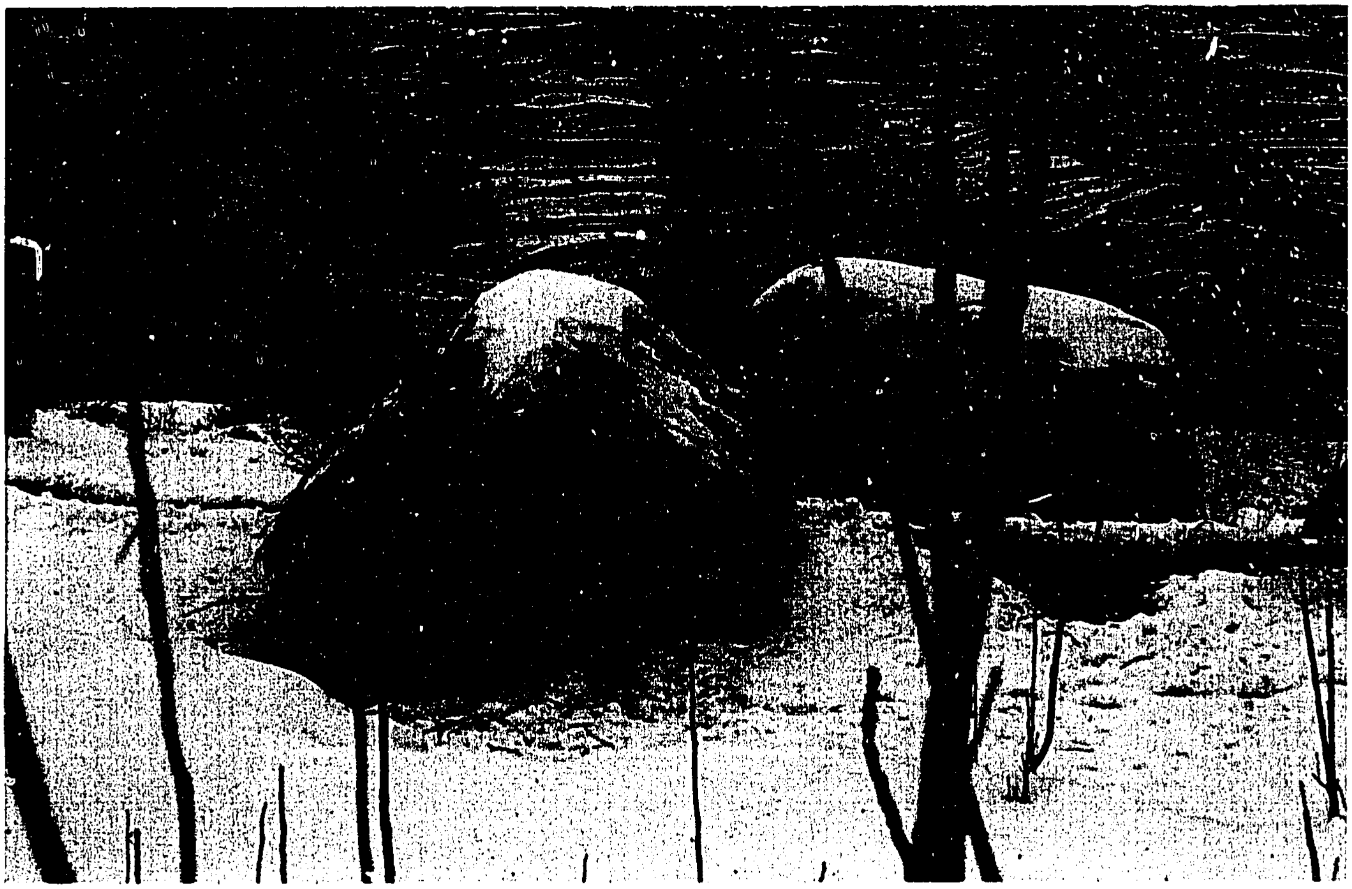
Diagnosing Research Priorities for Higher-Altitude Maize-Based Farming Systems in Swat



Paul Heisey
Munir Ahmad
E. John Stevens
Kiramat Khan
Jahan Zeb
Habib Iqbal Javed

PARC/CIMMYT Paper 90-3

Agricultural Economics Research Unit (PARC),
Tarnab, Peshawar, NWFP
PARC/CIMMYT Collaborative Program
Cereal Crops Research Institute, Pirsabak, Nowshera
National Coordinated Maize Program, NARC,
Islamabad

1990

DIAGNOSING RESEARCH PRIORITIES FOR HIGHER-ALTITUDE MAIZE-BASED FARMING SYSTEMS IN SWAT

Paul Heisey[2]
Munir Ahmad[1]
E. John Stevens[3]
Kiramat Khan[4]
Jahan Zeb[1]
Habib Iqbal Javed[5]

PARC/CIMMYT Paper 90-3

[1]Agricultural Economics Research Unit (PARC),
Tarnab, Peshawar, NWFP
[2]PARC/CIMMYT Collaborative Program
[3]Consultant, FAO, Islamabad
[4]Cereal Crops Research Institute, Pirsabak, Nowshera
[5]National Coordinated Maize Program, NARC,
Islamabad

1990

Acknowledgements

Many people have contributed to this study. They include the following individuals:

1985 Maize Harvest Survey:

- Munir Ahmad, Habib Iqbal Javed, Kiramat Khan, Derek Byerlee, Najjam-ul-Islam, Paul W. Heisey

On-Farm Program:

- Kiramat Khan, Adalat Khan, E. John Stevens, Mohammad Saleem

1987 Informal Farming Systems Survey:

- Munir Ahmad, Paul W. Heisey, E. John Stevens, Kiramat Khan, Shaukat Hayat, Jahan Zeb, Adalat Khan.

1987 Formal Farming Systems Survey:

- Munir Ahmad, Himayat Ullah, Jahan Zeb, A.D. Sheikh, Paul Heisey

Questionnaire Coding and Data Entry:

- Jahan Zeb, Munir Ahmad, Habib Iqbal Javed, Paul W. Heisey, Nancy Heisey

Data Analysis:

- Paul W. Heisey, Munir Ahmad, Jahan Zeb

Report Writing:

- Paul W. Heisey, Munir Ahmad, E. John Stevens

Comments and Editing:

- Derek Byerlee, Mohammad Saleem, Kelly Cassaday, Jim Longmire

In addition to the above people, we particularly wish to thank CIMMYT drivers Nasir Khan and Ismail Khan. Nasir has participated in every aspect of diagnostic and experimental work in Swat since the beginning of the current on-farm research effort. His skill at building relationships with the farmers was essential to the success of the current research. Ismail has been a full participant in the Swat work since 1985. He has contributed tremendously with his intimate personal knowledge of Swat agriculture and his understanding of farmers. We would also like to thank Haroon Pervaiz, A. Wahab, and M. Iqbal. Finally, we wish to thank the most important people in this study, the farmers in the Swat mountains, for their hospitality, patience, and cooperation.

CONTENTS

LIST OF TABLES

List of Figures

Executive Summary

During 1987, a diagnostic survey was conducted in the higher-altitude farming systems of Swat. This followed a field-specific crop-cut survey of maize fields in the same farming systems in 1985. These surveys were designed to develop research priorities for maize on the small farms of the area. The main findings follow:

Farm Households

- In the Swat mountains, farm size is very small. Sixty-two percent of the farmers have under 1 ha of land and 80 percent under 1.5 ha. Farmers with both irrigated and barani land tend to hold larger areas than farmers with a single land type.
- Around 90 percent of the farmers in the Swat mountains own livestock, nearly all with at least one dairy animal (an adult buffalo or cow). Seventy percent hold young stock, and just over half have bullocks. Relatively few farmers (14 percent) have sheep or goats.
- Most farmers do not meet food needs from their own crop production. In 1987, 95 percent of the farmers interviewed for this study bought wheat and 57 percent bought maize. Only 12 percent sold maize.
- Subsistence milk production, farmyard manure, and draft power are more important than cash income from livestock. The cash generated from livestock is much more likely to be through animal sales than through milk.
- Farmers' supplement farm income with off-farm work. Half said off-farm income was the most important source of cash, one-third said crops were most important, and only 10 percent indicated livestock.
- Eighty-seven percent of the farming households have family members working off the farm, and 58 percent have family members who work seasonally or longer term outside of Swat. Higher agricultural potential, particularly greater farm size and possession of some irrigated land, reduces the likelihood that families will have migrant members working outside of Swat.

The Cropping System

- Maize is the major crop in the system, grown by nearly every farmer in the kharif season.
- Potatoes are grown as an alternative cash crop in the kharif season, concentrated in a few catchment areas. The median altitude at which potatoes are grown is higher than the median altitude at which maize is grown. Farmers growing potatoes are significantly more likely to consider crops their most important source of cash income than other farmers.

- About half the farmers above 1500 m.a.s.l. grow wheat for grain. The median altitude at which wheat is grown for grain is 1700 m.a.s.l., lower than the median altitudes for potatoes or maize. The maximum altitude at which we found farmers growing wheat for grain is 1950 m.a.s.l.

- Cropping intensities are primarily related to whether or not the farmer grows a rabi crop, as most land is cropped during the kharif season.

- Increasing altitude is associated with decreasing cropping intensity. Intensity is higher on irrigated land. However, cropping intensity decreases more rapidly with increasing altitude on irrigated land than on rainfed land. Larger farms tend to have lower cropping intensities.

- The area between 1500 m.a.s.l. and 1950 m.a.s.l. may be regarded as transitional between double and single cropping. The primary rotational conflict occurs when harvesting a wheat crop delays maize planting.

Livestock

- The total number of animal units held by a farm household tends to increase with cultivated area. However, the number of animal units per hectare decreases with cultivated area and decreases with altitude.

- Buffaloes are more important in total herd composition on larger farms and on farms with some irrigated land. Buffaloes may be less important in herd composition at higher altitudes.

- Though bullocks are the major source of draft power for crop production, about half of the farmers own no bullocks and only 30 percent own a bullock pair.

- For both buffaloes and cows, milk production per lactation is well under desired levels. Production is higher in summer when both quantity and quality of fodder are greater, and higher for farmers with irrigated land.

- The most important summer fodders are cut weeds and grasses, maize thinnings, and weeds and grass the animals graze. The most important winter fodders are dry grass and dry maize. Animals are fed supplements of oilseed cake and wheat flour, particularly in winter. Greater amounts of supplement are fed to buffaloes than to cows, and to lactating animals.

- The months of greatest fodder shortage are March and April, when dry fodder is scarce and green fodder is not yet available.

- Generally, the diets of lactating animals do not contain enough energy and protein for optimum milk production.

Changes in the System

- Over the past 20 years, more farmers have come to own their land. Eighty percent or more of the farmers in the Swat mountains are owners.

- During the same period, much new land has been cleared for cultivation. In general, there is now less control over forest exploitation and grazing land than there was during the period when Swat was a state.

- Most farmers believe total livestock numbers have decreased, particularly because of increasing difficulties in producing or obtaining adequate fodder.

- More farmers are growing wheat for grain at higher altitudes than 20 years ago. This wheat is replacing rabi fallow and barley. This trend is related to the adoption of semidwarf wheats, which have shorter growing seasons than taller desi varieties. About two-thirds of the farmers growing wheat for grain now grow semidwarf varieties.

- Use of fertilizer has also spread to the Swat mountains in the past 20 years. Almost all farmers now use nitrogenous fertilizers.

Maize Practices and Production

- After fallow or fodder, maize is planted earlier with increasing altitude. At any given altitude, maize planted after fallow is planted earlier than maize planted after fodder.

- After wheat for grain, maize is planted later with increasing altitude, reflecting delays in maize planting caused by later wheat harvest. The difference for maize planted after wheat for grain compared with maize planted after fallow, tends to be about one week at 1500 m.a.s.l. and around four and a half weeks at 1900 m.a.s.l.

- After fallow or fodder, maize is generally planted later on south facing slopes.

- Farmers have little knowledge of improved open pollinated maize varieties, although some have penetrated into the Swat mountains and mixed with local germplasm. For the most part, farmers grow mid- to full-season white maize varieties.

- Farmers in the Swat mountains tend to make two passes with a bullock-drawn plow before planting maize. On the third pass, the maize seed is broadcast and incorporated.

- All evidence points to seed rates that are quite variable but very high, with a mean near 100 kg/ha. Seed rate are high because of the method farmers use to manage maize plant density. Broadcast planting requires higher seed rates. Farmers reduce densities after planting by hoeing or seeling (interculture with a local bullock plough), then thinning by hand. However, plant densities often exceed 90,000 plants/ha at harvest.

- The farmers' motivations for this plant density management are complex. Maize is managed to produce grain for human consumption, green fodder from thinnings, and dry fodder. In the Swat mountains, dry fodder is given more emphasis than in the Swat valley. This is because winters are more severe in the mountains and grasses and weeds relatively more abundant in the summer. High seed rates followed by density reduction also provide insurance against low germination caused by inadequate soil moisture and plant loss caused by insect attack. The most important insects are cutworms but borers are also present in the Swat mountains.

- Actual harvest densities were measured in crop cuts taken in 1985, and so they are not subject to as much error as other measures dependent on area. These densities increased significantly with increasing altitude. There did not appear to be any effect of irrigation on mean harvest density, but densities were more variable on rainfed than on irrigated land. At higher altitude, maize grain yields appear to be increasingly tolerant of higher plant density.

- Almost all farmers use nitrogen on maize. Average application of N was 100 kg/ha. Nitrogen application rates are higher on irrigated land, and higher if maize follows a rabi crop, rather than fallow. Increased use of nitrogen has a highly significant positive effect on yield.

- Half or fewer of all farmers use phosphorus on maize and the average application of P overall was 36 kg/ha. Farmer's knowledge of the nutrient content of compound fertilizers containing phosphorus is limited, and experimental evidence on phosphorus response is inconclusive. Farmers are more likely to use phosphorus if they operate larger farms, and less likely to use phosphorus if they apply greater amounts of farm yard manure. Yield response to phosphorus was generally insignificant, but there were some fields where the use of P would be justified, especially in maize-wheat rotations.

- Grain and stover yields on irrigated maize fields in the Swat mountains are higher and less variable than on rainfed land. In 1985, irrigated fields had an average grain yield (at 15% moisture) of 3.8 t/ha and a stover yield (at 10% moisture) of 4.9 t/ha. Rainfed fields averaged 2.5 t/ha of grain and 3.5 t/ha of stover. Many physical production parameters for irrigated mountain fields are similar to the Swat valley, except that harvest densities are higher, duration is much longer, stover yield is higher, and harvest indices are lower in the mountains. Generally, much more variability is observed in maize production in the mountains too.

- As in the Swat valley, farmers tend to harvest maize at high ear moisture content. This appears to reduce grain yields, although the practice is not well understood, particularly because farmers tend to leave the ear on the stalk for some time after cutting the stalk. Yield also increases with increasing altitude, probably because of greater precipitation at higher altitude, and the switch to a single crop per year at higher altitudes. There may also be physiological factors favouring yields at higher altitude. Maize planted after fodder on lower elevation irrigated land yields better than maize following wheat. On barani land, as noted, high plant densities only appear to reduce yield at the top end of the density range. No yield reducing effect from high densities was observable on irrigated land under 1985 conditions.

Research and Policy for the Swat Mountains

- A high priority for further research is the development of earlier-maturing, stress-tolerant and disease-resistant maize and wheat varieties for the higher altitude areas. Some varieties currently available have potential for the Swat mountains, but their usefulness is hampered by the lack of an adequate seed delivery system.

- Other priorities for research include evaluating the potential for more cash cropping, promoting fodder crops that might provide a more uniform supply over the winter, and improving the nutritional content of animal diets, for example, with sorghum-sudan grass hybrid and fodder oats, both of which have been pilot tested with farmers in Swat.

- Some agronomic recommendations can be translated directly from the Swat valley to the Swat mountains, particularly for irrigated land. The main differences between the mountains and the valley are the longer maturity periods in the mountains, the greater difficulty of fitting a rabi crop into the rotation there, and the higher density tolerance of maize in the mountains.

- Irrigated and barani land are clearly separate recommendation domains for maize. The major differences between the two land types include the greater difficulty in achieving desired density on barani land, and the greater variability in soil fertility and greater risk in using fertilizer on barani land. In all crop management research in the Swat mountains, site selection is particularly important.

- Some areas for future agronomic research in maize include appropriate density management, crop loss studies focusing on insects and disease, time of application for nitrogen on barani land, and the conditions under which phosphorus response is likely to be observed. Similarly, agronomic research should be undertaken on aspects of the maize-wheat rotation, since wheat is the main rabi crop, including P carryover and effects of maintaining a continuous maize-wheat crop rotation.

- With regard to policy, the development of an effective seed production and marketing system should be given top priority. This requires some important changes to develop an effective seed system, the lack of which is severely curtailing agricultural progress in the Swat mountains.

DIAGNOSING RESEARCH PRIORITIES FOR HIGHER-ALTITUDE MAIZE-BASED FARMING SYSTEMS IN SWAT

Introduction

With the vast diversity of agriculture in Pakistan, there are areas with poor resource bases and variable environments that continue to pose enormous challenges to agricultural development. Mountain agriculture, characterized by small farms, high variations in temperature, moisture and soils, and difficult access, constitutes one such challenging environment.

This paper reports results of research conducted in higher-altitude maize-based farming systems in the Swat mountains. Swat is the largest maize producing district in Pakistan. Much of this maize is grown in the Swat Valley, but a sizeable amount occurs at higher elevations adjoining the main valley. Considerable diagnostic and experimental work has been done for the valley (Byerlee, Sheikh, Khan and Ahmad 1987, Khan et al. 1986). In 1985, researchers, realizing that mountain environments represent a substantial proportion of Swat agriculture, began a maize research program in the Swat mountains.

Experimental results soon demonstrated that even less was known about the variable mountain agriculture than about the complex farming system of the valley. Therefore, in 1985, diagnostic work was extended to the mountains with a field-specific survey of maize production practices and yields in four catchment areas above 1500 m.a.s.l. This survey confirmed the impression of great yield variation in the area.

Maize is the one crop grown by nearly all farmers in the Swat mountains. It is a staple food, and maize fodder is important in livestock diets. This study will present more information on maize than on other crops or livestock. Both the maize production survey and subsequent experimentation, however, demonstrate the need to identify some of the larger interactions within the farming system in order to determine research priorities. Consequently, an informal survey of the mountain farming systems was conducted in March 1987, followed by a formal survey in June 1987.

Any dividing line between 'valley' and 'mountain' agriculture is arbitrary. Many features of agriculture in the main Swat valley (altitude 900-1300 m.a.s.l.) are found in the side valleys, changing gradually as altitude increases. There is comparatively little cultivated area high enough to be considered a 'single crop' zone. Much of the surveyed area, from the minimum altitude for this study of 1500 m.a.s.l. up to about 1950 m.a.s.l., can be regarded as a transition area from double cropping to single cropping. Using maps of Swat district (scale 1:50,000), we estimate cultivated area over 1500 m. comprises 35-45,000 ha. in the district, or about one quarter of the total for Swat.

Methodology and Survey Locations

Working in more difficult environments poses more than the usual tradeoffs between ease of generating information and representativeness. Sampled areas are shown in Figure 1. A truly random sample of all higher elevation agriculture would have proven too costly, because of difficult access. The areas surveyed for this study are all characterized by relatively easy road access for the mountain environment studied. The catchment areas chosen exemplify fairly striking distinctions in productivity, and cover much of the range in physical characteristics in agriculture in mountain areas of Swat. However, less accessible areas are likely to have less use of fertilizer, improved seed and other purchased inputs than those surveyed.

Details of the harvest survey are shown in Table 1. In this integrated agronomic-economic survey, field-specific information was collected regarding farmers' practices and yields. The latter measurement, along with measurement of other parameters such as harvest density and moisture, were based on crop cuts.

Table 1. Distribution of the Sample for the Crop-Cut Harvest Survey, 1985

Altitude Range (m.a.s.l.)	Sampling Area: Miandam	Shangla Par	Mallam Jabba	Sakhra	Total	Percentage
	(Number of Sampled Fields)					
1500-1599	1	1	7	6	15	15.3
1600-1699	3	10	5	3	21	21.4
1700-1799	12	-	6	8	26	26.5
1800-1899	8	-	6	3	17	17.3
1900-1999	4	-	8	-	7	7.1
2000 or more	4	-	8	-	12	12.2
Total	**31**	**11**	**34**	**22**	**98**	**100.0**

The farming systems survey of 1987 consisted of several parts. A comprehensive questionnaire was used to obtain information on farmer practices for maize, wheat and potatoes; crop rotations; livestock holdings and milk production; trends in wheat varieties, fertilizer use, and livestock numbers; grain production, consumption, and purchases; and off-farm occupations. Details of the sample for the farming systems survey are shown in Table 2. A subsample was interviewed to formulate a calendar for fodder use over the year.

Fig. 1 Map of the Survey Areas,
Swat District

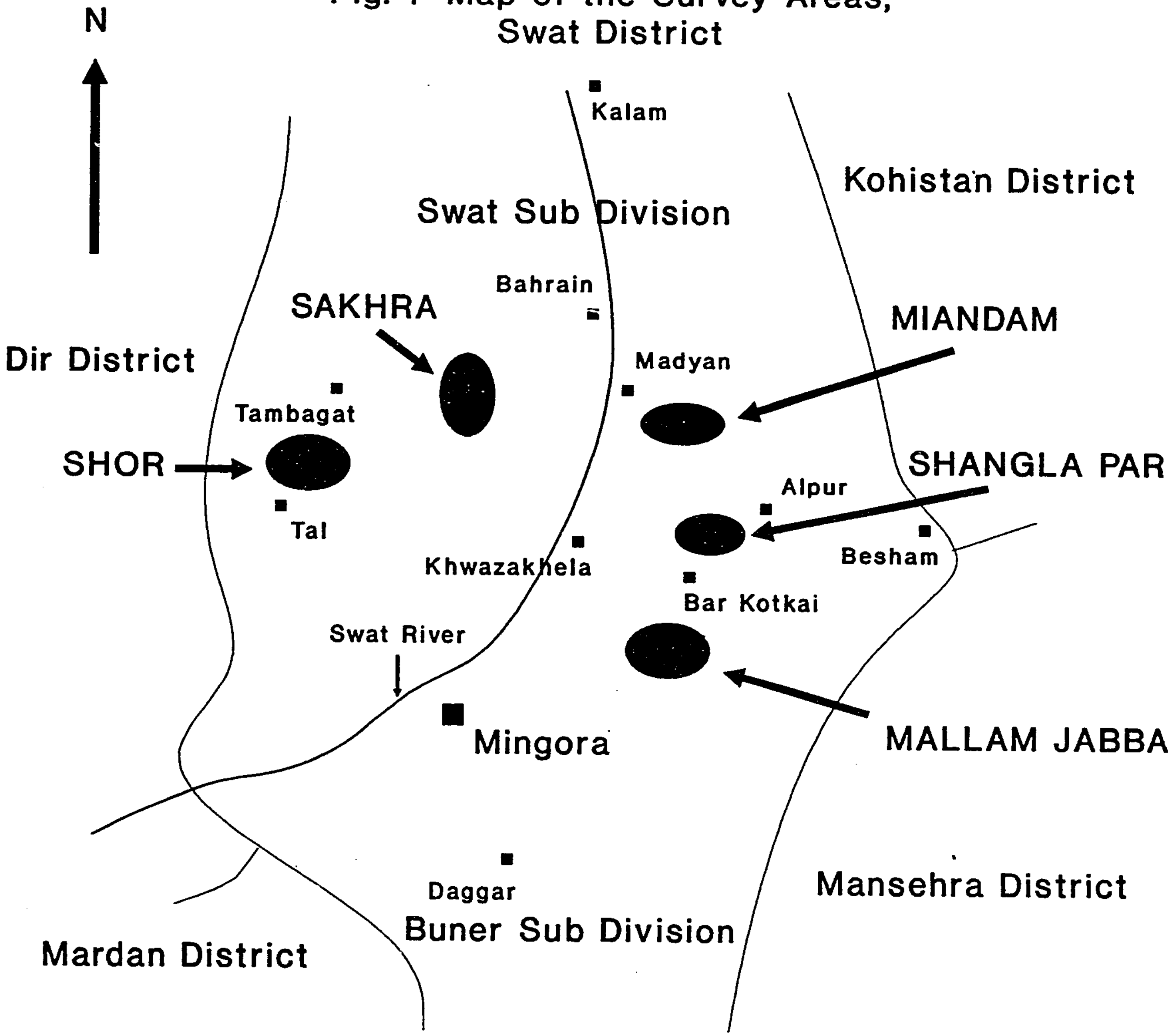


Table 2. Distribution of the Sample for the Farming Systems Survey, 1987

Altitude (m.a.s.l.)	Miandam	Shangla Par	Mallam Jabba	Shor	Sakhra	Total	Percentage
	Sampling Area						
	(Number of Sampled Fields)						
1500-1599	2	2	2	4	7	17	12
1600-1699	4	4	2	3	11	24	16
1700-1799	6	4	5	12	3	30	20
1800-1899	9	4	7	10	7	37	24
1900-1999	5	3	10	1	2	21	14
2000 or more	4	13	4	-	-	21	14
Total	**30**	**30**	**30**	**30**	**30**	**150**	**100**
Median Altitude	**1800**	**1950**	**1850**	**1700**	**1650**	**1800**	

In the farming systems survey, 44 percent of the sampled farmers (above 1500 m.) had at least some irrigated fields (Table 3). The table shows that in the five sampled areas, irrigation was concentrated in Miandam, followed by Sakhra. In the harvest survey, 48 percent of the sampled plots (above 1500 m.) were irrigated.

Table 3. Irrigation Status of Sampled Farmers, Farming Systems Survey, 1987

Sampled Area	Irrigated	Barani	Both
	(Percentage of Sampled Farmers)		
Miandam	40	10	50
Shangla Par	-	97	3
Mallam Jabba	20	60	20
Shor	23	63	13
Sakhra	33	50	17
Total	**23**	**56**	**21**

Altitude was measured using rotating dial, pressure-sensitive altimeters. Altimeters were set at known altitudes, taken from maps of Swat of scale 1:50,000. Readings were usually taken to the nearest 25 m.a.s.l. During the farming systems survey, particular efforts were made to reset altimeters with changing weather conditions, in an effort to improve the accuracy of altitude measurement.

Byerlee, Sheikh, Khan and Ahmad (1987) have noted some of the problems of recording information, notably on land area and timing of operations, peculiar to Swat. Obtaining accurate measurements of area is even more difficult in the mountains than in the valley, because of irregularly shaped terraces and variable slopes. Units of area are not known by most farmers. To estimate area, we gave first priority to areas stated by farmers, although only a minority of farmers could do this. Next, a wheat seed rate of 100 kg/ha was assumed. After this, the assumption was a potato seed rate of 1150 kg/ha. Finally, we attributed a maize seed rate of 70 kg/ha to land whose area could not be determined by any of the preceding means. This maize seed rate was based on the average for those farmers in the farming systems survey who cited actual areas.

We found the best approach to recording dates was to use the Pushtu equivalent of the Hijri, or Islamic lunar calendar. (In this calendar, for example, "Roza" is the equivalent of Ramadan.) If farmers knew the Hindi calendar familiar in other parts of Pakistan, or the English calendar, their response was recorded as such. Eventually all timing responses in the farming systems survey were translated to the English calendar.

Cropping Patterns and Seasonal Conflicts

Farm Size and Tenancy

Despite the difficulties in measuring areas, our estimates imply farms are generally very small in the Swat mountains. Sixty-two percent of the farmers sampled in 1987 farmed less than one hectare, and 80 percent less than 1.5 hectares. Farm size can be related to irrigation status; larger farmers tended to be those who held both irrigated and barani land. The median area for farmers with only irrigated land was .64, while that for farmers with barani land only was .8 hectares. For those farmers with both types of land, the median was 1.75 hectares.

In both surveys, fewer than 20 percent of the sampled farmers were tenants. Share tenancy can take two forms, 50-50 shares with greater tenant management, or an arrangement in which the tenant gets less. In this latter case, the tenant is in effect a laborer who is paid with a share of the produce. As in the valley (Byerlee, Sheikh, Khan and Ahmad 1987), tenancy arrangements in the mountains tend to give the cultivator a greater share in the fodder products of the land than in the grain.

Cropping Patterns and Altitude

All but one of the farmers interviewed in the farming systems survey grew maize (Table 4). Potatoes, which are the alternative kharif crop as well as a cash crop, were mainly grown in Miandam and Mallam Jabba, where 60 percent or more of the farmers grew them. Thirty percent of the farmers in the Shangla area grew potatoes, but the areas planted tended to be very small.

Wheat for grain was the most common rabi crop, grown by about half the sampled farmers in the 1986-87 rabi season (Table 4). This proportion of farmers growing wheat varied substantially by catchment area (Table 5). As might be expected, this partially reflects the different altitudes at which farmers interviewed in the five catchment areas were found (see Table 2).

Table 4. Crops Grown by Farmers, 1986-87, Farming Systems Survey

Farmers Growing Given Crop	Percentage
Maize--Kharif 87	99
Potatoes--Kharif 87	32
Wheat (Grain)--Rabi 86-87	49
Wheat (Fodder), Khid, Barley--Rabi 86-87	17
Shaftal, Berseem, Mustard--Rabi 86-87	6

Table 5. Median and Highest Altitude of Wheat Grown for Grain, Farming Systems Survey

	Percent who Grow Wheat	Median Altitude (m.a.s.l.)	Highest Altitude (m.a.s.l.)
Miandam	40	1700	1800
Shangla Par	13	1700	1950
Mallam Jabba	55	1775	1950
Shor	74	1725	1850
Sakhra	60	1600	1700
Total	48	1700	1950

Wheat for fodder, khid (wheat or barley mixed with clover or mustard, also sown for fodder), and barley were planted by 17 percent of the sampled farmers during the 1986-87 rabi season (Table 4). This was most common in Miandam, where the wheat variety Dirk was frequently grown by farmers with substantial numbers of livestock.

At lower elevations, shaftal (Trifolium persicum, or Persian clover) was sometimes grown as a rabi crop on irrigated land. In our sample of farmers 1500 m. and above, Sakhra is the only area where shaftal was widely grown. About one-quarter of the sampled farmers in that valley grew shaftal.

Table 6 summarizes the altitude ranges and median altitudes over which the major crops were grown on irrigated land in the farming systems survey. Table 7 does the same for barani land. Maize and potatoes were grown over the entire range, but potatoes were a slightly higher altitude crop. As expected, wheat for grain and shaftal were lower elevation crops. Wheat for fodder, khid, or barley tended to cover the same range as wheat for grain, although the median is somewhat higher than the median of wheat for grain on irrigated land.

Table 6. Altitude Ranges and Median Altitudes for Various Crops, and Irrigated Land, Farming Systems Survey

Crop	Altitude Range (m.a.s.l.)	Median Altitude (m.a.s.l.)	Number of Farmers
Maize	1500-2025	1710	64
Potatoes	1550-2025	1775	14
Wheat (Grain)	1500-1950	1650	42
Wheat (Fodder)/ Khid/Barley	1550-1925	1800	12
Shaftal/Berseem	1500-1725	1580	12

Table 7. Altitude Ranges and Median Altitudes for Various Crops, and Barani Land, Farming Systems Survey

Crop	Altitude Range (m.a.s.l.)	Median Altitude (m.a.s.l.)	Number of Farmers
Maize	1500-2200	1800	112
Potatoes	1500-2200	1900	42
Wheat (Grain)	1500-1950	1750	41
Wheat (Fodder)/ Khid/Barley	1550-1925	1750	15

Given the individual crops that enter into the system, it is useful to look at the more common rotations. Two-year rotations for irrigated land are shown in Table 8, and two-year rotations for barani land are shown in Table 9. These tables show the expected relationships between altitude and the likelihood of rabi cropping.

Table 8. Most Common Rotations, Irrigated Land, Farming Systems Survey

	Percentage of Farmers	Median Altitude
Wheat (grain)-maize-wheat (grain)-maize	35	1650
Fallow-maize-fallow-maize	27	1850
Wheat (grain)-maize-fallow-maize	18	1800
Wheat (grain)-maize-shaftal-maize	14	1560

n=66 farmers with irrigated land

Table 9. Most Common Rotations, Barani Land, Farming Systems Survey

	Percentage of Farmers	Median Altitude
Fallow-maize-fallow-maize	62	1850
Fallow-potato-fallow-potato	25	1900
Wheat (grain)-maize-fallow-maize	20	1700
Wheat (grain)-maize-wheat (grain)-maize	16	1760
Fallow-maize-fallow-potato	11	1875

n=114 farmers with unirrigated land

Cropping Intensity and Altitude

At higher altitude there is less likelihood that a rabi crop will be grown. It is also possible to look at this by considering cropping intensities. Cropping intensities were calculated separately for irrigated land and for barani land. In each valley, intensities on irrigated land were greater than on barani land (Table 10). We would like to test the independent effect of irrigation on cropping intensity. Aspect, or the direction the field faces, is likely to affect the possibility of rabi cropping. South facing slopes can be expected to have higher intensities as crops there receive more solar radiation. Information concerning aspect was collected during the farming systems survey, but since the interview schedule was not administered at a specific field, as in the harvest survey, this information proved highly unreliable and is not analysed here.

Table 10. Mean Cropping Intensities on Irrigated and Barani Land

Valley	Cropping Intensity on Irrigated Land	Cropping Intensity on Barani Land
Miandam	153	101
Shangla Par	...	115
Mallam Jabba	132	117
Shor	172	139
Sakhra	185	128
Total	160	121

... insufficient farmers to report result

The effect of altitude on cropping intensity is shown in Figure 2. Furthermore, at any given altitude, intensity on barani land was lower than on irrigated land. There appears to be some interaction between the two effects, as intensity decreased faster with increasing altitude on irrigated land than on barani land.

As hypothesized, larger farm size also reduced cropping intensity (Figure 3). The effect appears to be stronger on barani land than on irrigated land. At lower elevations, there was no difference between intensity on smaller and larger farms on irrigated land. Barani land belonging to smaller farmers was cultivated more intensively than larger farmers' barani land over all altitudes.

A more complete regression analysis of the combined effects of altitude, irrigation, farm size, and animal numbers on cropping intensity is shown in Table 11. Altitude, irrigation, and farm size have highly significant, expected effects. The interaction term between irrigation and altitude is also significant, again implying that intensity on irrigated land decreases more rapidly with altitude. On the other hand, the interaction between irrigation and farm size does not appear to be very strong. Intensities may be slightly higher on farms with draft power or with more animals (and thus more farmyard manure), but this effect is also relatively weak.

Taking farm size and animal numbers at the medians for the sample, the regression equations imply that a 100 m increase in altitude reduces intensity by about 17 points on irrigated land and by about 8 points on barani land. Alternatively, at 1500 m.a.s.l. irrigated land is almost sure to have two crops a year; barani intensity is around 145. At 1900 m.a.s.l. the index of cropping intensity on rainfed land is predicted to be just over 100.

Fig. 2 Cropping Intensity by Altitude For Irrigated and Rainfed Land

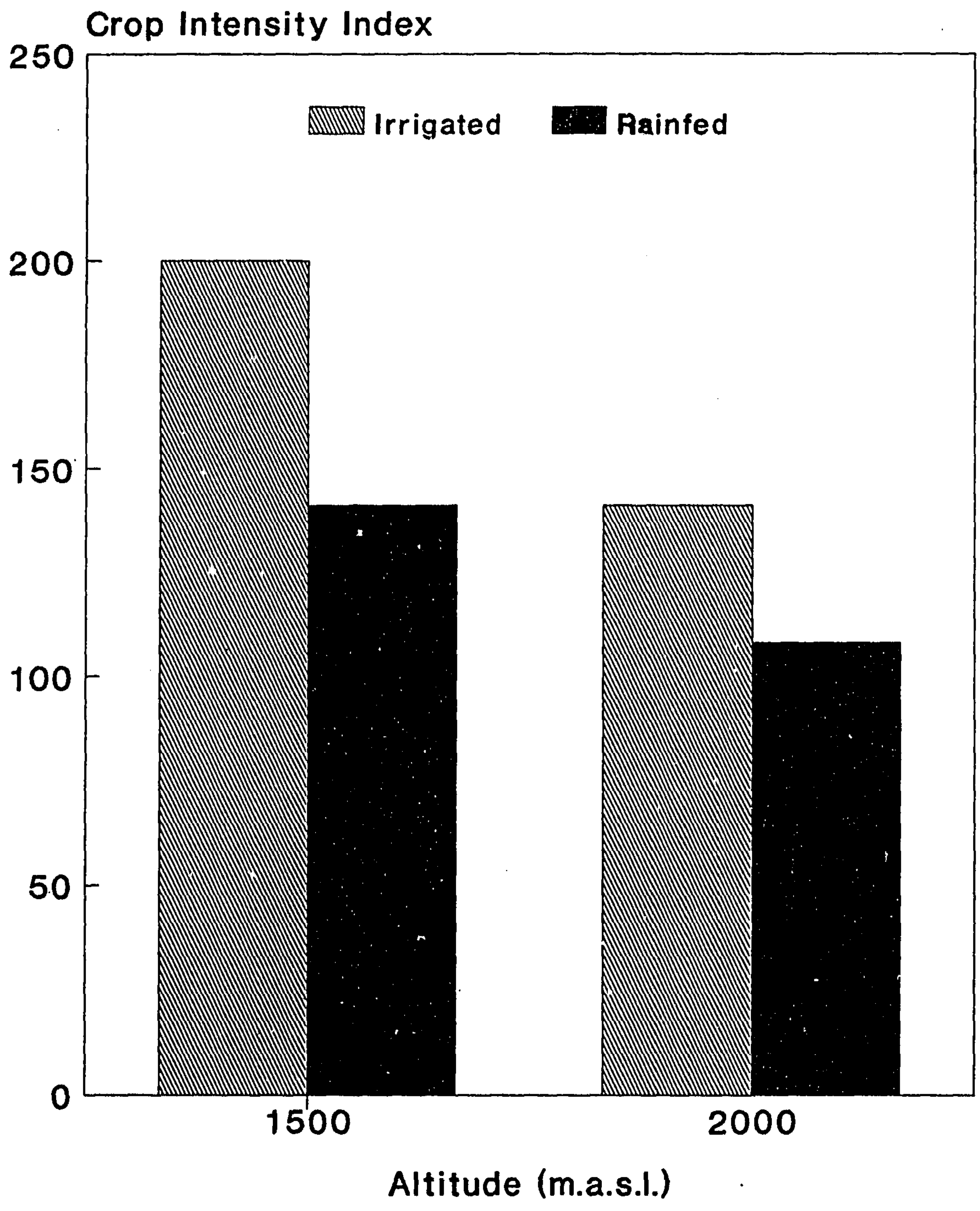


Fig. 3 Cropping Intensity by Farm Size
For Irrigated and Rainfed Land

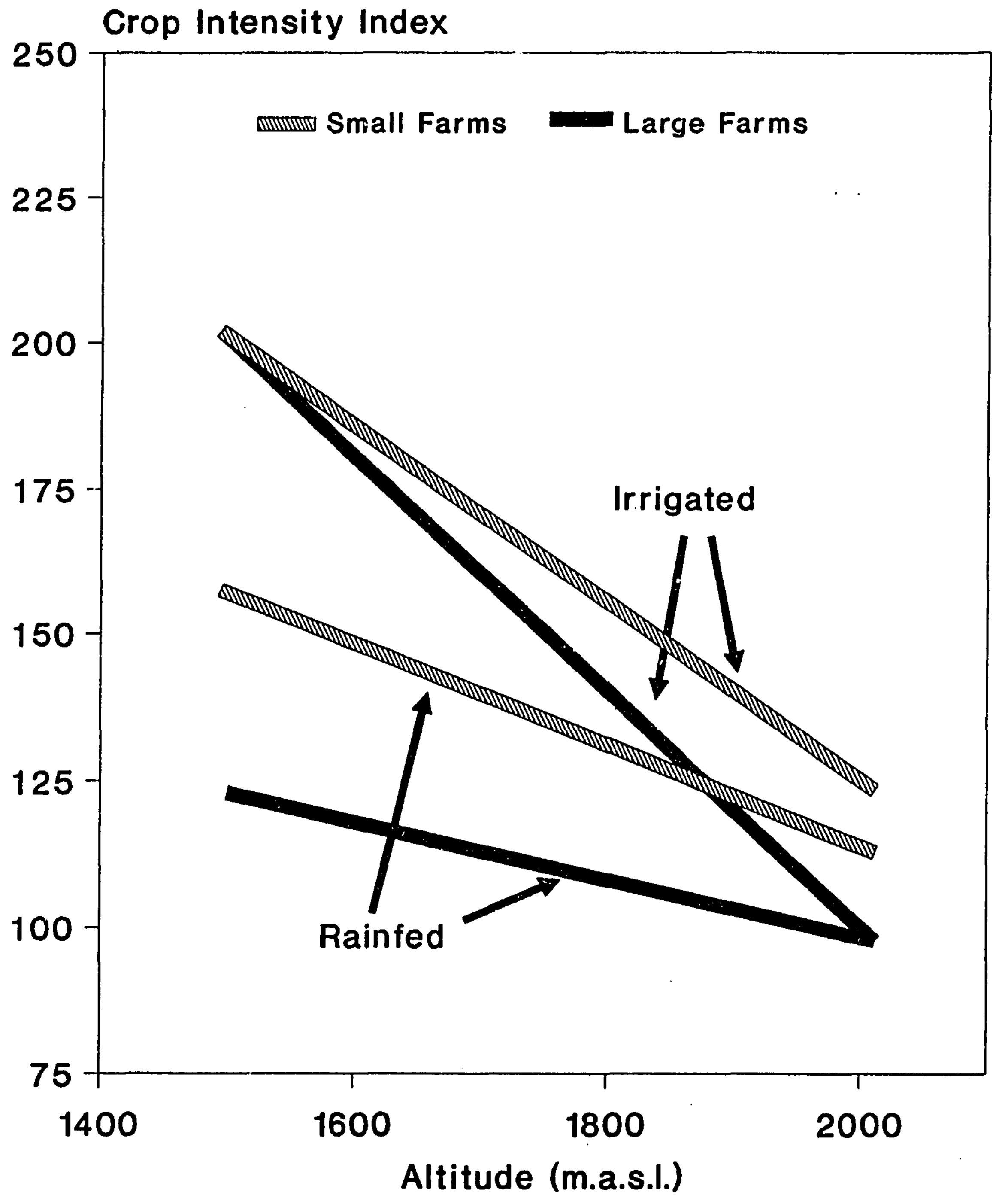


Table 11. Regression Analysis of Cropping Intensity Swat Mountains

Dependent Variable is Total Cropping Intensity

Independent Variables	Equation (1)	(2)	(3)
Altitude (m.a.s.l.)	-0.7555 (-3.42)***	-.0766 (-3.39)***	-0.750 (-3.30)***
Irrigation Dummy	203.2 (2.89)***	207.7 (2.96)***	203.8 (2.90)***
Log (Farm Size)	-13.7 (-3.59)***	15.8 (-3.88)***	-14.7 (-3.77)***
Animal Units (Weighted)		1.12 (1.46)	
Dummy for Ownership of one or More Bullocks			7.28 (1.25)
Interaction Irrigation x Altitude	-0.972 (-2.44)***	-.0999 (-2.51)***	-.0974 (-2.45)***
Interaction Irrigation x Log (Farm Size)	5.37 (.960)	5.63 (1.01)	5.37 (.960)
Constant	261.0	253.6	252.4
R^2 (adjusted)	.353	.357	.355
n	177	177	177

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

[a] Average of two years. Farmers with both irrigated and barani land are counted twice; once using intensity on their irrigated land and once using intensity on their barani land.

Rotational Constraints

The results suggest that the entire sampled area from 1500 m.a.s.l. up to about 1950 m.a.s.l. is a transitional zone between double and single cropping. A kharif crop is nearly always grown; increasing altitude and lack of irrigation decrease the likelihood of a rabi crop and therefore lead to lower cropping intensity. Though rabi fodder may be grown, the most common rabi crop is wheat for grain, a crop that has been increasing in area over the past two decades. Given the cool temperatures, rotational constraints in fitting a rabi crop are particularly severe. However, the advent of shorter duration high-yielding varieties of wheat has shifted the barrier to double cropping to a higher altitude (Appendix A).

The rotational constraint operates primarily in the turnaround from wheat to maize. In the fall of 1986, farmers in the farming systems survey growing wheat for grain reported a median turnaround time from maize to wheat of three weeks. This turnaround time did not appear to be related either to altitude or the farmer's perception of whether his maize variety matured early or late.

To sharpen the picture of this constraint for maize planted following wheat harvested for grain, we turn to data from the field-specific 1985 harvest survey. Regression results indicate that higher altitude appears to be associated with earlier planting date; planting after wheat seems to be related to a delay of almost three weeks in planting maize as compared to planting after fallow; planting maize after fodder delays planting 10 days compared with planting after fallow; and planting on fields with a southerly aspect appears to make planting a week later (Table 12, first column). It was also hypothesized that maize planting would be earlier on irrigated fields, but regression coefficients for an irrigation dummy were insignificant.

The effect of altitude on planting date should differ in sign, however, depending on whether the maize crop is planted after wheat, when we expect it to be positive, or after fallow, when we expect it to be negative. After fodder we might also expect the effect of altitude to be negative, as fodder cutting can be varied more than the harvesting of wheat grain.

The regressions reported in 2-4 columns of Table 12 confirm this hypothesis. After fallow, a 100 m increase in altitude tends to make maize planting two to three days earlier; after fodder, a 100 m increase in altitude makes maize planting eight days earlier. After wheat for grain, there is a slight tendency (the t-statistic has a probability level of 0.08) for maize planted after wheat to be planted half a week later for every 100 m increase in altitude. Experimental data from Azad Kashmir indicate an approximate increase of one week in maturity for wheat for every 100 m. increase in altitude, over the range 1300 to 1700 m. (Stevens et al. 1988).

After fallow or fodder, maize planted on southerly slopes may be planted five days to a week after maize on non-southerly slopes. After wheat, aspect appears to have little effect on maize planting dates. These regressions imply that on average in 1985, at 1500 m.a.s.l., maize planted after wheat would have been planted during the first week of June, about a week after maize planted after fallow but considerably earlier than maize planted after fodder. Planting date for maize after wheat at 1700 m.a.s.l. would be 20 days later than for maize following fallow and five days later than for maize after fodder. At 1900 m.a.s.l., these gaps would increase to 32 days and 28 days, respectively (Figure 4).

Fig. 4 Effect of Altitude on Maize Planting Dates for Main Crop Rotations

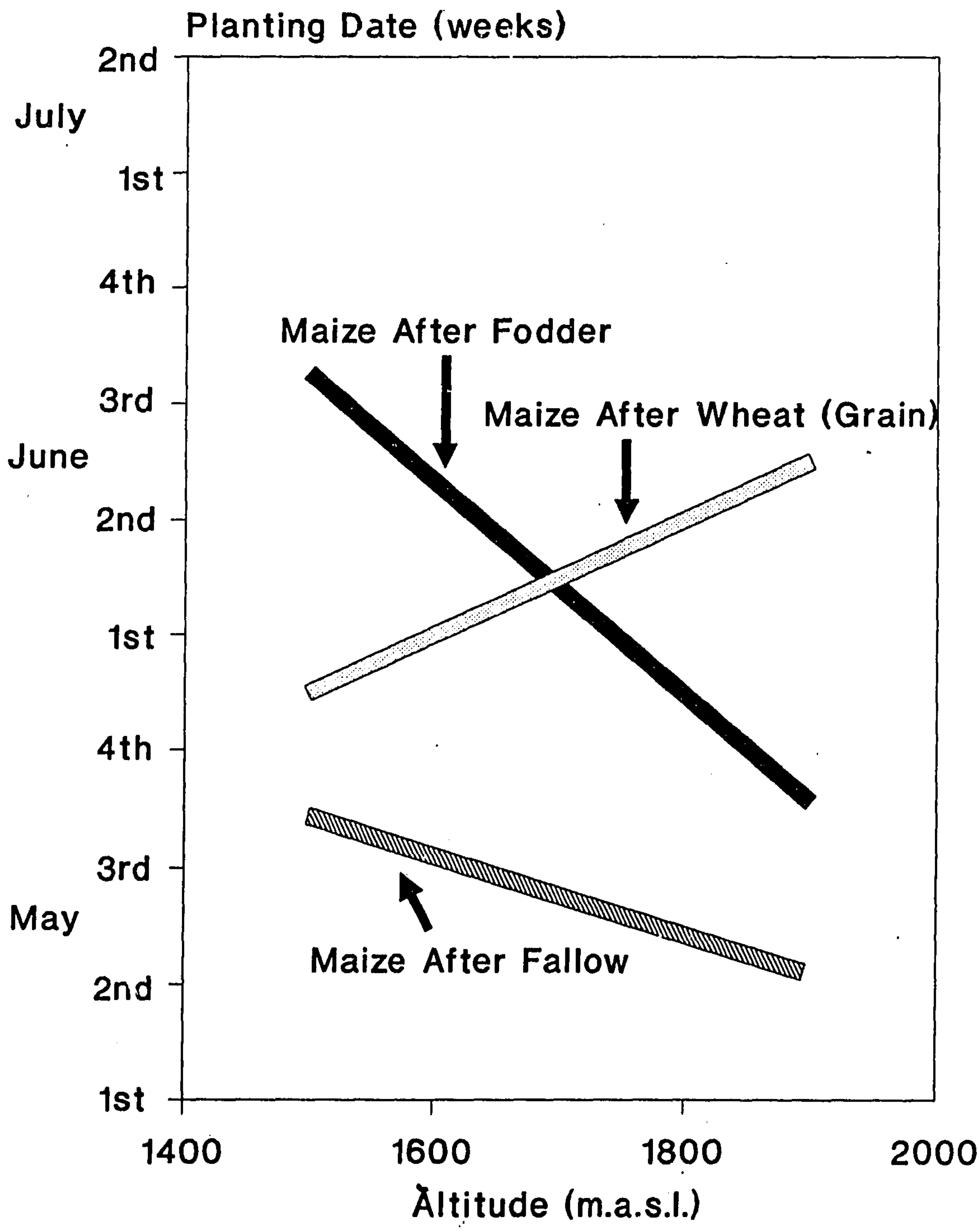


Table 12. **Regression Analysis of Planting Dates for Maize, 1985 Harvest Survey**

Dependent Variable is Planting Date[a]

Independent Variables	All Fields	After Fallow	After Fodder/ Barley	After Wheat (Grain)
Altitude (m.a.s.l.)	-.00369 (-3.33)***	-.00364 (-3.44)***	-.01141 (-2.85)***	.00520 (1.50)
Southerly Aspect	.644 (1.74)*	.709 (1.52)	1.04 (1.29)	-.243 (-.330)
Previous Crop Wheat (grain)	2.83 (5.65)***			
Previous Crop Fodder/Barley	1.50 (3.41)***			
Constant	12.4	12.3	27.3	1.05
R^2 (adjusted)	.453	.210	.195	.016
n	96	46	28	22

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

[a] 1=first week April; 2=second week April; etc.

The Role of Livestock

Livestock play an important role in the mountain farming systems of Swat. They are a source of milk and milk products, meat, and cash income. Income in kind from livestock is particularly important to the predominantly small farmers in the mountain areas of Swat. Livestock provide security against uncertainty in crop production and crop failure, particularly under rainfed conditions. In addition to complementing off-farm income and crops as income sources, livestock provide the direct inputs of draft power and farmyard manure to crop production.

Livestock Numbers, Animal Land Ratios, and Livestock Composition

Dairy animals predominate in the livestock holdings of farmers in the Swat Mountains. Summary statistics for livestock are presented in Table 13. Forty-five percent of all the buffaloes and 49 percent of all the cows were reported to be lactating at the time of the farming systems survey in June, 1987, a very low ratio of lactating: dry animals. Very few farmers have sheep and goats, although nomadic herdsmen with small stock exploit higher altitude grazing areas in Swat.

Along with Table 13, Figure 5 shows the distribution of livestock numbers by livestock type. Buffaloes appear to be slightly more uniformly distributed than cows or bullocks. Among the farmers in the farming systems survey, farmers who can increase their herd sizes tend to do so by increasing the number of buffaloes they own. In informal interviews, however, farmers indicated that the first type of animal they would buy given relaxed fodder constraints would be a bullock. This reflects the fact that most farmers did not have a complete plow team.

Table 13. Livestock per Farm in the Swat Mountains, Farming Systems Survey

	Percentage Farmers with Given Livestock Type	Average Numbers (All Farmers)	Median Numbers (All Farmers)
Buffaloes	61	1.5	1.0
Cows	57	1.0	1.0
Young Stock	71	1.4	1.0
Bullocks	53	.9	1.0
Sheep/Goats	14	.3	.0
Total Animals Units[a]	92	4.9	4.0

[a] Calculated with the following weights: buffaloes 1.5, cows and bullocks 1.0, young stock 0.5, sheep and goats 0.25.

Livestock composition and animal-land ratios depend upon the needs of the farm household, altitude, irrigation status, farm size, and topography, among other factors. These factors are also largely responsible for differences in animal holdings and herd composition by survey area. In the discussion that follows, the difficulties in obtaining accurate land measurements apply to animal-land ratios, and previous warnings hold.

The effects of altitude, farm size, and irrigation on herd size and composition are summarized in Table 14. In the first regression, the dependent variable is total animal units. In the second, the dependent variable is total animal units per hectare of cultivated land. In the third, the dependent variable is constructed by dividing buffalo numbers, weighted by 1.5, by total animal units. This is one measure of the importance of buffaloes in herd composition. In the final regression, the dependent variable is the percentage of buffaloes to total adult dairy animals.

Fig. 5 Distribution of Livestock on Holdings in Swat Mountains

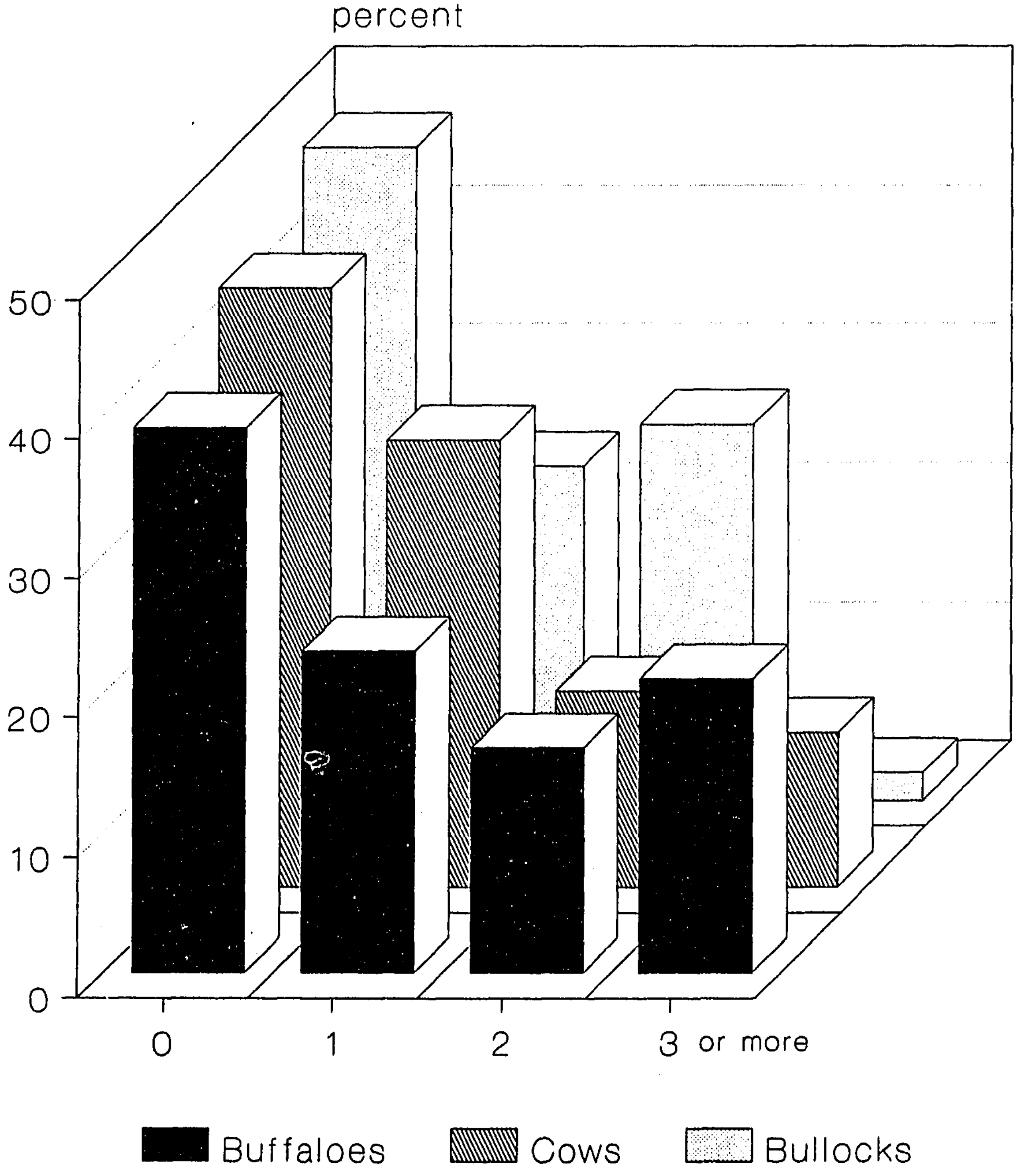


Table 14. Regression Analysis of Herd Size and Composition, Swat Mountains

Independent Variables	Total Animal Units	Total Animal Units Per Ha	Buffalo Animal Units as a Percentage of Total Animal Units	Buffaloes as a Percentage of Adult Dairy Animals
Altitude (m.a.s.l.)	-.00116 (-.64)	-.00701 (-2.60)**	-.000218 (-1.23)	-.000315 (-1.3)
Log (Farm Size)	1.75 (5.70)***	-3.45 (-7.59)***	.0624 (2.15)**	.0824 (2.16)**
Irrigation Dummy	.161 (.269)	.374 (.423)	.137 (2.39)**	.145 (1.89)*
Constant	7.01	18.0	.708	1.04
R^2 (adjusted)	.185	.296	.103	.086
n	148	148	136	132

Increases in altitude reduce the animal-land ratio, as expected, because of declining annual crop and fodder production per hectare with altitude. Increasing altitude also tended to lower the ratio of buffaloes to total animals or to dairy animals. Generally, large farms have more animals, but lower animal-land ratios.

Farmers who have some irrigated land do not have significantly more total animals or significantly higher animal-land ratios. However, farmers with some irrigated land tend to have higher proportions of buffaloes in their herds. Buffaloes require more green fodder than other large animals and are least dependent on grazing of all the livestock types encountered in the Swat mountains. The greater productivity of irrigated fields allows a greater concentration of buffaloes.

Farmers were asked about livestock numbers in 1987 compared to 10 years earlier. Ninety-seven percent of the farmers responding stated that livestock numbers had decreased. The major reasons given for reduction in livestock numbers were fodder problems, income or cash constraints, and less available grazing (Table 15). Grouping the various categories shows the clear dominance of feed-related constraints (fodder and grazing), followed by low income (poverty and cost of animals).

Table 15. Reasons for Perceived Decreases in Livestock Numbers, 1977-1987

	Percent of farmers
Fodder Problems	60.6
Short of Cash/Poverty	18.2
Less Grazing	9.8
Labour problems	5.3
Disease problems	2.3
Animals too costly	2.3
Other	1.5

Draft Power

Bullock ownership was related, as expected, to increasing farm size. In the farming systems survey, only 53 percent of interviewed farmers had bullocks and only 29 percent had two or more bullocks. Despite the fact that a majority of farmers in the surveyed areas did not have a complete team, most farmers used bullocks for land preparation. In most areas terraces are small, steep and relatively inaccessible, making tractor cultivation impractical. Farmers who did not have a complete bullock pair exchanged with other farmers or borrowed bullocks. Informal interviews did not indicate cash payment for borrowed bullocks. This lack of a formal rental market for bullocks conforms with other evidence from South Asia (Bliss and Stern 1982, Binswanger 1978).

Income From Animals

Cash Income: Livestock and livestock products contribute to the subsistence requirements and cash needs of the farming community in the study area. Subsistence production and the crop inputs of farmyard manure and draft power are probably more important than cash income. Only nine percent of surveyed farmers named livestock as their most important source of cash income, which ranked it a distant third behind off-farm income and crops.

If livestock alone were considered, sale of stock was ranked as the most important source of cash income by a large majority of farmers (Table 16). In all survey areas at least 60 percent of all farmers ranked either sale of old animals or sale of young stock as the most important source of livestock cash income. Production of milk and milk products appeared to be limited by supplies of fodder and therefore milk was used primarily for home consumption.

Milk Production: Although most cannot produce surplus milk, production of milk and milk products for home consumption is highly valued. Among other things, milk yield varies with type of animals (buffaloes or cows); fodder and feed supplements to which the animals have access; season, which is highly correlated with fodder availability; and point in the lactation cycle. Even in the surveyed catchments with the highest estimated milk production, average milk production was below the desired levels of 6 kg/day (mean for the entire lactation) for a 350 kg buffalo and 4 kg/day (mean for lactation) for a 250 kg cow, calculated by Coop (1987, personal communication) (Table 17). Milk production was higher in catchments with more irrigated land, and farmers with only irrigated land estimated higher milk production than farmers with only barani land (Figure 6).

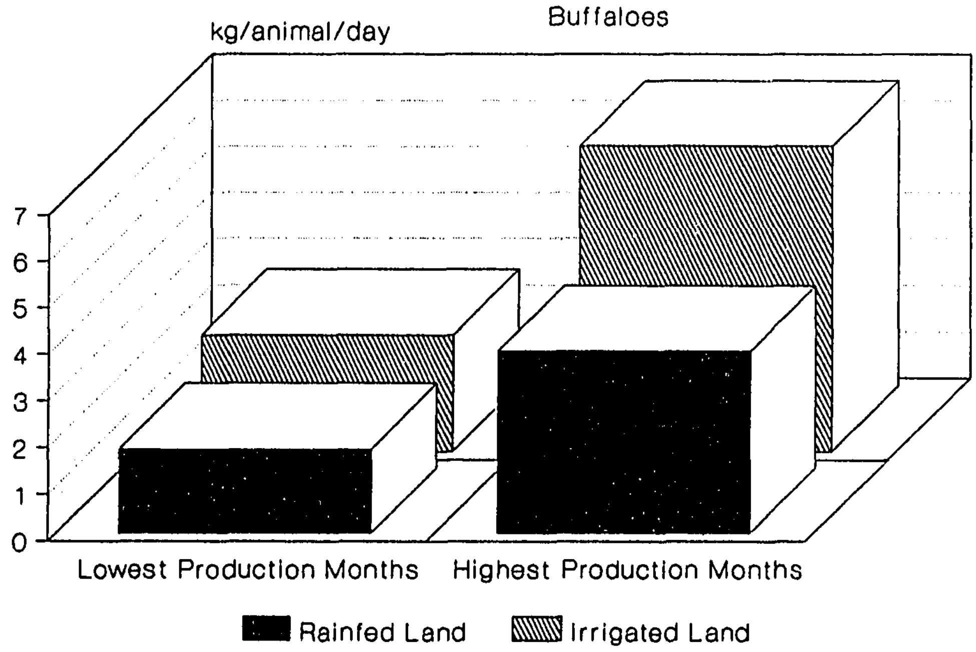
Table 16. Most Important Source of Cash Income from Livestock and Livestock Products, 1987 Farming Systems Survey

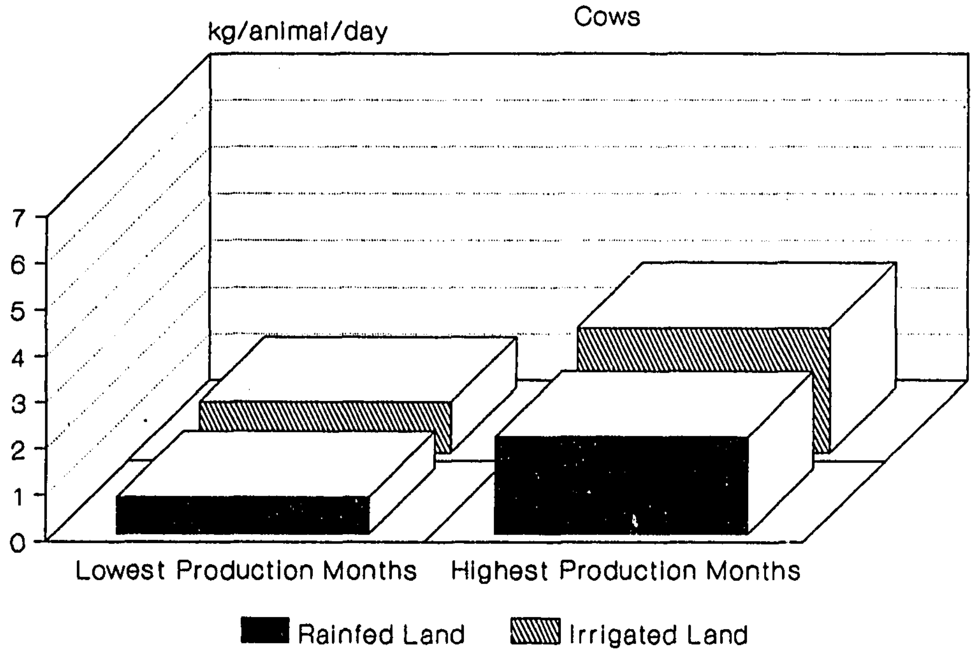
	Income Source			
Valley	Sale of Milk	Sale of Ghee	Sale of Old Animals	Sale of Young Stock
	(percent of farmers)			
Miandam	35	-	43	22
Shangla Par	-	19	59	22
Mallam Jabba	7	-	54	39
Shor	22	-	37	41
Sakhra	7	-	78	15
Total	14	4	54	28

Table 17. Mean Milk Production Per Day, Dummy Months of Lowest and Highest Production, 1987 Farming Systems Survey

	Months of Lowest Production	Months of Highest Production
	kg/animal/day	
Buffaloes	2.4	5.4
Cows	.9	2.3

Fig. 6 Milk Production on Irrigated and Rainfed Land, Swat Mountains





Seasonal variation in milk production is shown in Figure 7. For each month, mean estimates of milk production in lowest and highest months were weighted by the percentage of farmers stating it was a month of low or high milk output. Highest milk yield was reported for the months of June through September when fodder is abundant. Lowest production occurred from December through March, when there is intense cold and little green fodder is available.

Other Livestock Products: Farmers in the Swat mountains also use meat, wool, and skins from livestock, but usually manage livestock for milk and draft production. Red meat is seldom consumed, except for religious ceremonies. However, many farmers keep chickens for poultry meat.

Fodder Use

During the farming systems survey, less formal interviews with a subsample of 25 farmers (five in each survey area) were used to develop a fodder calendar (Figure 8). The most important general sources of fodder are non-cultivated weeds and grass, and cultivated maize. Weeds and grass are used as green fodder, cut from both crop fields and hillsides. Animals also graze both fallow and non arable land, but cut fodder tends to be more important in rainfed areas. In these areas, dry grass is an extremely important source of dry fodder. Cultivated maize is also a highly important source of fodder, through green maize thinnings and dry maize stover.

Starting in April, weeds and grasses begin to germinate. After the monsoon rains begin, weeds and grasses are abundant and they remain so up to October. From March to May, farmers in lower elevation, irrigated areas also use shaftal or khid as green fodder, mixed with dry grass and bhusa. We have seen the generally higher milk production and greater emphasis on buffaloes in the valleys where shaftal or khid are fed at lower elevations.

About four to six weeks after maize planting, thinnings from maize fields become an important source of green fodder. However, maize thinning may be somewhat less intensive than in the Swat valley. This is probably because dry stover from maize is a more important feed in the mountains. Maize density management and thinning practices are discussed further below.

As the season progresses, farmers begin to store dry grass for the winter, and after the maize harvest in late September and early October, dry maize stover is also stockpiled. As noted, dry fodder predominates in the winter months from November to February or March. The fodder calendar confirms that the months of greatest fodder shortage are March and April. During these months stocks of dry fodder have been drawn down and green fodder is generally not available in sufficient supply. Generally, fodder limitations on the number of animals that can be kept come from the availability of winter, not summer fodder (Barth 1956, see also "The Role of Livestock", above).

Fodder fed to cows does not differ substantially from that fed to buffaloes, but supplementary feeding of oilseed cake and flour is more restricted to the winter months for cows than for buffaloes. Amounts fed to cows also tend to be lower. Even for buffaloes, the maximum amount of concentrates fed in the winter months tends to be about 2 kg/animal/day, lower than the amount of 3 kg/animal/day reported for the barani areas of northern Punjab by Sheikh et al. (1988). Finally,

Fig. 7 Seasonality in Estimated Milk Production in the Swat Mountains

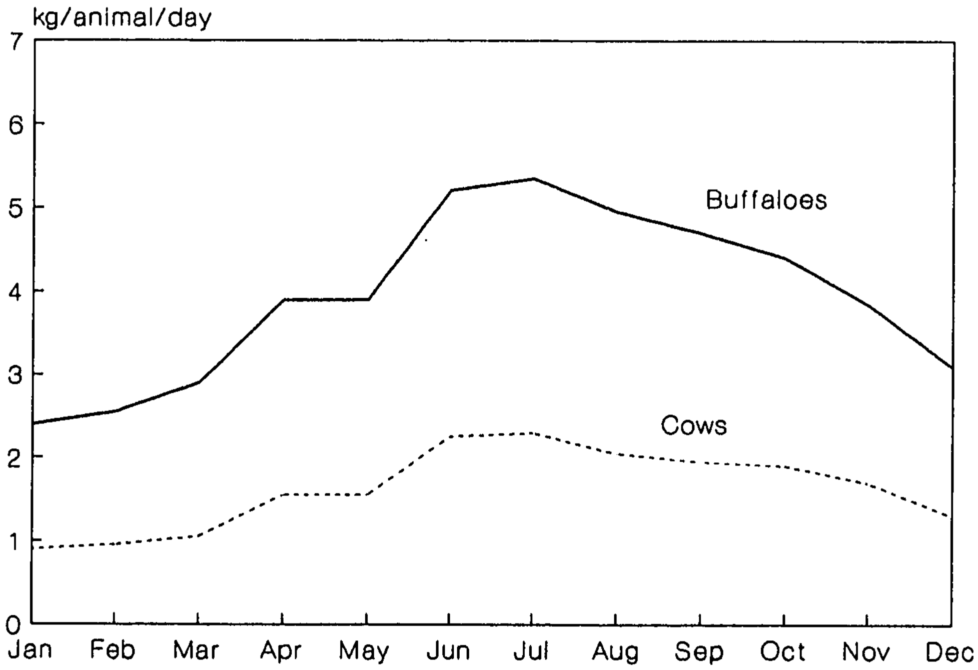
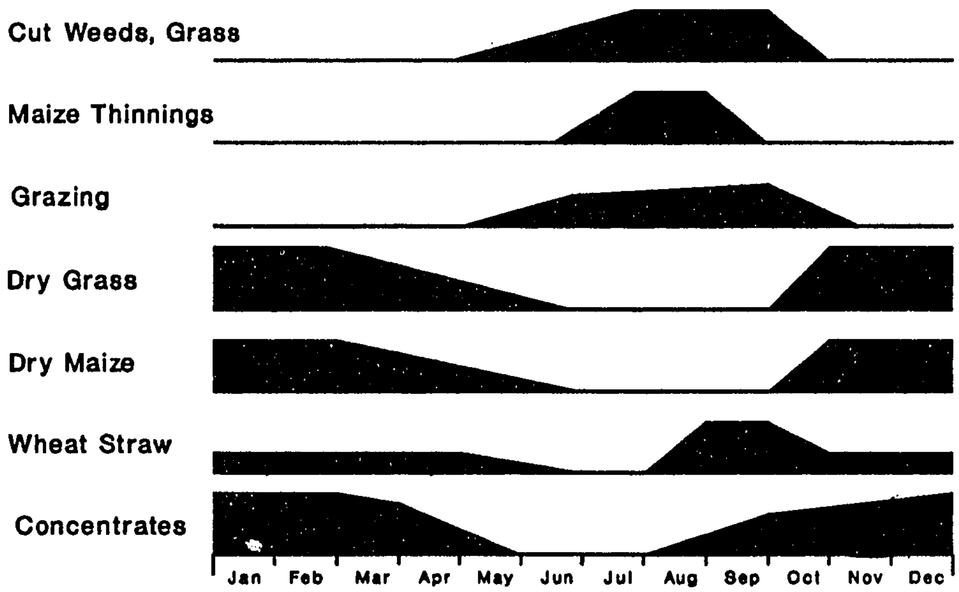


Fig. 8 Seasonal Patterns of Feed Supplies in the Swat Mountains



there may be some extra-seasonal variations in feeding, particularly of supplements, with higher amounts fed to lactating animals. During primary cultivation, working animals may also be fed more.

Comparing the fodder calendar to the hypothetical milk production curve (Figure 7), it is obvious that availability and use of green fodder is closely related to milk production levels. The somewhat lower level of protein in dry fodder may be a major constraint to higher milk production. Working with figures on energy and protein supplied by Coop (personal communication), and very rough estimates of total dry matter productivity from our data, we estimate that a farm of one hectare in the Swat mountains could support slightly under 3 buffaloes or slightly over 4 cows if irrigated, and just under 2 buffaloes or just under 3 cows if rainfed. Even under the best of circumstances, however, diets of lactating animals do not generally appear to contain more than 10-11 percent protein, compared to the 15 percent recommended by Coop. They also suffer from lower levels of energy than recommended.

Maize Management

Variety

Farmers usually have their own names the for maize varieties they grow, which are mostly white, and mid- to full-season materials. Duration lengthens by two to three days for every 100 m. increase in altitude, complicating the classification of varieties by maturity. Farmers who called their varieties "late" rather than "early" tend to grow maize at higher altitudes. The farmers' knowledge of improved open-pollinated material is limited, though some improved germplasm has penetrated into the mountains, often mixed with local germplasm. Table 18 summarizes the maize varieties which farmers stated they were growing in the two surveys.

Table 18. Maize Varieties Grown by Farmers, Harvest Survey and Farming Systems Survey

Variety	1985 Harvest Survey[a]	1987 Farming Systems Survey[b]
	(Percentage of farmers)	
Improved or Mixed Local and Improved	5	12
Local Maize	77	79
Local Yellow	8	6
Other (Mainly Mixed White and Yellow)	10	3

[a] n = 98
[b] n = 148

Early maturity is an important characteristic that farmers seek in their maize variety, particularly where the wheat-maize rotation is followed. Farmers may prefer an earlier-maturing maize over an earlier maturing wheat, as the maize may take better advantage of the increased heat units during its growing period. Furthermore, given the trend towards increasing wheat consumption (see below), farmers may be willing to sacrifice some maize grain yield by using an earlier maize variety. Disease resistance is also important; farmers in Mallam Jabba with whom trials were grown in 1985 liked the maturity characteristics of the improved variety Azam, but noted its greater smut susceptibility (Khan et al. 1986).

Planting Date

Both the harvest survey (1985) and the farming systems survey (1986 and 1987) indicated maize planting dates that ranged from early April to early July, with a median date of the third or fourth week of May. Maize planted after wheat for grain is planted late, with the gap between maize after wheat and maize after fallow or fodder increasing as altitude increases. Maize planted after fodder is planted later than maize after fallow at equivalent altitudes, but this gap decreases as altitude increases, since cutting fodder may be more flexible than harvesting wheat. Fields with a southerly aspect may make it possible to plant maize later.

Another important factor affecting planting date, soil moisture, is not captured as well in our data. Most farmers planting on barani land will not plant until there is adequate moisture from rainfall. By May there has usually been enough rain to encourage planting. Planting with acceptable moisture also lessens the likelihood of cutworm attack. In dry years, when farmers have to plant under less than optimum moisture conditions, insect attack is greater.

On irrigated land, pre-irrigation tends to delay maize planting. Generally, however, irrigation had little effect on planting dates for maize.

Land Preparation and Seed Incorporation

Nearly all farmers in the 1985 harvest survey used bullocks for land preparation and seed incorporation. Farmers made one to three passes before broadcasting seed, with another pass for incorporation after broadcasting. There were slightly more ploughings on irrigated fields (mean of 3.3) than on barani fields (2.8). The previous crop also influences the number of ploughings. After a fodder crop, more land preparation is required to create an adequate seedbed for maize, particularly on irrigated land. After wheat, since time is limited, there is a tendency towards fewer ploughings.

Seed Rate

Seed rate is extremely difficult to determine in the Swat mountains. In the harvest survey, for those few farmers who indicated plot area, seed rates ranged from 50 to 250 kg/ha, with a mean of 148 kg/ha. Results of the farming systems survey also suggested variable seed rates. Different rates reflect differences in moisture conditions at planting and farmers' density management strategies. More information on seed rates, based on physical measurement, would sharpen understanding of farmers' management strategies.

Fertilizer

Most farmers use chemical fertilizer, and use it on maize. Urea is the most common fertilizer, although ammonium sulphate is often used as top dressing. The major source of phosphorus is DAP. In the harvest survey, about half of the farmers indicated they had applied phosphorus to the sampled maize plot, a somewhat higher estimate of phosphorus use than obtained from the farming systems survey.

Rates of fertilizer application are no more reliable than estimates of area of land. Estimates in this section must be treated with considerable caution.

The results indicate that farmers used an average of 100 kg/ha nitrogen (106 kg/ha for only those using) and an average of 36 kg/ha phosphorus (67 kg/ha for only those using). Application rates varied widely by sampling area, reflecting both differences in actual use and different biases in estimating land area.

Generally, farmers tend to apply more nitrogen to irrigated land, and more nitrogen to maize planted after a rabi crop (wheat or fodder) than to maize planted after fallow (Table 19). On barani land, clearly more nitrogen is applied after a rabi crop, while on irrigated land, the difference is smaller.

Table 19. Application of Nitrogen to Maize, 1985 Harvest Survey

		Irrigated (kg/ha N)	Barani (kg/ha N)
Previous Rabi Cycle	Crop	138	112
	Fallow	103	59

Since only some farmers use phosphorus, and since actual application rates are subject to a great deal of measurement error, attempting to understand why a given farmer does or does not apply phosphorus may be preferable to analyzing application rates. Table 20 indicates the results of a probit regression for phosphorus application in the harvest survey. This suggests farmyard manure and phosphorus may be substitutes. The greater the rate of FYM application, the less likely the farmer was to use phosphorus. On the other hand, whether the field was irrigated or not appeared to make no difference to the probability of phosphorus use.

Table 20. Probit Estimation of Likelihood of Phosphorus Use, Maize Harvest Survey, 1985

Dependent Variable is USEP	1	if farmer applied phosphorus to maize
	0	if farmer did not apply phosphorus
Independent Variables	**Coefficient**	**Asymptotic t-value**
Constant	.702	2.00**
FYM (maunds/ha)	-.00891	-1.76*
Irrigation dummy	.220	.420
Dummy for maize after a rabi crop	.746	1.56
Miandam dummy	-1.88	-3.34**
Shangla dummy	-1.43	-2.13**
Sakhra dummy	.767	1.12
N = 75		

Hypothesis that non-constant coefficient jointly have no effect rejected at significance level .000.

***, **, and * indicate significance at .01, .05, and .10 levels, respectively.

Plant Density Management

The evidence suggests that farmers use much higher seed rates than the general recommendation (Byerlee and Hussain, 1986). One reason for the use of higher seed rates is the use of the broadcast planting method. In contrast, maize recommendations have been for line sowing.

Another reason is that maize is managed as a dual purpose crop, for grain and fodder as at lower elevations, (Fischer and Javed 1986, Byerlee, Iqbal and Fischer 1987). An additional reason is insurance against cutworm attack and drought. In 1985, for example, severe insect attack in Mallam Jabba was not accompanied by an equally severe problem in the valley (Khan et al. 1986). Finally, there is another explanation of high plant density unique to higher elevations. For physiological reasons, maize tolerates higher densities with increasing altitude (Fischer 1986, personal communication). This tolerance may be related to greater light availability, less daytime heat stress, and arrested respiration with lower night temperatures. We expect that in mountain agriculture, it is often difficult to calculate "optimal" density, since this will increase over an altitude sequence.[1]

About three weeks after planting, farmers either hoe, seel (perform interculture with a desi plow) or both. These operations tend to be substitutes for each other (Table 21). In addition to controlling plant density, these practices control weeds and aerate the soil, but density control is the most important motivation.

Table 21. Relationship Between Seeling and Hoeing (percentage of all surveyed farmers)

		Hoeing No	Hoeing Yes
		1985 Harvest Survey	
Seeling	No	22.4	60.2
	Yes	16.3	1.0
		1987 Farming Systems Survey	
Seeling	No	2.7	65.5
	Yes	18.2	13.5

In 1985, farmers were asked whether they thought their harvest densities were too high, too low, or about right. Fourteen percent of the farmers thought their harvest densities were too low. Sixty-seven percent thought they were about right. Eighteen percent of the farmers thought their harvest densities were too high. The median densities for these three groups were 72,000, 86,000, and 102,000 plants/ha, respectively.

Soon after seeling or hoeing, farmers further reduce densities by thinning weak, barren or diseased plants by hand. This practice was nearly universal among farmers in both surveys reported in this paper.

In many maize growing areas in northern Pakistan, this practice continues up to harvest, providing a supply of green fodder over the maize cycle (Byerlee, Iqbal and Fischer 1987). Farmer recall from both informal and formal interviews indicated thinning duration in the mountains usually of one to two weeks. This suggests that fodder production from maize is managed with greater emphasis given to dry fodder available after harvest than to green thinnings from maize and weeds from the maize fields.

1 Harvest density was estimated from crop cuts from three 2 m. by 4 m. sample plots, following the methodology outlined by Byerlee, Sheikh, Khan and Ahmad (1987), and this estimate is therefore not subject to the same difficulties as other estimates with area as denominator.

Regression analysis was used on the harvest survey data to summarize the effects of the various factors influencing final harvest density. The results of two equations, one excluding dummies for survey area, one including them, are shown in Table 22. The regression results indicate that altitude had a major influence on harvest density. This supports the contention that optimal densities for maize, are likely to increase with altitude. Hoeing reduced density by a little over 10,000 plants/ha on average. Irrigation appears to have little effect on harvest density. The effects of animal/land ratios are in the expected direction, and better data would probably confirm the effect of animal numbers on harvest density.

Table 22. Factors Influencing Final Harvest Density, 1985 Harvest Survey

Dependent variable is DENS:	harvest density in '000 plants/ha	
Variable	**Coefficient**	
Constant	4.15 (.145)	-14.9 (-470)
Seeling dummy	6.93 (.835)	.827 (.077)
Hoeing dummy	-11.2 (-1.54)	-10.3 (-1.26)
Irrigation dummy	-3.05 (-.531)	-5.27 (-.744)
Altitude (m.a.s.l.)	.0487 (2.90)***	.0554 (3.14)***
Animal Units Per Ha	.462 (1.46)	.336 (1.08)
Miandam dummy	--	15.4 (1.99)*
Shangla dummy	--	17.7 (1.86)*
Sakhra	--	17.0 (1.50)
n	92	92
R^2 (adjusted)	.129	.182

t-statistics in parentheses
***, **, * indicate significance at the .01, .05, and .10 level, respectively.

Weed and Insect Control

Many of the practices designed to manage density have the additional function of weed or insect control. Initial high plant densities, post-emergence seeling, hoeing, and manual cutting during thinning all help to control weeds. As in the main Swat valley, weed control does not appear to be a high priority for maize research (Byerlee, Sheikh, Khan and Ahmad 1987).

Planting date and its interaction with the risks of early cutworm attack, and possibly later damage by borers, pose important issues. At higher altitudes, the risk of cutworm damage is high when crops are planted early (April to early May) and the pest is active. Later planted maize escapes the worst of the cutworm activity. In 1985, harvest densities in farmer-managed verification trials in the mountains were reduced with increasing severity of insect damage (Khan et al. 1986). A few insecticide and planting date trials at carefully selected locations of different altitude over a number of years would provide an estimate of the losses to insects.

Harvesting and Shelling

Maize harvesting can take place any time from September to November, though it is usually concentrated in late September and the entire month of October. The harvest survey coincided with the height of the harvest, the last week of September and the first two weeks of October. Most maize was shelled by beating with sticks, although 19 percent of the farmers used mechanical shellers. Sheller use tended to be related to ease of access to the farm.

Harvest Results--1985 Survey

Physical Parameters: Harvest data for irrigated and barani plots are summarized in Table 23. In addition, Figure 9 shows the distributions for grain yields on irrigated and barani lands. The average levels of grain yield, stover yield, harvest index, and percent barren plants all show irrigated land, as expected, to be the more favorable environment.

These results for irrigated fields resemble those of the irrigated valleys of Swat (Byerlee, Sheikh, Khan and Ahmad 1987). One major difference is duration. On average, all sampled plots in the mountains, both irrigated and barani, took four weeks longer to mature than did fields in the valley. Harvest densities were higher in the mountains, reflecting the importance of dry fodder in upland areas and greater density tolerance with altitude. Though grain yields on irrigated mountain fields were only slightly lower than grain yields in the Swat valley, stover yields were higher in the mountains. Correspondingly, mountain harvest indices were lower. This also supports the hypothesis that dry fodder is more important in the mountains.

Fig. 9 Grain Yields on Irrigated and Rainfed Land, 1985 Harvest Survey

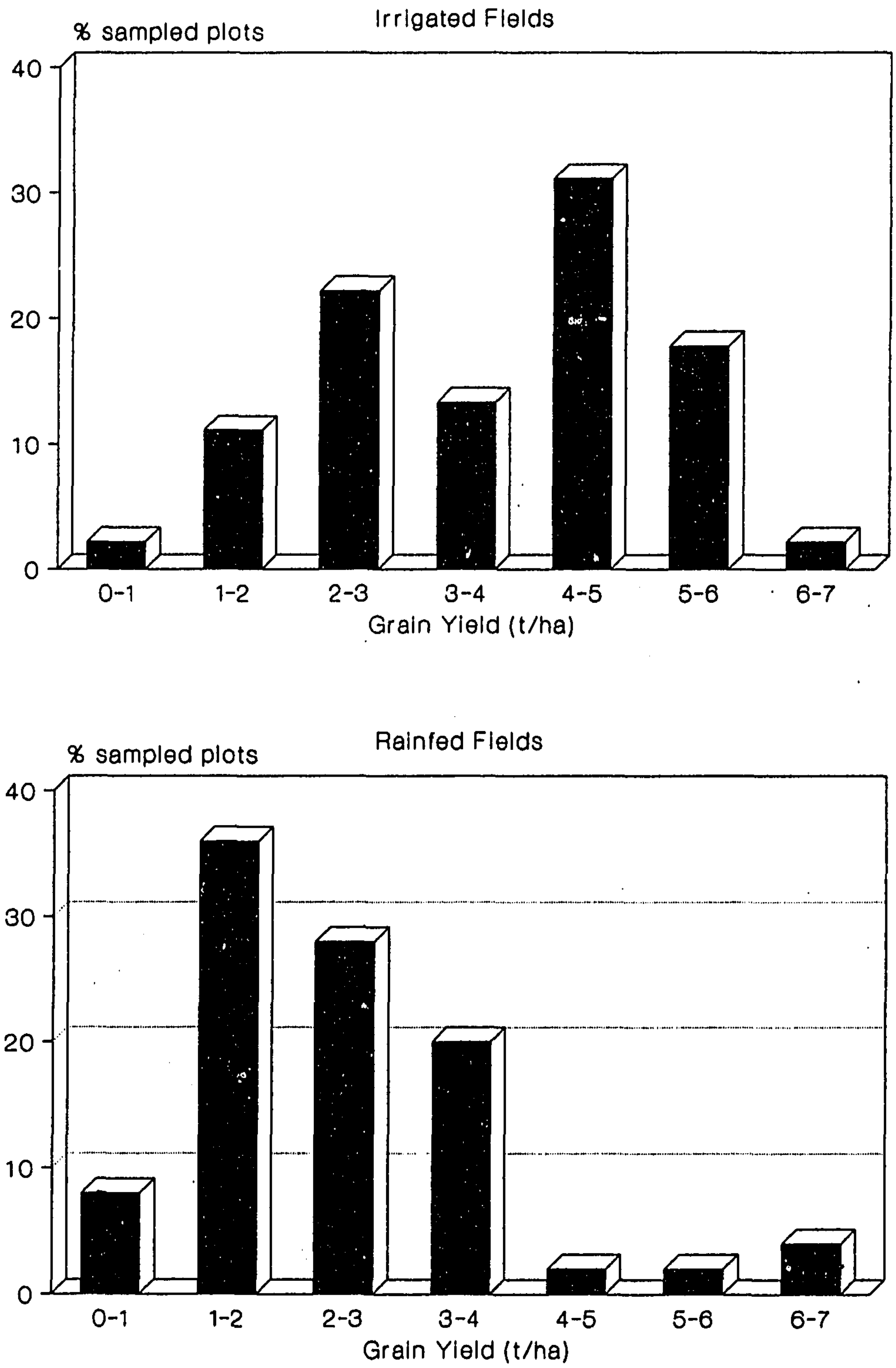


Table 23. Harvest Data for Swat Mountains, 1985

	Irrigated	Barani	Prob.[a]
Grain yield (t/ha)[b]	3.80 (37)	2.45 (52)	.00
Stover yield (t/ha)[c]	4.87 (35)	3.53 (44)	.00
Harvest index	43.3 (18)	40.3 (24)	.10
Harvest density (x 10^3/ha)	85	93	.15
Percent barren plants	17	28	.00
Percent ear moisture	42.4	43.5	.51
Shelling percentage	82.8	82.2	.47
Duration	132 (12)	135 (13)	.28
Adjusted duration[d]	126 (12)	128 (12)	.89

Figures in parentheses are coefficients of variation.

[a]level of significance of difference of means tests
[b]15% moisture
[c]10% moisture
[d]adjusted to 1500 m., assuming every 100m. above 1500 m. increases duration by 2.5 days.

Ear Moisture at Harvest: As in the Swat valley, ear moisture at harvest was very high--a mean of about 42-43 percent--and very variable. Normally, physiological maturity occurs in maize when grain moisture levels are from 30-35 percent (Hanway 1971, Sprague 1979). Harvesting before physiological maturity appears to limit grain yields, as ear moisture was negatively correlated with grain yield. This negative correlation was somewhat stronger on irrigated than barani land. In informal interviews, farmers listed two criteria, similar to those given by farmers in the valley, for determining time of harvest, "dry husk" or "drooping ear". The effect of high harvest moisture may also be somewhat tempered by the practice of leaving the cut maize for several days before removing the ear (Byerlee, Sheikh, Khan and Ahmad 1987).

In the mountains, both duration and duration adjusted to 1500 m.a.s.l. were strongly related to previous crop, with maize planted after wheat harvested after fewer days than maize after fodder, which in turn was harvested earlier than maize after fallow. In our sample, there was no relationship between ear moisture at harvest and late planting, probably because farmers planting at the tail end of the planting period chose earlier maturing varieties. Farmers harvest at high moisture levels to improve stover quality, as well as to lower risks of losses from weather and disease in the standing crop.

Analysis of Grain Yield

Methodology and Variables Used: The harvest survey results from both irrigated and rainfed land were separated into two groups: low yielding and high yielding fields. Various factors thought to influence yield were compared for fields falling into the two categories. Then, various regressions of grain yield on causal factors were run.

Following Byerlee, Sheikh, Khan and Ahmad (1987), we estimated models sequentially emphasizing proximate variables (those, like ear moisture and plant density, which impinge directly on estimated grain yield), intermediate management variables (those which are partly managed by farmers but with uncertainty about their outcome, like plant density and duration), and management (e.g. fertilizer) and system variables (e.g. previous rabi crop). This is an attempt to avoid simultaneity problems in situations where causation exists among the independent variables. In some cases, notably regarding fertilizer and altitude, mentioned above, the rule of avoiding causal relationships was not strictly followed.

Results: Results of the first regressions are shown in Table 24. As expected, both increased harvest ear moisture and barrenness significantly reduced grain yields. The magnitudes of these effects were somewhat greater on irrigated land than on barani land. On irrigated land, the decreases in yield associated with a one percent increase in harvest moisture were similar to those recorded in the Swat valley. These decreases are likely to have been overestimated, however, because the harvest moisture variable was used in the calculation of yield, and positive (negative) errors in the measurement of harvest moisture would result in negative (positive) errors in the measurement of yield (Byerlee, Sheikh, Khan and Ahmad 1987). On barani fields, the effect of increasing harvest moisture was about half that on irrigated fields, although still highly significant. Similarly, the effect of a one percent increase in the number of barren plants was two-thirds to three-quarters as large on barani fields as on irrigated fields.

Nitrogen appeared to increase yields, particularly on barani lands. On the other hand, neither the phosphorus dummy nor farmyard manure application (the latter in unreported regressions) were significant and were dropped in further analysis.

Table 24. **Regression Results Showing the Influence of Harvest Moisture and Barren Plants on Maize Grain Yield, 1985 Harvest Survey, Irrigated and Barani Fields**

Dependent Variable: Grain Yield (kg/ha)

Independent Variables	Irrigated Fields		Barani Fields	
Constant	6400 (2.27)***	5230 (2.15)**	1270 (.844)	647 (.353)
Nitrogen (kg/ha)	3.55 (1.96)*	.731 (.426)	7.32 (3.85)***	5.17 (2.24)***
Phosphorous Use Dummy	-423 (-1.10)	-283 (-.587)	-34.0 (-.111)	-11.0 (-.031)
Harvest Moisture(%)	-81.6 (-3.12)***	-87.3 (-3.82)	-43.8 (-2.90)***	-43.9 (-2.77)***
Percent Barren Plants	-63.4 (-3.10)***	-45.2 (-2.38)**	-42.0 (-3.20)***	-32.6 (-2.40)**
Altitude (m.a.s.l.)	.984 (.760)	1.28 (1.12)	2.01 (2.86)***	2.18 (2.44)**
Miandam Dummy		1140 (2.30)**		468 (.711)
Shangla Dummy				65.1 (.144)
Sakhra Dummy		1950 (3.42)***		686 (1.58)
n	38	38	50	50
R^2 (adjusted)	.448	.601	.439	.439

t-values in parentheses.
***, **, and * denote significance at the .01, .05, and 10 levels, respectively.

Table 25 shows the influence on grain yield of harvest density on irrigated land, and Table 26 for barani land. Various combinations of functional forms were tried for these equations, including logarithmic and quadratic for density and linear and quadratic for nitrogen. For irrigated fields, the logarithmic form was superior while for barani, the quadratic form was.

For irrigated land, grain yield increases with density over the entire range. For barani fields, the equations imply a maximum grain yield at a harvest density of around 110,000 plants/ha. Visual inspection of yields graphed against densities indicates a decline in yield above 120,000 plants per hectare. To summarize, our 1985 data suggest that the yield-maximising density was likely to be quite high. These high densities help farmers to meet the requirements for stover. Under 1985 conditions, with local varieties, farmers' plant density management appears quite rational.

Regressions concentrating on management and system variables are presented in Table 27 for irrigated fields and Table 28 for barani fields. In both instances, regressions with hoeing or seeling as dummy variables for density control indicated that they were not significant. This was because individual farmers were responding to different conditions such as germination or severity of early insect attack. Where germination was poor, or early insect damage greater, farmers would be less likely to hoe or seel.

Phosphorus use did not appear to be related to yield even in the preliminary investigation of high and low yielding fields. As in the valley, farmers who use phosphorus tend to use it on both rabi and kharif crops, if a rabi crop is grown. Experimental data from the mountains also tend to show no significant response to phosphorus. This is not to say that there are not some soils that suffer from phosphate deficiency (Khan et al. 1986). Recommendations should acknowledge this variability and encourage use of phosphatic fertilizers where deficiencies can be found by simple field trials or soil tests.

There was a clear response to nitrogen on the fields sampled in the harvest survey. Most farmers could be making higher net returns from applying additional fertilizer. However, it is likely that for the small, poor farmers of the Swat mountains, cash constraints could limit nitrogen application. Despite this, a few of the farmers were at the extremely high end of the distribution of application rates.

Turning to systems variables, the animal-land ratio had little statistical significance. On irrigated land, maize planted after fodder was out-yielding maize after wheat by over 500 kg/ha, although the effect was weakly significant. This result is similar to one found by Byerlee, Sheikh, Khan and Ahmad (1987) for the Swat valley. On barani land, maize after fallow appeared to have yields at least 300 kg/ha higher than maize after a rabi crop.

Site variables play a significant role in most of the equations in which they were included. The most significant and most complex site variable is altitude. On barani land, this variable tended to be significant in those equations emphasizing proximate or management variables. On irrigated land, altitude was significant or nearly significant in the intermediate and management equations. Yield probably

Table 25. Regression of Maize Grain Yield Against Fertilizer and Harvest Density, 1985 Harvest Survey, Irrigated Fields

Dependent Variable: Grain Yield (kg/ha)

	Equation			
Independent Variables	**(1)**	**(2)**	**(3)**	**(4)**
Constant	-7560 (-2.46)	-364 (-.172)	-3980 (-1.15)	102 (.045)
Nitrogen (kg/ha)	4.88 (2.58)**	5.00 (2.71)**	2.87 (1.38)	3.02 (1.46)
Ln (Harvest) Density '000 plants/ha)	2480 (3.52)***		1530 (1.87)*	
Residual Regression of Density on Altitude		31.4 (3.28)***		20.3 (1.74)*
Altitude (m.a.s.l.)		31.4 (3.28)*		203 (1.74)*
Miandam Dummy			1190 (2.37)**	1070 (2.14)**
Sakhra Dummy			1060 (1.37)	1060 (1.33)
n	50	50	50	50
R^2 (adjusted)	.347	.358	.409	.409

t-value in parentheses.

***, **, and * denote significance at the .01, .05, and 10 levels, respectively.

Table 26. Regression of Maize Grain Yields Against Fertilizer and Harvest Density, 1985 Harvest Survey, Barani Fields

Dependent Variable:	Grain Yield (kg/ha)			
		Equation		
Independent Variables	(1)	(2)	(3)	(4)
Constant	-1260	826	-998	2310
	(-.868)	(.870)	(-.726)	(2.08)**
Nitrogen (kg/ha)	14.7	14.2	12.8	13.0
	(1.86)**	(1.80)*	(1.71)*	(1.73)**
Nitrogen Squared	-.0318	-.0299	-.0361	-.0372
	(-1.06)	(-.999)	(-1.29)	(-1.32)
Harvest Density ('000 plants/ha)	57.7		56.9	
	(1.97)*		(2.05)**	
Density Squared	-.260		-.258	
	(-1.70)*		(-1.78)*	
Residual, Regression of Density on Altitude		10.3		11.5
		(1.77)*		(2.04)**
Residual Squared		-.289		-.289
		(-1.74)*		(1.83)*
Altitude		.582		-.131
		(1.14)		(-.232)
Miandam Dummy			702	785
			(1.06)	(1.17)
Shangla Dummy			-876	-1000
			(-2.20)**	(-2.13)***
Sakhra Dummy			511	466
			(1.17)	(1.04)
n	50	50	50	50
R^2 (adjusted)	.201	.196	.308	.295

Table 27. Regression of Grain Yields on Management Practices and System Variables, 1985 Harvest Survey, Irrigated Fields

Dependent Variable: Grain Yield (kg/ha)

Independent Variables	Equation (1)	(2)	(3)
Constant	-964 (-.419)	-1560 (-.670)	-1070 (-.478)
Nitrogen (kg/ha)	5.57 (2.75)***	3.09 (1.36)*	2.37 (1.16)
May-July Irrigation Dummy	479 (.933)	376 (.673)	
Dummy for Maize after Fodder	701 (1.32)	531 (1.04)	641 (1.42)
Altitude (m.a.s.l.)	2.21 (1.64)	2.40 (1.74)*	2.08 (1.60)
Miandam Dummy		764 (1.24)	1140 (2.26)**
Sakhra Dummy		1690 (2.45)*	1810 (2.73)**
n	36	36	38
R^2 (adjusted)	.301	.382	.409

t-values in parentheses

***, **, and * denote significance at .01, .05 and .10 levels, respectively.

Table 28. Regression of Grain Yield on Management Practices and System Variables, 1985 Harvest Survey, Barani Fields

Dependent Variable: Grain Yield (kg/ha)

Independent Variables	Equations (1)	(2)	(3)	(4)
Constant	-1050	1650	-1700	2010
	(-.693)	(4.29)***	(-.989)	(3.75)***
Nitrogen (kg/ha)	8.19	8.66	3.27	3.85
	(3.64)***	(3.78)***	(1.22)	(1.38)
Animals/ha (Weighted)	-25.2	-25.2	-27.7	-27.0
	(.736)	(-1.19)	(-1.45)	(-1.35)
Dummy for Maize After Fallow	267	560	141	325
	(.736)	(1.67)	(.343)	(.772)
Altitude (m.a.s.l.)	1.61		2.08	
	(1.84)*		(2.26)**	
Miandam Dummy			-543	-104
			(-.698)	(-.132)
Shangla Dummy			-79.8	-468
			(-.154)	(-.915)
Sakhra Dummy			1180	957
			(2.77)***	(2.20)*
n	49	49	49	49
R^2 (adjusted)	.236	.195	.278	.278

t-value in parentheses.

***, **, and * denote significance at the .01, .05, and 10 levels, respectively.

increased with altitude for the physiological reasons noted earlier. Furthermore, barani areas at higher altitudes may have better moisture than at lower altitudes.

These results indicate the complexity of developing specific agronomic recommendations for maize in the mountain environment. At this point, emphasis on nitrogen is strongly suggested. More understanding of the reasons for the wide variation in application rates would be useful. Campaigns to encourage phosphorus use generally do not seem warranted unless they include ways of efficiently testing phosphate deficiency. A systems emphasis on rabi fodder, or a breeding emphasis on stay-green characteristics or early maturity for maize, seem more useful than attempting to reduce the farmers' levels of plant density. Under 1985 conditions, there did not appear to be a great tradeoff between grain and stover yields.

Consumption and Off-Farm Labour

Most farmers do not meet their food needs from their own agricultural production because of the small size of land holdings. Maize and wheat are their major food crops, but they have no significant surplus to sell. Only 12 percent of the farmers surveyed in 1987 sold maize, and only one percent sold wheat. On the other hand, 95 percent and 57 percent of the farmers bought wheat and maize, respectively, in order to meet their food requirements. Although some maize purchased may originate with local farmers, purchased wheat comes from the outside market. The few farmers who did not buy food grains had much larger farms than those who did. Similarly, the farmers who sold maize had much larger farms than those who did not (Table 29).

Table 29. Buying and Selling of Grain by Sampled Farmers

Categories	Percent of Farmers	Mean Area (ha)
Did Not Buy Wheat	5	4.51
Bought Wheat	95	1.50
Did Not Buy Maize	43	2.70
Bought Maize	57	0.80
Did Not Sell Maize	88	1.30
Sold Maize	12	4.20

Farmers have to supplement their own production with off-farm income to meet food needs at times of shortage, as well as other cash needs. A majority of the farm households (87 percent) in the survey area had family members who did off-farm work. A significant number of farm households (58 percent) supply manpower for off-farm activities outside of Swat. Some households have family members working both in Swat and outside (Table 30).

Table 30. Percentage of Farm Households with Members Who Work Off-Farm

Valley	Do Not Work Off-Farm	Work Off-Farm in Swat Only	Work Off-Farm Outside Swat
Miandam	13	70	17
Shangla Par	3	27	70
Mallam Jabba	13	10	77
Shor	17	23	60
Sakhra	17	17	66
	---	---	---
All	13	29	58

In most surveyed catchments, a sizeable number of households had family members working in local occupations, often in small shops or in woodcutting. Outside of Swat, family members work elsewhere in NWFP, often in the Peshawar/Mardan area, Punjab or Sind. Some workers spend the winter months as laborers in Hyderabad, Karachi or Baluchistan. Only one household surveyed had a family member working outside of Pakistan (Table 31). Informal interviews suggested that the cost of obtaining the necessary documents for migration to the Middle East has risen so high as to foreclose this option to all but the wealthiest families.

Table 31. Percentage of Farm Households with Family Member Who Work Off-Farm in Various Locations

Valley	Swat	NWFP	Baluchistan	Other Areas of Pakistan	Outside Pakistan
Miandam	67	7	3	7	-
Shangla Par	23	13	10	57	-
Mallam Jabba	63	57	10	23	-
Shor	50	40	-	20	-
Sakhra	50	47	20	3	3
	---	---	---	---	---
All	51	33	9	22	1

Differences in migration patterns can be related to location and to irrigation status. Farmers from the agriculturally poorest area, Shangla, were more likely to send family members to work outside of NWFP. Family members of the more-favored Miandam were more likely to work only near the home. Farmers with only barani land had the poorest income-generating potential from crops and livestock and thus more incentive to send family members to work outside of Swat. Farmers with only irrigated land were somewhat better off. Larger farmers had more diversified income sources within Swat, and thus they were the least likely to send family members migrants outside of the district (Table 32).

Table 32. Irrigation and Percentage of Farm Households with Members Who Work Outside of Swat

Irrigation Status	Percent with Family Members Working Outside of Swat
Both Barani and Irrigated Land	35
Only Irrigated Land	49
Only Barani Land	70

In the survey, farmers were asked to rank their three main sources of cash income. Off-farm work was chosen first by the majority of farmers (51 percent) as the most important source of cash income. Crops were chosen first by 34 percent of the farmers. In the two valleys with significant levels of potato production, Miandam and Mallam Jabba, 68 percent and 43 percent of the farm households selected crops as most important for cash income. Off-farm income was ranked highest by the majority of farmers in the other three valleys. Livestock was only chosen first by nine percent of the farmers (Table 33).

Table 33. Most Important Source of Cash Income from the Farmer's Point of View

Valley	Off-Farm	Crops	Livestock	Forest	Other
Miandam	27	67	3	3	-
Shangla Par	59	34	7	-	-
Mallam Jabba	37	43	10	7	3
Shor	70	10	17	3	-
Sakhra	63	17	7	3	7
All	51	35	9	3	2

A probit analysis of the likelihood the farmer would rank crops as the most important source of income is shown in Table 34. This confirms the highly significant effect of potato production on cash income from crops. For example, the regression implies that "average" farmers would be more than twice as like'y to rank crops as their most important source of income if they grew potatoes than if they did not. Farmers with some irrigated land were also more likely to state crops were the most important cash source.

Table 34. Probit Estimation of Likelihood Farmer Considers Crops the Most Important Source of Cash Income

Dependent Variable is CROPS	1	if farmer said crops were his most important source of cash income
	0	otherwise

Independent Variables	Coefficient	Asymptotic t-value
Constant	-.919	-5.02***
Ln(farm size per ha)	.136	1.12
Dummy for Growing Potatoes	.766	3.38*
Irrigation dummy	.411	1.79***
n = 148		

Hypothesis that non-constant coefficients jointly have no effect rejected at significance level .000.

***, **, and * indicate significance at .01, .05, and .10 levels, respectively.

Adjusting Development Strategies to the Special Problems of Mountain Agriculture

Summary

Farms in the mountain areas of Swat are, in general, extremely small. Most farmers are not self-sufficient in basic grains. Wheat in particular is purchased, but many farmers also purchase maize, the major crop for their own consumption. Only a small minority of farmers sell maize.

In two of the five areas surveyed for this study, potatoes are grown as a cash crop and contribute substantially to some farmers' incomes. But families from all areas often rely on off-farm income sources. Smaller farmers and those who depend upon rainfed crop land are particularly likely to have family members working elsewhere in Pakistan, outside of Swat, to generate additional income.

The farming system is primarily based on maize. Maize provides grain for human consumption, dry stover to feed animals over the harsh winters, and green fodder through thinnings. Nonetheless wheat area has increased over the past 20 years, first with the adoption of chemical fertilizer, and then with the spread of earlier-maturing, semi-dwarf wheat varieties bred primarily at lower altitudes and for a milder growing season. Up to 1950 m.a.s.l., the area surveyed for this study may be regarded generally as transitional between double and single cropping. Rotational constraints are evident from 1500 m.a.s.l., the lowest elevation surveyed, and become increasingly severe as altitude becomes higher. The attempt to grow a wheat crop for grain delays planting of the subsequent maize crop, so further shortening of duration of the wheat crop would be beneficial to the maize-wheat rotation.

Livestock are also an important part of the farming system, valuable more for in-kind outputs than for cash income. Ninety percent of the farmers in the farming systems survey had dairy animals, and slightly over half had bullocks. Livestock contribute farm yard manure and draft power to the cropping enterprise. Most primary tillage is done with bullocks, even though many farmers have to borrow or exchange bullocks in order to complete a team. In turn, crops provide some of the fodder requirements for livestock, particularly through maize thinnings and maize stover. Farmers at lower altitudes, and particularly those with irrigated land, may also grow rabi fodder.

Fodder is a major constraint to milk production, particularly during the winter months. Even under the best of circumstances during summer, most animals do not appear to get enough protein for optimum milk production. Only about half the farmers reported sales of milk or milk products, and this in general was ranked a less important source of cash than sale of stock.

Maize is subject to change from the interactions with other enterprises. In the few valleys where potatoes are produced, the cash commanded by potatoes makes them an alternative to maize on some of the farmers' land. The spread of shorter duration wheat to higher altitude has increased cropping intensity and lifted the altitude limit to double cropping, with maize as the summer crop, thereby placing greater emphasis on shorter-duration maize varieties. Maize cropping interacts with livestock, providing green and dry fodder, and receiving farm yard manure. The changes resulting from increasing human population in the area, and pressure on forests and grazing, mean that maize value as a feed source will remain high, and there will remain a high priority on developing alternative sources of fodder (oats, sorghum-sudan grass, vetch and other fodders).

As altitude increases, optimal densities for grain production appear to increase as well, making the tradeoff between fodder and grain production less severe than it would first appear. Under conditions observed in 1985, only at densities above 110,000-120,000 plants/ha did total grain yield appear to decrease. Given uncertain moisture levels at planting and incidence of insect pests, farmers' strategies of planting at extremely high seed rates and then thinning appears rational.

Besides uncertainties at planting, another reason for the high density of maize is that, in the mountains, farmers give more emphasis to dry stover from maize and less to green thinnings than do farmers in the valley. This is because in the mountains summer grasses and weeds are more plentiful and growing winter fodder on crop land is limited.

There is a definite and strong response of maize grown in the mountains to nitrogen, though actual rates of farmer application vary widely. Though phosphorus response may be observed in certain locations, a general phosphorus recommendation for maize is not warranted.

It is clear that irrigated and barani lands form distinct recommendation domains. Some farmers, of course, particularly those with relatively large areas, fall into both domains. Crop yields are both higher and more stable on irrigated land. The agronomic characteristics of irrigated land in the Swat mountains are similar enough to those in the Swat valley to translate directly some production recommendations from the valley to higher altitudes. The main differences in cropping circumstances between the irrigated valley and the irrigated mountain environments are the fewer growing degree days, the greater difficulty of growing a rabi crop, and the higher density tolerance of maize in the mountains.

Higher elevation barani farms are also different from lower elevation barani farms in these respects. In addition, density management is more problematic on barani lands, insect attack is more likely to be severe, and variability in soil fertility greater. Furthermore, as in rainfed land elsewhere, more risk is involved in the use of nitrogen fertilizer.

Agricultural Development Strategies

Research for the Mountain Environment of Swat: A high priority for the higher-altitude environment is development of earlier-maturing stress-tolerant maize and wheat varieties and wider dissemination of varieties currently available. Earlier varieties which might even be lower yielding but permit a second crop in the system are likely to be popular with farmers in the mountains. Earlier maize and wheat varieties could benefit farmers considerably in intensifying production. Earlier maize varieties would also benefit those at higher altitudes where growing seasons are even shorter, by giving them more planting date flexibility. Any varietal evaluation in the mountains should consider total economic returns from the maize, grain and fodder and the rabi crop (wheat usually) in the 12-months use of land. Furthermore, maize should be evaluated at high harvest densities, say 70,000-130,000 plants per hectare, following farmer practices.

An existing improved variety, Azam, has maturity characteristics similar to those of much of the genetic material farmers are currently using. It would probably yield more than farmers' present varieties if it were not susceptible to smut (Khan et al. 1986). Decreasing smut incidence in varieties similar to Azam is a definite priority for breeders, probably second to shortening maturity.

A severe constraint to expanding use of existing or earlier-maturing maize varieties is the lack of an adequate seed production and distribution system. Until this problem is solved, very few maize farmers, especially in more remote areas, will start using new maize varieties in any reasonable amount of time. One major problem is that the public sector has been ineffective and the private sector has not been encouraged to develop a maize seed system. A major effort to develop the seed sector is urgently required. Strategies to develop local seed producers and to distribute seed in many villages should be pursued, along with strategies to encourage farmers to maintain their seed and crops to minimise seed contamination.

Another way the farming system could be made more productive is through the introduction of rabi fodder crops, vetch and fodder oats, or other suitable crops. This would help to ease the winter fodder constraint. Currently shaftal or khid provide an important source of rabi fodder, but they are limited to lower elevations, and particularly in the case of shaftal, are dependent on irrigation. Even if farmers can raise their standard of animal nutrition somewhat, more supplements need to be fed to lactating animals.

Finally, the introduction of cash crops (including vegetables and pulses) that are sustainable both economically and from a production point of view would raise farmers' incomes. The market for potatoes is fairly well developed, but they are a relatively bulky crop. Other crops, such as vegetables, are fairly well suited to mountain agriculture in Swat from a production standpoint, but they are subject to a relatively limited or volatile market. Market evaluation is likely to be an important part of determining if the introduction of alternative cash crops is warranted.

Crop Management Research: Any agronomic research on maize should clearly differentiate irrigated from barani environments. One area of crop management research already mentioned is appropriate density management. The farmers' current strategy may be close to optimal, so new varieties should be evaluated over a range of densities that appear quite high in comparison to maize grown in other environments. Though likely to be high, optimal harvest densities for total economic (grain plus stover) production are likely to be lower on rainfed than on irrigated land.

Crop loss evaluation would help to focus further work in both crop management research and varietal development. The two major areas of study should be insect damage and losses due to disease. Study of insect damage is probably more important on barani land. Research into disease losses might cover both irrigated and barani land; some work in this area has already been started (A. Khan, 1988).

Research on soil fertility should be continued, and focus on two issues: time of application of nitrogen on rainfed plots; and phosphorus response. Experimental design should be quite simple, but careful attention should be paid to site selection. On the narrow terraces in the Swat mountains, particular care should be taken in measuring amounts applied, and application of farmyard manure should be properly accounted. Site variables should be correlated with the presence or absence of phosphorus response. As indicated, split dosages of nitrogen should be investigated on barani land.

Finally, there is scope for further research on maize-wheat rotations, and alternatives, in the area. Items of special interest would be to compare a continuous wheat-maize rotation with rotations involving a more balanced cropping sequence, including fodder crops as break crops. Special attention could also be given to soil nutrient status over time and to the use of different rotations and tillage practices to control weeds and to minimise soil erosion.

References

Akhtar, M.R., D. Byerlee, A. Qayyum, A. Majid and P.R. Hobbs. 1986. Wheat in the Cotton-Wheat Farming Systems of the Punjab: Implications for Research and Extension. Islamabad: PARC/CIMMYT Paper No. 86-8.

Barth, F. 1956. "Ecologic Relationships of Ethnic Groups in Swat, North Pakistan." American Anthropologist Vol. 58, No. 6, 1079-1089.

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

Bliss, C.J. and N.H. Stern. 1982. Palanpur: The Economy of an Indian Village. Oxford: Clarendon Press.

Byerlee, D. and S.S. Hussain. 1986. Maize Production in NWFP: A Review of Technological Issues in Relation to Farmers' Circumstances. Islamabad: PARC/CIMMYT Paper No. 86-1.

Byerlee, D., M. Iqbal and K.S. Fischer. 1987. "Quantifying and Valuing the Joint Production of Grain and Fodder from Maize Fields: Evidence from Northern Pakistan". Experimental Agriculture Vol 25, 435-445.

Byerlee, D., A.D. Sheikh, K. Khan and M. Ahmad. 1987. Diagnosing Research and Extension Priorities for Small Farmers: Maize in the Swat Valley. Islamabad: PARC/CIMMYT Paper No. 87-19.

Coop, I.E. 1987. Personal communcation

Fischer, K.S. 1986. Personal communication

Fischer, K.S., and H.I. Javed. 1986. Production of Maize Grain and Fodder in the Northwest Frontier Province and Islamabad Capital Territory of Pakistan. Islamabad: PARC/CIMMYT Paper No. 86-3.

Hanway, J.J. 1971. How a Corn Plant Develops. Iowa State University of Science and Technology Special Report No. 48 (Revised). Ames, Iowa.

Hobbs, P.R., I. Saeed, and U. Farooq, 1990. "Dynamics of Technological Change in Rainfed Areas: Wheat in Northern Punjab". Chapter 9 in D. Byerlee and T. Hussain, eds. Farming Systems of Pakistan: Diagnosing Priorities for Agricultural Research. Lahore: Vanguard Press.

Husain, T. 1986. Wheat in the High Mountain Valleys of Gilgit. Rural Sciences Research Programme Report No. 2. Gilgit: The Aga Khan Rural Support Programme, April.

Khan, A. 1988. Screening of Maize Germplasm Against Head Smut and Common Smut. M.Sc. Thesis, NWFP Agricultural University.

Khan, K. 1986. Study of Different Varieties of Maize under Traditional and Modified Management Practices in Swat, NWFP. M.Sc. Thesis, NWFP Agricultural University, Peshawar.

Khan, K., D. Byerlee, M. Ahmad, M. Saleem and E.J. Stevens. 1986. Farmer Managed Verification of Improved Maize Technology: Results and Experiences from Swat, 1985. Islamabad: PARC/CIMMYT Paper No. 86-12.

Sheikh, A.D., D. Byerlee and M. Azeem. 1988. Analytics of Barani Farming Systems of Northern Punjab: Cropping Intensity, Crop Livestock Interactions and Food Self-Sufficiency. Islamabad: PARC/CIMMYT Paper No. 88-2.

Sprague, G.F. (ed.), 1977. Corn and Corn Improvement. American Society of Agronomy, Inc. Madison, Wisconsin.

Stevens, E.J., C.O. Gardner, S.J. Stephens, J. Dumanovic, A. Khan, M. Saleem and M. Aslam. 1988. Maize Improvement for Tolerance to Environmental Stress. In Proceedings of Workshop on Maize Breeding and Maize Production, EUROMAIZE'88. Belgrade, Yugoslavia. Oct 6-8.

Appendix A.

Adoption of Chemical Fertilizer and Semi-Dwarf Wheats in the Mountains of Swat

In the maize-based cropping systems which predominate in the Swat mountains there have been major changes in technologies over the past twenty years. Such changes have increased the upper altitude limit at which wheat is grown for grain. This wheat has been replacing rabi fallow and barley.

Part of the phenomenon is the displacement of the old, tall desi wheat varieties with the semi-dwarf wheats that have been the backbone of the Green Revolution elsewhere in Pakistan. In systems marked by seasonal conflict, one of the major advantages of semi-dwarf wheats is their shorter maturity period. In the Swat mountains, the kharif cycle is particularly short because of cool temperatures. The main constraint to double cropping maize and wheat is the short turnaround time between wheat harvest and maize planting. Wheats that can be harvested earlier allow wheat to precede maize at altitudes where formerly only maize could be grown.

Elsewhere in Pakistan, seasonal conflicts may occur because the higher profitability alternative in kharif implies a later kharif harvest. In the rice-wheat rotation, basmati rice, which commands a higher price, matures later than IRRI rice. In the cotton-wheat rotation, an extra cotton picking is more profitable than planting wheat at the optimal time (Akhtar et al. 1986). In these situations semi-dwarf wheats are advantageous because they can be planted later than the old, taller wheats.

The adoption of chemical fertilizer has been intimately involved with the adoption of high-yielding varieties of wheat and rice elsewhere in the world. In most cases improved varieties have tended to be adopted first. In the Swat mountains, however, adoption of chemical fertilizer is clearly in advance of the adoption of semi-dwarfs (Figure 10). This pattern has also been recorded in the Northern Areas (Husain, 1986) and in the barani areas of northern Punjab (Hobbs et al. 1988).

In all three areas the ratio of grain price to bhusa price has been lower than in the main wheat growing areas of Pakistan. In addition, the bhusa yield of traditional varieties, real or as perceived by farmers, may be higher than the bhusa yield of the semi-dwarfs, particularly at low levels of soil fertility. Under these conditions, only at higher fertilizer levels with increased production of both grain and bhusa would the value of total biomass of the semi-dwarfs be great enough to induce farmers to change varieties. An additional factor that has possibly influenced the sequence of adoption in mountain areas is that nitrogen speeds crop maturity. This would be another reason why farmers in the mountains initially perceived advantages to using fertilizer before they saw advantages in using semi-dwarf wheats. On the supply side, the fertilizer distribution network in Pakistan has been better developed than the seed marketing system, which has probably contributed to earlier availability of fertilizer in mountain areas. Phosphorus adoption is not as advanced as the adoption of chemical fertilizer in general (Figure 10).

Cumulative curves give a clear picture for the sampled farmers as a whole, but they do not indicate order of adoption for individual farmers. For farmers growing wheat for grain, the order of adoption is shown in Table 35. This table demonstrates that only nine percent of these farmers said they adopted semi-dwarfs before fertilizer; half adopted fertilizer first, a third had not adopted semi-dwarfs, and five percent said the innovations were adopted simultaneously.

Table 35. Adoption of Chemical Fertilizers and Semi-Dwarf Wheats by Farmers who Sometimes Plant Wheat for Grain

Percentage Distribution of Farmers Who:	
- adopted chemical fertilizer first	51
- adopted at the same time	5
- adopted semi-dwarfs first	9
- have not adopted semi-dwarfs	35

Fig. 10 Adoption of Chemical Fertilizer and Semi-Dwarf Wheat Varieties