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EX-ANTE ECONOMIC TECHNOLOGY EVALUATION FOR RESEARCH AND EXTENSION PROGRAM DESIGN: SHEEP PRODUCTION IMPROVEMENT IN BALUCHISTAN, PAKISTAN

by

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EX-ANTE ECONOMIC TECHNOLOGY EVALUATION FOR RESEARCH AND EXTENSION PROGRAM DESIGN: SHEEP PRODUCTION IMPROVEMENT IN BALUCHISTAN, PAKISTAN

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SUMMARY

An *Ex ante* economic evaluation of eight health (vaccination and dipping), flock management, high energy feeding, and breeding intervention combinations for the improvement of sheep production in Baluchistan were analyzed using a sheep flock budgeting model. The objective was to provide information for research and extension program design prior to the undertaking of a full experimentation program. The budgeting model included both technical performance and economic parameters using synthesized data from limited available experiments supplemented by informal and formal farmer and key informant survey information. Results indicated that health and flock management interventions were highly profitable, suggesting that vaccine and dipping solution availability and farmer knowledge were the key constraints to their further usage. Interventions involving feeding failed to prove to be economical, suggesting that research programs should turn to lower-cost feeding regimes.

INTRODUCTION

Research undertaken within a farming systems perspective follows a pattern of descriptive and diagnostic studies, research design, on-farm testing and evaluation, and dissemination and monitoring (Nagy and Sanders, 1989). Descriptive and diagnostic studies are used to identify farmers' major production and marketing constraints and priority problems. This information is then used to form hypotheses about major research and extension opportunities and incorporated into the design of these programs. On-farm testing and evaluation of the interventions include an assessment of the technical viability in the field, economic profitability and risk, and the fit of the interventions within the farming systems.

Ex-ante economic analysis has been used as part of the evaluation process to assess new technologies and management interventions once research has been designed and completed (Goodwin *et al.*, 1980; Ghodake and Hardaker, 1981; Nagy *et al.*, 1988). *Ex-ante* economic analysis is used to screen interventions to identify those that have a high likelihood of being profitable for the farmer to adopt. This information is then provided to extension services and is also used as feedback for the modification of the research program. Various approaches have been used in conducting the economic analysis and these include partial budgeting, budgeting models, and mathematical programing models (Anderson *et al.*, 1985; Ghodake and Hardaker, 1981).

The objective of this paper is to use *ex-ante* economic analysis to screen alternative interventions prior to the design of a research and extension program. This makes the economic analysis part of the descriptive and diagnostic process. The main purpose of this type of analysis is to provide information for the design of a research program so that limited research resources can be used more effectively. The results of the analysis will indicate the most economic interventions which can thèn be considered in the research and extension program design.

An *ex-ante* economic analysis of health, feed, flock management, and breeding interventions for the improvement of sheep production in upland Baluchistan is presented. The *ex-ante* economic evaluation is undertaken with the aid of a flock budgeting model which evaluates flock productivity and economic performance of the interventions. This paper follows from descriptive and diagnostic survey work that hypothesized that health, feed, and management interventions are a high priority research area that could alleviate major constraints to sheep production in Baluchistan. (Nagy *et al.*, 1989a).

MAJOR CONSTRAINTS OF THE SHEEP FARMING SYSTEMS

Nagy *et al.*, (1989a) have undertaken descriptive and diagnostic studies of the sheep and goat farming systems of upland Baluchistan. The 11.1 million sheep and 7.3 million goats represent 93% of all livestock in Baluchistan and accounts for 25% of the Gross Agricultural Product of Baluchistan. Most flocks are small - between two to ten ewes. Sheep and goats obtain most of their feed from rangelands and there is evidence of overgrazing and deforestation. Transhumant production systems account for over 50% of sheep and goat production; 30% are nomadic and the remainder are household and sedentary. Sheep are mainly of the fat-tailed type, a number of breeds exist and flocks contain a mixture of these breeds (Hasnain, 1985). Most of the rangelands are tribally controlled but are grazed in common by farmers of the same tribe with no rangeland management. Few farmers use veterinary services or other modern inputs.

The major limiting factor to increasing sheep and goat productivity in Baluchistan is the harsh climatic environment with low (50 - 400 mm) and erratic intra- and inter-year rainfall (less than 100 mm rainfall four years in ten) and cold winter and hot summer air temperatures (-10^{o} to $+40^{o}$ C) (Rees *et al* 1987). Important constraints to increased sheep and goat productivity which largely stem from the harsh environment include:

1. Nutritional Deficit

Ninety to ninety-five percent of all sheep and goats rely on rangeland for their feed and few farmers supplement rangeland feed. Crop stubble, when available, is grazed but most crop residues are sold in the market for draft animal use or used for building purposes. Overgrazed rangeland, which represents most of the Baluchistan rangeland, provides only 30-50 Kg/ha of dry mater (DM) (FAO, 1983). There is also a deficiency of cool-season range grasses which could provide early spring forage. Estimates indicate an overall deficit of 7% total digestible nutrients (TDN), 16% digestible protein (DP) and 11% DM (FAO, 1983). The nutritional deficit appears to be correlated with disease incidence and mortality in the winter months. Low conception, lambing and weaning percentages reflect the low nutritional status of the animals (Nagy et al., 1989a).

2. Animal disease and health problems

Mortality and morbidity losses are high from disease and parasites. Enterotoxaemia is a major disease. The incidence of endo-parasitism is high: Nematodirus spp. 86%, Haemonchus contortus 63%, Strongyloides papillosus 49%, trichostrongylus spp. 42%, and Marshallagia marshalli 41%. They also reported an ecto-parasitism incidence of tick infestation (Ixodes ricinus) at 35% and sheep scab (Psoroptes ovis) at 23% (Khan et al., 1988). The above study also reported that 100% of the animals in the sample had one or more of the above parasites.

3. Poor flock management

Flock management practices by farmers are a major constraint to increased productivity: (1) the young are not allowed access to the ewe for the entire day while the ewe is grazing which causes high mortality and morbidity losses due to stress and diarrhea, (2) shearing practices - leaving wool on the belly and head at shearing time - result in increased parasitism and also prevents effective dipping, (3) at birth, the umbilical cord is often dried and sealed with manure or dirt, causing tetanus and joint ill, (4) lambs from birth to two weeks old are often not picked up properly damaging muscles and rib cages, and (5) poor overall flock inspection and culling procedures result in poor flock composition and health (Nagy et al., 1989a).

4. Poor genetic potential of animals

Breeding animals are first selected for their ability to survive because of the harsh environment and secondly - if at all - for growth rate, wool production and quality, and lambing percentage. Animals that survive the low rainfall and poor forage years may not have great potential in good rainfall years that produce better forage or when given supplemental feed.

Other important constraints and priority problems include (1) limited industry infrastructure including poor credit, transportation, veterinary and marketing facilities, (2) no rangeland management or control, and (3) no overall government research, extension and industry strategy.

METHODS AND PROCEDURES

The Model

A sheep flock budgeting model was used to evaluate the impact from a set of selected interventions on overall flock productivity and economic performance (Model initially developed by E.R. Mallorie and available from the Authors). Physical and financial coefficients describing sheep production are linked together in the model by equations and made operational by using the LOTUS 123 or SUPERCALC computer programs. The model compares the costs and benefits of traditional farming practices with selected interventions. The main criteria for screening the interventions are economic profitability using benefit-cost ratios (B/C), dominance analysis, and marginal rates of return.

Given specific data, the model calculates the input requirements and the output of a unit of 100 breeding females under existing and improved conditions. The model is currently able to evaluate interventions resulting from supplementary feeding of fodder and concentrates, vaccination and parasite control, improved management, and improved breeding practices. It is sufficiently flexible to handle seasonal and year-round lambing patterns and feeding programs. Both technical and financial performance indicators are made available to the researcher. It is also able to account for changes in herd structure which result in increased pressure on grazing and can adjust results so similar numbers of "ewe" equivalent units" are used in both traditional and intervention situations.

The model is static and accounts for a one year production cycle. While production takes place in a dynamic environment and actual flock productivity depends on flock structures inherited from the previous period as well as performance parameters in the current period, static models are an appropriate method for comparing technologies (Anderson *et al*, 1985).

The Interventions

Eight health-feed-management interventions were evaluated using the model. Two scenarios were followed: (1) analysis of the interventions with technical coefficients and prices representing a good agricultural rainfall year (> 250 mm rainfall) and good feed supplies, and (2) an analysis of the interventions with technical coefficients and prices representing a poor agricultural rainfall year (< 150 mm rainfall) with poor feed availability.

The model was run under traditional farmer practices and under 8 intervention packages which comprised combinations of health, feed, flock management, and breeding practices. The traditional farmer practices have been outlined above. The eight intervention scenarios for both good and poor rainfall years as used in the model are as follows:

1. Vaccination against enterotoxaemia of ewes, rams and unweaned lambs ("V").

2. "V" as given above, and de-worming in March and July and dipping at the end of May ("D").

3. "V" plus "D" as given above plus Improved Management ("M"). Improved management factors consist of: (1) keeping lactating mothers and their lambs together at all times, (2) proper shearing of animals, (3) treatment of lambs at birth by treating the umbilical cord with an iodine solution, (4) proper handling of the very young lambs, and (5) proper flock inspection and culling procedures and, (6) the use of a higher ram/ewes breeding ratio.

4. "V" plus "D" as given above plus flushing ewes and supplementary feeding of ewes during lactation at the levels presented in Table 1 under heading F1.

5. "V" plus "D" plus "M" as given above plus flushing ewes and supplementary feeding of ewes during lactation at the levels presented in Table 1 under heading F2.

6. "V" plus "D" plus "M" as given above plus flushing ewes and supplementary feeding of ewes during lactation plus feeding pre-weaned and post-weaned lambs at the levels presented in Table 1 under heading F3.

7. "V" plus "D" plus "M" as given above plus flushing ewes and supplementary feeding of ewes during lactation plus feeding pre-weaned and post-weaned lambs and feeding ewe and ram replacements in poor years at the levels presented in Table 1 under heading F4.

8. "V" plus "D" plus "M" plus flushing ewes and supplementary feeding of ewes during lactation plus feeding pre-weaned and post-weaned lambs, and feeding ewe and ram replacements in both good and poor years at the levels presented in Table 1 under heading F5 plus improved ram breeding stock.

The Data

The stage in the research process which the economic analysis is being undertaken requires that data and information be synthesized by experienced researchers from limited available experimental data supplemented with information from the descriptive and diagnostic surveys. Synthesized data have been previously used by Goodwin et al., (1980) in their appraisal of sorghum technologies in Brazil.

The technical coefficients used in the model for the good and the poor rainfall year scenarios for each of the eight intervention packages are presented in Tables 2 and 3, respectively. The technical coefficients are synthesized from preliminary research results from Stubbs, (1988) and from the descriptive and diagnostic data and information from Nagy et al., (1989a). Informal information from researchers from the Baluchistan Livestock Department and from AZRI were also used. Vaccination, de-worming and dipping costs are presented in Table 4.

In the good rainfall year scenario, feed costs of Rs. 1500/tonne for lucerne, Rs. 500/tonne for straw and Rs. 3058/tonne for concentrates were used. The costs of lucerne and concentrates were increased by 25% and straw by 100 % for the poor rainfall year scenario. The live weight prices per kg used in the model are Rs. 17 for young male stock, Rs. 15 for young female stock, Rs. 14 for culled ewes and Rs. 18 for culled rams in the good rainfall year scenario. Poor rainfall year scenario prices are Rs. 27 for young male stock, Rs. 25 for young female stock, Rs. 24 for culled ewes and Rs. 28 for culled rams. The good rainfall year feed and animal prices are based on a survey in 1986-87 when rainfall averaged between 350 mm to 700 mm across

Baluchistan. The poor rainfall year prices are based on a survey of 1987-88 prices where rainfall averaged 100 mm.

From the animal price survey, lower market prices for sheep have been observed in good rainfall years (1986-87) relative to poor rainfall years (1987-88) when crop and range production are very low. Farmers seem not to sell off their flocks in poor rainfall years even though there is a decrease in feed availability. This is contrary to conventional thinking on the relationship between animal prices and feed availability. A possible explanation is that most sheep flocks are kept as a store of wealth and used as collateral for borrowing money from village money lenders in poor agricultural years. Farmers are more likely to pay off their loans in kind (sheep) or by the sale of sheep in good rainfall years when crop production is high. Farmers are able to maintain their sheep flocks on the meager rangeland in poor rainfall years although in a much poorer condition giving rise to increased mortality and morbidity rates and to decreased birth rates. Thus it appears that more sheep are on the market in good rainfall years than in poor rainfall years. The decreased numbers available for sale in poor rainfall years have the effect of raising prices.

The feeding regimes presented in Table 1 for good rainfall years represent about 40 to 45 % of the adult sheep requirements for high production - the remainder is obtained from the range. In the poor rainfall year, the feeding regimes presented in Table 1 represent about 90% of adult sheep requirements for high production.

To indicate the sensitivity of the B/C ratios and marginal rates of return, the model was run with: (1) poor rainfall year coefficients (Table 3) and a 20% decrease in poor rainfall year sheep prices, (2) changing the feed prices for both good and poor rainfall year scenarios by plus and minus 20% and (3) changing the technical coefficients (from Tables 2 and 3) by decreasing the % ewes lambing and lamb weights and increasing the technical coefficients of pre-weaning mortality, % breeding stock mortality and % lamb mortality from weaning to sale - values used were the mean of the traditional coefficients and that of the intervention coefficients.

RESULTS

Good Rainfall Year Scenario

The B/C ratios of the good rainfall year scenario (Table 5) are all greater than 1.0. To disclose the relative economic performance of each intervention, dominance analysis is presented in Table 6 and is depicted in Figure 1 for the good rainfall year scenario interventions (see Perin et al., 1976 for a discussion on dominance analysis). The interventions on the net revenue curve in Figure 1 are the undominated interventions. That is, a farmer might choose all interventions with the exception of interventions 4 and 6. Interventions 4 and 6 would not be chosen because they are "dominated" - a farmer can choose other interventions (i.e., intervention 3) that will give the farmer a higher net revenue at a much lower cost per ewe.

Poor Rainfall Year Scenario

The B/C ratios of the poor rainfall year scenario (Table 5) are not all greater than 1.0 - interventions 4, 5, and 6 have a less than 1.0 B/C ratio indicating that the traditional practice would be chosen over these three interventions. The dominance analysis presented in Table 6 and depicted in Figure 2 indicates that intervention 7 is dominated along with interventions 4, 5, and 6 (not shown on Fig 2.) For all of these latter four interventions, there is an alternative that will give a larger net revenue at a lower cost.

Sensitivity Analysis

A 20% decrease in poor rainfall year prices resulted in all interventions with feed (4 through 8) to be dominated (results not presented). Interventions 1, 2, and 3 retained their previous relative ranking.

Intervention 5 became dominated when feed costs were increased by 20% in the good rainfall year scenario (Table 7). When prices were decreased by 20%, intervention 5 became viable and the economic performance of interventions 7 and 8 was strengthened. In the poor rainfall year scenario, a 20% increase in feed costs resulted in interventions 4 through 8 (those with feed) to be dominated. A decrease in feed costs by 20% resulted in a substantial increase in the marginal rate of return of intervention 8.

When the technical coefficients were changed *to bias* the economic results downward, model results indicated the following B/C ratios of 31.0, 3.6, and 4.4 for interventions 1, 2, and 3 respectively in the good rainfall year. The B/C ratios for the poor rainfall year were 41.2, 4.5 and 5.6 for interventions 1, 2 and 3 respectively. B/C ratios for interventions 4 through 8 for both good and poor rainfall years were less than 1 (results not presented).

DISCUSSION AND CONCLUSIONS

Socio-economic research suggests that farmers adopt single technologies or "clusters" of technologies en route to the adoption of technology packages - farmers will adopt technologies in a stepwise pattern or in clusters based on the criteria of their profitability relative to on-farm and off-farm alternatives, riskiness, initial capital requirements, complexity and availability (Byerlee and Hesse de Polanco, 1986). The net revenue curves depicted in Figures 1 and 2 indicate the paths that farmers might follow in sequentially adopting the set of selected interventions based on net returns. The interventions not on the net revenue curve are dominated because there is an intervention on the net revenue curve that will return a higher net revenue at the same or lower cost. It is, therefore, unlikely that the dominated interventions would be adopted by farmers unless an intervention on the curve does not fulfill the risk, capital, complexity or availability criteria, thereby making a dominated intervention the next best alternative.

Of the eight, interventions 1, 2, and 3 involving vaccination, de-worming, dipping and flock management were economically profitable under both good and poor rainfall year scenarios. Although the economic returns seem satisfactory, research is required to confirm the robustness of the coefficients used in the model for the three interventions - especially the performance coefficients for flock management improvement. It is encouraging, however, that the economic returns remained high for all three interventions when the sensitivity analysis was run with less robust performance coefficients. These three interventions, especially if used in combination, seem viable opportunities to increase sheep productivity in Baluchistan. The interventions are not costly, the risk of using them is low, they are not complex and are within the farmers' ability to undertake themselves. Given that further research supports the model results, why are not more farmers using the interventions today? The key to their adoption may be increasing the availability of vaccines and medicines along with increasing the farmers' knowledge through demonstration and extension programs.

Interventions 4 through 8, which involve *feeding*, did not prove to be highly economical overall with B/C ratios around 2 and less. In the good rainfall year scenario, interventions 4 through 8 all had a B/C ratio of 1 or greater but, given feed availability, only interventions 5, 7 and 8 would be considered by farmers and would appear on the net revenue curve (Fig 1). The cost of financial capital and the farmer's risk premium would likely rule out intervention 5 with a marginal rate of return of 16% - the sensitivity analysis of 20% increase in feed prices caused intervention 5 to be dominated.

In the poor rainfall year scenario, only interventions 7 and 8 had a B/C ratio greater than 1 but intervention 7 is dominated (Fig 2). It is unlikely that farmers would choose intervention 8, which includes improved ram breeding stock, with a marginal rate of return of only 0.6%. A 20% increase in feed costs caused interventions 4 through 8 to be dominated while a 20% decrease in feed prices substantially increases the viability of intervention 8.

The model results coincide with farmer feeding practices - high costs limit the amount fed and only some sheep and goats are given limited supplementary feed. The non-profitability of interventions 4 through 8 in poor rainfall years is disruptive to a sustained feeding regime and may be the reason why intervention 8 would not be adopted in a good rainfall year even though the model results suggest that it may pay.

Interventions 4 through 8 have a high energy feeding level with the best available feeds which are priced at the market level. While research can further validate the model coefficients related to the feeding of these rations, it may be more appropriate to spend limited research resources to research different feed sources and feeding rations at lower levels (maintenance levels and above) rather than at full productivity levels as was done in the model. For example, feed availability could be increased by the use of forage reserves. Preliminary research on fourwing saltbush, Atriplex canescens, a nutritious, palatable, drought tolerant forage shrub, indicates that it could, at the very least, be used as survival feed in poor years (Atiq-ur-Rehman et al. , 1988). Fourwing saltbush might, however, provide more than a survival ration and further research is necessary to assess its role in combination with other supplemental feeds in both good and poor agricultural years, and in different periods in the annual production cycle of animals.

The information from the model has pointed out broad directions that research and extension might follow to ensure that interventions are economically viable and are, therefore, given a better chance at being adopted by farmers. Limited research is required on interventions 1, 2 and 3 but the main thrust would seem to be making the interventions available and organizing extension activities. The research on feeding requires interventions such as farmers growing their own fodder (Nagy et al., 1989b; Rees et al., 1987) and fodder reserves that may be more economical and, for now, not on high energy, high production diets. Production performance coefficients associated with health, flock management, maintenance and above feeding regimes, and improved breeding requires further research. The information from the model also clearly indicates that feeding interventions for Baluchistan must take note of the difference in requirements for both good and poor rainfall years.

The model building exercise has also pointed out the type of data and information that are required for technology screening (Tables 2, 3, and 4). It may also be appropriate to build a model to follow the flock dynamics over a period of years to fully assess the profitability of the interventions. To do this, research must be carried out over weather cycles to obtain information and coefficients similar to those found in Tables 1 and 2. A future step is to model improved range management interventions and other available management and health interventions.

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Table 1. Supplementary feeding regimes for ewes, lambs and replacement stock during good and poor agricultural years.

	Supplementary Feed Interventions for Good and Poor Rainfall Years									
	(4)		(5)		(6)		(7)		(8)	
	Good	Poor	Good	Poor	Good	Poor	Good	Poor	Good	Poor
	F1		F2		F3		F4		F5	
	Kg/DM/Head/Day									
Dry Ewe (Flushing)										
Lucerne	0.2	0.6	0.3	0.6	0.3	0.6	0.3	0.6	0.3	0.6
Wheat straw	0.0	0.6	0.0	0.6	0.0	0.6	0.0	0.6	0.0	0.6
Concentrates[1]	0.0	0.0	0.0	0.0	0.2	0.2	0.2	0.2	0.2	0.2
Days on feed	30	60	30	60	30	60	30	60	30	60
Lactating Ewe										
Lucerne	0.3	0.6	0.3	0.6	0.3	0.6	0.3	0.6	0.3	0.6
Wheat straw	0.0	0.6	0.0	0.6	0.0	0.6	0.0	0.6	0.0	0.6
Concentrates	0.2	0.3	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2
Days on feed	90	60	90	90	90	90	90	90	90	90
Lambs: Pre-Weaning										
Lucerne					0.1	0.2	0.1	0.2	0.1	0.2
Wheat straw					0.0	0.0	0.0	0.1	0.0	0.1
Concentrates					0.0	0.0	0.0	0.0	0.0	0.0
Days on feed					60	90	60	90	60	90
Lambs: Post-Weaning										
Lucerne					0.1	0.3	0.1	0.3	0.1	0.3
Wheat straw					0.0	0.2	0.0	0.2	0.0	0.2
Concentrates					0.0	0.0	0.0	0.0	0.0	0.0
Days on feed					60	60	60	60	60	60
Ewe & Ram Replacements										
Lucerne								0.3	0.1	0.3
Wheat Straw								0.2	0.0	0.2
Concentrates								0.0	0.0	0.0
Days on feed								60	30	60

[1]Concentrates milled at local mill in Quetta containing 40% peas, 25% molasses, 15% wheat bran, 12% rice polishings, 5% barley, and 2% limestone: 87% DM, 14.6% DP and 68% TDN.

Table 2. Technical coefficients of the flock model, good rainfall year, Baluchistan, Pakistan.

		Health, Feed & Breeding Interventions[1]							
	Traditional (T)	V (1)	V,D (2)	V,D,M (3)	V,D F1 (4)	V,D M,F2 (5)	V,D M,F3 (6)	V,D M,F4 (7)	V,D, M,F5,R (8)
Lambing interval (months)	12	12	12	12	12	12	12	12	12
% Ewes lambing -1st lambing	45	47	47	65	60	70	70	70	70
% Ewes lambing -2nd+ lambing	90	91	91	92	92	95	90	95	95
Lambs born/ewe -1st lambing	1	1	1	1	1.1	1.1	1	1.1	1.1
Lambs born/ewe -2nd+ lambing	1.1	1.1	1.1	1.1	1.3	1.3	1.1	1.3	1.3
%Pre-weaning mortality -1st	18	5	5	4	9	2.5	2.5	2.5	2.5
%Pre-weaning mortality -2nd	8	3	3	2	4	1	1	1	1
Lamb birth weight kgs	2	2.2	2.2	2.2	2.8	3.7	3.7	3.7	3.7
Lamb weaning age (months)	6	6	6	6	5	5	4	4	4
% females of lamb births	50	50	50	50	50	50	50	50	50
Male lambs weaning weight kgs	15	15	17	18	20	21	22	23.5	23.5
Fem. lambs weaning weight kgs	12	12	14	15	16	17	18	20	20
Sale age of lambs (months)	12	12	12	10	10	10	9	9	9
Male lamb weight at sale kgs	28	30	32	32	32	33	35	38	40
Fem. lamb weight at sale kgs	22	23	25	25	25	26	27	28	30
%Breeding stock mortality/yr	8	4	4	4	4	4	4	4	4
Ewe Age at 1st mating (months)	12	12	12	16	12	16	16	16	16
Culled breeding ewe age (years)	5. 25	5.25	5.2 5	6	5.25	6	6	6	6
Ewe weight at first mating kgs	22	23	25	28	28	31	31	32	32
Culled ewe weight kgs	28	28	30	32	33	34	34	34	34
No. rams/100 ewes	2.5	2.5	2.5	4	2.5	4	4	4	4
Ram age at 1st mating (months)	18	18	18	18	18	18	18	18	18
Culled ram age (years)	5	5	5	6	5	6	6	6	6
Ram weight at 1st mating kg	28	28	30	35	35	35	38	40	40
Culled ram weight kgs	40	40	43	43	45	45	46	46	46
% Wt Lamb mortality weaned-sale	5	5	5	3	5	2	1	1	1
No. of ewe & ram shearings/yr	1	1	1	1	1	1	1	1	1
Fleece weight of ewes/rams kgs	1	1	1	1	1.25	1.5	1.75	2	2
Fleece weight of lambs kgs	0.75	0.75	0.75	0.75	0.7 5	0.75	1	1	1

Source: Coefficients based on Stubbs, 1987 and discussions with personnel from the Baluchistan Livestock Department, Quetta, and from the Arid Zone Research Institute, Quetta

[1]V = Vaccination of rams, ewes and unweaned lambs against entrotoxemia ; D = De-worming and dipping; M = Improved management as described in the text; F1 to F2 represent feeding regimes as presented in Table 1; R = Improved ram breeding stock.

Table 3. Technical coefficients of the flock model, poor rainfall year, Baluchistan, Pakistan.

		Health, Feed & Breeding Interventions[1]							
	Traditional (T)	V (1)	V,D (2)	V,D,M (3)	V,D F1 (4)	V,D M,F2 (5)	V,D M,F3 (6)	V,D M,F4 (7)	V,D, M,F5,R (8)
Lambing interval (months)	12	12	12	12	12	12	12	12	12
% Ewes lambing -1st lambing	30	35	35	40	50	55	60	65	70
% Ewes lambing -2nd+ lambing	60	65	65	70	70	70	80	85	90
Lambs born/ewe -1st lambing	1	1	1	1	1.1	1.1	1	1.1	1.1
Lambs born/ewe -2nd+ lambing	1.1	1.1	1.1	1.1	1.1	1.3	1.1	1.3	1.3
%Pre-weaning mortality -1st	20	10	10	8	7	2.5	2.5	2.5	2.5
%Pre-weaning mortality -2nd	10	7	7	5	3	1	1	1	1
Lamb birth weight kgs	1.7	1.8	1.8	2.0	2.2	2.5	3.0	3.7	3.7
Lamb weaning age (months)	6	6	6	6	6	5	5	4	4
% females of lamb births	50	50	50	50	50	50	50	50	50
Male lambs weaning weight kgs	13	13	14	16	18	21	22	23.5	23.5
Fem. lambs weaning weight kgs	10	10	11	13	15	17	18	20	20
Sale age of lambs (months)	12	12	12	12	12	10	10	10	10
Male lamb weight at sale kgs	23	25	27	28	30	33	35	38	40
Fem. lamb weight at sale kgs	17	18	20	21	23	26	27	28	30
%Breeding stock mortality/yr	10	6	6	6	6	6	6	6	6
Ewe Age at 1st mating (months)	12	12	12	16	12	16	16	16	16
Culled breeding ewe age (years)	5.25	5.25	5.25	6	5.25	6	6	6	6
Ewe weight at first mating kgs	17	18	20	21	23	31	31	32	32
Culled ewe weight kgs	28	28	30	32	33	34	34	34	34
No. rams/100 ewes	2.5	2.5	2.5	4	2.5	4	4	4	4
Ram age at 1st mating (months)	18	18	18	18	18	18	18	18	18
Culled ram age (years)	5	5	5	6	5	6	6	6	6
Ram weight at 1st mating kg	28	28	30	35	35	35	38	40	40
Culled ram weight kgs	40	40	43	43	45	45	46	46	46
% Wt Lamb mortality weaned-sale	7	6	6	5	5	2	2	2	2
No. of ewe & ram shearings/yr	1	1	1	1	1	1	1	1	1
Fleece weight of ewes/rams kgs	1	1	1	1	1.25	1.5	1.75	2	2
Fleece weight of lambs kgs	0.75	0.75	0.75	0.75	0.7 5	0.75	1	1	1

Source: Coefficients based on Stubbs, 1987 and on discussions with personnel from the Baluchistan Livestock Department, Quetta and Arid Zone Research Institute, Quetta.

[1]V = Vaccination of rams, ewes and unweaned lambs against entrotoxemia ; D = De-worming and dipping; M = Improved management as described in the text; F1 to F5 represent alternate feeding regimes as described in Table 1; R = Improved ram breeding stock.

Table 4. Vaccination, de-worming and dipping material costs, upland Baluchistan, 1988.

	Ewes & Rams	Unweaned Lambs	Weaned Lambs	Ewe & Ram Replacements
	Rupees/Head/Year[2]			
Vaccination[1]	0.70	0.35	-	0.35
De-worming	9.60	0.80	1.60	2.40
Dipping	0.80	0.80	0.80	0.80

Source:Livestock Department, Government of Baluchistan.
[1] Vaccination against enterotoxaemia.
[2] 17.5 Rupees = US $1.00.

Table 5. Costs, revenues, and benefit cost ratios of eight health, feed and breeding interventions for the sheep industry, upland Baluchistan, Pakistan.

		Health, Feed & Breeding Interventions[1]							
	Traditional (T)	V (1)	V,D (2)	V,D,M (3)	V,D F1 (4)	V,D M,F2 (5)	V,D M,F3 (6)	V,D M,F4 (7)	V,D, M,F5,R (8)
GOOD RAINFALL YEAR				Rupees[2] per 100 ewe flock					
Costs									
Feed Costs	0	0	0	0	10454	10904	12704	14539	14989
Vet. Costs	0	111	1355	1603	1638	1710	1631	1712	1712
Ram Costs	0	0	0	0	0	0	0	0	724
Total Costs	0	111	1355	1603	12093	12614	14335	16251	17425
Revenue	29269	35445	37801	42282	46790	55001	50629	62144	65168
Net Revenue	29269	35334	36446	40679	34697	42387	36293	45893	47742
Benefit-Cost Ratio[3]	-	55.8	6.3	8.2	1.5	2.0	1.5	2.0	2.1
POOR RAINFALL YEAR									
Costs									
Feed Costs	0	0	0	0	27581	37997	44147	50769	50769
Vet. Costs	0	102	1289	1470	1482	1569	1558	1656	1687
Ram Costs	0	0	0	0	0	0	0	0	1244
Total Costs	0	102	1289	1470	29063	39566	45705	52425	53700
Revenue	26910	34476	36886	42560	48971	64153	65349	85443	95101
Net Revenue	26910	34374	35597	41090	19908	24587	19644	33018	41401
Benefit-Cost Ratio[3]	-	74.1	7.7	10.7	0.8	0.9	0.8	1.1	1.3

Source: Output from sheep model using the coefficients from Tables 1, 2, 3, and 4.

[1] V = Vaccination of rams, ewes and unweaned lambs against entrotoxemia ; D = De-worming and dipping; M = Improved management as described in text; F1 to F5 represent alternate feeding regimes as described in Table 1; R = Improved ram breeding stock.

[2] 17.5 Rupees = US $1.00

[3] Benefit-Cost Ratio = additional revenue from intervention over that of revenue from Traditional divided by the total cost of the intervention.

Table 6. Marginal analysis of undominated sheep interventions.

Intervention/ net revenue (1)	Costs (2)	Change from next highest revenue: Marginal increase in net revenue (3)	Marginal increase in cost (4)	Marginal rate of return[1] (5)
----- Rupees[2] per 100 Ewe Flock -----				%
GOOD AGRICULTURAL YEAR				
(8) 47742	17425	1849	1174	158%
(7) 45893	16251	3506	3637	96%
(5) 42387	12614	1708	11011	16%
(3) 40679	1603	4233	248	1707%
(2) 36446	1355	1112	1244	89%
(1) 35334	111	6065	111	5464%
(T) 29269	0	-	-	-
POOR AGRICULTURAL YEAR				
(8) 41401	53700	311	52230	0.6%
(3) 41090	1470	5493	181	3035%
(2) 35597	1289	1223	1187	103%
(1) 34374	102	7464	102	7318%
(T) 26910	0	-	-	-

Source: Columns 1 and 2 from Table 5.
[1]The marginal rate of return is calculated by dividing The marginal increase in net revenue (column 3) by the marginal increase in cost (column 4) multiplied by 100.
[2]17.5 Rupees = US $1.00.

Table 7. Sensitivity analysis: benefit cost ratios and marginal rates of return from a plus and minus twenty percent change in feed costs.

	Health, Feed & Breeding Interventions[1]				
	V,D F1 (4)	V,D M,F2 (5)	V,D M,F3 (6)	V,D M,F4 (7)	V,D, M,F5,R (8)
			GOOD RAINFALL YEAR SCENARIO		
Increase in Feed Costs by 20%:					
Benefit-Cost Ratio	1.2	1.7	1.3	1.7	1.8
Marginal Rate of Return	D[2]	D	D	13%	139%
Decrease in Feed Costs by 20%:					
Benefit-Cost Ratio	1.8	2.5	1.8	2.5	2.6
Marginal Rate of Return	D	44%	D	145%	179%
			POOR RAINFALL YEAR SCENARIO		
Increase in Feed Costs by 20%:					
Benefit-Cost Ratio	0.6	0.8	0.7	0.9	1.1
Marginal Rate of Return	D	D	D	D	D
Decrease in Feed Costs by 20%:					
Benefit-Cost Ratio	1.0	1.3	1.2	1.5	1.8
Marginal Rate of Return	D	D	D	17%	673%

Source: Output from sheep model using the coefficients from Tables 1, 2, 3, and 4.

[1]V = Vaccination of rams, ewes and unweaned lambs against enterotoxaemia; D = De-worming and dipping; M = Improved management as described in text; F1 to F5 represent alternate feeding regimes as described in Table 1; R = Improved ram breeding stock.

[2]Dominated interventions.