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QUANTIFYING AND VALUING THE JOINT PRODUCTION OF GRAIN AND FODDER FROM MAIZE FIELDS: EVIDENCE FROM NORTHERN PAKISTAN

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SUMMARY

Simple methods are proposed for measuring the relative importance of grain and fodder produced jointly from maize fields in four zones in northern Pakistan. These methods suggest that the joint production of grain and fodder from maize is important in all four zones and that fodder accounts for between one-third and one-half of the total value of the crop. The relative value of fodder production is particularly high in two of the zones (the irrigated mid-altitude Swat Valley and the rainfed low altitude Islamabad District), both characterized by a high ratio of animal numbers:maize area. The results suggest that maize research and extension recommendations that do not take into consideration the fact that farmers produce maize for fodder as well as grain will often not be accepted by farmers.

Derek Byerlee, Muzaffar Iqbal y K. S. Fischer: *Cuantificación y valoración de la producción conjunta de grano y forraje en campos de maíz: evidencia de Pakistán del norte.*

RESUMEN

Se proponen métodos sencillos para medir la importancia relativa del grano y el forraje producidos conjuntamente en campos de maíz en cuatro zonas del norte de Pakistán. Los métodos sugieren que la producción conjunta de grano y forraje del maíz es importante en las cuatro zonas y que entre la tercera parte y la mitad del valor total del cultivo corresponde al forraje. El valor relativo de la producción de forraje es especialmente elevado en dos de las zonas (el valle Swat, regado y de altura intermedia, y el distrito de Islamabad, zona de temporal de baja altura), ambas caracterizadas por una alta relación números de animales:superficie cultivada de maíz. Los resultados sugieren que la investigación sobre el maíz y las recomendaciones de extensión que no tomen en cuenta el hecho de que los agricultores producen maíz para forraje además de grano a menudo no será aceptado por los agricultores.

INTRODUCTION

The joint production of grain and fodder from maize fields is practised on many small-scale farming systems of the Third World, especially in the Middle East, south Asia and the densely populated highlands of Africa and Latin America (e.g. Fitch, 1983). Farmers often plant maize by broadcasting seed densely and then thin the stand throughout the growing season. The plant density is therefore often higher than optimal for grain production, but that may be compensated by the value of maize thinnings used as fodder. This system can therefore be analysed as an intercrop system, with fodder maize intercropped with maize for grain.

In northern Pakistan, most farmers follow practices that suggest joint grain and fodder production in maize fields. This has led to considerable controversy about the appropriate research and extension strategy for improving these systems. Research recommendations have emphasized grain production and given little attention to the importance of fodder. However, many of the recommendations which maximize grain production, such as a lower seed rate, line planting and early thinning, have been consistently rejected by farmers, despite major farm demonstration programmes in the 1970s (Byerlee and Hussain, 1986).

Joint production of grain and fodder in maize represents a conflict in management since the optimal density for grain production is considerably below that for fodder production (Edmeades and Daynard, 1979; Duncan, 1958). Maize yields show an inverse U-shaped response to density; plant barreness increases with density to a point where it negates any increase in yields brought about by an increase in the number of plants (Holliday, 1960). Delayed thinning increases plant competition and reduces grain yields (Schoper *et al.*, 1982; Eddowes, 1969; Francis *et al.*, 1978). However, Duncan (1972) and Fischer and Javed (1986) have suggested that, under favourable growing conditions, a greater initial density that increases Leaf Area Index early in the growing season may increase total dry matter yields. Hence the tradeoff between grain and fodder production will depend critically on the plant population at each stage in the growing season. Farmers' willingness to make a tradeoff is also likely to be related to the relative prices of maize grain and fodder. Furthermore, this tradeoff is likely to be a function of genotype, since genotype × density interactions have been widely observed in maize (e.g. Francis *et al.*, 1978; Bunting, 1973). Hence a better understanding of farmers' crop management may also have important implications for developing varieties appropriate to grain and fodder intercrop systems.

To date no quantitative data is available on the relative value of maize for grain and maize for fodder in systems where maize grain and fodder are jointly produced. This paper presents simple methods which can be used, 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. These methods are illustrated by application to four distinct agro-ecological zones in Pakistan. The results lead to a better delineation of the relative importance of maize as a grain and fodder crop in these areas and so provide a basis for formulating appropriate research and extension strategies.

METHODS

Data sources

During the 1984 season, between 15 and 20 maize fields were selected in each of four districts in the main maize producing areas of northern Pakistan –

Table 1. *Maize production seasons in the four zones of northern Pakistan studied*

	Altitude (m above sea level)	
	< 650	650–1250
	Islamabad	*Mansehra*
Rainfed (800–1200 mm)		
Planted	Early July	Early June
Harvested	Late September	Early October
	Mardan	*Swat*
Irrigated		
Planted	Late July	Mid-June
Harvested	Late October	Early October

Mardan, Swat, Mansehra and Islamabad Capital Territory. These districts were chosen to represent 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 increases the need for fodder supplies and so increases their value. In these areas, maize is planted early to provide a longer growing season. Under rainfed conditions, this involves planting in June when germination losses may be large because of marginal moisture conditions.

Farm size and the importance of livestock vary considerably between zones (Table 2). Farm size is smallest and the number of livestock per cultivated hectare highest in the mid-altitude irrigated zone, Swat. In addition, most of the cropped area in the summer (kharif) season is planted to maize so that pressure for fodder production is likely to be greatest in this area. Islamabad has the most animals per hectare of maize and Mardan the least.

In each of the selected fields, plant stands were counted at three- to four-weekly intervals during the growing season in four randomly selected plots of 4 m^2. At each visit the cultivator of the field was 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 and dry fodder fed to animals, but accurate estimates of the amount of green fodder used were difficult to obtain without weighing the fodder at the time it was being fed to animals. This was not possible within the resources of this study. Nonetheless, the estimates were thought sufficiently reliable to rank the different sources of green fodder in order of importance. Additional data on maize management

Table 2. *Selected characteristics of maize farms in the four zones*

	Islamabad	Mardan	Mansehra	Swat
Average farm size (ha)	4.5	3.1	2.2	1.6
Maize area (ha $farm^{-1}$)	1.0	1.9	1.5	1.3
Large animals ha^{-1} cultivated (including adult buffaloes, cows, and young stock)	2.6	2.4	3.2	4.4
Large animals ha^{-1} maize	11.3	3.7	4.6	5.8

practices and yields, as well as other aspects of the farming system, were obtained from a survey of approximately 100 farmers in each zone at harvest time.

Quantifying the rate of plant removal

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

$$D_t = a + bS + rt \quad (1)$$

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

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

These three forms are illustrated in Fig. 1a, b and c, respectively. In the linear model (Equation 1), farmers are assumed to remove plants at a fixed rate from emergence to harvest (i.e. $dD/dt = r$). The disadvantages of this model are two-fold. First, to provide a constant daily fodder supply, more plants are likely to be removed early in the season when plants are smaller. Conversely, later in the season the removal of fewer and larger plants should provide an equivalent amount of fodder. Second, to minimize the tradeoff between fodder and grain production, an early reduction in plant density is needed (Fischer and Javed, 1986; Chaudhry, 1983).

The second model (Equation 2) assumes that the *proportion* of remaining plants removed per day is constant. That is, in logarithmic terms:

$$\ln(D) = a + \ln(S) + rt,$$

$$(dD/dt)/D = r,$$

and

$$dD/dt = raS^b e^{rt} \quad (4)$$

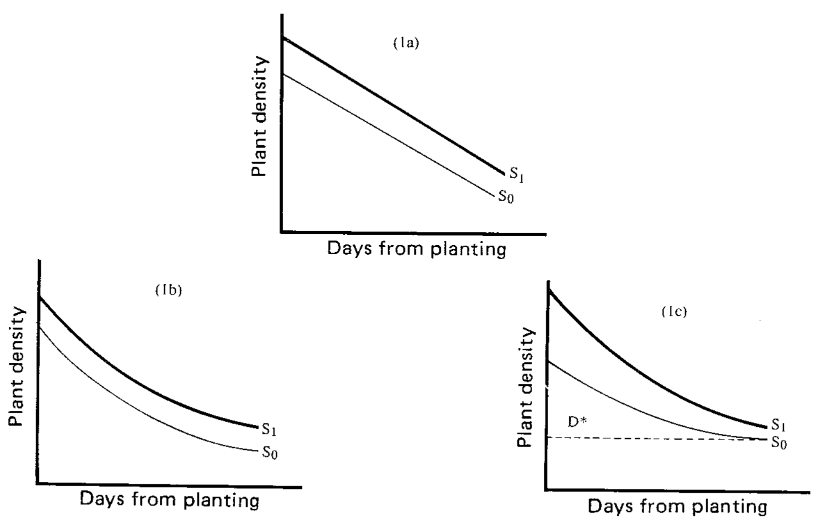

Fig. 1. Three models of maize plant removal at seed rates S_0 and S_1; D^* is target final density.

This implies that a decreasing number of plants are removed daily over the season. However, this may approximate to 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 $Q^t = nIe^{gt}$, where n is the number of plants removed per day, g is the rate of growth of dry matter per day and I is a constant. Since $n = dD/dt$, from Equation 4 we get by substitution:

$$Q_t = -raS^b e^{rt} Ie^{gt} = -raS^b Ie^{(r+g)t},$$

and

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

There are also disadvantages with this specification. First, plant growth is exponential only for the first 30–40 days before interplant competition becomes important. Second, r is constant regardless of initial plant density. If farmers, in fact, use high 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 Fig. 1. For these reasons, Equation 3 is a better specification. That is,

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

and

$$(dD/dt)/D = r\ln(S).$$

Equation 3 can be estimated in logarithmic form by setting:

$$\ln(D_t) = \ln(a) + b\ln(S) + rt\ln(S). \qquad (5)$$

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 u can be estimated by computing $D_0 = aS^b$ at $t = 0$ so that:

$$u = mS/D_0 = ms^{1-b}/a$$

where m is the number of seeds per kilogram.

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. The results for Equation 3 are therefore presented here.

Estimating the value of green fodder

There were two difficulties in placing a value on the green fodder 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 put a value on green fodder in rural areas. In many cases, exchange type relationships are used (for example, a livestock farmer is given the right to take fodder from a field in return for supplying farmyard manure to the owner).

Because of these difficulties an indirect method was used. This compared the animal diets at the beginning of the maize season, when no green maize fodder was available, with the diet later 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) mixed with purchased concentrates (usually cottonseed cake and wheat bran) which could be easily valued. The value of green fodder is thus given by:

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

where V_g is the value of green fodder ha^{-1} (indirectly estimated), p_i the price of fodder i (straw or concentrate), $X_{i,1}$, $X_{i,2}$ the quantity of dry fodder and concentrates given animals in period 1 (June) and period 2 (August), and A the farmers' total area of maize (ha).

This indirect method assumes that maize thinnings constitute the bulk of the green fodder that replaces dry fodder and concentrates. This is a reasonable assumption for Mardan, Mansehra and Swat where the bulk of the cropped area is maize and hence green fodder must be either maize thinnings or weeds from the maize fields. However, in Islamabad maize accounts for only 23% of farm area; most of the remaining area is left fallow and animals grazed on it during the summer. In this case, the assumption may lead to an over-estimate of the value of maize thinnings. Likewise, the method assumes that no green fodder is 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

Maize production practices in each zone are summarized in Table 3. In Islamabad, Mansehra and Swat, most farmers plant maize by broadcasting seed at well above the recommended rate of 30 kg ha^{-1}, followed by the 'seel' practice – that is, interculture with a local plough or tractor-drawn cultivator with some of the tynes removed. The seel has a number of purposes, especially weed control, but, most importantly for this analysis, it uproots and removes a significant number of maize seedlings. Hence, except for Mardan (where the seel is not practised), the decline in plant density in the first three to four weeks after planting is largely due to the seel operation. Maize seedlings uprooted by the seel are not generally used for fodder.

It is clear from Table 3 that maize management in Mardan is somewhat different from the other zones. In Mardan more 'conventional' practices are used – relatively small seed rates, mostly line planting and no seel to uproot plants.

The estimated coefficients of the regression analysis of plant density from Equation 5 are shown in Table 4. Seed rate has a significant positive effect on plant density in all zones except Islamabad District. The coefficient of tln(S) is

Table 3. *Summary of maize production practices in the four zones, 1983–84*

	Islamabad	Mardan	Mansehra	Swat
Seed rate (kg ha^{-1})	60	40	80	90
Fields broadcast sown (%)	100	39	98	100
Fields with 'seel' (%)	84	0	79	53
Plant density at harvest (10^{-3} ha^{-1})	103	65	63	80

Table 4. *Coefficients of the regressions of log plant density on log days from planting and log seed rate, with t values in parenthesis*

	Islamabad	Mardan	Mansehra	Swat
ln(S)	0.104 (0.73)	0.326 (1.87)*	0.398 (2.20)***	0.511 (3.72)***
tln(S) (× 10^3)	−4.39 (8.25)***	−3.06 (6.34)***	−1.41 (4.17)***	−2.44 (7.57)***
Constant	12.0	10.7	9.8	10.1
R^2	0.55	0.43	0.21	0.56
n	59	59	79	53

*, *** denote significance at the 0.05 and 0.001 levels, respectively.

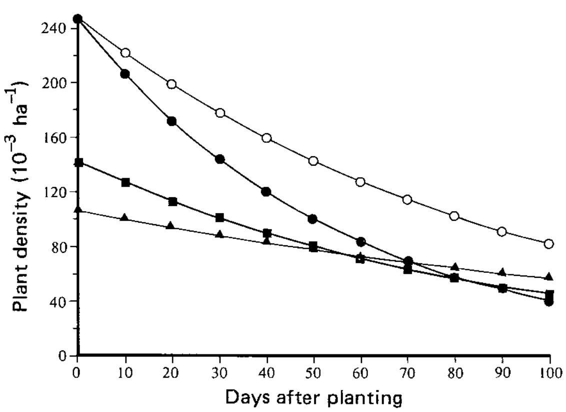

Fig. 2. Estimated relation between plant density and days after planting for four maize production zones in northern Pakistan (Swat o——o, Islamabad •——•, Mardan ▪——▪, and Mansehra ▲·——▲).

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. The estimated relations between plant density and days after planting are given in Fig. 2.

Parameters estimated from Table 4 are shown in Table 5. The estimated germination rate is high in all areas, except Mansehra, where very 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 averaged about 1% per day. The number of plants removed for fodder was computed as $D_{30}-D_h$, where D_{30} is the plant density 30 days after planting and D_h the density at harvest. (This assumes that plant removal prior to D_{30} is due to the seel and these plants are not used as fodder.) The results

Table 5. *Estimated germination percentage and number of plants removed for fodder*

	Islamabad	Mardan	Mansehra	Swat
Mean seed rate (kg ha^{-1})	60	40	80	90
Initial density (10^3 ha^{-1})	248	141	106	248
Estimated germination (%)†	92	100	38	79
Rate of plant removal (% day^{-1})	1.80	1.13	0.62	1.10
Total number of plants removed for fodder from 30 days after planting (10^3 ha^{-1})	95.4	49.5	40.9	95.7

† Based on 3500 seeds kg^{-1} except for Islamabad, where 4500 seeds kg^{-1} was used for the small kernel local variety.

Table 6. *Animal feed ingredients (kg $head^{-1}$ d^{-1}) used in the four zones in northern Pakistan, July to September 1984*

		Oilseed cake	Wheat flour	Wheat straw	Main green fodder
Islamabad	July	2.6	0.2	10.2	Other†
(rainfed	August	2.5	0.1	3.1	Maize thinnings
low altitude)	September	1.7	0	1.3	Maize thinnings
Mardan	July	0.0	1.3	4.8	Other†
(irrigated	August	0.5	1.0	5.2	Other†
low altitude)	September	0.3	0.7	3.5	Maize thinnings
Mansehra	July	0.7	0.6	6.4	na
(rainfed	August	0.6	0.8	2.3	Maize thinnings
mid-altitude)	September	0.6	0.7	0.8	Maize thinnings
Swat	July	1.1	1.3	14.9	Other†
(irrigated	August	0.4	1.0	0	Maize thinnings
mid-altitude)	September	0.7	0.6	0	Maize thinnings

Source: Farmer interviews at three-weekly intervals.
† Mostly weeds from outside maize field. Also includes grazing in Islamabad and special fodder plots in Mardan; na, not applicable.

indicate high rates of green plant removal in Islamabad and Swat but a low rate in Mansehra.

The importance of maize thinnings as fodder is shown by the data on animal diets in Table 6. Maize thinnings are an important livestock feed in all areas, especially in August and September. As the amount of green fodder used increases, the amount of concentrates and particularly dry fodder falls off.

From these data, the value of green fodder (thinnings plus weeds) was calculated using Equation 6; the results are shown in Table 7. The value of green fodder is greatest 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, such as 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 hypothesize that this is an under-estimation, since even in July some Mardan farmers have access to green fodder; in fact

Table 7. *Opportunity value of maize green fodder (Rupees 17 = $US 1.00)*

	Rupees animal^{-1} day^{-1}	Rupees ha^{-1} maize day^{-1}
Islamabad (rainfed low altitude)	6.46	36.4
Marden (irrigated low altitude)	0.14	0.8
Mansehra (rainfed mid-altitude)	1.40	6.7
Swat (rainfed mid-altitude)	7.42	29.6

Table 8. *Economic yield (t ha^{-1}) and value (Rupees ha^{-1}) of grain (15% moisture) and sun dried fodder, with estimated percentage total value of fodder (Rupees 17 = $US 1.00)*

	Yield		Value			Proportion of total value derived from green and dry fodder (%)
	Grain	Stover	Grain	Stover	Green fodder	
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

many farmers plant maize or sorghum fodder plots for this purpose. Hence in Mardan, green fodder removed from maize fields is used as a substitute for other sources of green fodder available earlier in the season.

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

Islamabad and Swat, where the relative value of fodder production is greatest, represent opposite extremes in agro-ecological variation. The high value of fodder production in Swat is a reflection of very small farm size combined with relatively large animal herds. This places considerable pressure on fodder production from the cropped area available. About one-third of the farm area is sown to fodder crops (*Trifolium persicum*) in the winter season, and maize fields provide a substitute for this green fodder in the monsoon period as well as providing dry fodder for the long winter (Byerlee *et al.*, 1987). In spite of the priority given to fodder production, maize grain yields averaged close to 4.0 t ha^{-1}. With a total dry matter production close to 10 t ha^{-1} despite relatively low input use, the joint production of maize grain and fodder in Swat is a very productive system. Total yields of maize grain would have to increase by 1.3 t ha^{-1} to compensate the farmer for the value of green fodder removed if the crop were grown for grain alone. In fact, on-farm yields from experimental plots managed according to recommended practices - that is, with no green fodder production - were only 5.5 t ha^{-1} despite much higher levels of inputs. In addition, it is unlikely that it would pay the farmer to plant separate fields of maize for grain and fodder as often recommended by researchers and extension workers. Khan *et al.* (1986) and Khan (1987) measured no significant effect of the recommended density management (early thinning to 60 000 plants ha^{-1}) on final grain yield, compared to farmers' density management.

In contrast to Swat, in Islamabad zone the farm size is much larger but rainfall limits productivity. Proximity to urban areas increases the importance of livestock as a commercial enterprise. Grain yields are low in this system (1.2 t ha^{-1}) where moisture is often limiting, and high density and moisture stress lead to a high proportion of barren plants at harvest (over 40% in 1984). In these circumstances, system productivity may be improved by planting separate fields for grain and fodder (Fischer and Javed, 1986).

CONCLUSIONS

Simple methods have been proposed for measuring the relative importance of grain and fodder produced jointly in maize fields in four distinct climatic zones of 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 fed to animals at different points in the season provided an estimate of the opportunity value of green fodder, most of which was supplied from maize fields. The results strongly suggest that the joint production of grain and fodder in maize fields is important in all the zones studied, fodder accounting for between one-third and one-half of the total value of production from maize fields. The relative value of fodder production was particularly high in the irrigated mid-altitude Swat Valley and the rainfed low altitude Islamabad District. Both zones are characterized by a high ratio of animals to maize area.

These results suggest that maize research and extension recommendations that 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 reduced seed rates, line planting and early thinning, that have been extensively demonstrated to farmers in northern Pakistan since 1970. The results also suggest that maize breeding programmes in northern Pakistan should give greater emphasis to varieties that minimize the conflict between grain and fodder production. Varietal characteristics such as capacity to yield at high densities, and fodder production characteristics such as leafiness and leaves which remain green near maturity, should improve the acceptability of varieties to farmers.

The data also show the substantial variability in production 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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