MODELING OF CROP-LIVESTOCK INTEGRATION: EFFECT OF CHOICE OF ANIMALS ON CROPPING PATTERN

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SUMMARY

Many small farmers that practise rainfed agriculture have low incomes and they are seasonally underemployed. Introduction of dairy animals on their farm increases the opportunity for employment and potentially adds to their income. This paper reports a study undertaken to design new farming systems with crops and dairy, for conditions which are representative of rainfed farming around Baroda in Gujarat. Linear programming was used to optimise the number, type and production level of animals that could be maintained on feed, from different cropping patterns. Also, the usefulness of feeding urea treated straw was tested. Two farm models were designed. The first model cultivated 1 ha sorghum, had access to freely available roadside grass and 3 kg concentrate, which gave a maximum total milk production per farm of 10.6 l/day by using animals of 8 l/day. Beyond a production level of 8 l per animal per day, the program selected cultivation of a cash crop (cotton) because animals with low individual production could utilize the grain straw. A higher animal production level implies that the poor quality feed cannot be used, i.e. the straw is not put to value and the straw plus grain loses its attractiveness as compared to cotton. Urea treatment of stover resulted in an increased total production of milk per farm and per animal. The magnitude of improvement due to treatment is low in animals producing less than 2 l milk per day, but larger at higher individual production levels.

The second model cultivated 0.9 ha of sorghum and 0.1 ha of Leucaena leucocaephala *with no grass. The number of animals was lower than in the first model, as insufficient DM was available. The production of animals almost doubled when the diet was supplemented with 3 kg concentrate. The total farm income increases with milk production, though at low levels the increases were small. The use of urea treated straw or supplementation with concentrate is most advantageous when fed to high productive animals. The mixed farming system is more remunerative than cash crops only, provided that the animal productivity is adjusted to the feed quality, in order to be able to utilize the available feed biomass.*

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INTRODUCTION

Many farmers with small landholdings in rainfed agriculture conditions have low farm incomes, and they are seasonally severely underemployed. Estimates for employment opportunities on rainfed crops vary from 100 - 200 man days/ha/yr, depending on the type of crop cultivated (Euroconsult, 1989). Thus a family of two adults is engaged in on-farm income generation activities for only a small part of the year. Inclusion of suitable dairy animals is reported to generate additional employment of 60 - 100 days, thus potentially adding to the income of the family depending on the productivity of the animal and on input/output prices in the particular farming system (Singh, 1987; Singh *et al.*, 1993). In order to maximize the farm income, the available resources must be identified carefully when selecting new crop and/or animal combinations. This paper describes a modeling excercise to design farming systems for the conditions of Baroda district in Gujarat. The work represents an example of a branch of Farming Systems Research that is called New Farming Systems Development by Simmonds (1986). Whereas he reserves the term for field testing of entire new systems, we feel that it can also be applied to desk excercises to test the possiblities of new designs. It is a simplified and hypothetical model along the lines of work by Morrison *et al.* (1986) and Vijayalakshmi *et al.* (1993), that is done to determine the value of the introduction of known transferable technologies.

THE MODELS

This study aims to maximize family income by selecting an optimum combination of livestock and (cash) crop cultivation for rainfed conditions around Baroda, the agro-ecological zone 3 in Gujarat according to Ghosh (1991). The crops selected for the model were sorghum and cotton as these are the preferred crops of the region. Cotton is a cash crop that fits the agro-climatological conditions and that absorbs much labour. The transferable techniques tested in the model are:

- urea treatment of stover;
- supplementation of the crop residue diet with small amounts of forage.

Linear programming was used to maximize farm gross margins and to determine the:

- optimum number of animals that should be maintained;
- optimum total and individual cow production of milk that could be sustained with available feeds;
- effect of stover treatment or supplementation on these parameters;
- livestock options;
- total gross margins income generated.

The model was kept very simple, and details are available upon request from the authors. Rather than to have one large matrix to choose between several individual production levels of cows in one model, the model was run for one level of individual cow production at the time with nutrient requirements as belonging to the production level under study. This simplification has two advantages:

- the matrix is kept small;
- the model gives not one single optimum solution, but it shows how the solution changes when cows of different production levels are used.

Two farm designs were tried with cows producing from 0 to 16 l/animal/day.

- Case I: consisting of 1 ha sorghum cultivation and roadside grass. The daily DM availability from roughage was 6.5 and 6.0 kg respectively from these two sources besides a fixed amount of 3 kg of concentrate per farm. This case was tried with and without treatment of the sorghum stover.
- Case II: no access to roadside grass, 0.9 ha of sorghum cultivation and 0.1 ha of a legume tree (Leucaena). The total available DM from these two sources was 5.85 and 2.2 kg/day respectively. This case was tried with and without 3 kg of concentrate per farm/day.

The following assumptions were made for the design of the hypothetical farm, being realistic for the conditions of Gujarati farming under consideration and based on a BAIF survey, with prices at 1989 levels.

a. A landholding of one hectare per farmer is based on the BAIF survey of 1987 (unpublished).
b. Yields of sorghum grain and stover under rainfed condition are 2000 and 2400 kg DM/ha respectively.
c. Forage yields of cotton and Leucaena were assumed to be zero and 8000 kg DM/ha respectively.
d. DM intake of a cow of 350 kg bodyweight varies between 2.2 and 3.4% of bodyweight, increasing with the production from zero to 16 l milk/animal/day.
e. Maintenance requirements of cows for energy and protein were assumed to be 30 g TDN and 5 g CP/kg$^{0.75}$/day. The requirement of these nutrients for milk production was taken at 350 g TDN and 87 g CP/kg fat corrected milk (4% fat). (Euroconsult, 1989) which is based on NRC-standards.
f. Availability of homemade concentrate (18% CP and 65% TDN) was assumed at 3 kg/day/farm. This restriction may sound a bit odd, since increased income from increased milk production would allow increased concentrate purchases, but the case is quite common in the reasoning of cash strapped farming systems for which this model is meant.
g. Concentrations of TDN and CP in forages are shown in Table 1.
h. Roadside grass is freely available in Case I but one adult can only harvest a maximum of 6 kg grass DM in one hour, i.e. the total amount is limited by the amount of labour on the farm.
i. Farm gate price of milk, sorghum grain and cotton is 3, 1.5, and 6 INR/kg respectively.

j. Net income from sorghum and cotton is INR 1.26 and 3.5/kg (allowing for expenses incurred on seeds, fertilisers and pesticides but excluding labour, land rent, depreciation and interest).

Table 1 Energy and crude protein contents of forages (% of DM)

Forage	CP	TDN
Sorghum stover	4	50
Grass	11	55
Leucaena	24	60

RESULTS

Case I

The best combination was mixed farming, with a total milk production of 10.6 l/day, obtained from animals with a production level of 8 l/animal/day (Table 2). Beyond this level of production per cow, the cash crop (cotton) cultivation replaced grain production. This is because a higher production per animal makes it impossible to utilize the sorghum stover in the ration. If stover cannot be put to use through the production of milk then the income from grain alone is less then cotton. If stover can be used, then the combined value of grain and stover is higher when stover is only considered as animal feed and when its value such as for fuel in the household is ignored.

The analysis shows that the limiting factor for increased dairy production per farm and per cow is the availability of CP. This would suggest that research and extension should focus on provision of crude protein, by methods such as:

- additional concentrates or use of concentrate with a higher protein content,
- supplementation with protein rich forage,
- urea supplementation or treatment of the stover.

Two such alternatives were actually studied in case I. The first is urea treatment of the stover. Use of urea treated stover increased the number of animals that could be supported and also the total production per farm improved at all levels of individual cow production. Use of straw treatment had little effect on the total system production when animals of low individual production (< 2 l/animal/day) were used. The individual production that gave maximum income of this mixed farming was 10 l/day giving a total production of 14 l/day/system. Beyond 10 l/animal/day, cotton cultivation was selected in a progressive manner (Table 2). In that case either the energy content or the dry matter intake of the available feeds became the limiting factor for increased milk production per cow and the system.

The total income of the farm followed a trend similar to the individual animal production, and was highest at 10 l/animal/day on TS. It is also apparent from Table 2 that urea treatment of stover does not offer much advantage when the individual productivity of the animals is low, which agrees with the findings of Nell *et al.* (1986), Rai *et al.* (1988) and Kumar *et al.* (1993). At a production of 10 l/animal/day, the use of treated stover resulted in additional income of INR 10/farm/day, i.e. INR 49 versus INR 39 on untreated stover which can easily cover the cost of treatment.

Table 2 Optimum crop combinations, herd size and production at different individual cow productions with or without treatment of stover (Case I)

Individual production (l/day/cow)	Total production (l/day/system)		Herd size		Cotton* (ha)		Total income from milk and crops (INR/day/farm)	
	US	TS	US	TS	US	TS	US	TS
0.3	1.0	1.1	3.5	3.6	0	0	10.5	10.5
2.0	5.1	5.6	2.5	2.8	0	0	22.2	23.8
4.0	7.8	9.2	1.9	2.3	0	0	30.4	34.4
6.0	9.5	11.6	1.6	1.9	0	0	35.4	41.7
8.0	10.6	13.0	1.3	1.6	0	0	38.9	45.9
10.0	10.6	14.0	1.1	1.4	0.4	0	39.1	49.0
12.0	10.4	12.9	0.9	1.1	0.8	0.4	38.9	45.9
16.0	6.6	6.6	0.4	0.4	1.0	1.0	27.6	27.6

Note: * total area is 1 ha, i.e. 0 ha cotton implies 1 ha of sorghum, 0.4 ha cotton implies 0.6 ha sorghum

Case II

The number of animals in case II was lower than in case I, due to less available DM from Leucaena than from roadside grass. Without concentrate supplementation the maximum total milk production of the system was 5.4 l/farm, which increased to 10.7 l after supplementation with 3 kg of concentrates. The individual animal production was also higher on the supplemented as compared to the unsupplemented diet.

The limiting nutrients in case II are shown in Table 3. Without concentrate supplementation, CP was the limiting nutrient for all production levels while TDN became limiting for the production levels beyond 10 l/animal/day. With concentrate supplementation, TDN was the critical nutrient at low levels of milk production (< 6 l/animal/day) while CP became limiting at 8 l/animal/day. At high milk yields per animal, it becomes impossible to use high levels of stover in the cows diet, just as in case I, because of the low nutrient concentration of the stover. This means that the stover becomes without value (again ignoring its use as fuel, thatch etc.), and the income from the cotton cash crop alone becomes higher than from the grain crop alone when the stover cannot be fed.

The total farm income increased initially in case II (as in case I) with higher individual milk production both with or without supplement. It decreased again when the individual animal production became too high to incorporate the stover in the animal diet. The extra gain was small at lower production levels, and higher at the highest level of milk production where the increase was INR 14/day/farm which at current prices is more than the concentrate costs. It indicates that at low levels of milk/animal it is not wise to suggest supplementation, unless the supplement substantially increases milk production or improves lactation persistency, fertility etc.

The cost of treating stover is reported to be INR 180 per 1000 kg in this region (Rangnekar *et al.*, 1986). For treatment of 2400 kg of stover the total cost would be INR 430 as against the cultivation cost of Leucaena which is reported to be INR 2250 per hectare excluding irrigation costs and opportunity cost of the land (Relwani, 1983) as in our model. Thus for the case under

Table 3 Optimum crop combination, herd size and production at different individual cow productions with or without concentrates for case II (sorghum/cotton/*Leucaena*)

Cow type (l/day/cow)	Production (l/day/unit)		Herd size		Value (INR/unit)		Cash crop (ha)	
	C0	C3	C0	C3	C0	C3	C0	C3
0.3	0.5	0.8	1.8	2.6	8.0	8.8	0	0
2.0	2.6	4.0	1.3	2.0	14.3	18.2	0	0
4.0	4.0	6.5	1.0	1.6	18.3	25.7	0	0
6.0	4.9	8.2	0.8	1.4	20.9	30.9	0	0
8.0	5.4	9.4	0.7	1.2	22.8	34.6	0	0
10.0	5.4	10.2	0.5	1.0	22.6	36.8	0.22	0
12.0	4.2	10.7	0.3	0.9	19.4	38.1	0.59	0.1
14.0	0	8.0	0	0.5	7.9	31.1	1.0	0.8

Note: C0 = no concentrate; C3 = 3 kg concentrate/farm/day

Table 4 Limiting nutrients for production in the case of *Leucaena* but no grass.

Cow type	Production (l/animal/day)		Herd size		Surplus CP		Surplus TDN	
	C0	C3	C0	C3	C0	C3	C0	C3
0.3	0.5	0.8	1.8	2.6	0	0.26	0	0
2.0	2.6	4.0	1.3	2.0	0	0.15	0.16	0
4.0	4.0	6.5	1.0	1.6	0	0.08	0.42	0
6.0	4.9	8.2	0.8	1.4	0	0.03	0.56	0
8.0	5.4	9.4	0.7	1.2	0	0	0.7	0.03
10.0	5.4	10.2	0.5	1.0	0	0	0.30	0.21
12.0	4.2	10.68	0.3	0.9	0.09	0	0	0.18
16.0	0	8.0	0	0.5	0	0.27	0	0

Note: C0 = no concentrate; C3 = 3 kg concentrate/farm/day consideration, the cost of leucaena would be INR 225 per year as per 0.1 ha. These cultivation costs were based on prices in 1985 and assuming 25% increase it would work out to approximately INR 280. Thus, use of treated stovers seems to be more attractive than planting of *Leucaena* or any other similar crop when income is considered (INR 10.93 per day, i.e. INR 3989 per year). However it may be added that under dry farming conditions the forage would be available for a period of 8 months and very little production of roadside grass can be obtained during the summer months.

The use of such models can be helpful to understand the systems. The models however need to be refined, and should include refinements of the models, such as the use of integer planning, effect of herd composition and season effects. The inclusion of season effects by using multiperiod LP is shown in this workshop by Vijayalakshmi *et al.* (1993).

CONCLUSIONS

The quality of (un)treated stovers with or without supplements are insufficient to provide the nutrients for the animal beyond 10 l productivity (Tables 2 and 3). The model then suggests that use of cotton should replace the combination sorghum and livestock, though total income will decline. This clearly illustrates that livestock production cannot be seen in isolation of the cropping system. Integration of two sub-systems may require that the production levels of individual sub-systems may have to be adjusted to reach maximum total system productivity. Use of urea treated stover does not appear to be economical when fed to either low or very high producing animals. Mixed farming systems are potentially more remunerative than cotton or sorghum alone. They can provide additional labour opportunity, provided the individual animal productivity is adjusted to nutrient availability. The simple model of this paper is far from perfect, but it shows that optimum cropping patterns are affected by the type of animals or additional feeds available.

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