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Economic Analysis of Range and Forage Management Strategies for Increasing Small Ruminant Productivity in the Peruvian Andes

Winrock International Institute for Agricultural Development

Department of Range and Wildlife Management
Texas Tech University

ECONOMIC ANALYSIS OF RANGE AND FORAGE MANAGEMENT STRATEGIES FOR INCREASING SMALL RUMINANT PRODUCTIVITY IN THE PERUVIAN ANDES

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FOREWORD

This study represents the first major publication resulting from a long-term collaborative effort between Winrock International, Texas Tech University, and a group of Peruvian institutions. It is also the first major publication of Winrock International dealing with alpacas. The research upon which this publication is based represents a long-term continuing effort between Peruvian and American collaborators which started in 1980.

Most of the analysis and writing was carried out by Mr. Mauricio Jaramillo, Winrock Research Associate during 1984-85, who collaborated closely with a group of researchers from Peru and Texas Tech University who work on the Range Management component of the SR-CRSP. In similar projects, Winrock has been able to work on multidisciplinary, multi-institutional research projects in close collaboration with national research programs. An additional feature of this project was the opportunity to carry out some in-depth research on the economics of alpaca production, a topic of particular relevance to Peru.

The majority of this research is a result of the Small Ruminant Collaborative Research Program (SR-CRSP), a joint effort between a group of U.S. universities and developing country institutions with financial support from the United States Agency for International Development and the collaborating U.S. and overseas institutions.

Winrock International has participated in the SR-CRSP through its inception with a subgrant to conduct agricultural economics research in Brazil, Indonesia, Kenya, and Peru.

I would like to thank Mr. Jaramillo for spending a productive year with Winrock International and to acknowledge the excellent support provided by collaborating institutions in Peru and by the Department of Range and Wildlife Management, Texas Tech University.

R. D. Havener
President

PREFACE AND ACKNOWLEDGMENTS

This report stems from a collaborative effort among Winrock International, Texas Tech University (Department of Range and Wildlife Management), National Agrarian University in Lima, and National University of the Altiplano in Puno, Peru (Departments of Range Sciences) and the National Institute of Agricultural Research and Extension (INIPA) in Lima. In 1980, these institutions established a series of grazing and range management experiments in the Peruvian highlands designed to improve productivity of both sheep and alpacas. Inputs of economic analysis were soon needed to help establish priorities for additional research and to identify profitable management-investment opportunities.

To conduct the required analysis, Texas Tech University contributed animal production data collected over a 3-year period and funds that allowed Winrock to hire a Research Associate, Mr. Mauricio Jaramillo, for a 1-year contract. The research program required that Mr. Jaramillo spend extended periods at Texas Tech, in Peru, and at Winrock International.

The research design used the theory of farm-firm investment decision-making to compare alternative strategies defined by the range management experiments, as well as to rank investment-management strategies. This procedure was applied to two major sets of experiments: the first dealing with alpaca herd productivity under yearlong continuous grazing of cultivated irrigated pastures, while the second set examined strategic use of cultivated irrigated pastures as a dry season supplement for both sheep and alpacas. A flock model was also developed to assist in examining alternative stocking rates in mixed sheep-alpaca grazing systems. A key economic question was to determine the feasibility of improving growth rates of young alpaca females to enable them to reproduce a full year earlier than those in traditional systems.

The authors wish to acknowledge the comments, assistance, and encouragement of Hank Fitzhugh, Enrique Ospina, Nestor Gutierrez, and Ned Raun at Winrock International and Ing. Juan Astorga of the National Technical University of the Altiplano in Puno, Peru and Ing. Ramiro Farfan of IVITA, La Raya, Peru. The paper has benefited greatly from editorial inputs by Essie Raun and word processing by Tammie Chism. This research was supported by the United States Agency for International Development through Grant No. DAN-1328-G-SS-4093-00 to Winrock International and Texas Tech University in collaboration with the National Institute for Agricultural Research and Extension (INIPA) and the National Agrarian University (UNA), Lima, Peru.

EXECUTIVE SUMMARY

In 1984, a research project was conducted to evaluate the economies of grazing management practices and improved forages in an integrated range-livestock production system for the Andes of central and southern Peru. Animal production data from numerous research projects on native range and improved forages were supplied by the Department of Range and Wildlife Management, Texas Tech University. These data were major outputs for analysis. Production costs and constraints were assembled by Winrock International. Subsequent economic analyses of production interventions were completed by Winrock International using farm-firm investment and decision-making criteria. Discounted cash flow (CF) analyses were used to estimate net present value (NPV) or internal rate of return (IRR). Analyses were examined from the financial viewpoint of the investor and from the economic viewpoint of society as a whole. Sensitivity analyses were used to evaluate needed incentives for investors to adopt various interventions. At least 25% financial IRR for the producer assumed to represent minimum payoff needed for a farmer to adopt an intervention.

Using improved forages as the base for an alpaca production system yielded a financial IRR of 13.3%, a return too low to be considered by alpaca producers in the Andes. In order to be profitable, the following examples are illustrative of changes that would have to take place: 1) increase alpaca stocking rates from 20 to 35 alpacas/ha, 2) increase birth and survival rates from 60% to 85%, 3) sell alpaca fiber at $11.00/kg instead of $7.00/kg, 4) reduce pasture investment to 25% of the current estimate, 5) reduce pasture operating expenses to 60% of the current estimate, or 6) obtain a 85% increase in the price for mature tuis.

Based upon our criteria for minimum rate of return required, the use of improved forages as the base for sheep production was also unattractive given a 14.9% financial IRR. Examples of interventions needed to raise the financial IRR to the required 25% include: 1) increase stocking rates from 30 ewes/ha to 49 ewes/ha, 2) increase birth and survival rates from 80% to over 100%, 3) sell wool for $1.71/kg instead of $0.60/kg, 4) reduce pasture investment to 25% of the current estimate, 5) reduce pasture operating costs to 67% of the current estimate, or 6) obtain a 50% increase in the price/kg of mutton.

Improved pastures were profitable if used as a supplement (rather than the base) to the vast hectares of native range. These supplementation practices might include 1) restricted grazing of improved pastures, 2) harvest of hay from improved pastures during the rainy season to be fed in the dry season, 3) flushing at breeding and late gestation, 4) fattening lambs and tuis during the rainy season, 5) grazing female alpacas on improved pasture during the dry season, and 6) using improved pastures to induce earlier sexual maturation of alpaca female tuis to produce one extra offspring in the production life of a female.

Mixed alpaca/sheep production systems also appear promising. These include 1) raising alpaca female tuis to one year of age on improved pasture plus cutting hay from improved pastures in the rainy season to be fed to ewes in late gestation -- 55% financial IRR, 2) raising alpaca female tuis to one year on improved pasture plus fattening wethers on improved pastures during the rainy season -- 85% financial IRR, or 3) a combination of raising alpaca female tuis to one year and dry season grazing ewes on improved pasture after weaning plus fattening wethers on improved pasture in the rainy season -- 90% financial IRR.

Under "range-only" production systems without improved pastures, rotational grazing under herding at 3 ewes/ha yielded about the same net value ($32.40/ha/yr) as continuous yearlong grazing ($34.12/ha/yr). Because rotational grazing is best for the health of the range resource, this practice is recommended. Under native range in good condition, rotationally grazing 4 ewes/ha/yr yielded a net return of $53.40/ha/yr. Complimentary grazing of cattle with sheep yielded $59.20/ha/yr. Rotational grazing of fertilized range with cattle and sheep yielded the best return at $100/ha/yr.

If irrigated cultivated pastures are to be successfully promoted and encouraged in the Peruvian Andes, their practical use will be for strategic grazing during critical periods of interactions between the animals biological cycle and biomass production of the range when maximum returns to this expensive investment can be realized. These limited areas of potentially highly productive pastures must be integrated into a range management strategy since our analysis has shown that year-round use of irrigated cultivated pastures as the sole source of feed for sheep and alpacas is uneconomic.

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1. INTRODUCTION

STUDY AREA

Peru is located on the central-pacific coast of South America between the equator and 18°S latitude and 68°W and 81°W longitude. Cold ocean currents decrease the temperature and limit evaporation along the Peruvian coast. The high Andean mountains act as a barrier to westward movement of the humid and hot air fronts of the Amazon. These physical features produce conditions that divide the country into 3 distinct ecological zones that form strips running from northwest to southeast:

Coastal zone. A narrow strip of desert with a few fertile valleys formed by rivers coming from the Andes or irrigation projects. The altitude ranges from sea level to 2500 m above sea level. This region produces most of the cash crops and a large share of the commercial dairy and poultry products. These operations are located near Lima -- Peru's capital and largest city, with about one-third of the country's population.

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Selva zone. The only truly tropical region of Peru is part of the Amazon Basin and includes the area east of the Andes. Its elevation varies from about 2500 m on the eastern Andean slopes down to the lowlands for the tributaries of the Amazon River. Coffee and fruits are grown here. Much of the agriculture, however, is slash-and-burn agriculture that provides no more than subsistence living. The area has a great productive potential; however, the major constraints are minimal infrastructure and the distance from this region to the coastal cities and ports.

Sierra zone. The mountainous Andean zone that runs from north to south across the center of Peru. This area averages about 4,000 m above sea level, with the highest peak (Huascaran) reaching 6,767 m. Crops or mixed crop/livestock units are the main activity in the valleys between the mountain ranges. On lands located at elevations higher than ± 3,800 m, the environment allows only grazing of sheep and camelids. The high-altitude rangelands between 4000 m and 4800 m (the "Puna") comprise about 24 million hectares that support 75% of the Peruvian livestock industry (Tapia and Flores, 1984).

Climatic differences within each region are common. Microclimates are scattered across the Sierra; for example, the central Puna, which gets higher rainfall than does the southern Puna, is more fertile. (Discussion here is confined to the Sierra and, more specifically, to the Puna of the central province of Junin and the southern provinces of Cusco and Puno.)

The semiarid Sierra of Peru is inhabited by over 1 million people, primarily Indians who live in either autonomous communities or communities associated with large cooperative ranches, called SAIS or CAP, that were created about 12 years ago by the agrarian reform.[1] Only about 2% of the land is tillable and the risk of hail and frost is very high for at least 6 months of the year; consequently, inhabitants rely heavily on the use of the 24 million hectares of natural grasslands of the Puna to raise livestock. Even though soil quality and annual precipitation are

adequate for productive pastures, the extended cold, dry season (late March to early November) is a serious limitation because pasture growth is restricted. During late June to early September, the days are warm but the clear skies cause extremely cold nights and low temperatures inhibit pasture growth more than does the lack of water. Despite the constraints, pasture and livestock management and production can be improved. In the next section, economic analysis is applied to some potential technologies developed for this region.

2. THE ECONOMICS OF IRRIGATED CULTIVATED PASTURES

FIRM INVESTMENT THEORY

This analysis compares budgets of anticipated farming operations with and without investment to determine the attractiveness of a proposed investment to farmers and to other participants such as lending agencies (financial analysis) and the society (economic analysis). The method projects the effect of the particular investment on farm income, using the principles of discounted cash flow (CF) analysis to estimate returns to capital invested using measures of net present value (NPV) or internal rate of return (IRR) (Gittinger, 1982). The technique uses constant prices rather than projected (inflated) real prices. The NPV (an absolute measure) is the present net worth of a flow of money throughout a period of time, whereas the IRR (a relative measure) estimates a discount rate at which the present worth of the sum of the outflows is equal to the present worth of the sum of the inflows (i.e., that rate which makes NPV = 0). Additional details are provided by Gittinger (1982), and Simpson (1984).

The NPV is an important complement to the IRR, particularly when comparing mutually exclusive projects or those with rates of return over 50% (Brown, 1982). The NPV always gives correct rankings of alternatives as long as the lifespan and size of the investment are comparable. In absolute terms, the NPV is not an effective tool to compare the profitability of alternative investments unless they are standardized in size and(or) lifespan. The main criticism of the NPV is that it requires the analyst to assume an opportunity cost of capital -- usually difficult to estimate -- to be used as the discount rate. The NPV is the value added to the firm's worth; therefore, the decision rule is to choose those projects with a NPV $\geq$ 0.

IRR also gives correct rankings -- as long as there is no more than one change of sign in the cash flow. Unlike the NPV, its relativeness makes it an effective criterion to choose between alternative investments, with the added advantages of 1) having inflation incorporated, and 2) not requiring the analyst to make any assumptions about the opportunity cost of capital. The decision rule is to choose those projects with an IRR higher than the marginal cost of capital.

Both measures are used in this paper as decision tools to 1) rank treatments within experiments based on the estimated profitability of the activity represented, or 2) aid in judging different systems of production that include such activities. The measures are complemented by: 1) descriptions of the environment, and 2) sensitivity analysis, which adds information useful in the assessment of the project's financial impact, efficiency of resource use, and incentives for adoption. A sensitivity analysis looks at the extent to which the results change when the variables affecting them are changed.

Two types of closely related analyses are carried out: the financial analysis, which looks at the problem from the viewpoint of the individual investor(s); and the economic analysis, which looks at the problem from the viewpoint of the society as a whole. Financial analysis represents profit opportunities open to the producer based upon costs and revenues that he actually faces in the marketplace. Divergence between these costs and revenues and those facing society as a whole are a result of subsidies or taxes, artificial currency exchange rates, or government regulations which distort prices and returns to resources. Partial budgeting is used because the techniques studied imply relatively minor changes in the organization of the ranches. Partial budgets are derived from experimental results and regional information. They compare the marginal costs and benefits brought by the addition of the new production activity. (For further details on the theory behind the analysis, see Gittinger, 1982; Brown, 1982; or Simpson, 1984.)

Finally, the important behavioral assumption of profit maximization should be put in the proper context. The majority of producers in the Puna are small farmers oriented towards semi-subsistence agriculture. The analysis was oriented towards those producers whose primary goal is profit maximization, and the results are most relevant to them.

PASTURE COSTS AND RETURNS

Table 1 presents detailed costs and the discounted sum of establishing and maintaining 1 ha of pasture. The most recent prices (October 1984) are converted to constant terms as dollars. The dollar figures used in this study are based on the price structure prevalent in the third quarter of 1984. The financial environment parameters assumed here are as follows:

- A nominal interest rate of 72%, which is an average of the nominal interest rate faced by the producer. This is estimated to be the effective interest rate paid by those producers able to obtain Banco Agraria loans of 72% interest.
- An inflation rate of 112%, assumed to be constant.
- A real interest rate of -40% for the producer is the difference between the 2 figures above.
- A discount rate for economic analysis of 3.75% equal to the estimated real marginal cost of capital to society.[2]
- A discount rate for financial analysis equal to the estimated marginal cost of money. This is the firm's weighted average cost of capital, assuming an amount is borrowed that is equal to the investment needed to finance everything except livestock. The basic scenario assumes that livestock are brought to the pasture from the producer's own herd.

A description of the other assumptions on this table follows. Estimates of the lifespan of pastures in the Puna range from 5 years to 10 years (Allan and Stevens, 1981). For the purpose of this analysis, 7

Table 1. Establishment and maintenance costs for 1 hectare of cultivated irrigated pasture on the Peruvian Andes (1984 US$)

Item	Year 0	1	2	3	4	5	6	7
Investment	499.00							-68.65
Fencing	125.00							
Seeds	120.00							
Fertilizer	90.00							
Labor	10.00							
Tractor	120.00							
Miscellaneous	34.00							
Operating expenses	.00	132.50	182.00	182.00	182.00	182.00	182.00	132.50
Fertilizer	.00	105.00	150.00	150.00	150.00	150.00	150.00	105.00
Land rent	.00	.45	.45	.45	.45	.45	.45	.45
Labor	.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
Miscellaneous	.00	12.05	16.55	16.55	16.55	16.55	16.55	12.05
Working capital	132.50	49.50	.00	.00	.00	.00	-49.50	-157.59
Total cost/ha/year[a] (TC/ha/yr)	631.50	182.00	182.00	182.00	182.00	182.00	132.50	-68.65

Economic NPV = $1,500.54

TC/ha/yr[a] = $247.72 (economic)
TC/ha/yr[b] = $ 73.90 (financial)

[a]Without interest and taxes.
[b]Annualized discounted sum of total cost.

years is chosen. The risk of the pasture not becoming established is practically eliminated when the pasture is fenced in at the beginning of the rainy season, densely seeded, fertilized, and irrigated. Even though table 1 presents the costs on a per hectare basis, the estimates of the investment and operating expenditures should remain fairly constant when the total area planted and fenced is between 5 ha and 10 ha.

Fencing is considered necessary for proper pasture management. The assumption here is a rectangle formed by 2 permanent electric fences along the length of the area and 2 portable fences across the width. This was found to be the cheapest fencing alternative for areas larger than 5 ha because the energizer is too large a fixed cost for smaller areas where other types of fencing (barbed wire or stone-pile fences) are less costly.

Because of the combined effectiveness of seed, planting season, irrigation, and fertilizer, the risk of a poor pasture stand is almost nil and the readiness of the pasture for grazing 1 year later is ensured, assuming the site is properly selected. The seed density assumed is equivalent to 22 kg/ha of ryegrass, 1 kg/ha of dactylis, and 8 kg/ha of white clover, making seed the most expensive item (after machinery) in pasture establishment.

Fertilizer used for establishment is 100 kg ammonium nitrate and 100 kg P_2O_5/ha followed by 100 kg/ha of P_2O_5 and 400 kg/ha of ammonium nitrate (80 kg after each of 5 cuts) annually for maintenance. Eight man-days of labor ($1.25 daily wage) for seeding and fertilizing, and 15 hours of a tractor use at $8.00/hr are calculated. A miscellaneous category equal to 10% of all of the above, is included to cover any additional costs and those that are difficult to estimate, such as administration charges. Initial investment per hectare thus equals $499.00.

The operating expenses are composed of the annual fertilizer cost, the labor cost for gravity-flow irrigation 5 to 10 times during the dry

season, an estimated land charge of $.45/ha, and miscellaneous costs that are difficult to estimate. The $15.00 charged annually for irrigation labor allows for one man to spend 12 days/ha in irrigating once every 3 weeks during the 8 dry months of the year. The pasture is not grazed the first year, thus with frequent irrigation, it grows rapidly, assuring early establishment. Since most of the area is used for grazing in a purely extractive sense and there are practically no alternative uses, so the opportunity cost of the land is minimal.

According to table 1, the discounted present cost of establishing and maintaining 5 ha to 15 ha of cultivated pasture under irrigation (for 7 years) is about $1,500.00/ha. The table shows a skewed pattern of outflows through the life of the pasture. If these outflows could be equalized,[3] they would cost society $247.70/yr or the investor(s) $73.90/yr, assuming all the capital needed was borrowed at a subsidized real rate of -40% (nominal rate = 72%). This yearly payment of $73.90 is an estimate of the actual annual cost per hectare of feeding an alpaca or sheep herd on cultivated irrigated pastures. This estimate is valid within an interval of 5 ha to 15 ha of total planted area. Assuming that a decision has been made to supplement the feeding of livestock, cultivated irrigated pasture will be the best supplement, unless another supplement source can be found that will yield the same net benefits for less than $73.90 per year.

A sensitivity analysis of the data in table 1 indicates that the annual cost of the pasture (establishment and maintenance) varies from about $74.00 to $250.00, depending on the amount of financing obtained to cover the expenses involved (table 2). Even at $250.00 per year (± $.70/ha/day) this cost would be much less than that of any other source of supplement for the 20 alpacas or 30 ewes that can be supported on one hectare.[4]

Figure 1 sketches the assumed productivity of the pasture if it is either over- or undergrazed. The pasture reaches full production the second year and plateaus through the 5th year before productivity

Table 2. Sensitivity Analysis for Pasture Cost Results Given in Table 1.

Total cost financed[a] (%)	Real MCC [b] (%)	TC/ha/yr[c] (1984 $)
100	-40.0	73.90
75	-29.06	108.30
50	-18.125	147.90
0	3.75	247.70

[a] With subsidized loans of 72% effective nominal interest.
[b] Marginal (or weighted average) cost of capital (MCC) to the firm defined as % subsidized loan (subsidized rate-inflation rate) and % unsubsidized (market rate-inflation rate). For 50% the calculation is: 0.5 (72-112) + 0.5 (115.75-112) = -20 + 1.875 = 18.125.
[c] Annualized total cost per hectare per year (see footnote 3). Real cost to the farmer.

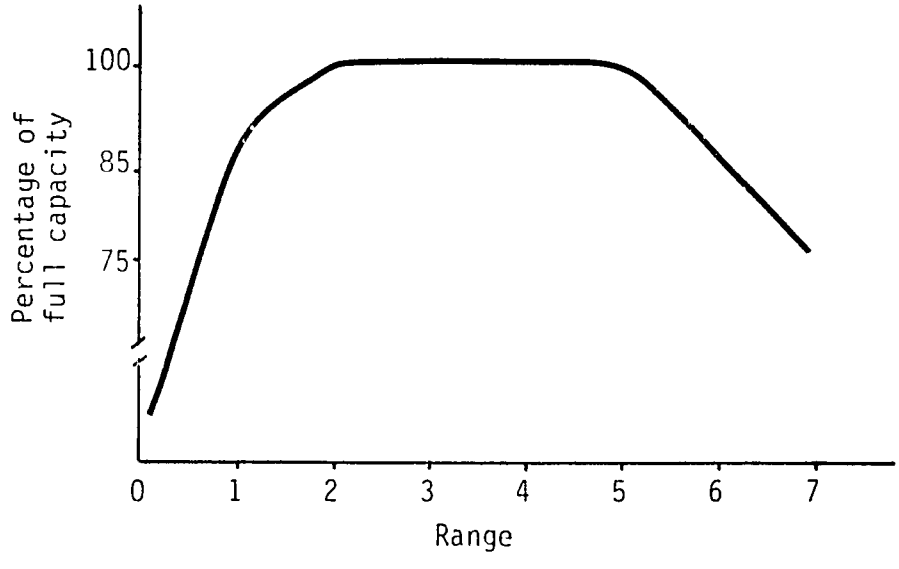


Figure 1. Production curve assumed for the improved irrigated pasture.

declines. However, the reliability and precision of the data available are so questionable and the variability of the pasture lifespan is so high and influenced by so many variables that it would be quite interesting to set up long-term regional studies to estimate the economic soundness of plowing and replanting for various periods of time after establishment and various stocking rates.

ALPACA PRODUCTION

Llamas *(Lama glama)*, alpacas *(Lama pacos)*, and sheep *(Ovis aries)* are the domestic animals best adapted to the Puna environment. They are also the only ones able to efficiently utilize the Puna resources. Alpacas belong to the camelidae family and ruminant suborder. Importance of small ruminants lies in their ability to convert the otherwise useless resources of the Puna into products useful to mankind, mainly fiber, meat, and hides. High-quality fiber of alpaca is highly prized in international markets by the textile industry and its price is now about seven times higher than sheep wool. Alpaca meat is an important source of protein in the diets of the local people. The pelts are used by the Indians for handicrafts that are sold for cash to obtain staples that are not produced in the region.

Peru has a population of about 2.4 million alpacas, thus providing Peru with a near world monopoly on alpaca fiber supply. Bolivia has the second largest number of alpaca with about .3 million and Argentina and Chile have small herds of slight economic significance (Fernandez Baca, 1975; Calle-Escobar, 1982). These authors estimate that about 80% of the Peruvian alpacas belong to small producers with herds of fewer than 50 head. At least 200,000 peasant families depend on raising these animals for their livelihood. However, a disproportionately large share of marketed alpaca products come from large commercial herds. About 90% of the Peruvian alpacas are found in the southern provinces of Apurimac (.21 million), Ayachucho (.18 million), Arequipa (.29 million), Cusco (.29 million), and Puno (1.1 million).

Grazing Trials

The La Raya research station of the Instituto Veterinario de Investigaciones Tropicales y de Altura (IVITA) of San Marcos University is located in Cusco province. This station is where the alpaca experiments described below were carried out. It is located in the heart of the Andes between 4,050 m and 4,800 m above sea level, with a mean temperature of 6.5°C (± 20°C).

The La Raya grazing trials were initiated to test the assumption that livestock production in the highlands of Peru could be expanded by the use of cultivated pastures under irrigation. The use of non-irrigated cultivated pastures was not considered because the bulk of their production comes during those times of the year when the range provides an abundant supply of good-quality forage. The study, therefore, investigated the use of cultivated irrigated pastures to supplement the animals when the range supply is scarce and(or) of low quality (see Appendix Figure 1). It was hypothesized that, for maximum economic benefit, cultivated irrigated pastures should be grazed strategically as part of an integrated system with the rangelands. One experiment sought to determine whether it is profitable to raise alpacas using cultivated irrigated pastures as the sole source of feed. A second experiment studied the use of these pastures to supplement rangeland-based alpaca during the dry season. The two experiments are summarized below.

Evaluation of alpaca productivity of a herd maintained continually on cultivated irrigated pastures. An abused 5-ha pasture of *Festuca pratensis*, *Lolium perenne*, and *Trifolium* spp. was regenerated, with fencing, a rest period, soil ripping, fertilization, and irrigation required to restore the plant cover and normal forage production of the experimental area. A one-herd (85 adult alpaca females and offspring) six-pasture, short-duration grazing system was set up to be compared with a control treatment consisting of a similar herd maintained on range.

Data from the 2-year trial include measures such as animal condition at different ages and at different times of the year, fiber production, birth and weaning weights, growth rates, and age at puberty. As expected, a significant improvement in animal performance was obtained on cultivated irrigated pasture. The most striking result was to nearly eliminate early mortality of the alpaca juveniles (tuis) and to dramatically accelerate the development of replacement female tuis.

Restricted grazing of cultivated irrigated pastures to supplement sheep and alpacas during the dry season. This study was conducted for 2 years to evaluate the use of restricted grazing in ryegrass pastures to supplement alpacas during the dry season. The treatments included: 1) native range plus access to ryegrass pasture for 1 hour at the end of the day; 2) native range plus access to ryegrass every other day (all day); 3) native range plus access to ryegrass 1 day per week (all day); 4) ryegrass only; and 5) native range only (control). Results for alpaca are reported here while results in the sheep component of this experiment are reported on page 35.

There were no significant differences among treatments in alpaca body weights. However, the average weight for treatment 4 was higher (144 lb) at the end of the dry season, than those for treatments 1, 2, and 3 (135 lb). Mean body weight of the control alpacas was slightly lower (133 lb). Alpaca wool production did not differ significantly between treatments and averaged 4.2 lb/head.

Economic Analysis

A benefit/cost analysis (B/C) was conducted to assess potential profitability of a traditional range-grazing scheme of alpaca production to the proposed system in which the herd is kept on irrigated pastures all year round. The analysis is based on the results of the first set of experiments discussed above, on informal and random producer surveys, and on previous studies.

Table 3. Production traits in traditional and yearlong systems of management for alpacas.

Production trait		Traditional[a] system	Yearlong[b] system
Birth rate (%)		60	60
First yr mortality (%)		30	3
1 to 2 yr juvenile alpaca (tui) mortality (%)		10	N/A
Adult mortality (%)		5	3
Age at first breeding (yr)		2	1
Stocking rate			
With bofedales, (alpaca units/ha[c])		1	N/A
Without bofedales, (alapaca units/ha)		2/3	20
Yearly culling rate (%) and approximate productive lifespan (yr), in parentheses	Females	13 (8)	11 (9)
	Males	16 (6)	14 (7)
	Studs	18 (5)	18 (5)

[a] Traditional management was a range-grazing system.
[b] Yearlong management was the use by alpaca of cultivated irrigated pasture the entire year.
[c] Studs, breeding females, and castrated males = 1 alpaca unit (AU); nursing tuis = .2 AU; tuis $\leq$ 1 year = .4 AU; tuis 1 to 2 year = .6 AU. An alpaca unit = 1.5 ewe-equivalent units (EE) of the Peruvian stocking rate system and .3 animal units of the U.S. system.

"Traditional" vs "Yearlong" Use of Cultivated Irrigated Pasture

The "yearlong" system consisted of grazing an alpaca herd continuously on cultivated irrigated pasture throughout the year. The main advantages of the proposed system are a 90% reduction in first-year mortality (table 3) and production of one additional offspring during the reproductive life of each female as a result of earlier puberty. The animals are considered sufficiently mature to be bred when they weigh about 40 kg (Novoa et al., 1972). Females do not usually reach this weight under range conditions until at least 18 months of age, thus producers must wait 4 to 6 months until the next breeding season to breed their young females (Appendix Figure II).

Traditional grazing consists of native rangeland pastures. A differentiation is made between range-grazing systems that make use of *bofedales* (alpine meadows with year-round irrigation from snow-fed streams) and those that do not. Bofedales supply dry-season moisture to native pastures and significantly increase the year-round carrying capacity of the whole ranch. The carrying capacity (alpaca units per hectare [AU/ha]) are listed in table 3. Vegetation found in these areas is very different from that of the open range. Sedges and reed dominate the area (±42% of total cover), followed by forbs (33%) and grasses (22%). The dominant species are *Distichia muscoides*, *Luzula peruviana*, and *Elzocharis albibactrata;* associated with forb species of *Plantago*, *Werneria*, *Alchemilla*, and *Hypocharis;* and grass species of *Calamagrostis* and *Festuca* (Reiner, 1985).

Some scientists argue that an earlier puberty will result in a shorter lifespan that subsequently decreases productivity. Having found no literature to corroborate this hypothesis, no such negative effects are assumed. Therefore, the differences in productive life are not considered to be a result of an increase or decrease in the lifespan of the animals, but are attributed to the finding that young alpacas (tuis) can enter the breeding herd one year earlier as a result of faster development induced by improved nutrition.

Herd Characteristics

Table 4 indicates the inventory of animals from a stable herd on range and the inventory changes that occur over time as a result of our analysis. Traditionally, the breeding and lambing seasons coincide during the first 10 weeks of each year, while shearing is done around mid-October and weaning around mid-September.

The "breeding females" term includes former "babies" that replace the dead and the culled. "Babies" refers to those born at the beginning of the year. In our analysis, the "babies" at the end of the year are ready for breeding or for sale; under traditional management, the "babies" are in the tuis category one more year before being ready for breeding. The category "tuis" therefore is eliminated under our assumptions.

Castrated males are used for fiber production. According to the data used to plot figure 2, their fiber productivity is about 20% higher than that of females.

The price of the fiber probably affects the ratio of breeding females to castrated males -- i.e., when the price goes up (down), the ratio widens or narrows depending on the strength of the two offsetting effects. The short-term response would be to increase the percentage of fiber-producing castrated males, and the long-term response would be to increase the percentage of females. A time-series analysis of the 2 variables and their correlation would be useful; however, data are not available to examine this hypothesis, so the ratio assumed for the range herd (100 breeding females to 85 castrated males) is kept constant throughout the analysis.

The maximum number of alpaca units (AU) is calculated at the peak of the herd's population curve each year. This ensures no overstocking. The tuis sold are the 1-year-old "babies" that remain after replacements have been made for females and castrated males that have died or been

Table 4. Alpaca herd composition and sales.[a]

Item	Range herd[c]	Pasture herd[b] Year 1	2	3	4	5	6	7
				Inventories[d]				
Studs	5	5	5	5	5	5	4	4
Breeding females	100	100	100	100	100	85	73	70
Babies[e]	42	0	58	58	58	58	50	42
Tuis (1 to 2 years)	38	-	-	-	-	-	-	-
Castrated males	85	85	85	85	85	70	60	62
Maximum number AU/year	240	217	241	241	241	241	205	174
				Sales				
Mature tui females	0	0	29	29	29	29	25	21
Mature tui males	0	0	29	29	29	29	25	21
Culled alpacas	28	28	24	24	24	24	17	0

[a]The technical coefficients assumed are presented in table 1.
[b]Herd on cultivated irrigated pasture.
[c]Stable herd on range. This structure was found in a herd development exercise, and is similar to that reported by Fernandez-Baca (1975) as the most common.
[d]At the end of the year.
[e]Born at the beginning of the year.

culled. Offspring mortality under traditional management is so high that the number of 2-year-old tuis is just sufficient to replace the herd mortalities and culled animals, so there are no sales of tuis.

Improved pasture dramatically increases the number of tuis available for sale, especially between the first and second year. This increase is largely due to the decrease in mortality and faster growth resulting from the improved diet. In years 5, 6, and 7, there are even more tuis to be sold, but fewer alpaca units, because of the herd reduction needed to compensate for the declining production of the pasture (figure 1). In this particular case, a production curve such as the one shown in figure 1 is assumed and the stocking rate (herd size/ha) is changed accordingly. No alpacas are culled in the last year, since it is assumed that the whole herd is sold.

Baseline Financial and Economical Analysis

Table 5 shows the actual partial budget for each hectare of cultivated irrigated pasture on the 12.0 ha needed to feed the alpaca herd shown in table 4. The yearly stocking rate is 20 AU/ha. The same herd on range would need 120 ha of a combination of range and bofedales that permits a stocking rate of 2 AU/ha. The "bofedal system" is found in most of the large commercial ranches, whereas the open range system is mostly seen in peasant communities or areas of small ranchers. The people in this latter system not only have priority goals other than profit maximization (e.g., social status, risk-minimization, capital accumulation, etc.), but usually have little access to credit and other inputs. As a result, small ranchers are less likely to accept new technology than are the larger commercial ranchers. Thus the proposed system was first compared with the "bofedales," then compared with the more traditional open-range system of production.

The estimated prices for 1-year-old mature tuis ($25 for males and $60 for females) were based on average market prices of equivalent animals and the present value of their discounted potential production. Even

Table 5. Marginal returns from 1 hectare of pasture with an alpaca herd (vs. range-bofedal traditional system)[a].

Item	Year 0	1	2	3	4	5	6	7
	(1984 US$)							
Inflows	.00	-24.71	317.20	317.20	317.20	423.01	354.59	760.78
Livestock residual								415.34
Pasture residual[b]								68.65
Net livestock benefits	.00	-24.71	317.20	317.20	317.20	423.01	354.59	276.79
Tuis		.00	98.76	98.76	98.76	204.56	176./35	148.13
Fiber		-21.12	191.49	191.49	191.49	191.49	159.25	132.24
Culling		-3.59	26.95	26.95	26.95	26.95	18.99	-3.59
Outflows	611.67	877.17	268.25	268.25	268.25	249.15	196.11	19.04
Livestock investment		623.23						
Pasture investment[b]	499.00							
Operating expenses (OE)	.00	125.19	268.25	268.25	268.25	268.25	247.02	190.45
OE pasture[b]	.00	132.00	206.59	206.59	206.59	206.59	206.59	157.09
Livestock replacement[c]	.00	-1.16	10.46	10.46	10.46	10.46	-1.16	-1.16
Health[d]	.00	-5.03	45.59	45.59	45.59	45.59	37.92	31.49
Miscellaneous	.00	-.62	5.60	5.60	5.60	5.60	3.68	3.03
Working capital	112.67	128.75	.00	.00	.00	-19.10	-50.92	-171.40
Net incremental benefit before financing -- remuneration to all resources engaged, including return to and of capital.								
EBIT[e]	-611.67	-901.88	48.95	48.95	48.95	173.86	158.48	741.74
Economic NPV (discounted at 3.75%) = $-504.57								
Net incremental benefit after financing and taxes, with principal indexed to inflation.								
EBT*(1-t)[f]	.00	-623.23	38.89	39.97	40.93	166.70	152.08	763.03
Financial IRR to farmer's own resources = 13.3%								

[a] Assumes a 72% nominal cost of debt and the financing of everything except livestock.
[b] From table 2. All OE adjusted by: 1) subtracting land charge and 2) adding herder labor cost.
[c] Cost of stud replacement.
[d] Health cost/animal/year = $2.50.
[e] Earnings before interest and taxes.
[f] EBT = earnings before taxes after debt payments; t = tax rate.

though males produced more fiber than did females (figure 2), and even though there was a slight difference in the yearly production throughout the life of the animal that followed a biological curve and plateaus between ages 3 and 8 (see figure 2), the data reflected no significant differences across sexes and through the years. Given the high variability of the fiber production figures, a weighted average (by sex and age) of the herd's production was considered to be the most reliable. The estimated 1.5 kg/yr of fiber is comparable to the yields reported in the literature by alpaca specialists in Peru. The price used for the fiber ($7/kg) was the lowest price paid during 1984, thus no financial advantages gained from storing were claimed for the pasture. All the prices were farm-gate prices expressed in constant 1984 U.S. dollars.

The benefits of cultivated irrigated pastures are shown to stem mainly from increased carrying capacity of animals (output/ha) and the decrease in mortality and acceleration in the maturity of young alpacas (tuis). The new inflows are derived from an increase in tuis to be sold, from an increase in kilograms of fiber (obtained only from the increased carrying capacity of animals -- for the fiber production was assumed not to be affected by the better nutrition), and from an increase in the number of animals culled per hectare. Because the cultivated irrigated pasture was idle during the first year, the rancher loses the production he would have had if that plot had been grazed as open range; this is reflected by the negative figures in the column under year 1. The entire budget shows the difference between what can be obtained on improved pasture and what might have been obtained in the range-bofedal system. An intangible benefit is the range that becomes idle for regeneration or available for grazing when the animals pasturing it are moved to the intensive systems. This is reflected in the livestock investment charge.

In the outflow section, the livestock investment represents the value of the initial herd introduced at the end of year 1, minus the value of the herd that would have been there, if it were open range. The cultivated

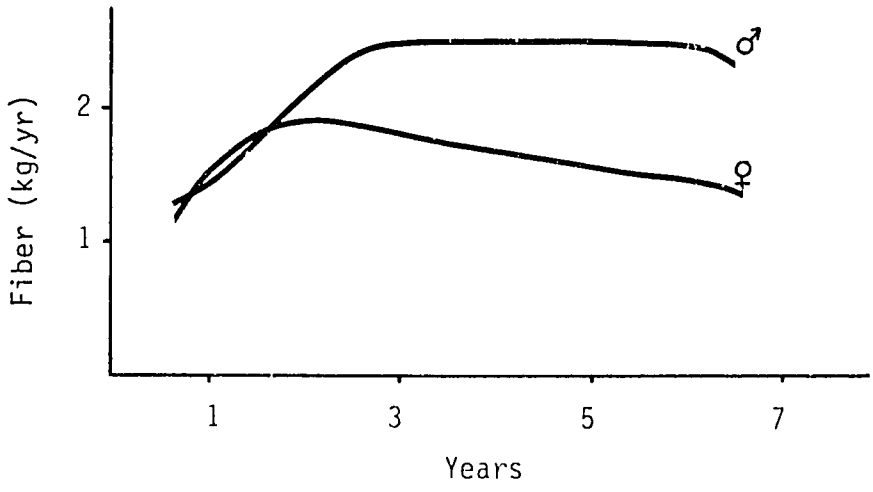


Figure 2. Typical alpaca fiber production curves
Source: Condorena, N. 1980.

irrigated pasture investment and the subsequent operating expenses (except the land charge, which is the only cost common between the 2 alternatives) came from table 1. The livestock replacement and the health charge are explained at the bottom of table 4; the miscellaneous item here is 10% of the last two charges only. The working capital is 90% of the increase in operating expenses between the present and the following year.

As expected, the result is a variable cash flow stream with high negative entries in the first and second years (stemming mainly from investment in pasture and livestock) and increasingly large returns in later years. The economic discounting process yields a negative NPV ($-504.57/ha), whereas the financial discounting procedure with the negative real cost of capital faced by the ranchers yields a highly positive NPV. The $-504.57/ha is an estimate of the cost to society since, in this case, there are no adjustments made between the economic analysis and the financial analysis. Taxes are not included, because they are very seldom paid, and no subsidies or other transfer payments are involved.

The difference between the two NPV figures indicates that, given the assumptions explained above, the farmer profits from the loan subsidy but not at all from the real effects of changing to the full time use of irrigated pastures for alpaca production. However, the 13.3% rate of return for the producer's own resources (in this case, mainly livestock) is too low for farmers to be interested in adopting this new technology. The International Center for the Improvement of Maize and Wheat (CIMMYT) has estimated that a marginal rate of return of at least 40% is needed for agriculturalists to accept new technology throughout the developing world. According to conversations with Peruvian scientists (Ponce de Leon, A, 1985), at least a 15% return on each US$ invested is required in the Lima area. Since the risk is much higher in the harsher environment of the Sierra (Puna), it is most likely that the required rate of return there on livestock investment is much higher than 15%, probably around 25% to 30%.

Sensitivity Analysis

When the same comparison is made to an open range system, the economic NPV changes to $-443.43, and the farmer's rate of return climbs to 14.1%, which is still marginal for adoption.

Table 6 shows changes in the parameters that have the greatest impact on the economic NPV (society's return) and the financial rate of return (IRR), which are indexes of profitability. The base figures come from table 5. The 72% nominal cost of debt is an estimate of the effective rate paid by those producers that borrow the very cheapest capital available -- from government agencies whose loans are subsidized.

The changes occur one at a time -- i.e., all other exogenous variables are held constant. The results show that if the economic NPV is to become greater than or equal to zero, the following changes must be made: 1) a 42% increase of the stocking rate to 28.4 AU/ha; 2) a 57% increase in the price of fiber to $11.00/kg; 3) a $\geq$ 50% reduction in the pasture investment; 4) a 65% increase in the birth rate to 99%; 5) a $\geq$ 40% reduction in the pasture operating expenses; or 6) an 85% increase in the price of mature tuis.

Assuming that 25% is the minimum required rate of return that induces producers to invest, table 6 indicates the parameter changes needed before such a rate can be obtained. Assumptions 2 and 6 are the most likely to occur because animal prices and fiber prices are closely linked and because the fiber price assumed, $7/kg, is well below historical levels. Prices in late 1985 were already $10 to $11 per kg so these prices make the NPV about equal to zero and give IRR of about 30%. Since prices of mature tuis have also increased simultaneously, this would push up the NPV and IRR figures. However, as we show later, other options based upon strategic supplementation and mixed species grazing (where ecologically feasible) offer better economic returns than does full-time use of irrigated improved pastures for alpaca production.

Table 6. Sensitivity analysis of results presented in table 4.

Parameter change	Economic[a] NPV, $	Financial[b] IRR, %
Base	-504.57	13.3
Stocking rate		
From 20 to 35.2	+417.23	25.0
to 28.4	0	21.4
$/kg fiber		
From 7 to 10.05	-119.67	20.0
to 11.00	0	28.7
Reduction in pasture investment		
To 1/4 of base	-170.10	12.8
Birth rate		
60% to 85%	-150.00	25.0
to 99%	0	32.0
Reduction in OE of pasture		
To 60% of base	-32.65	24.4
Prices for mature tuis		
85% increase	+19.23	23.8

[a] Return to society. Present worth of the sum of cash flow discounted at 3.75%.

[b] Real return to investors' resources after debt payment (with principal not indexed to inflation).

Perhaps similar gross benefits could be obtained with less cost by using these pastures strategically -- i.e., only for weaning of tuis, and(or) final fattening of market animals, and(or) breeding purposes. These hypotheses are examined in the following section.

"Traditional" vs Use of Irrigated Pastures for Strategic Supplementation

As indicated in the previous section, alpaca production is probably not feasible if based totally on cultivated irrigated pastures. The findings do point out the advantages obtained from improved nutrition that have the greatest economic impact. In this section, these findings are used to determine those stages of the alpaca production system that might be adjusted to make efficient use of cultivated pasture.

The inflow section of table 5 shows that "tuis" and "fiber" provide most of the returns from livestock. The increase in fiber comes solely from the higher stocking of animals, since the improved nutrition is assumed not to affect fiber production per head. However, the "tuis" inflow stems from an increase in the availability of tuis for sale (see table 4), which is the result of both the increased carrying capacity and the faster development of the young alpacas.

Table 7 shows the results of using the cultivated irrigated pasture for 1) seasonal maintenance of breeding females, from parturition through sometime between weaning and the next breeding season; and 2) full-time maintenance of male and female tuis until they are 1 year old. The stocking rate is 20 AU/ha, with the units represented by 16 alpaca mothers with their babies, and adjusted after weaning by taking the adults back to range as the tuis grow. The different compositions of the pasture herd account for the outflow and inflow differences during years 2 through 7 which are shown in tables 5 and 7. The negative figures in year 1 are those that would have been obtained if the land were open range. An intangible benefit, not accounted for explicitly, is that range which becomes available -- to be left idle or for grazing -- when the females are moved to the cultivated irrigated pasture.

Table 7. Marginal returns from 1 hectare of pasture with lactating alpacas and their tuis.

Item	Year 0	1	2	3	4	5	6	7
	(1984 US$)							
Inflows								
Livestock residual	.00	-25.12	242.87	242.87	242.87	607.16	494.64	542.51
Pasture residual								-9.07
Net livestock benefits	.00	-25.12	242.87	242.87	242.87	607.16	494.64	68.65
Tuis		.00	242.86	242.86	242.86	607.14	495.71	482.93
Fiber		-21.48	.02	.02	.02	.02	-.92	485.71
Culling		-3.65	.00	.00	.00	.00	-.15	-1.74
								-1.04
Outflows	611.57	195.62	206.61	206.61	206.61	206.04	161.24	15.63
Livestock investment		-2.84						
Pasture investment	499.00							
Operating expenses (OE)	.00	125.08	206.61	206.61	206.61	206.61	205.98	156.27
OE pasture	.00	132.00	206.59	206.59	206.59	206.59	206.59	157.09
Livestock replacement	.00	-1.18	.00	.00	.00	.00	-.34	-.34
Health	.00	-5.11	.01	.01	.01	.01	-.22	-.42
Miscellaneous	.00	-.63	.00	.00	.00	.00	-.06	-.08
Working capital	112.57	73.38	.00	.00	.00	-.56	-44.74	-140.64
Net incremental benefit before financing -- remuneration to all resources engaged, including return to and of capital.								
EBIT[a]	-611.57	-220.74	36.26	36.26	36.26	401.11	333.40	526.88
Economic NPV (discounted at 3.75%) = $281.17								
Net incremental benefit after financing and taxes, with principal indexed to inflation.								
EBT*(1-t)[b]	-152.89	-54.24	29.38	30.12	30.78	396.21	329.03	522.97
Financial IRR to farmer's own resources = 41.3%								

[a] Earnings before interest and taxes.
[b] EBT = earnings before taxes after debt payments; t = tax rate.

The analysis results in a positive economic NPV of $281.20 and a financial IRR of 41.3%. This IRR is calculated with a marginal cost of capital that assumes only 75% of the pasture expenses are financed with the subsidized 72% interest rate. This proportion (75%) seems more realistic than the 100% used in table 5. The positive NPV ($281.20) is an estimate of the benefit society derives from each hectare planted (i.e., the addition to national income) and indicates the desirability of granting subsidized loans for such an activity. The 41.3% return to the producer's own resources makes it likely to be an attractive alternative for risk-takers or for ranchers with problems of overstocking during the dry season. If for comparison, the cash flows of table 5 are discounted with the 75% assumption, the result is an equal economic NPV of $-504.57 and a financial IRR of 6.6% (vs 13.3%).

As a management tool, all adult females could be taken out after weaning in September, which will not only make weaning easier also reduces the stocking rate on the pasture. If it is assumed that during the rainy season, the range is at least as good as any cultivated pasture,[4] it could be argued that the alpacas (adults and tuis) need to be on the cultivated irrigated pasture only during the 8 dry months (April through November) of the year. This would permit use of the cultivated irrigated pasture for oth r activities (e.g., to make hay or silage to be sold or used to supplement sheep[5] during the following dry season). It also will allow the alpaca activity to be charged for only 8/12 of the total pasture cost. This cost reduction adds $541.90 to the economic NPV. As a result, the alpaca component of the whole system (8 months lactating females, plus tuis, and 4 months of some other use) would add $823.10/ha to the total economic NPV obtained and provide an interval rate of return of 71.8%.

SHEEP PRODUCTION

Peru has about 15.3 million head of sheep that are kept primarily in the Puna. The southern departments raise 56% of the total population, while

the central departments raise 36%. The provinces of Puno, Junin, and Cusco lead in sheep production, with estimated populations of 33%, 12%, and 10% of the total, respectively (Ministerio de Agricultura, 1976).

The national offtake rate for slaughter is about 13% annually. The meat is consumed in the local and urban markets, and most of the wool is exported. As with alpacas, more than half of the national herd belongs to small herders whose output makes up for less than half of the total production. They own "criollo" sheep that are smaller and less productive than are the improved breeds (Corriedale and Junin) raised by the larger ranches, but are well adapted to the Puna environment.

Grazing Trials

Four sets of research data were used to evaluate strategic use of improved pasture to enhance sheep production. In the southern Sierra, restricted dry-season use was evaluated to improve both ewe-lamb development and adult ewe production and flushing[6] was evaluated to improve production of adult ewes. In the central Sierra, only flushing with improved pasture was evaluated to enhance productivity of adult ewes.

In the southern Sierra, data were collected from Chuquibambilla research station which belongs to the Universidad National Tecnico del Altiplano (UNTA) and is located in the Department of Puno, halfway between the citi s of Puno and Cusco, in the heart of the altiplano (Puna plains around Lake Titicaca). Altitude is 13900 m above sea level. The mean diurnal temperature is 12°C and the precipitation varies from 500 to 1000 mm per year, falling mostly from December through April.

In the central Sierra, data were collected on an agricultural cooperative (SAIS Pachacutec) located in Department of Junin. Altitude is 4,200 m above sea level. The mean daily temperature is 5°C and the precipitation varies from 700 mm to 1,000 mm.

Flushing experiments in the southern Sierra. These experiments were carried out in 1983-1984 at Chuquibambilla. They were set up to test potential ways of increasing the low average conception rate (±80%) in Corriedale found in the southern Puna.

Each treatment consisted of 20 adult Corriedale ewes grazing open range except when ewes were provided access to cultivated irrigated pastures. The treatments were 1) flushing by allowing ewes to graze an irrigated ryegrass pasture for 30 days before the breeding season; 2) flushing on native range by providing ewes a commercial energy-protein concentrate 30 days before the breeding season; 3) flushing with access to the same irrigated ryegrass pasture 25 days post-breeding; 4) flushing during the last 6 weeks of gestation; and 5) a control group without flushing (native range only). The purpose of treatments 1 and 3 was to improve ewe condition at breeding and increase ovulation, whereas that of treatment 2 was to foster embryo implantation and growth. Treatments 1, 2, and 3 were designed to raise conception rates and lamb live weight at birth while the purpose of treatment 4 was to increase birth weight of lambs. There was no significant difference between treatment 4 and the control so the practice of flushing ewes during the last 6 weeks of gestation does not appear to be justified, based on birth weights found in this research.

All flushing treatments increased the ewes' rate of weight gain (average of .136 kg/day/ewe vs. .009 kg/day/ewe) over the control group. Lambing rates averaged 95% and were not significantly different; however, large differences were observed in the percentage of ewes that conceived on first service: 55%, 45%, 25%, and 10% for treatments 1, 3, 2, and 5, respectively. These results were obtained with artificial insemination (AI). The reduction in average number of services needed to attain pregnancy would imply a reduction in total cost equal to the reduction in variable cost per service(s). However, the most common practice is the use of rams (not AI), in which case the differences above would suggest lower gross benefits because of later birth dates and lighter lambs at weaning for the control group.

Previous research suggests that differences in conception rate at first breeding would be negligible if rams were used (Fierro 1985). For ranchers using rams, therefore, there may be no economic advantages from, or incentives for, the use of any of these flushing practices to increase conception. Flushing at breeding time may be attractive only to those sheep producers who use AI, and only when they are able to flush at a cost per ewe less than the cost of the ≥ 2 services saved by this practice. In such cases, the flushing should be done 30 days prebreeding on cultivated pasture; the practices represented by the dominant treatments 1 and 3 would require flushing costs of about $.40 and $1.25 per ewe. This cost estimates assume 1) that the rancher is able to borrow at $\leq 72\%$ interest at least 75% of the investment expense of establishing and maintaining cultivated irrigated pastures; and 2) that the cultivated irrigated pasture is used the rest of the year for other activities, thus allowing the producer to value the flushing cost/ha as equal to 1/12 of the annual pasture cost.

If the first assumption is valid, cultivated pasture would be cheaper as long as the ewes can be charged for $\leq 1/4$ of the annual pasture cost (3 months out of each year). As long as the second assumption holds true, cultivated pasture would be significantly cheaper than commercial supplement even if the former has to be sown with equity capital, having an opportunity cost of 3% to 4% real interest.

Flushing experiment in the central Sierra. This experiment was carried out from 1981-1983 at SAIS Pachacutec. Each treatment consisted of 40 Corriedale ewes grazing open range except when ewes were provided access to improved pasture. The treatments were 1) flushing by allowing ewes to graze improved orchardgrass/whiteclover pastures for 21 days before the breeding season plus 21 days more after the rams were introduced to the ewes; 2) in addition to treatment 1, flushing with access to the same irrigated pasture during the last 6 weeks of gestation and the first 8 weeks of lactation; and 3) a control group on native range only. The purpose of treatment 1 and 2 was to increase ovulation and foster embryo implantation and growth (i.e., conception rates). The

purpose of treatment 2 was to both increase conception rates and improve birth and, hopefully, weaning weights. In all treatments, rams were placed with ewes on May 15. Lambs were born in October and November and weaned in March.

Both flushing treatments improved lamb crop at birth and weaning. The birth rate of 94% and lamb crop at weaning of 85% on the range-only treatment did not leave much room for improvement. Still, flushing at breeding raised lamb crop weaned to 93%. Flushing in the last one-third of gestation increased birth weights by only 0.3 kg. Wool production was not affected by nutritional supplement from improved pasture. The most significant improvement of flushing over range-only was in weaning weights and lamb produced per hectare at weaning. Lambs weaned 4% heavier (22.6 kg vs 21.8 kg) if their mothers were flushed at breeding and lamb offtake was 13% higher (63.1 kg/ha vs 55.6 kg/ha). Lambs whose mothers were flushed at breeding and in the last trimester of gestation were 12% heavier at weaning (24.4 kg vs 21.8 kg). Lamb offtake per hectare was 20% higher (66.6 kg/ha vs 55.6 kg/ha).

The assumptions relative to production costs were the same as with the southern Sierra data. That is, a producer has the ability to borrow at 72% interest on 75% of the investment and the pasture has alternative uses the rest of the year.

Restricted dry-season use of cultivated irrigated pastures for ewe lamb development. The development of ewe lambs is an important issue in sheep production in the Andean areas of southern Peru. They are weaned around March to April, at the onset of the dry season, and thus have poor nutrition during this growth stage. As a result, most of these females do not reach breeding condition until about 2 years old. They are bred when 30 months old, and are 3 years old at first lambing. This trial is based on the assumption that flushing of the ewe lambs will allow them to reach breeding weight 1 year earlier, thus permitting lambing for the first time at 2 years of age.

The experiment was conducted at the Chuquibambilla research station. Newly weaned Corriedale ewe lambs grazing on *Festuca-Calamagrostis* range were supplemented with irrigated ryegrass pasture and commercial supplement during the critical dry period in Southern Peru (May to November). The five treatments were 1) access to ryegrass pasture 1 hour a day and native range the remainder of the day; 2) ryegrass all day 1-day/week and native range; 3) commercial protein supplement and native range; 4) ryegrass pasture only; and 5) native range only (control).

Reproductive performance of the animals was measured until lambing (see figure 3 below). More rapid lamb growth was associated with treatments 1, 3, and 4. Treatments 1 and 3 were similar, but superior to the control group (3 kg/head heavier, on average). Treatment 4 was superior to all treatments with ewe lambs 25% heavier than the control group. Wool production was significantly higher in treatments 1 and 4 (3.1 kg/head) and ranged from 20% higher than treatments 2 and 3, and 40% higher than the control group.

Treatment 1 outperformed treatment 3, producing higher gross benefits (20% higher wool production) at a lower cost. The differences between treatments 1 and 4 appear to be relatively small and tend to indicate that the practice of flushing 1 hour per day could be very attractive if a pattern of improved pasture use could be devised such that the cost of treatment 1 would be less (at the most 1/8th, assuming 8 hours of total grazing per day) than that of treatment 4. An example would be a community that establishes a pasture plot and allows community animals 1 hour grazing per day. The long-term reproductive effects remain to be seen. From a wool production standpoint, the 20% to 40% increase in wool production does not warrant the addition of either flushing practice to the traditional system of ewe lamb rearing.

Near the end of the 1st breeding season (July 28), the average weight of the 1-year-old ewe lambs was 25.0, 24.25, 25.1, 27.3, and 24.40 kg for treatments 1 through 5, respectively. If 30 kg is accepted as the minimum weight needed for breeding, none of the treatments were successful.

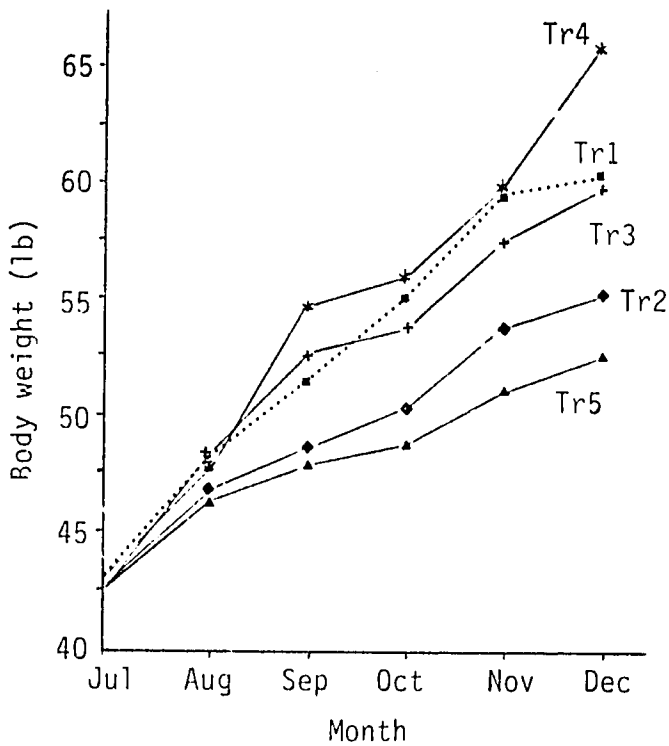


Figure 3. Body weight changes (lb) of ewe lambs under dry season supplementation treatments in the Andes of Peru.

Source: Luis Carlos Fierro, Godofredo Atamari, Rolando Alencastre, Juan Astorga, and Frank Craddock. 1984. Use of cultivated pastures for flushing sheep to improve reproductive performance in the Altiplano of Peru. In: Research Highlights-1984. Noxious Brush and Weed Control; Range and Wildlife Management, Vol. 15, Texas Tech University, Lubbock, Texas.

Laparoscopy exams of the animals at breeding time showed no differences among treatments in reproductive tract development or ovarian activity, and indicated that the young ewes had not yet reached physiological sexual maturity (Fierro 1985).

Restricted grazing of cultivated irrigated pastures to supplement adult sheep during the dry season. This is the sheep component of tne experiment reported earlier on page 14 and was conducted at the La Raya-IVITA research station in the Department of Cusco. Body weights for treatments 1, 2, and 4 (40 kg, 40 kg, and 45 kg, respectively) were significantly higher than those for treatment 3 and the control (37.5 kg). Wool yields showed parallel increase with averages of 3.7 kg/head for treatment 4; 3.3 kg/head for 1, 2, and 3; and 2.8 kg/head for the control. Wool production increases of about 20% to 30% are similar to those obtained in the ewe lamb experiment described above.

Economic Analysis of Results

This section explains the details of the benefit/cost analysis carried out to evaluate the profitability of the change from the traditional range-grazing scheme to systems that use cultivated irrigated pasture either as a supplement or all year round. The following analysis is based on the results of the 4 experiments discussed above, informal and random producer surveys, and previous studies.

"Traditional" Management vs "Yearlong" Use of Cultivated Irrigated Pastures

In the "yearlong" system, the sheep herd is maintained on irrigated pasture all year round. As table 8 shows, the main advantages over the traditional system are derived from the concentration of animals and from the 1-year reduction in time required for the ewe lambs to reach breeding weight (±30 kg) and for the wethers to reach market weight (±40 kg). This latter reduction accounts for the elimination of the 1- to 2-year-old lamb category. The low birth rate is believed to be the result

Table 8. Production traits and stocking rates of sheep used in the economic analysis.

Item	Traditional[a] system	Yearlong[b] system
Birth rate, %	80	80
First yr mortality, %	10	5
1 to 2 yr lamb mortality, %	5	N/A
Adult mortality, %	4	2
Ewe lambs age at first breeding, months	30	18
Wethers age at market time, months	28	16
Stocking rate, ewe equivalent/ha (EE/ha)[c]	1	30
Yearly culling rate, %		
Ewes and rams	20	20

[a] Traditional management was a range-grazing system.
[b] Yearlong management was the use by ewes of improved pasture the entire year.
[c] Five EE of the Peruvian stocking rate system = 1 animal unit of the U.S. stocking rate system. 1 ewe = 1 EE. Ewe lambs and wethers = .7 EE. Rams = 2 EE.

of factors other than nutrition (e.g., altitude and breed) and therefore does not change.

Herd Characteristics

Table 9 lists the animal inventory of a stable herd on range as well as inventory changes that occur over time as a result of undertaking the project in question. Traditionally, in the southern Sierra the breeding season is in June-July, with lambing from mid-October through mid-December (peaking in November), shearing in January, and weaning sometime in March. In the central Sierra, however, the higher rainfall pattern allows producers to start the breeding season in May, with the peak period of lambing in October. This schedule of events is more advantageous than that of southern Peru because the weaning is done in January when two additional months of good range are available. Shearing is done in February.

In the range herd, the ewe lambs and wethers (36 each) are the growing animals that will be marketed during the following year. The fat wethers and breedable ewe lambs for sale are the 28- to 30-month-old animals remaining after replacement of dead or culled ewes during the year.

On the cultivated irrigated pasture herd, the inventories of breeding stock change through the life of the project, according to pasture availability (figure 1). The elimination of the "ewe lambs" and "wethers" categories is a result of a reduction in the maximum number of EE and the number of head to be shorn per 100 ewes. The maximum number of EE is calculated at the peak of the herd's population curve each year, thus ensuring no overstocking. The fat wethers and breedable ewe lambs for sale are those 16- to 18-month-old animals remaining after restocking of the breeding herd. No animals are for sale in year 1 because, with the pasture idle and being established, only the breeding stock is introduced at the end of the year. Cultivated pasture dramatically increases the number of breedable ewe lambs available for sale,

Table 9. Herd composition and sales.[a]

Item	Range herd[c]	Pasture herd[b] Year 1	2	3	4	5	6	7
			Inventories of Stock[d]					
Rams	5	5	5	5	5	4	4	3
Ewes	100	100	100	100	100	85	70	69
Ewe lambs[e]	36	-	-	-	-	-	-	-
Wethers[e]	36	-	-	-	-	-	-	-
Maximum number EE	180	110	140	166	166	166	150	128
Head to be shorn	225	105	153	179	179	163	148	137
			Sales					
Fat wethers	35	0	25	38	38	38	38	33
Open ewe lambs	10	0	23	16	16	31	34	33
Culled ewes	20	0	0	20	20	20	17	0

[a]The technical coefficients assumed are presented in table 5.
[b]Herd on cultivated irrigated pasture.
[c]Stable herd on range. This structure was found in a herd development exercise.
[d]At the end of the year.
[e]Born at the beginning of the year.

beginning the second year. This is due to the assumed faster growth, resulting from the improved diet. There is a two-fold increase in breedable ewe lambs available for sale in the 5th year as a result of the overall reduction in herd size.

Baseline Financial and Economic Analysis

Table 10 shows the partial budget for each hectare of cultivated irrigated pasture required to feed the sheep flock on the 5.5 ha shown in table 9. The annual stocking rate is 30 EE/ha. The same herd or open range would need 180 ha at an annual stocking rate of 1 EE/ha.

The estimated values of fat wethers, culled ewes, and breedable ewe lambs ($24, $16, and $28, respectively) are based on average market prices of equivalent animals and their discounted potential production. The prices used are based on those quoted in the third quarter of 1984 and are estimates of farm-gate prices in the Puna expressed in 1984 U.S. constant dollars. Wool production per year is estimated at 2 kg/head in open range and 2.40 kg/head (20% increase) in cultivated irrigated pasture. The price of wool ($.60/kg) is the lowest price paid during 1984; this ensures no introduction of financial advantages gained from storing. The annual health cost per head is estimated at $2.00.

Increases in number of animals available for sale and the concentration of animals are the main determinants of the increase in gross benefits. Because the cultivated irrigated pasture is idle until the end of the first year, the negative entries for ewe lambs, culling, and fat wethers reflects the loss of production for that year. The total budget provides a comparison of the 2 systems.

In the outflow section, the livestock investment (residual) entry is the value of the initial (ending) herd brought into the pasture at the end of year 1, minus the value of the herd that would be on that hectare if it were open range. This entry reflects the intangible benefit that

Table 10. Marginal returns from 1 hectare of pasture with a sheep flock (vs. open-range traditional system)[a].

Item	Year 0	1	2	3	4	5	6	7
	(1984 US$)							
Inflows		13.41	256.74	342.82	342.82	414.99	417.61	850.85
Livestock residual								443.83
Pasture residual[b]								68.65
Net livestock benefits		13.41	256.74	342.82	342.82	414.99	417.61	338.37
Ewe lambs (breedable)		-1.56	115.54	79.90	79.90	156.26	171.54	166.44
Wool		21.41	38.56	45.37	45.37	41.18	37.25	34.37
Culling		-1.78	-1.78	56.40	56.40	56.40	47.68	-1.78
Fat wethers		-4.67	104.42	161.15	161.15	161.15	161.15	139.33
Outflows	651.33	827.46	291.78	294.82	271.06	263.02	213.91	20.85
Livestock investment		572.56						
Pasture investment[b]	499.00							
Operating expenses (OE)		169.25	264.42	294.82	294.82	268.42	262.42	208.52
OE pasture[b]		132.00	206.59	206.59	206.59	206.59	206.59	157.09
Livestock replacement		-1.82	-1.82	16.36	16.36	-1.82	-1.82	-1.82
Health		35.68	54.39	63.84	63.84	58.02	52.57	48.57
Miscellaneous		3.39	5.26	8.02	8.02	5.62	5.08	4.68
Working capital	152.33	85.65	27.36	.00	-23.76	-5.40	-48.51	-187.67
Net incremental benefit before financing -- remuneration to all resources engaged, including return to and of capital.								
EBIT[c]	-651.33	-814.05	-35.04	48.00	71.76	151.98	203.70	830.00
Economic NPV (discounted at 3.75%) = $-432.38								
Net incremental benefit after financing and taxes, with principal indexed to inflation.								
EBT*(1-t)[d]	.00	-572.56	-44.89	39.20	63.91	144.96	197.44	824.40
Financial IRR to farmer's own resources = 14.9%								

[a] Assumes a 72% nominal cost of debt and the financing of everything except livestock.
[b] From table 2. All OE minus land charge, plus shepherd labor cost.
[c] Earnings before interest and taxes.
[d] EBT = earnings before taxes after debt payments; t = tax rate.

comes from the range that becomes idle when the animals pasturing it are moved to the more intensive system. The pasture investment and residual entries are derived from table 1 after two adjustments: 1) subtraction of the land charge, which is the only cost common between the two alternatives; and 2) addition of a sheepherder labor charge of $12.80/ha for every year except year 1, when there are no animals on the pasture. The livestock replacement is the cost of ram replacement minus any benefits obtained from the sale of culled studs. The health cost is estimated at $2.00 per head. The miscellaneous charge is 10% of the last two items only. The working capital is 90% of the increase in operating expenses between the present and the following year.

Use of these assumptions results in an uneven cash flow stream, with negative entries up to the second year and positive entries in later years. The economic discounting process (with society's real cost of capital = 3.75%) yields a negative NPV of $-432.38, whereas the financial discounting (with a negative real cost of capital to the farmer of -23.25%) yields a highly positive NPV. The $-432.38/ha is an estimate of the cost to society.

After subtracting debt repayment and interest, the EBT*(1-t) figure shows no actual cash flow at the beginning of the project, diminishing negative entries for year 1 and 2, and positive cash flows for the following years. Notice, however, that the $-572.56 of year 2 is exactly the value of the livestock investment; so, in reality it will not be an actual out-of-the-pocket expense for the producer if he moves in animals from the rangeland. The resulting 14.9% internal rate of return to the farmer's own resources is likely to be too low for farmers to adopt the yearlong system. This conclusion is even more likely if it is taken into account that the increase in breedable ewe lambs available for sale (which make up for a large share of the benefits) is questionable (as suggested by the results of Fierro, 1985) as discussed in the experiment above.

Sensitivity Analysis

Table 11 shows some of the effects having the greatest impact. The left-hand-side column shows the changes needed (assuming that other parameters remain constant) to attain or get close to either an economic NPV = $0.00 or a financial IRR = 25%.

To attain an NPV = 0, the findings suggest the following: 1) increase the stocking rate of the pasture by 37% to 41 EE/ha; 2) increase the birth rate to $\geq$ 100%; 3) obtain a wool price increase of about 185%; 4) obtain a mutton price increase of 30%; 5) reduce the initial pasture investment more than 75% (to < $125/ha); or 6) reduce the operating expenses of the pasture about 35%.

For the farmer to obtain a real return on his (her) investment of at least 25%, table 11 indicates that the following changes must first occur: 1) increase stocking rate by about 64%, 2) increase the birth rate to $\geq$ 100%, 3) obtain a wool price hike of ±185%, 4) obtain a mutton price increase of 50%, 5) reduce the initial pasture investment more than 75%, or 6) reduce the operating expenses of the pasture more than 35%.

The probability is low for the occurrence of any of the required parameter changes indicated above. The findings are similar to those obtained for alpacas, adding further question of the need for research of yearlong livestock grazing on cultivated pastures in the Puna of Peru. The findings are substantiated by the fact that no such production systems currently exist. However, the above exercise indicates that the use of these irrigated cultivated pastures as supplement for the rangelands is an important area of research that should be studied more deeply. The next section explores some alternative, potential uses that were suggested by the analyses above and by many discussions among collaborators.

Table 11. Sensitivity analysis of results presented in table 9.

Parameter change	Economic[a] NPV, $	Financial[b] IRR, %
Base	-432.38	14.9
Stocking rate		
From 30 to 41	0	21.7
to 49	+336.80	25.0
Birth rate		
From 80% to >100%	0	25.0
$/kg of wool		
From .6 to 1.71	-12.60	25.7
$/kg mutton		
30% increase	0	22.4
50% increase	+200.00	25.0
Reduction in pasture investment		
To 1/4 of base	-98.00	14.5
Reduction in OE of pasture		
To 2/3 of base	-39.00	23.8

[a] Return to society. Present worth of the sum of cash flow discounted at 3.75%.
[b] Real return to investors' resources after debt payment (with principal not indexed to inflation).
Note: OE = operating expense.

Alternative Uses

Dry-season supplementation of ewes bred in June to July with rams did not significantly affect either weaning weight of the lambs or conception rate of the ewes in the southern Sierra experiment discussed above. However, simulation runs of a model used by Fierro (1985) indicate that such supplementation may increase average lamb weaning weight by 1.8 kg (from 17.8 kg without supplementation to 19.1 kg) for lambs of ewes bred June to July and by 4.8 kg (from 15.7 kg to 19.6 kg) for lambs from ewes bred May to June.

Assuming 10% digestible protein (17% crude protein hay with ±60% digestibility) and an annual digestible protein (presumably the most limiting nutrient) deficit of 130 gr/ewe/day occurring during the last 8 weeks of gestation, the amount of supplemental forage needed can be met with 36.4 kg of hay per ewe. Given an estimated hay-making cost of $.05/kg, 36.4 kg cost $1.80 plus the forage cost (Farfan, 1985). Given the increases in lamb weaning weight representing $1.26 (1.8 kg) or $3.36 (4.8 kg) revenue per ewe, dry season supplementation would be an attractive component of a mixed production system only for those ranches breeding sheep during the May to June period -- but not for those with the traditional June-July breeding season. This practice could be an incentive to harvest the surplus forage either during the rainy season when all the livestock are on open range, or during periods of understocking.

Another phase of sheep production likely to fit and add positive NPV to a mixed system is that of wether fattening. This could be done either by supplementing with hay during the dry season or allowing the animals to harvest the pasture by themselves. Assuming a digestible protein deficit of 5 grs/day/wether during at least 6 months of the year (mid-May through mid-November) for wethers gaining 100 gr liveweight per day, the supplemental forage requirement per wether can be met with 9 kg of 10%-digestible-protein hay. This will allow the ranchers to market the wethers at the end of the dry season (October-November). It will

mean foregoing the yield of the January shearing (about $1.20/wether), and perhaps getting a much better price per kg of wether. However, it will also mean the reduction of livestock numbers during a period of increased nutrient supplies. It is very unlikely that this latter change will fit any management scheme and(or) justify the trade-off of wool yield for mutton price, and therefore this alternative (wether supplementation during dry season) is not studied further in this paper.

At a stocking rate of 30 EE/ha and a daily liveweight gain of 60 gr/head/day, a wether fattening activity that allows the animals to graze the rainy-season surplus of pasture (4 months out of each year) provides about $1,000/ha more to the economic NPV of the total system. This result is most relevant on ranches that are fully stocked with breeding sheep and wether lambs must be sold at weaning time. These lighter lambs are sold at a lower price than that which would be obtained if they were fattened and shorn so the producer loses the wool yield of one shearing. Therefore, the system just discussed should be very attractive to such ranches.

MIXED ALPACA-SHEEP PRODUCTION SYSTEMS

The three systems diagrammed and analyzed next are not an exhaustive list of the possible combination that might be analyzed; however, they can serve as examples that apply to the majority of ranches in the area.

Figure 4 depicts system #1 for which results are presented in table 12 below. It consists of using the cultivated irrigated pasture to: 1) raise tuis with their mothers until they are 10 to 12 months old; and 2) supplementing, during the last 6 weeks of gestation, those ewes bred in May to June with hay made the previous rainy season.

The $378 "+kg lamb" benefit is derived from the additional 540 kg of lamb weaned as a result of supplementing 135 ewes with 5 tons of hay obtained from the pasture during the previous rainy season. Notice that

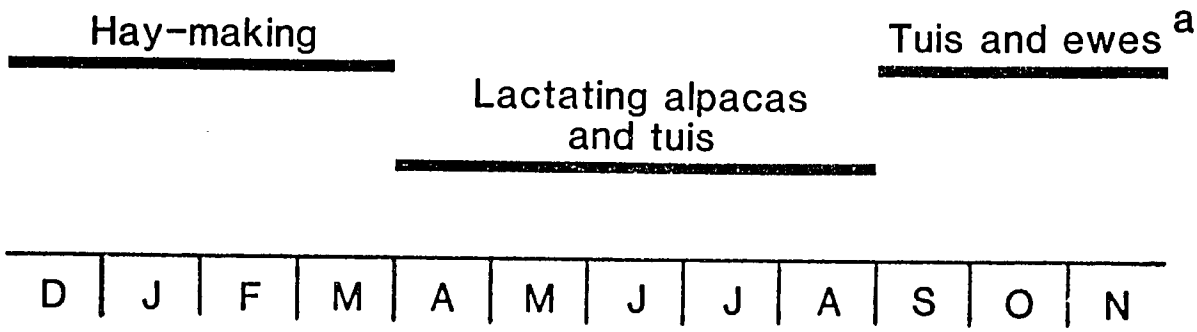


Figure 4. Mixed system #1
[a]Ewes supplemented with hay

Table 12. Marginal returns from 1 hectare of pasture with mixed sheep-alpaca production system #1.

Item	Year 0	1	2	3	4	5	6	7
	(1984 US$)							
Inflows								
Livestock residual	.00	-25.12	620.87	620.87	620.87	985.16	872.64	920.51
Pasture residual[b]								-9.07
Net livestock benefits	.00	-25.12	620.87	620.87	620.87	985.16	872.64	68.65
Tuis		.00	242.86	242.86	242.86	607.14	495.71	860.93
Fiber		-21.48	.02	.02	.02	.02	-.92	485.71
Culling		-3.65	.00	.00	.00	.00	-.15	-1.74
+kg lamb		378.00	378.00	378.00	378.00	378.00	378.00	-1.04
								378.00
Outflows	836.57	445.62	456.61	456.61	456.61	456.04	186.24	15.63
Livestock investment		-2.84						
Pasture investment[b]	499.00							
Operating expenses (OE)	.00	375.08	456.61	456.61	456.61	456.61	455.98	156.27
OE pasture	.00	132.00	206.59	206.59	206.59	206.59	206.59	157.09
Livestock replacement	.00	-1.18	.00	.00	.00	.00	-.34	-.34
Health	.00	-5.11	.01	.01	.01	.01	-.22	-.42
Miscellaneous	.00	-.63	.00	.00	.00	.00	-.06	-.08
Hay-making	.00	250.00	250.00	250.00	250.00	250.00	250.00	
Working capital	337.57	73.38	.00	.00	.00	-.56	-269.74	-140.64
Net incremental benefit before financing -- remuneration to all resources engaged, including return to and of capital.								
EBIT	-836.57	-470.74	164.26	164.26	164.26	529.11	686.40	904.88
Economic NPV (discounted at 3.75%) = $840.74								
Net incremental benefit after financing and taxes, with principal indexed to inflation.								
EBT*(1-t)	-209.14	-117.17	152.88	154.10	155.19	521.01	679.17	898.42
Financial IRR to farmer's own resources = 54.5%								

[a] Assumes a 72% nominal cost of debt and the financing of 75% of everything except livestock.
[b] From table 2. All OE adjusted by: 1) subtracting land charge and 2) adding herder labor cost.

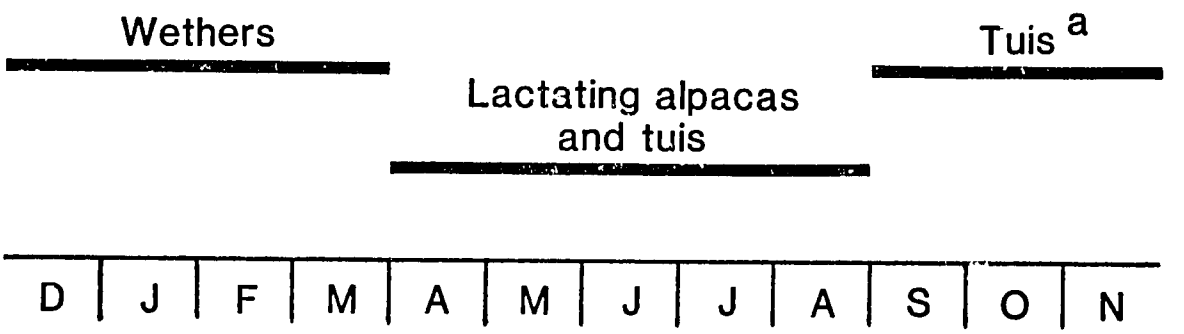
this row and "hay making" in the outflow section reflect the only cash flow differences between this table and table 7. The resulting NPV ($840.74) and IRR (54.5%) are much higher than those in table 7 and represent attractive returns on investment in this area.

Another system (#2) that makes a different use of the wet season forage surplus is depicted in figure 5, with results shown table 13. It consists of using the pasture to fatten wethers during the rainy season, and raising tuis with their lactating mothers until one-year old.

The key assumption is that a hectare of pasture can support 40 wethers gaining 60 gr/day/wether from December through March. This system takes advantage of the animal's ability to harvest the forage and avoids the cost of hay making. The additional return obtained from the wethers is also higher than that received in system #1 by supplementing the ewes with hay, thus the returns are also much higher. Table 13 indicates an economic NPV of $1912.24/ha, and an IRR of 84.9%.

Figure 6 depicts system #3, the alternative yielding the highest estimated return. The combination of animals described in the footnote of the diagram results in a yearly stocking rate of about 30 EE/ha. System #2 differs in the utilization of the surplus pasture left when the alpaca breeders are taken back to range at weaning time (early September).

It is estimated that supplementing ewes during the final one-third of the gestation period (by allowing them to graze on cultivated irrigated pasture one hour each day) will increase the crop of lambs weaned per hectare by 170 kg of live weight -- valued at $120.00. Assuming an additional $20.00 cost for the daily handling of the ewes, the results on table 13 indicate an NPV of $2,420.00 and a IRR of 98.8%. The management strategies involved in implementing such a system would require modifications according to the particular conditions of each ranch.



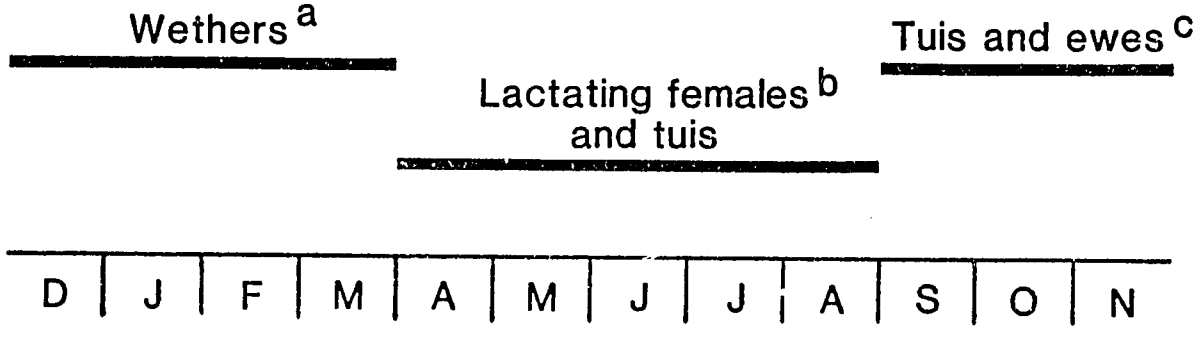
a. Plus some adult females as explained in text.

Figure 5. Mixed system #2.

Table 13. Results of comparable mixed sheep-alpaca production systems.

System no.	Main components[a]	Economic[b] NPV/ha	Financial[c] IRR
1	DS[d]: raising tuis ≤ 1 yr old RS: hay to supplement ewes in late gestation	$ 840.70	54.5%
2	DS: raising tuis ≤ 1 yr old RS: fattening wethers	$1,912.00	84.9%
3	DS: raising tuis ≤ 1 yr old and supplementing pregnant ewes with surplus forage after weaning of tuis RS: fattening wethers	$2,420.00	98.8%

[a] Uses of the pasture throughout the year.
[b] Society's return.
[c] Investor's return.
[d] DS = dry season (December-March); RS = rainy season.



a. 40 fattening wethers/ha
b. 16 lactating females with tuis
c. 16 weaned tuis, & 400 ewes supplement with 1 hour pasture per day

Figure 6. Mixed system #3

3. STOCKING RATES AND ALTERNATIVE GRAZING SYSTEMS FOR NATIVE RANGE

DESCRIPTION OF GRAZING TRIALS

This series of experiments was conducted in the central Andes of Peru, on the agricultural cooperative (SAIS Pachacutec) located in the Department of Junin. The range site is glaciated upland with typically herbaceous vegetation dominated by *Festuca* spp. and *Calamagrostis* spp. (Carey, 1984). The altitude is about 4,200 m above sea level and the precipitation ranges from 700 to 1,000 mm, falling primarily from October to April. Even though the average daily temperature (5°C) remains relatively constant throughout the year, the area is characterized by diurnal temperature variation of as much as 20°C.

In early 1981, the study was initiated with 20 freshly shorn Corriedale ewes grazing on native range with the following seven treatments (the original experiment numbers are retained): 1) continuous grazing at a stocking rate (SR) of 3 EE/ha, which in Peru is a widely accepted estimate of the optimal SR; 2) rotational grazing, SR = 3 EE/ha; 7) rotational grazing, SR = 2 EE/ha; 8) rotational grazing, SR = 4 EE/ha; 9) rotational grazing, SR = 6 EE/ha; 10) common-use rotational grazing on fertilized native range, 5 EE/ha; and 11) common-use rotational grazing, 3 EE/ha. Treatments 10 and 11 involved cattle grazing after the sheep, thus taking advantage of the complementarity of the grazing habits of these two animal species. The 8-paddock rotational system allowed 6 days of grazing per paddock followed by 42 days of rest for the pastures in treatments 2, 7, 8, and 9; and only 36 days of rest for those pastures under treatment 10 and 11.

Treatments 3, 4, 5, and 6 were added in 1982 to examine the effects of flushing, when animals were grazed on cultivated pastures. Treatments consisted of 3 EE/ha continuous and rotational grazing each with flushing at breeding time only, and flushing at breeding and late gestation.

The following analysis includes 3 years of data for all treatments except 3-6. Treatment 1 is basically a repetition of the practices followed in the SAIS; however, its yields in terms of kg of weaned lamb per ha per year were on the average 65% higher than those obtained from the commercial herd of SAIS Pachacutec. Data from the control experiment (C3) which represents researcher managed animals on a SAIS and actual conditions on a SAIS (control SAIS) indicate that there is also a considerable gap between output levels from traditional grazing practices under high levels of management (experiment C3) and under current levels of SAIS management (control SAIS). In the analysis which follows, however, no comparisons are made with the control SAIS. The valid comparisons are treatments 2-7 with the control treatment (treatment 1). Table 14 shows for each treatment the average yield per ha of lamb and wool, the assumed beef production, and the value of the total output given product prices per kg of $.70, $.60, and $.70, respectively; a total cost item which is the sum of those costs that vary across treatments (opportunity cost of capital tied up in livestock, fertilization cost, and flushing cost); and the resulting net benefits per hectare. All flushing treatments (3-6) as well as treatments 2 and 9 are dominated (these treatments produced less output at the same or higher cost) by treatment 8. These treatments are thus not considered in the economic analysis which follows. Flushing can still be considered as an option in further research as a component of various improved grazing management systems. Table 15 ranks the remaining five treatments according to net benefits and also presents their marginal rates of return and coefficients of variation.

ECONOMIC ANALYSIS

The MRR of going from C3 to R4 (12.4%) is so low that it makes R4 (rotational grazing system with a stocking rate of 4 EE/ha) very unlikely to be accepted by the area ranchers, because of higher labor and management inputs. However, if the health and productivity of the

Table 14. Average yields (1981-83), value of output, costs, and net benefits for stocking rate experiments.

Treatment		Production, kg/ha/yr			$/ha/year (1984)		
#	Code	Beef	Wool	Lamb	Output	Costs	Net benefit
1	C3		10.50	43.19	39.52	5.40	34.12
2	R3		10.00	41.28	37.80	5.40	32.40
3	C3-FB[a]		13.65	57.86	52.70	7.50	45.20
4	R3-FB[a]		13.00	61.90	55.40	7.50	47.90
5	C3-FB&L6[a]		13.65	61.74	55.70	9.00	46.70
6	R3-FB&L6[a]		13.00	68.28	60.30	9.00	51.30
7	R2		7.30	35.28[b]	31.50	3.60	27.90
8	R4		12.15	69.07	60.40	7.00	53.40
9	R6		17.90	47.93[c]	47.60	10.80	36.80
10	COMP5	130	15.00	98.20	172.04	72.00	100.00
11	COMP3	60	9.35	35.86	75.20	16.00	59.20
Control	SAIS		7.50	26.92			

[a] Two-year averages.

[b] Understocking was evident resulting in a high coefficient of variation of 17.4%.

[c] Overstocking was evident and resulted in yields of 92 kg, 32.5 kg, and 20 kg in 1981, 1982, and 1983, respectively, and a high coefficient of variation (80.8%).

Table 15. Net benefits, marginal rates of return (MMR) and coefficients of variation (CV) of remaining treatments.

Treatment #	Code	Net benefit $/ha	Cost $/ha	MRR,%[a]	CV, %[b]
10	COMP5	100.00	72.00	137.2	1.4
11	COMP3	59.20	16.00	155.2	1.4
8	R4	53.40	7.00	12.4	7.4
1	C3	34.12	5.40	28.9	8.7
7	R2	27.90	3.60		

[a] MRR = marginal cost/marginal net benefit.
[b] CV = standard deviation/mean.

range improves, rotational grazing must be an ecologically acceptable alternative, if not economically acceptable.

MRR's obtained by going to livestock-sheep complementary grazing systems -- with or without fertilization -- indicate the desirability of such alternatives. However, such changes would be affected by many factors that are specific to individual ranches. The higher profits obtained by running cattle after sheep would have to be weighed against the marginal cost of the more complicated management scheme; this is an especially important consideration in ranches with large flocks/herds. The next step, fertilizing native range being grazed by both sheep and cattle, appears very profitable also, but the decision to do so would have to consider many other factors such as the uncertainty of pasture response to the fertilizer and the availability of both fertilizer and capital.

The analysis above assumes that the rotational systems can be implemented without additional fencing costs, which is realistic. In practice, the "continuous" grazing carried out in most ranches is very much rotational, because the shepherds on a production cooperative move the herds through the pastures according to forage availability. Only for the complementary grazing treatments is this assumption unrealistic.

Adding a fencing cost to all the rotational systems, treatments 7 and 8 are dominated by the remaining treatments. The MRR of going from continuous sheep grazing (C3) to complementary cattle-sheep grazing (Comp3) is 122% while the MRR to fertilizing is 137%.

The results above seem to indicate that the prevalent 3 EE/ha continuous grazing is the optimal system of range utilization when sheep are the only animal species being exploited. However, they also indicate the economic feasibility of taking advantage of the complementary grazing habits of sheep and cattle whenever the conditions (i.e., management scheme, fertilizer and capital availability, etc.) allow for the successful implementation of mixed production systems.

4. CONCLUSIONS

The results present further evidence of the rationality of the predominant production systems, given the environment and economic conditions under which the ranchers of the Peruvian Andes operate. The harsh environment and the consumer-oriented agricultural policies of Peru, which result in little or no incentives for the producers, seem to be largely responsible for the common exploitive use of renewable natural resources like the range.

The results point out that yearlong use of cultivated irrigated pastures by a few elite animals is not economically viable. Strategic use of these pastures as a supplement to native range offers attractive economic returns to the nation and attractive financial returns to producers. Research on mixed production systems (alpaca-sheep, or cattle-sheep, depending mainly on the altitude), appears to be the best alternative to increase range productivity and livestock production.

5. FOOTNOTES

1 For a detailed description of the cooperative production units, see Martinez (1983).

2 $$r = \frac{i - e}{1 + e}$$

r = real interest rate
i = nominal interest rate
e = inflation rate

As of April 1983, the effective return on adjustable term deposit certificates was 104.6% (Resena Economica, Banco Central Reserva, April 1984) and the prevalent inflation rate was 97.2%. This gives us an r of 3.75%, which is fairly close to the return on US$ saving accounts in Lima -- 3 percentage points below LIBOR (9.5%) minus U.S. inflation rate (± 3.5%) = 3% -- which is considered a proxy for the opportunity cost of capital in Peru.

3 This is done by finding out the annuity payment whose discounted sum is equal to the discounted sum of the actual cash flow. The resulting uniform cash flow could be conceptualized as the actual outflow of the rancher who, wanting an equal yearly expense, sets up a borrowing and loan repayment scheme. The process of equalizing the cash flows is a tool used only for comparative purposes.

4 Some producers argue that the range is an even better and more palatable nutritional source during the rainy season because of the variety of plant species -- usually more than 20 different species -- from which the animals choose their diet.

5 There is in Peru a widespread belief that alpacas do not eat any forage not harvested by themselves.

6 The term "flushing" describes the practice of improving the nutrition of the animals during short, critical periods of the year (weather and(or) physiological-stage-related) to increase productivity.

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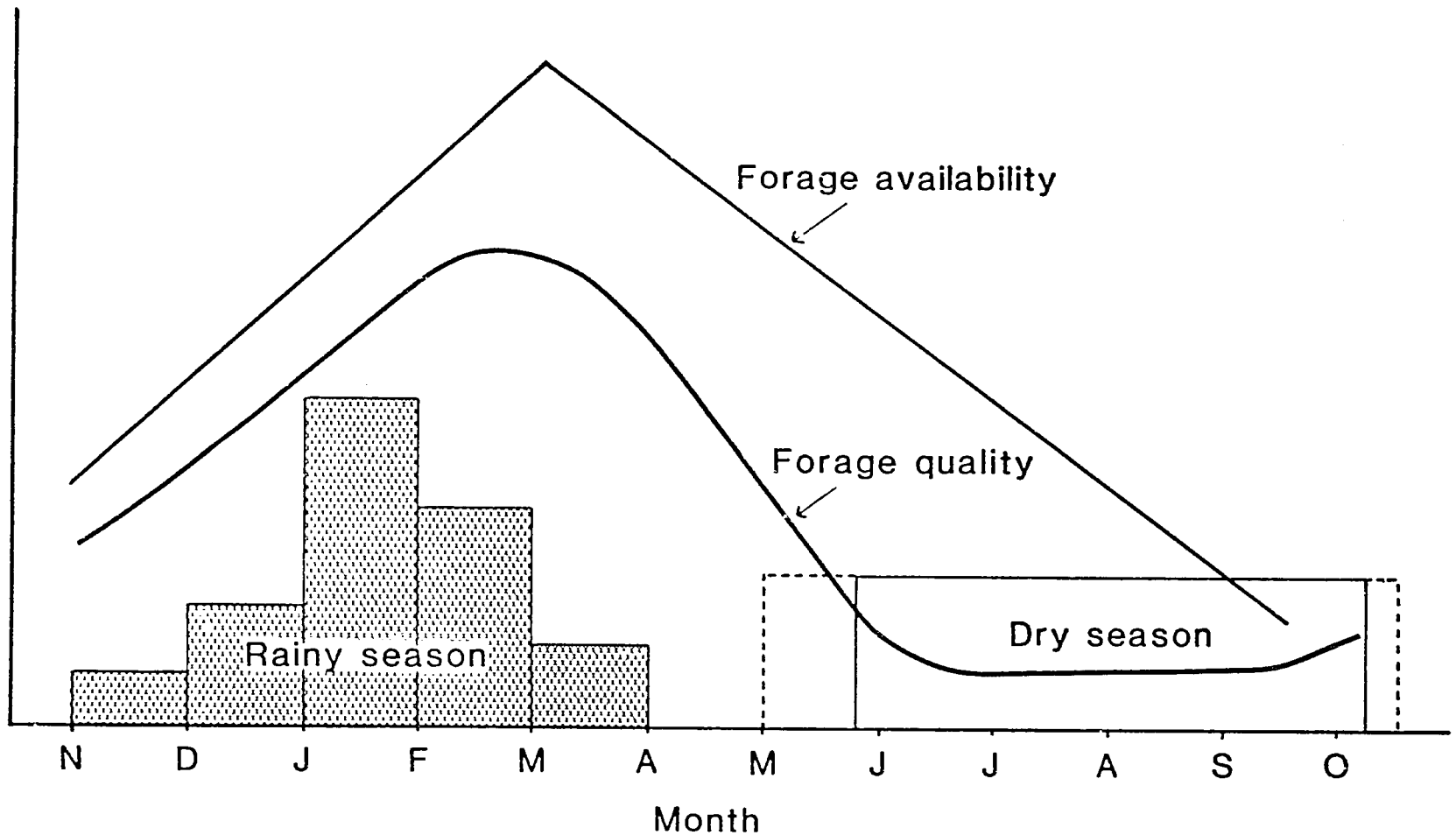
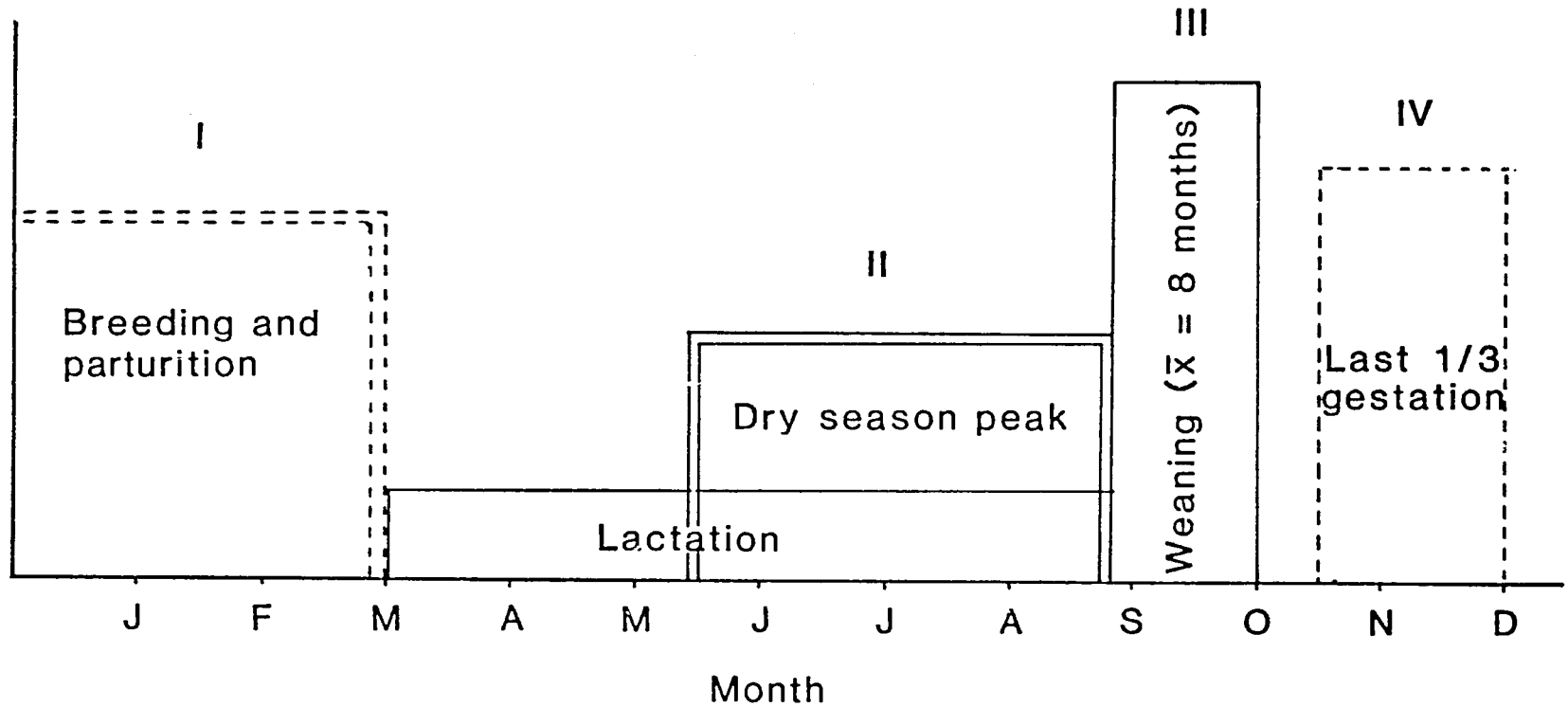


Appendix Figure 1. Seasonality of rainfall, availability of native forage, and quality of range in the Andean region of southern Peru.



Appendix Figure 2. Productive cycle of the Alpaca. Note: Possible strategic uses of cultivated pastures include grazing by mothers and babies during parturition and breeding, support of lactating mothers and their babies during the dry season, development of tuis during critical 6 weeks post weaning, and supplementation of pregnant females during last 1/3 of gestation.
Source: J. Sumas-La Raya, personal communication.