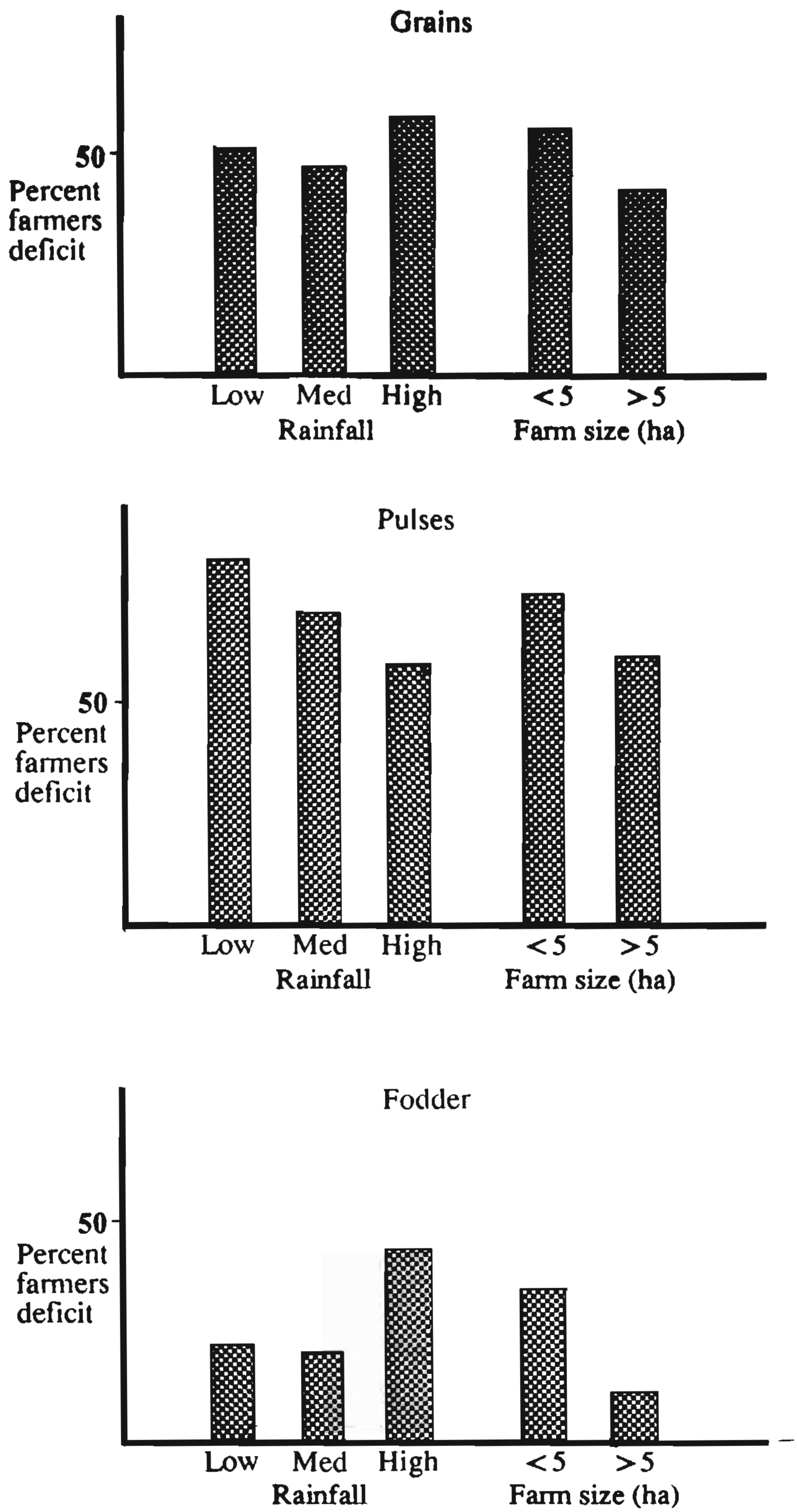

Figure 10. Percent farmers in grains, pulses, and fodder, by rainfall zone and farm size, barani areas, Punjab.

Table 19. Percent farmers ranking a given cash income source as most important, Barani areas, Punjab

Most important source cash income	Rainfall zone			Farm size		
	Low	Medium	High	<5 ha	>5 ha	All
Sale of livestock products	41	21	14	18	39	25
Sale food crops	26	15	4	6	17	8
Sale cash crops[a]	31	13	14	17	28	19
Off-farm work	20	44	66	55	17	44
Remittances	2	8	2	4	3	4
All sources	100	100	100	100	100	100

[a] Groundnuts, melons, etc.

stock, are the main source of cash income (Table 19). In contrast, off-farm income is the major source of cash income in the wetter zones where farmers have ready access to the Islamabad/Rawalpindi urban labour market. Off-farm work was especially important to small farmers (Table 19).

By regressing marketed surplus of grain on farm size or crop area in grains (wheat and maize) we could also estimate the area needed to reach self-sufficiency in grains.[4] This varied from a farm size of 2.5 ha with 2.0 ha devoted to grains in the medium and higher rainfall zones to 6 ha with 4.6 ha devoted to grains in the dry zone, reflecting the very different levels of productivity in these zones. Average household grain consumption was around 2000 kg, so that grain yields would need to be about 1.0 t/ha in the medium and wet zones, and about 0.5 t/ha in the dry zone to meet subsistence requirements. These figures seem low in relation to yields achieved by farmers (Table 11) but they apply to 1984, an exceptionally dry year.

Synthesis

The major influences on management of Barani farming systems revolve around the various interactions between crop production and livestock production. Both enterprises are an integral part of the farming system and it is difficult to analyse one in isolation from the other. These various interactions include the following components: (1) use of draught animals for farm power, (2) use of farm yard manure for crop production, (3) provision of fodder to animals, and (4) generation of cash income and stabilization of incomes through livestock production.

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4 That is, $S = a + bA$, where S is marketed surplus (net of any purchases) and A is area. Breakeven for self-sufficiency is estimated by setting $S = 0$ and computing $A = -b/a$.

Traditionally, draught animals have been the major source of farm power. Poor draught animal nutrition in the dry season at the time of land preparation for wheat was often a major constraint on increasing cropping intensity (Rochin, 1971). This interaction has become less important in recent years with the widespread introduction of tractors and the development of rental markets for privately owned tractors. Tractor power now constitutes the major source of farm power even for small farmers. Nonetheless, a significant minority of farmers still depend on draught animal power and cropping intensity on these farms is correspondingly lower. With increasing mechanization over the next few years, draught power is likely to disappear as a major constraint on increasing cropping intensity.

Farm yard manure has traditionally been important as a means of maintaining soil fertility. The vast majority of farmers now use chemical fertilizer and this reduces the need for farm yard manure in fertility maintenance. However, the use of farm yard manure to build soil structure, especially moisture holding capacity, is still critical. The strategy of concentrating farm yard manure on selected fields - that is, lepara land, near the village - enables these fields to be cropped at double the cropping intensity of land away from the village, especially in the high rainfall zone. This 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 about 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 with regular FYM 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 competing uses of FYM. Over the past decade, farmers estimate that there has been a decline in the number of animals in Barani areas as tractors have replaced bullocks. However, there is evidence from census data that, especially in the wet zone, the composition of animals has shifted away from grazing animals (i.e., cattle, sheep and goats) to stall-fed animals (i.e., buffaloes). Since FYM is largely produced by stall fed animals, this shift in animal composition may have compensated for the effect of any decline in animal numbers on the availability of FYM.

FYM is not exclusively used for crop production. About 40% of farm households used FYM as a cooking fuel and Barani farmers estimated that about 20-25% of FYM was used in this way, with the greatest use occurring in the higher rainfall areas. With increasing population density and the declining availability of fuel wood this competition is likely to grow. Hence one strategy to preserve the productivity of lepara land will be to evaluate alternative means of providing cooking fuel, including increased emphasis on agro-forestry.

Production of fodder is a major subsistence priority of Barani farmers. On average, self-sufficiency is higher for fodder than for food grain production. Production of fodder leads to a number of compromises in crop management. The practice of intercropping of fodder in grain crops (wheat and maize) leads to lower grain yields but may help stabilize yields over time (Hobbs et al., 1988). The grazing of animals both individually and communally, especially in the Kharif season, also appears to be a factor in leaving land fallow. In addition, the planting of speciality fodder crops, such as sorghum or barley and oats, is at the expense of area in grain crops, or, for larger farmers, the area in cash crops. Although the number of draft animals has declined, there is no evidence that the demand for fodder has decreased; rather the shift in animal composition toward stall-fed animals tends to place greater pressure on fodder supplies. The real price of fodder in Barani areas has not changed, in contrast to irrigated areas of the Punjab where real fodder prices have fallen sharply in the past two decades.

Finally, crop-livestock interactions are reflected in efforts by small farmers to balance subsistence needs. Small farmers crop considerably more intensively, both because they have a larger proportion of farm area as lepara land, but also because they crop both land types more intensively than larger farmers. Since yields on lepara land are considerably higher than on mera land, small farmers also achieve higher average farm yields for those crops, such as wheat, grown on both land types. Small farmers also have three times the number of animals per unit of crop land and hence face greater pressures to trade off grain for fodder production. Most small farmers depend on the market for their secondary food, pulses, but nearly half of small farmers are also deficit by 10% or more in their food grain requirements. Only in the high rainfall area near the Rawalpindi urban complex are a significant number of small farmers depending on the market for fodder. The cash needed by small farm households to sustain this dependency on the market for subsistence food requirements is in large part generated by livestock production, although earnings from off-farm work are also very important, especially in the high rainfall zone. In this paper, we have not investigated year-to-year variability in farm income, but we would also hypothesise that livestock income serves as a stabilizing influence on farm income in dry years, especially in the low rainfall zone.

Implications for Research

The analysis of this paper suggests three major implications for research for the Barani tract. First, land type is clearly a major factor in farmers' crop management decisions. Research on crop management, such as fertility and tillage, as well as research on crop rotations and cropping patterns, should always consider at least two major recommendation domains - lepara land and mera land. Until recently, recommendations for rainfed agriculture in the Punjab were only disaggregated by rainfall zone. However, recent research on fertilizer response in wheat (Hobbs et al., 1986), has found very different responses on lepara and mera land. Hence stratification by land type is as important, or even more important, than stratification by rainfall zone.

Second, fodder production should receive high priority in research for Barani areas in the future. Not only is fodder a critical constraint on livestock productivity, but the close interaction between fodder production and grain production leads to reduced grain yields. There is a need to explore more efficient ways of producing <u>and</u> conserving fodder. Speciality fodder crops are one possibility, and means to improve the productivity of sorghum as a fodder should have high pay-offs. More importantly, there is a need to understand better the trade-offs in intercropping of fodder and grain in wheat and maize production. Some useful work on wheat-mustard intercropping has already been initiated (Hobbs et al., 1985), but more needs to be done. Similar work on joint production of grain and fodder in maize has been initiated (Byerlee and Iqbal, 1987a) but follow up work is needed.

Finally, increasing cropping intensity is a major opportunity for increased productivity in Barani areas. 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%. 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 models could help analyse some of these relationships over the long term. On the socio-economic side, a better understanding of farmers' decision criteria for fallowing is needed. Since these decisions are often communal, some analysis of group decision making at the village level and the potential for influencing these decisions is required. The role of risk aversion in the decision to crop or fallow land also needs further research.

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