Quantifying and Valuing the Joint Production of Grain and Fodder from Maize Fields in Northern Pakistan

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PARC/CIMMYT Paper No. 87-24

PARC/CIMMYT Collaborative Program
Animal Sciences Division (PARC)

1987

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Introduction

The joint production of grain and fodder from maize fields in much of northern Pakistan has been a subject of long standing controversy (Byerlee and Hussain, 1986).[1] It has been widely observed that farmers plant maize by broadcasting seed at a high seed rate. The resulting plant density is often higher than optimal for grain production and farmers also stagger thinning throughout the growing season. It is hypothesised that farmers following these practices value the green fodder produced by maize thinnings as an important source of fodder. The issue is important because research recommendations, such as lower seed rate, line planting and early thinning, which were formulated in terms of grain production, have been consistently rejected by farmers, despite widespread demonstration programs in the 1970s (Byerlee and Hussain, 1986).

To date no quantitative data is available to substantiate the relative role of maize as a grain crop and as a fodder crop in different zones of northern Pakistan. This paper aims first, to quantify the extent to which maize plants are removed during the season as a fodder crop and second, to place an economic value on this fodder in relation to the value of grain production.

Methods and Materials

Data Sources

During the 1984 season, approximately 15-20 maize fields were selected in each of four districts in the main maize producing areas of northern Pakistan - Mardan, Swat, Mansehra and Islamabad Capital Territory. These districts were chosen to represent quite different agro-climatic zones for maize production (Table 1). They were equally divided between rainfed and irrigated areas and between low-altitude and mid-altitude areas. In mid-altitude areas, there is a long winter which places greater pressure on fodder supplies. In these areas, maize is also planted earlier to provide a longer growing season. Under rainfed conditions this involves planting in June in marginal moisture conditions when germination losses may be high. Farm size and the importance of livestock also vary considerably between zones (Table 2). In the mid-altitude irrigated zone, Swat, farm size is smallest and the number of livestock per cultivated hectare highest. In addition, most of the kharif area

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[1] The practice is also widely observed in other countries of South Asia and the Middle East.

is planted to maize so it is expected that pressure for fodder production would be highest in this area. The number of animals per ha of maize is highest in Islamabad and lowest in Mardan.

Table 1: Maize Production Seasons in Various Zones, Northern Pakistan.

	Altitude	
	Low	**Mid**
	< 650 m.a.s.l.	**650-1250 m.a.s.l.**
Moisture	**Islamabad**	**Mansehra**
Rainfed (800-1200 mm)	P - early July H - late Sept.	P - early June H - early Oct.
	Mardan	**Swat**
Irrigated	P - late July H - late Oct.	P - mid June H - early Oct.

P = Common planting date H = Common harvest date

Table 2: Summary of Selected Characteristics of Maize Farmers

	Islamabad	Swat	Mansehra	Mardan
Farm size (ha)	4.47	1.63	2.19	3.06
Maize area (ha)	1.02	1.25	1.50	1.94
Maize area as percent of farm area.	23	77	68	63
Number of large animals[a]	11.5	7.20	6.92	7.25
Large animals/cultivated ha.	2.58	4.42	3.16	2.37
Animals/ha maize	11.30	5.76	4.61	3.73

[a] Includes adult buffaloes and cows and young stock.

In each selected field, plant stands were counted at 3 to 4 week intervals during the growing season in four randomly selected plots of 2m x 2m. At each visit the cultivator of the field was also interviewed about the fodder fed to his domestic animals on the previous day. Farmers were able to provide reasonably good estimates of the amount of concentrates fed to animals but estimates of the amount of dry fodder and green fodder were difficult to obtain without weighing them at the time they were being fed to animals. This was not possible within the resources of this study. Nonetheless, the estimates were felt sufficiently reliable to rank the different sources of green fodder in order of importance.

Quantifying the Rate of Plant Removal

Plant density at time t, D_t, was described as a function of the initial seed rate, S, as well as the number of days, t, since planting. Three alternative functional forms were considered to describe the relationship between D_t and S.

$$D_t = a + bS + rt \qquad \text{.......} \quad (1)$$

$$D_t = aS^b e^{rt} \qquad \text{.......} \quad (2)$$

$$D_t = aS^{b+rt} \qquad \text{.......} \quad (3)$$

These various specifications are illustrated in Figure 1a, 1b and 1c. In the linear specification (Equation1), farmers are assumed to remove plants at a fixed rate from emergence to harvesting (i.e., $dD/dt = r$). The main disadvantages of this specification are that:

a) to provide a constant fodder supply, more plants are expected to be removed early in the season because each plant is smaller. Conversely later in the season the removal of fewer and larger plants should provide an equivalent amount of fodder.

b) to minimize the tradeoff between fodder and grain production early reduction in plant density is needed (Fischer and Javed, 1986).

The second specification assumes that the proportion of remaining plants removed per day is constant, i.e. in logarithmic terms; $\ln(D) = \ln(a) + b\ln(S) + rt$, $(dD/dt)/D = r$, and

$$dD/dt = r\, aS^b e^{rt} \qquad \text{.........} \quad (4)$$

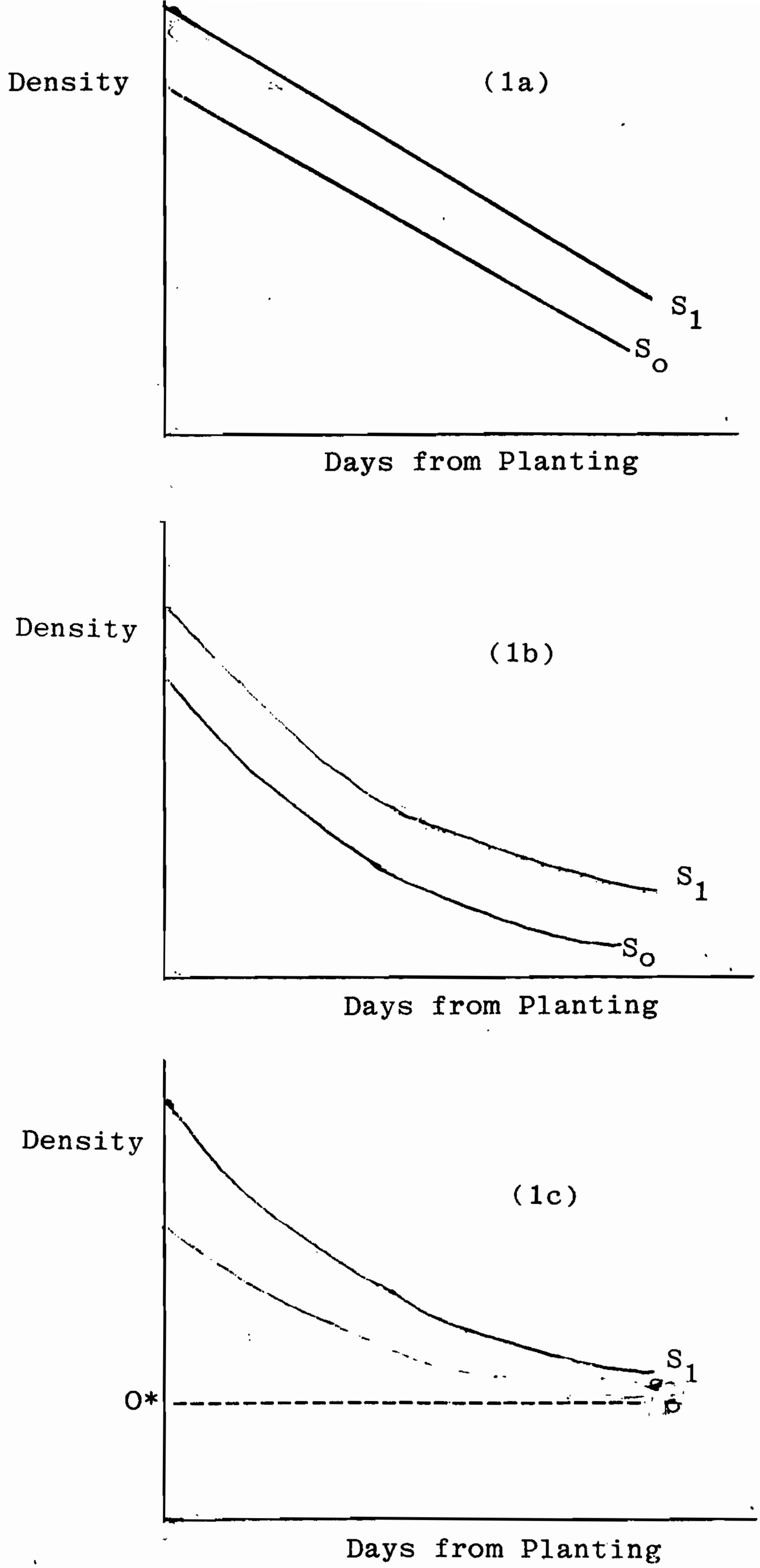

Figure 1: Alternative Models of Maize Plant Removal at Two Seed Rates, S_o and S_1

This implies a decreasing number of plants removed daily but may approximate a constant daily fodder supply if a) the fresh weight supplied per plant can be represented by an exponential growth curve and b) the rate of plant removal is set equal to the rate of plant growth. That is, the fodder yield at time t, Q_t, is given by $Q_t = nI e^{gt}$, where n is the number of plants removed per day and I is a constant. Since $n = -dD/dt$, from (4) above we get by substitution:

$$Q_t = -ra S^b e^{rt} I e^{gt} = -raS^b I e^{(r+g)t}$$

$$\text{and} \quad dQ_t/dt = -r(r+g)aS^b Ie^{(r+g)t} = 0 \text{ if } r = -g.$$

The main disadvantage of this specification is that r is constant regardless of initial plant density. If farmers, in fact, plant higher seed rates to provide more fodder we would expect the rate of plant removal to be positively related to the initial seed rate in order to reach a target final density, D* in Figure 1c. For this situation, equation 3 is a better specification. That is:

$$dD/dt = aS^{b+rt} r\ln(S).$$

$$\text{and} \quad (dD/dt)/D = r\ln(S).$$

Equation 3 can be estimated in logarithmic form by setting:

$$\ln(D_t) = \ln(a) + b\ln(S) + rt\ln(S) \qquad \text{.........} \quad (5)$$

The estimated equation can be used to predict density at various values of t for a given seed rate. In addition, the implicit germination/emergence rate can be estimated by computing $D_o = aS^b$ at $t = 0$ so that;

$$g = mS/D_o = mS^{1-b}/a,$$

where m is the number of seeds per kg of seed planted.

In general the exponential forms (equations 2 and 3) provided a much better fit than the linear form (equation 1) and the exponential form of equation 3 gave a slightly better fit than equation 2. Results of equation 3 will be presented here.

Estimating the Value of Green Fodder

There were two difficulties in placing a value on the green fodder progressively removed from maize fields. First, we had no reliable estimate of the quantity of green fodder removed although we had estimates of the number of plants removed. Second, although there is a market for green fodder near urban areas it is very difficult to value green fodder in rural areas. In many cases exchange type relationships are used (e.g. a tenant is given the right to take fodder from a field and in return farm yard manure is applied to the next crop).

Because of these difficulties, an indirect method was used by comparing the animal diets at the beginning of the maize season when no green maize fodder was available, to the diet in the maize season when maize thinnings were being used as fodder. The diet at the beginning of the season (usually June) consisted mostly of dry fodder (wheat straw) and concentrates which could be easily valued. That is the value of green fodder is given by

$$V_g = (p_i X_{i,1} - p_i X_{i,2})/A \qquad ....(6)$$

where:

V_g = value of green fodder/ha (indirectly estimated)
p_i = price of fodder i (straw or concentrate)
$X_{i,1}$, $X_{i,2}$ = quantity of fodder given animals at period 1 (June) and period 2 (August) and,
A = farmers' total area of maize (ha).

This indirect method, of course, assumes that maize thinnings constitute the bulk of green fodder that replaces dry fodder and concentrates. This is a reasonable assumption for Mardan, Mansehra and Swat where maize constitutes the bulk of cropped area and hence green fodder must be either thinnings or weeds from the maize fields. In Islamabad, where maize accounts for only 23% of farm area in kharif season, this assumption may lead to an over-estimate of the value of maize thinnings. Likewise, the method assumes that no green fodder was available at the beginning of the maize season. This is a reasonable assumption except in irrigated Mardan where separate fodder plots are often planted.

Results

Table 3 summarizes maize production practices in each zone. In Islamabad, Mansehra and Swat, most farmers practice broadcast seeding at a seed rate well above the recommended rate of 30 kg/ha followed by the practice of "seeling", that is interculture with a local plough or tractor drawn cultivator with some tynes removed. Seeling has a number of purposes, especially weed control, but most important for this analysis, it uproots and removes a significant number of maize seedlings. Hence, except for Mardan, the decline in plant density in the first 3 to 4 weeks after planting is largely due to the seeling operation. Uprooted maize seedlings are not generally used for fodder.

Table 3: Summary of Selected Maize Production Practices, 1983-84.

	Islamabad (rainfed low altitude)	Mardan (irrigated low altitude)	Mansehra (irrigated mid-altitude)	Swat (rainfed mid-altitude)
Seed rate (kg/ha)	60	40	80	90
Percent fields broadcast	100	39	98	100
Percent fields seeled	84	0	79	53
Harvest density	103	65	63	80

It is clear that Mardan is somewhat apart from the other zones. In Mardan more "conventional" practices are used - relatively low seed rates, mostly line planting and no "seeling" to uproot plants.

Table 4 shows the estimated coefficient of the regression of plant density of equation 3 above. Seed rate has a significant positive effect on plant density in all but Islamabad district. The coefficient of tln(S) is also highly significant and negative in all zones indicating the decline in plant density over the season. The R^2 indicates a reasonable fit for cross-sectional data for all zones, except Mansehra.

Table 4: Regression of Log of Plant Density on Days from Planting and Seed Rate

Independent variables	Islamabad (rainfed low altitude)	Mardan (irrig. low altitude)	Mansehra (rainfed mid altitude)	Swat (irrig. mid altitude)	All
ln(S)	.104	.326	.398	.511	.385
	(.73)	(1.87)*	(2.20)***	(3.72)***	(5.49)***
tln(S) ($x10^3$)	-4.39	-3.06	-1.41	2.44	2.32
	(8.25)***	(6.34)***	(4.17)***	(7.57)***	(10.55)***
Constant	11.99	10.65	9.83	10.12	10.36
R^2	.55	.43	.21	.56	.32
n	59	59	79	53	250

t - values in brackets. ***, **, * indicate significance at the 1%, 5% and 10% level, respectively. Dependent variable is $\ln(D_t)$ in equation 5.

Estimated parameters from Table 4 are shown in Table 5. The implicit germination rate is high in all areas, except Mansehra, where hot dry weather prevailed at planting. This suggests that high seed rates are not used to insure against germination and emergence problems, except in Mansehra. The rate of plant removal averages about one percent per day. The number of plants removed for fodder was computed as $D_{30}-D_h$, where D_{30} is density at 30 days after planting and D_h is density at harvest. This indicates a high rate of green plant removal in Islamabad and Swat and a low rate of removal in Mansehra.

Table 5: Estimated Germination Percentage and Number of Plants Removed for Fodder.

	Islamabad (rainfed low altitude)	**Mardan (irrig. low altitude)**	**Mansehra (rainfed mid altitude)**	**Swat (irrig. mid altitude)**
Seed rate (kg/ha)	60	40	80	90
Initial density ($plx10^3$/ha)[a]	248	141	106	248
Implicit germination percent [a,b]	92	100	38	79
Rate of plant removal[a] (%/day)	1.80	1.13	.62	1.10
Total number plants removed for fodder ($plx10^3$)[c]	95.4	49.5	40.9	95.7

[a] Calculated at mean seed rate for the zone
[b] Based in 3500 seeds/kg except for Islamabad where 4500 seed/kg was used for the small kernel local variety.
[c] From 30 days after planting only.

The importance of these maize thinnings as a fodder is shown by the data on animal diets in Table 6. Maize thinngs are important in all areas, especially in August and September. Note also that as the amount of green fodder increases, the amount of concentrates and particularly dry fodder falls off.

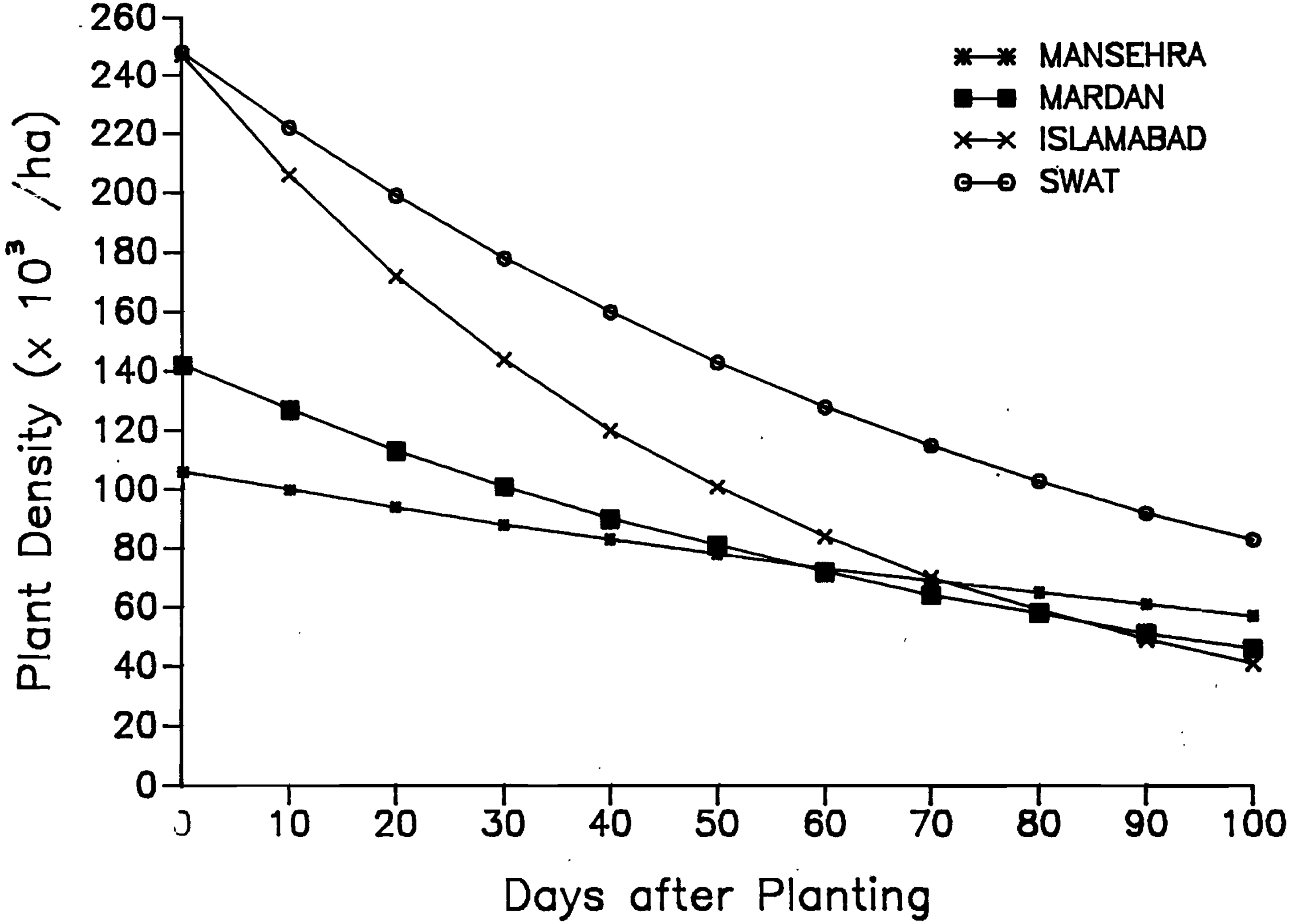

Figure 2:— Plant Density Counts Plotted Against Days from Planting.

Table 6: Animal Feed Ingredients in Northern Pakistan Kharif Cycle, 1984.

		Oilseed cake	Flour	Wheat straw	Main green fodder
		(kg/head/day)			
Islamabad	July	2.6	0.23	10.2	Other[a]
(rainfed low	August	2.5	0.13	3.1	Maize thinnings
altitude)	Sept.	1.7	.00	1.3	Maize thinnings
Mardan	July	.0	1.25	4.8	Other[a]
(irrigated	August	.5	1.00	5.2	Other[a]
low altitude)	Sept.	.3	.74	3.5	Maize thinnings
Mansehra	July	.7	.58	6.42	na
(rainfed mid	August	.6	.82	2.28	Maize thinnings
altitude)	Sept.	.6	.74	.80	Maize thinnings
Swat	July	1.1	1.34	14.9	Other[a]
(irrigated	August	.4	1.00	0	Maize thinnings
mid altitude)	Sept.	.7	.63	0	Maize thinnings

[a] Mostly weeds from outside maize field. Also includes grazing in Islamabad and special fodder plots in Mardan.

Given these data the value of green fodder (thinnings plus weeds) was calculated by Equation 6 and is shown in Table 7. The value of green fodder is highest in Islamabad and Swat as predicted by the number of plants removed from maize fields in these zones. However, we have probably overestimated the value of green fodder in Islamabad because other sources of green fodder (e.g., grasses) are also available to farmers in this area. The estimated opportunity value of fodder is lower in Mardan than would be predicted by the number of plants removed. We hypothesise that this is an under-estimation, since even in July, Mardan farmers have access to green fodder. In fact many farmers plant maize or sorghum fodder plots for this purpose. Hence in Mardan, green fodder removed from maize fields substitutes for other sources of green fodder available earlier in the season.

Table 7: Opportunity Value of Maize Green Fodder

Zone	Rupees/ animal/day	Rupees/ha. maize/day
Islamabad (rainfed low altitude)	6.46	36.4
Mardan (irrigated low altitude)	0.14	0.8
Mansehra (rainfed mid altitude)	1.40	6.7
Swat (rainfed mid altitude)	7.42	29.6

The final table (Table 8) gives the estimated percent of total value of production from maize fields provided in the form of grain, dry fodder and green fodder. Fodder (dry and green fodder) accounts for about half the value of maize production in both Islamabad and Swat. In the other areas it provides about one third of the value of production.

Islamabad and Swat, where fodder production is the most important, represent opposite extremes in agro-ecological variation. A high value on fodder production in Swat reflects a very small farm size combined with relatively large animal herds. This places considerable pressure on available cropped area to produce fodder. About one third of this land is sown to rabi fodder crops (Trifolium alexandrinum) and maize fields substitute for this green fodder in the monsoon period as well as provide dry fodder for the long winter period (Byerlee et al., 1987). In spite of the priority on fodder production, grain yields average close to 4.0 t/ha. This system seems to be quite productive and production of grain and fodder in separate fields is likely to reduce system productivity (Khan, 1986; Fischer and Javed, 1986).

Table 8: Economic Yield of Fodder in Relation to Grain Production.

Zone	Yield		Value			Total value from fodder[d]
	Grain	Stover	Grain[a]	Stover[b]	Green[c] fodder	
	(t/ha)		(Rs/ha)			
Islamabad (rainfed low altitude)	1.2	1.5	1800	750	1640	57%
Mardan (irrigated low altitude	2.5	3.0	3750	1500	45	29%
Mansehra (rainfed mid altitude)	3.0	3.7	4500	2257	350	37%
Swat (irrigated mid altitude)	4.0	4.9	6000	3000	2000	45%

[a] Field price Rs. 1.5/kg
[b] Field price 0.50 in low altitude areas and 0.61 in high altitude areas.
[c] Based on Table 7 and assuming 45 days fodder supply in low altitude areas and 50 days fodder supply in high altitude areas.
[d] Value (Stover+Green Fodder)/Value(Grain+Stover+Fodder).

In Islamabad zone, farm size is much larger but rainfall limits productivity. The proximity to urban areas increases the importance of livestock as a commercial enterprise. Given that grain yields are low in this system (1.2t/ha) where moisture is often limiting, high density stress causes a high level of barrenness of plants (over 40% in 1984). System productivity may be improved by planting separate fields for grain and fodder (Fischer and Javed, 1986).

Conclusions

Two simple methods have been proposed for measuring the relative importance of grain and fodder produced jointly in maize fields in four distinct zones in northern Pakistan. The recording of plant density over the growing cycle provided an estimate of the rate of plant removal for fodder. The recording of fodder given to animals at different points in the season provided an estimate of the opportunity value of green fodder, most of which was provided from maize fields. Both methods suggest that joint production of grain and fodder in maize fields is important in all zones and that fodder accounts for about one third to one half of the total value of production from maize fields. The relative value of fodder production was particularly high in two zones - the irrigated mid-altitude Swat Valley and the rainfed low altitude Islamabad district. Both zones are characterised by a high ratio of animals to maize area.

These results suggest that maize research and extension recommendations which do not consider the fact that farmers' produce maize for fodder as well as grain will often not be accepted by farmers. In particular, our data explain farmers' rejection of several of the recommendations including lower seed rates, line planting and early thinning, that have been extensively demonstrated to farmers since 1970. However, the data also show the substantial variability in practices and in the importance of fodder between zones. Hence, research and extension recommendations should be developed for each zone only after a careful diagnosis of the agro-climatic and socio-economic circumstances of farmers in that zone.

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