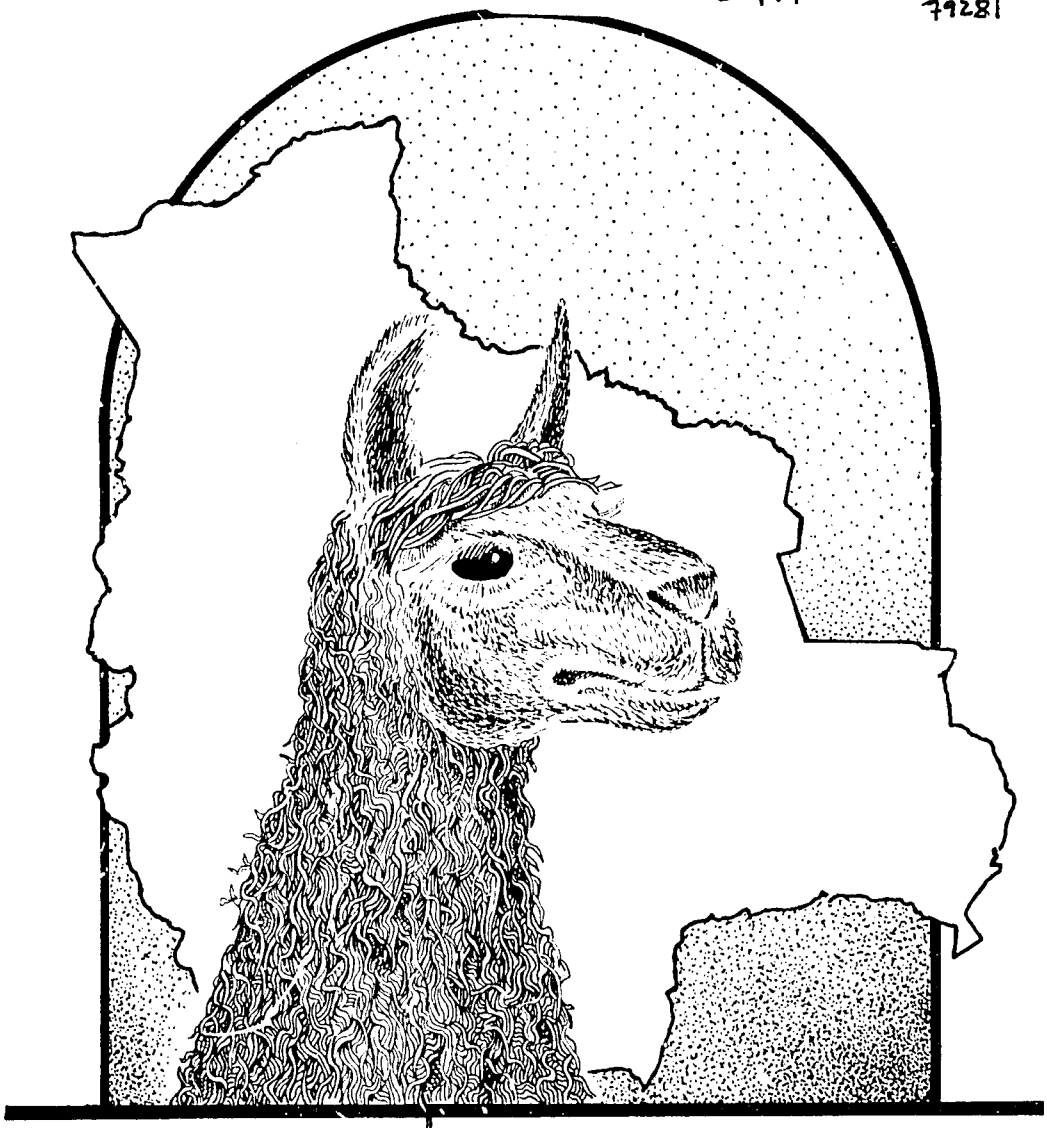
PN-ABM-283
79281



Sustainable Crop-Livestock Systems *for the* Bolivian Highlands

PROCEEDINGS OF AN SR-CRSP WORKSHOP

Sustainable Crop-Livestock Systems *for the* Bolivian Highlands

Proceedings of an SR-CRSP Workshop

Edited by
Corinne Valdivia

Sustainable Crop-Livestock Systems *for the* Bolivian Highlands

PROCEEDINGS OF AN SR-CRSP WORKSHOP

Editor: **Corinne Valdivia**
Cover illustration and maps: **Dennis Murphy**
Design and production management: **Sharon Wood-Turley**
Editorial and production assistance: **JoAnne Williams, Heinz Woehlk**

Printing: University of Missouri-Columbia Printing Services

Copies may be obtained from:
SR-CRSP
228 Gentry Hall
University of Missouri-Columbia
Columbia MO 65211 Phone: 314-882-6085

or

Management Entity
SR-CRSP
University of California, Davis
Davis, CA 95616-8700

Funding provided by:
United States Agency for International Development
Grant No. DAN-1328-G-SS-4093-00

February 1992

Published by University of Missouri-Columbia
© 1992 University of Missouri

Workshop Participants

Humberto Alzérreca, IBTA, Bolivia
Robert Washington Allen, Utah State University
Fred Bryant, Texas Tech University*
Peter Burfening, Montana State University
Deborah Caro, The Futures Group, Washington D.C.
Sam Curl, Texas Tech University
James Ellis, Colorado State University
Arturo Flórez Martínez, INIAA, Peru
Jere Gilles, University of Missouri-Columbia*
John Glenn, Director SR-CRSP
Thurman Grove, Winrock International Institute for Agricultural Development
Keith Jamtgaard, Montana State University
Robert Lawless, Texas Tech University
Máximo Liberman, Instituto de Ecología, Bolivia
John Malechek, Utah State University
Domingo Martínez, University of Missouri-Columbia
Constance McCorkle, Institute for International Research
Michael Nolan, University of Missouri-Columbia*
David Norman, Kansas State University
Ben Norton, Utah State University*
Morty Ortega, Texas Tech University
Enrique Ospina, Winrock International Institute for Agricultural Development*
Jim Oxley, Past Director SR-CRSP
Michael Painter, Institute for Development Anthropology
Kevin Pond, North Carolina State University
Juan Carlos Quiroga, CUMAT, Bolivia
Eduardo Segarra, Texas Tech University
Jeremy Taylor, Texas A & M University
Joyce Turk, United States Agency for International Development, Washington, D.C.
Corinne Valdivia, University of Missouri-Columbia

Collaborating Institutions of the SR-CRSP in Bolivia

Texas Tech University
University of Missouri-Columbia
Utah State University
Winrock International Institute for Agricultural Development

Host Country Counterpart Institution

Instituto Boliviano de Tecnología Agropecuaria (IBTA)

**Principal investigators of the Bolivia SR-CRSP*

Table of Contents

FOREWORD viii

Jere L. Gilles and Corinne Valdivia, University of Missouri-Columbia

CHAPTER 1

James E. Ellis, Colorado State University

Recent Advances in Arid Land Ecology 1
Relevance to Agro-Pastoral Research in the Small Ruminant CRSP

CHAPTER 2

Thurman Grove, Winrock International Institute for Agricultural Development
Clive Edwards, Ohio State University

Agroecological Perspectives on Agricultural Research and Development 15

Figures:
1. *Conceptual model of a farm* 32
2. *Key factors and relationships in the management of a traditional agroecosystem* 33
3. *Key processes and functional relationships in a traditional agroecosystem* 34
4. *Key factors and relationships in the management of a conventional monocultural agroecosystem* 35
5. *Key processes and functional relationships in a sustainable agricultural agroecosystem* 36
6. *Social and economic processes and functional relationships in a sustainable agroecosystem* 37

CHAPTER 3

D.W. Norman, Kansas State University

Household Economics and Community Dynamics 39

Figures:
1. *Schematic representation of some farming system determinants* 69

CHAPTER 4

Deborah A. Caro, The Futures Group, Washington, D.C.

The Socioeconomic and Cultural Context of Andean Pastoralism 71
Constraints and Potential for Biological Research Interventions

Table of Contents, continued

CHAPTER 5

Michael Painter, Institute for Development Anthropology

Changes in Highland Land Use Patterns and Implications for Agropastoral Development 93

CHAPTER 6

Ing. Juan Carlos Quiroga M., Executive Director, CUMAT

Agroecological Characterization of the Bolivian Altiplano 123

Figures:

1. *Mosaico semicontrolado de la República de Bolivia (Satellite Imagery of Bolivia)* 124
2. *Mapa Ecológico Generalizado de Bolivia (General Ecological Map of Bolivia)* 125
3. *Perfil aproximado de las lineas guías para definir regiones latitudinales y fajas altitudinales (Approximate Delineation of Altitudes within Various Latitudes)* 127
4. *Mapa de Unidades morfoestructurales Con las subdivisiones consideradas en el cuadro estratigráfico (Stratified Map of Land Forms and Geo-Morphology)* 129
5. *Altiplano norte (Northern Altiplano)* 132
6. *Thorn steppe lower montane transition to montane subtropical* 136
7. *Steppe montane subtropical* 138
8. *Moist forest montane subtropical* 140
9. *Desert montane temperate* 143
10. *Desert shrub montane temperate* 144
11. *Thorn steppe montane temperate* 146

CHAPTER 7

Humberto Alzérreca Angelo, Bolivian Institute of Agricultural Technology

Overview of Small Ruminant Research in the Bolivian Andean Zone 165

Figures.

1. *Map No. 1, Distribución porcentual del territorio y la población por regiones (Percent Distribution of the Land Area and Population by Regions)* 166
2. *Map No. 2, Mapa simplificado de las ecoregiones (Simplified Map by Ecoregions)* 168
3. *Map No. 3, Mapa de susceptibilidad o de erosión hídrica (Susceptibility for Erosion Map)* 173

Foreword

Sustainable Crop-Livestock Systems for the Bolivian Highlands

Proceedings of the SR-CRSP Workshop on Research Priorities

Jere L. Gilles and Corinne Valdivia
University of Missouri-Columbia

Most of the world's small ruminants live in the world's arid and semi-arid zones. It is in these regions where the fortunes of the rural poor depend most heavily on livestock production. Small ruminants, sheep, goats, alpaca and llama are particularly important for the livelihood of small rural producers in these regions. This is particularly true in areas characterized by "agropastoralism," the combination of livestock and rainfed crop production. Crop production in these areas is the most important source of livelihood, but it is also a risky endeavor. Crops and animals alike are threatened by frequent droughts. Livestock often play a crucial role in these systems because they are the only "perennial crop" that farmers have. They can utilize native rangelands and the residues of failed crops and provide the capital reserves needed to meet financial emergencies.

While animal production is important for the economic survival of farmers living in drought prone environments, there is some question as to whether production systems in such areas are themselves sustainable. Periodic droughts that expose soils to erosion, clearing of fragile soils for crop production, and overgrazing, all contribute to the deterioration of these production systems.

Although agropastoral systems contain the largest numbers of animals and people in the arid and semi-arid regions, relatively little research on the sustainability of these systems has been conducted. Studies have either concentrated on the use of natural pastures by domesticated animals or upon the impacts of crop production on soils. Thus past research has avoided examination of the most important part of any agropastoral production system—the interaction between crops and animals. The articles found in this book are the first step toward a study of agropastoral systems in the Bolivian Altiplano.

THE GENESIS OF THE CURRENT VOLUME

The Small Ruminant Collaborative Research Support Program (SR-CRSP) is a research program on small ruminant production sponsored by the United States Agency for International Development (USAID). The program involves 10 U.S. institutions and counterpart research institutes in Kenya, Morocco, Indonesia and Bolivia. SR-CRSP research is intended to improve the production and utilization of small ruminant products by small farmers and the rural poor. The U.S. institutions involved in the semi-arid agropastoral research are Texas Tech University, University of Missouri-Columbia, Utah State University, and Winrock International Institute for Agricultural Development. The University of California-Davis is the management entity of all the SR-CRSP.

Research on sustainable agropastoral systems has been a major program area of the SR-CRSP since 1989. At that time it was recognized that there was a need for new approaches to the sustainable management of Third World rangelands. Most attempts to develop pasture management systems in the Third World over the past 30 years had failed, and there was a pressing need for new approaches to the protection of these fragile environments. At the same time, theoretical developments in arid land ecology, had called into question the basis for many of the techniques used by resource managers in drought prone areas. Thus research on sustainable agropastoral systems was seen as an important area for small ruminant research.

After searching the globe for possible research sites of an agropastoral research program, Bolivia was chosen as the site for this effort. A memorandum of understanding was signed in 1991 between the SR-CRSP and IBTA (*Instituto Boliviano de Tecnología Agropecuaria*) to begin research on Bolivian agropastoral systems. One of the first steps toward developing a research program in Bolivia was to familiarize U.S. scientists with the latest thinking on agricultural sustainability under semi-arid conditions, and research on small ruminant agropastoral production systems, their ecology, and internal dynamics. Previous research in Peru had shown feed resource as a main constraint to livestock production.

The mechanism chosen to do this was a workshop ("Sustaining Agropastoral Systems in the Bolivian Altiplano: SR-CRSP Research Priorities for the Next Decade," Lubbock, Texas, May 14-17, 1991). Presenters were experts on Bolivian agropastoral production systems, their ecology as well as their dynamics and constraints, and scientists who could outline recent methodological and theoretical developments relevant to the

study of agropastoral systems in arid environments. Seven papers were commissioned to serve as the basis of discussions at the workshop about critical research issues in the Bolivian Altiplano. Bolivian, U.S., and Peruvian researchers and potential participants in the SR-CRSP in Bolivia participated in the discussions. This volume contains these papers.

We would like to take this opportunity to thank all those that in many ways made the workshop possible. We would like to acknowledge the presenters for their excellent job. In Texas Tech we need to thank Fred Bryant and his team, among them Morty Ortega, Karen Davis, Lisa Bradley, David Miko and Ernesto Flores, for the organization of the logistics, and making us all feel welcome. In Missouri we need to thank JoAnne Williams for all her work to get all of the participants to Lubbock We appreciate Joyce Turk, and John Malechek, for accepting the role of chairpersons, and Eduardo Segarra for facilitating the discussions. We also thank Keith Jamtgaard for conducting the panel discussions, and Peter Burfening, Arturo Flórez and Domingo Martínez for their participation as panelists. We also appreciate the participation of Constance McCorkle, who was in the original planning of this workshop. A very special thanks to Sharon Wood-Turley for her dedication and patience in putting this publication together.

CONTENTS OF THIS VOLUME

Even though the SR-CRSP will conduct its research on agropastoral systems in Bolivia, the program's goal is a global one. Consequently it was important to identify research issues which would contribute to the sustainable development of agropastoral systems in drought prone areas throughout the world. In order to achieve this objective, two types of papers were commissioned —three papers which took a broad theoretical perspective and four which focussed specifically on Bolivia. Workshop discussions were directed towards developing linkages between the two types of papers.

The first three papers were commissioned from persons who are recognized experts in the areas of ecological theory, sustainable agriculture and farming systems research. The purpose of these papers was to focus the attention of those interested in the Bolivia research program on issues that had global importance. The first paper in this group is that of James Ellis. Ellis outlines the recent theoretical developments in ecological theory which served as the catalyst for the development of the SR-CRSP research program on sustainable agriculture. Next Thurman Grove and Clive Edwards provide us with a general framework for studying agricultural systems, the interrelationship between animals and crops and the sustainability of these systems. David Norman's paper builds upon his considerable experi-

ence with farming systems research and discusses ways for integrating social, economic, biological and ecological data in order to understand the logic of production systems. Norman also discusses how theories of household or peasant economics contribute to this process.

The four papers specifically concerned with Bolivia were designed to give an overview of the nature of agropastoral systems in the Bolivian highlands. Deborah Caro's chapter presents three types of livestock production systems in the Bolivian Altiplano. She describes the dynamics of these systems as well as the constraints faced by producers in each one of them. Juan Michael Painter looks at changing patterns of land use in the Bolivian Highland and indicates what the impact of these changes has been on agropastoral production systems. Both the Caro and the Painter papers discuss the implications of their findings for agropastoral development. Carlos Quiroga's paper gives an overview of the ecology of Bolivia with special reference to soils, climate and physical features. The final paper in this group, by Humberto Alzérreca, gives an overview of Bolivian research to date on small ruminants and on Bolivian pastures and ranges.

Together the seven papers assembled in this volume, represent an excellent statement about the state of our knowledge of research on the sustainability of production systems in drought-prone areas, as well as the nature of agropastoral systems in highland Bolivia. We hope that these papers will be of as great a use to their readers as they were to the participants in the Lubbock workshop.

Recent Advances in Arid Land Ecology

Relevance to Agro-Pastoral Research in the Small Ruminant CRSP

James E. Ellis
Colorado State University

TRADITIONAL AND RECENT CONCEPTS IN ARID LAND DYNAMICS

The small ruminant CRSP appears to be one of the few successes of international livestock development in recent years. More generally, livestock development is seen as a failure because of the very low rate of return on investment achieved by livestock projects—less than 2% per annum on average (World Resources Institute 1990-91). The reasons for the failure of livestock development are many. De Haan (1990), in discussing livestock programs in Africa, attributed the lack of success to:

(1) a general misunderstanding by developers of traditional livestock systems and their adaptability and efficiency;
(2) an attempt to apply a western model of ranch management directly to third-world situations;
(3) the introduction of inappropriate technologies;
(4) detrimental pricing policies and incentives in developing countries; and
(5) inadequate institutional and implementational support from the recipient governments.

Obviously, livestock development is a complicated business and requires the understanding of a variety of problem dimensions and some skill at predicting the future. This paper focuses on problem (2) above, the ecological assumptions underpinning the western model of range management and explores how we can utilize new knowledge about grazing system behavior to provide better concepts and models for range management and livestock development.

When de Haan refers to the western model of range management, he presumably has in mind the range condition and trend model (Sampson 1919) derived from the Clementsian theory of succession, a concept developed to explain the dynamics of the mesic prairies of North America (Clements 1916). This range condition and trend (RC&T) model assumes that range-livestock systems op[illegible] nments that are generally stable or equilibrial (Dyksterhuis 1[illegible] management of grazing systems consists

largely of determining carrying capacity and regulating animal stocking rates to maintain the range in good condition. The RC&T model implies that for all practical purposes, the ecosystem is under the control of the range manager.This general assumption, that rangeland ecosystems are potentially stable, may be responsible for the prevalent idea that if vegetation change is observed, it is the result of misuse by herbivores. Thus desertification (Stebbing 1935) is most often attributed to over-exploitation by livestock and people rather than to other causes such as climate change (Lamprey 1983; Stiles 1983; Sinclair and Fryxell 1985). As a result, range- livestock development projects often proceed from the premise that rangelands are overstocked and degraded and reduction of animal numbers is an obvious necessity which need not be further justified (Sandford 1983).

However, range managers have recognized for a long time that the RC&T model doesn't work well everywhere; it is particularly weak when applied to dry rangelands (Hyder et al. 1966, Smith 1989, Wilson 1989). Thus the whole fabric of assumptions— including successional sequences, carrying capacities, and livestock-induced degradation, all of which are part and parcel of the condition and trend model—ought to be reevaluated where arid or semi-arid rangelands are concerned.

In recent years, ecologists have demonstrated that many rangelands exist under climate regimes that are far from stable (Wiens 1977; Caughley et al. 1987; Walker 1989; Ellis et al. 1991); dramatic year-to-year variations in rainfall, as well as long-term shifts in the climate patterns of arid lands, have been analyzed by climatologists (Tyson 1986; Neilson 1986; Nicholson 1986). In response to this information, alternative paradigms and models have been put forward in an attempt to explain the observed dynamics of rangelands and to better incorporate the effects of climate variability on grazing systems. These new models fall into two general categories: those which emphasize that high-magnitude recurring climate variability drives both vegetation and herbivore dynamics (non-equilibrial, centripetal, or chaotic models) and those which emphasize that herbivore grazing pressure and irregular climate events interact to push ecosystems over thresholds to new states (the state and transition model). In both cases, the authors of these models point out that the traditional range condition and trend concept is inadequate when and where such ecosystem instabilities occur. Some critical questions arising from these new formulations are the following:

(1) what sorts of dynamics can we expect from non-equilibrial grazing systems which are under the influence of highly variable climates?
(2) what pushes an ecosystem over a threshold to a new state?
(3) what prevents systems from returning to former states once they pass over a threshold into a new state?

(4) are these new models of ecosystem dynamics compatible in that they simply represent different time frames of analysis?
(5) how should highly dynamic range ecosystems be managed?

THE STATE AND TRANSITION MODEL

The traditional RC&T model designates the regional vegetation climax as the maximum range condition. Departures from this condition occur along a retrogressive succession: range condition decreases as the vegetation community departs further from the climax state. Departures are generally viewed as induced by grazing, although drought may lead to the same results. The state and transition (S&T) model focuses not on successional sequences and the climax condition, but on existing vegetation states and the probability and causes of shifts from one state to another. The S&T model was proposed in 1989 (Westoby et al. 1989) and amplified in 1991 (Laycock in press), but it has a longer intellectual legacy (Noble 1986). Noy-Meir (1975, 1978, 1982) and Walker and Noy-Meir (1982) used the concept of multiple stable states in grazing systems to describe how herbivores might drive system structure from one stable state to another. Although the state and transition model is related to the multiple stable state concept, it emphasizes the importance of irregular events (climatic events, fire, etc.) in causing transitions from one state to another. Laycock (in press) and Friedel (in press) emphasize the role of thresholds which act to prevent the system from returning to its former state once it has undergone a transition. This is an important point; unlike successional systems, S&T systems will not necessarily return to a higher successional state or better range condition if released from grazing. Active management may (or may not) succeed in restoring former states. In this formulation, herbivores modify the ecosystem in ways that make it more vulnerable to change (Foran et al. 1986, Friedel in press); the actual change in state is often triggered by a climatic or other type of "event" (Westoby et al. 1989).

THE NON-EQUILIBRIAL MODEL

The S&T model reviewed above takes account of long-term shifts in climate patterns and/or major climate events such as droughts or heavy rains, which combine with grazing pressure to alter ecosystem state (Stafford-Smith and Morton 1990). The non-equilibrial (N-E) model emphasizes the ongoing role of climate variability in regulating the population dynamics of herbivores as well as influencing vegetation production and state (Wiens 1977; Caughley et al. 1987). Because herbivore populations are

limited by frequent climate perturbations (droughts, blizzards), plant-herbivore interactions in non-equilibrial (N-E) systems are proposed to be loosely coupled with reduced impact of herbivores on vegetation. Herbivore populations may seldom expand to reach the carrying capacity of the ecosystem, due to the density-independent effects of climate perturbations on their populations (Ellis and Swift 1988; Goldstein et al. 1990). Thus in these models, the concepts of thresholds and state changes are less relevant in the short run than questions about how ecosystems maintain their stability in the face of high climate variability (DeAngelis and Waterhouse 1987). Stated another way: what properties maintain the ecosystem in certain states or domains of attraction, despite the high frequency of external perturbations?

CASE STUDIES: TRANSITIONS IN ECOSYSTEM STATE

Numerous examples illustrate the sorts of dynamics proposed in the state and transition model (Westoby et al. 1989, Laycock in press). However, some of the best documented examples of large-scale vegetation transitions to a new and more stable state are from the southwestern U.S.

DESERT GRASSLANDS

The dry rangelands of southern Arizona and New Mexico underwent a shift from a semi-desert grassland to desert shrubland over the last 100-150 years. Much of the northeastern portion of this region, the Chihuahuan desert of southern New Mexico, was formerly dominated by grasses, including black grama (*Bouteloua eripoda*), but large areas of this grassland have been replaced by shrubs, including creosote bush (*Larrea tridentata*) and mesquite (*Prosopis glandulosa*). This shift in vegetation state occurred in conjunction with a dramatic rise in grazing by domestic livestock in the late 1800s and early 1900s; stocking rates peaked around the 1920s. It is clear that heavy grazing contributed to the transition in vegetation state. What is less clear is the role of climate change and the interactions between climate and grazing in instigating and maintaining this transition.

Some authorities suggest that grazing impacts alone are sufficient to account for this desertification of the region, and they seem to infer that climate change had little significant impact on the transition (Schlesinger et al. 1990). In this interpretation, the shift from grassland to shrubs could have resulted from the grazing process alone. Heavy grazing during the growing season could have contributed to the loss of grass cover and to lowered competitive potential of grasses. Trampling reduces soil water infiltration rates, leading to greater runoff and erosion and losses of soil nutrients. Together these effects lead to lower levels of available soil moisture and nutrients and a more hetero-

geneous distribution of both. This is advantageous to shrubs which exploit the non-uniform concentrations of water and nutrients. Once the threshold of shrub dominance was breached, a positive feedback situation may have been set up with shrub microsites capturing more of the available moisture and nutrients while the bare soil interses between shrubs generated overland flow, soil erosion, and nutrient loss (Schlesinger et al. p. 1044, 1990). This scenario might account for the failure of the system to return to its former (grass-dominated) state even after the total removal of grazing. Once the nutrient and water-sequestering shrub communities were established, grasses would fail to reinvade the shrub interses due to the degraded nature of these microsites.

The above explanation for the observed desertification of the region generally discounts the importance of major changes in climate pattern which were coincident with the vegetation transition. "A marked shift in the climate at about 1900 (the end of the 'little ice age') was coincident with a rapid and extreme rise in (livestock) stocking rates. ... From 1900 to 1940 the globe experienced the first major warming trend since the beginning of the 'little ice age' in the 15th century" (Neilson p. 29, 1986). Although his analysis of climate is complicated, Neilson makes a compelling case that long-term shifts in climate pattern have controlled vegetation state in the southwest over the last 20,000 years, and that alterations in rainfall and temperature patterns over the last 130 years are sufficient to explain the shift in dominance from grasses to shrubs in the Chihuahuan desert.

Neilson (1986) argues that prior to 1900, black grama (a C4 grass) was favored by a climate pattern of relatively consistent late summer/autumn precipitation and winter drought. The 1900 to 1940 global warming trend was accompanied by a shift to lowered summer and increased winter rainfall which inhibited the establishment of black grama and enhanced the establishment and growth of mesquite and creosote bush (both C3 shrubs). He proposes that the black grama grasslands of the late 1800s were established under and adapted to 300 years of the little ice age climate and are not well adapted to the present climate. For example, between 1915 and 1968, black grama produced seedlings in only seven years. Although capable of asexual reproduction, reduction of black grama by heavy grazing, combined with poor seedling establishment and expansion of shrubs during favorable winter rainfall periods, could account for the observed shift in vegetation state. Neilson agrees with Schlesinger et al. (1990) that once the nutrient and water-sequestering shrubs are established, they have a strong competitive advantage. In addition, precipitation patterns since 1940 still appear to favor C3 shrubs over C4 grasses.

These two alternative hypotheses are consistent in some ways. They both identify heavy livestock grazing as instrumental in the vegetation transition; both maintain that the period of the transition covered a multi-decade-to-century time frame; and both suggest that a threshold of sorts (the establishment of dominance by the shrubs) militates against the return of the system to its previous state. They disagree as to the role of climate change in causing the transition. Overall, Neilson's hypothesis is more consistent with the state and transition model of Westoby et al. (1989), because it accounts for effects of both herbivores and climate change in mediating the vegetation transition.

SAVANNAS AND WOODLANDS

The Rio Grande plains of southern Texas and northern Mexico have also undergone a transition in vegetation state over the last 200 years. Experimental work on the processes of the transition, plus a review of a rich literature on the subject, have been conducted by Archer (1989, 1990) and his colleagues.

Grasslands and savannas, dominated by C4 grasses, including *Paspalum setaceum*, *Setaria geniculata*, *Bouteloua rigidiseta*, and *Chloris cucullata*, have apparently been invaded by shrubs and small trees (mesquite), leading to the development of dense woodlands. Archer and his co-workers explored the mechanisms of the woody plant invasion in some detail (Archer et al. 1988). However, the important results of their work, for the purposes of this discussion, relate to the probable causes for the shift from grass to tree dominance. Their conclusions focus on the interactive effects of livestock grazing, fire, and climate alteration.

The increase in abundance of woody plants in southern Texas coincides with the development of the livestock industry in the region starting in the early 1800s. Large numbers of livestock probably facilitated the spread of mesquite by enhancing seed dispersal and establishment. Increased grazing presumably also reduced grass biomass and fire frequency and/or intensity, favoring the expansion of woody plants. At the same time, changes in the rainfall regime, including increased winter precipitation, may have favored the C3 woody plants. "Thus, climatic changes such as those of the past 100-200 yr may have been necessary, but by themselves were perhaps not sufficient, to have caused a shift from grassland or savanna to woodland" (Archer p. 555, 1989; 1990). However, rainfall amount, as well as seasonality, appears to affect woodland expansion. The relative growth rate of shrub clusters was low or negative during a 20-year drought period, while cluster growth rates were positive and higher during a 20-plus-year wet period

(Archer 1989). As in the case of the transition from desert grassland to shrubland, livestock grazing appears to have been an important facilitator of the observed transition, but the accompanying climate changes were also important.

These two examples (desert grassland and Texas savanna) of shifts in vegetation, from grassland to shrubland or woodland, have commonalities: (1) both implicate the interactive effects of increased grazing and changes in rainfall patterns, and (2) both imply the existence of a threshold preventing the return of the system to its former state. Neither of these concepts is consistent with the traditional range condition and trend model, but both are consistent with the S&T model and provide support for its validity. However, it is not clear in either of these examples just how grazing and climate alterations interact to produce the vegetation transition. In other explorations of the threshold phenomenon, Foran et al. (1986) and Friedel (in press) have used ordination techniques to show that heavily grazed systems are more dynamic, with more frequent small changes in species composition, than lightly grazed systems. Thus herbivores may make these systems more susceptible to major shifts in vegetation composition as well as inducing small changes themselves. Current evidence could be interpreted as follows: Herbivores cause changes in vegetation composition through grazing activities alone; however, these changes are most likely to alter the balance among the existing components of the plant community. Where major changes in life form or vegetation type occur, additional factors, such as climate change, or alterations in fire regime are likely involved.

The major management implications of the state-transition concept indicate that manipulating stocking rates is an inadequate approach to range management. The manager must also pay attention to climate patterns, be sensitive to occasional "events," and be opportunistic. Managers may occasionally need to exert considerable management effort in order to move the vegetation from an undesirable to a desired state (Westoby et al. 1989).

CASE STUDIES IN NON-EQUILIBRIAL DYNAMICS

The above examples of vegetation transitions demonstrate the inadequacy of the range condition and trend model, both as a conceptual construct and as a management guide, where ecosystems have been subject to major climate shifts and/or radical changes in herbivory. Other conditions also render the RC&T approach inappropriate.

One of the fundamental assumptions of the RC&T model is that managers can estimate carrying capacities for range ecosystems, and by matching stocking rate to carrying capacity, a range can be maintained in good condi-

tion. It is implicit in this assumption that the climate is reasonably stable, so that establishing a carrying capacity is a useful exercise. Following from this assumption, poor range condition or departures from the hypothesized climax condition are, *ipso facto*, indicative of overstocking and overgrazing. In contrast, the concept of non-equilibrial dynamics focuses on the variable nature of climate and its effects on range ecosystems. The examples presented below demonstrate that it is sometimes impossible to manage through manipulation of carrying capacities, when climate variability is great. Instead, vegetation and livestock production are likely to be highly dynamic, requiring a very different approach to management than is useful under relatively stable climatic situations.

KANGAROOS ON THE SHEEP RANGELANDS, EASTERN AUSTRALIA

Arid and drought-stressed ecosystems in eastern Australia, grazed by kangaroos and sheep, have been studied by Caughley et al. (1987). The rainfall in this region averages 200-300 mm per year but is highly variable; the coefficient of interannual rainfall variation is 45%: "In three of ten years the annual rainfall is more than fifty percent above or below the annual average. Floods and droughts are common" (Caughley et al. p. 159, 1987). The effects of this variability on pasture and herbivores is substantial. Pasture biomass fluctuated by two orders of magnitude over a three-and-a-half-year study, which included a severe drought and a recovery period. Plant species composition also varied over this period with alterations among annual grasses, forbs, and perennial sub-shrubs. These changes in dominance appear to be influenced more by rainfall patterns than by the grazing process. Kangaroo populations fluctuated from a low of near 15 to a high of 50-60 per km^2, over an 8-yr period coincident with a drought and recovery. These high densities collapsed during a subsequent drought (1982) to less than half their previous numbers (Caughley et al. 1987).

The 100-year rainfall record indicates that the dynamics of pasture and herbivores observed during this study are likely to be the common pattern in these rangelands. Vegetation biomass varies drastically from year to year; plant species composition changes rapidly depending on both amount and seasonality of rainfall, and herbivore population dynamics reflect these rainfall and vegetation changes. The investigators conclude that the dynamics of the system reflect the variance of rainfall more than the mean. Their model simulation of the long-term dynamics of this ecosystem confirmed strong fluctuations of forage availability and herbivore numbers over time but did not suggest transitions in vegetation state or extinctions of animals. They suggest that where climatic variance is high, the concept of an ecological carrying capacity is "largely an abstraction, not entirely meaningless, but

not very useful ...; it cramps our understanding of that system" (Caughley et al. p. 194, 1987).

THE SOUTH TURKANA ECOSYSTEM

Results of a long-term study of a dry tropical ecosystem in Turkana District, northern Kenya, inhabited by nomadic pastoralists, demonstrated dynamic patterns similar to those observed in eastern Australia. The coefficient of interannual rainfall variability in central Turkana is slightly higher than 50%. Ellis and Swift (1988) noted large variations in both primary production and in livestock numbers (near 50% mortality) in response to droughts and heavy rainfall periods. However, no major changes in livestock herd composition or in vegetation state were observed over a ten-year study period, despite the high climate variability. Nevertheless, model simulations of the long-term (65-yr) dynamics of this ecosystem suggest that a long, severe drought early in this century might have altered herd composition as well as reducing overall vegetation and livestock production (Ellis et al. 1991). Other evidence raises the possibility that moderate magnitude changes in vegetation state (shifts in tree cover) may have coincided with major shifts in rainfall patterns over the last sixty-five years. The results of this study, like those of Caughley et al. and Wiens (1977), show that in highly variable environments ecosystems are likely to operate far from equilibrium much of the time. Thus concepts like the RC&T model, based on assumptions of stable climates and equilibrial ecosystem dynamics, are inappropriate as a basis for either science or management under these climatic conditions.

These new concepts of grazing system dynamics (the S&T and N-E models) seem better suited to the dynamics of many arid and semi-arid rangelands than the classical range condition and trend model. Both the S&T and the N-E concepts are attuned to a highly variable climate which is characteristic of most arid and semi-arid grazing lands. Both concepts reflect that these grazing lands are susceptible to change but are often surprisingly stable unless seriously abused. From a managerial viewpoint, both the S&T and N-E models suggest that opportunism, vegetation monitoring, and active management are appropriate in these dynamic systems, and that carrying capacity and stocking rate are insufficient as concepts for successful grazing system development and management. Sandford (1983) and Ellis and Swift (1988) have argued that the opportunistic strategy practiced by many African pastoralists is the appropriate and rational mode of livestock and range management where climate variability induces non-equilibrial dynamics in grazingland ecosystems.

IMPLICATIONS FOR HIGH-ANDEAN PASTORAL AND AGRO-PASTORAL SYSTEMS

Do these new concepts in range ecology and management have any relevance to the agro-pastoral systems of the Bolivian Altiplano? The answer to this question depends upon the climate patterns of the altiplano, the current state of rangeland vegetation, and how that vegetation state is related to current exploitation patterns and to the grazing history of the region.

If the climate of the altiplano is quite stable with little interannual variation and a low frequency of droughts or other climatic perturbations, then it could be concluded that altiplano ecosystems operate near equilibrium most of the time and thus the RC&T concept is probably appropriate for management. Criteria for judging the variability of climates are only now being developed. Caughley and his associates (1987) suggest that if the interannual rainfall CV is greater than about 30%, then the ecosystem is probably better defined by its variability than by its mean; i.e., it operates as a non-equilibrial ecosystem.

Referring to the well established relationship between precipitation variability and its mean value, Coppock (1990) proposed that tropical regions with less than 400-500 mm annual rainfall might demonstrate non-equilibrial dynamics; alternately, in regions with greater rainfall, concepts of succession, carrying capacity, and herbivore-driven degradation might be appropriate.

The climate patterns of the Bolivian altiplano should be examined to see where they fall on this scale of variability. If it is established that climate variability is low, then livestock development and range management procedures can probably be safely based on the RC&T model. If, on the other hand, climate variability is high, then the RC&T model is not applicable, and opportunistic management, based on tracking the changes in plant biomass through rapid destocking and restocking, should be explored (Sandford 1983; Stafford-Smith and Foran in press).

It would also be useful to determine if the current vegetation (1) represents a major departure from a historical state, (2) is currently undergoing transition, or (3) is in a relatively stable state. It has been suggested that the altiplano has been overgrazed for 2000 yrs (Browman 1974). If this is the case, the vegetation should have reached a stable state which is relatively resistant to further overgrazing; it would be expected to be in a degraded but relatively stable state. If there is evidence of recent, widespread vegetation change (not just around villages or other livestock concentration points), then it should be determined if this is related to changes in grazing pressure, climate, or both. If the regional vegetation appears reasonably stable, then management and development strategies must be based on that vegetation

state. Alteration of the current state to a more desirable one is likely to be practical only if it can be justified in cost-benefit terms and only if the proposed new state can be shown to be stable (sustainable) in the long run.

The major lesson of these recent advances in arid land ecology is the following: we cannot assume that rangeland ecosystems are stable or that change occurs only as a response to alterations in grazing pressure; grazed ecosystems and their management and development are more complicated than this. It is therefore important to attempt to understand the long-term dynamics of these ecosystems before selecting a management or intervention strategy. The alternative is to pursue the same procedures that have led to twenty years of failure in livestock development.

BIBLIOGRAPHY

Archer, S. 1989. "Have Southern Texas Savannas Been Converted to Woodlands in Recent History?" Amer. Natur. 134(4):545-561.

Archer, S. 1990. "Development and stability of grass/woody mosaics in a subtropical savanna parkland, Texas, U.S.A." J. Biogeog. 17:453-462.

Archer, S., C.J. Scifres, C.R. Bassham, and R. Maggio. 1988. *Autogenic succession in a subtropical savanna: Conversion of grassland to thorn woodland.* Ecol. Monogr. 58:111-127.

Browman, D.L. 1974. "Pastoral nomadism in the Andes." Current Anthrop. 15:188-196.

Caughley, G., N. Shepherd, and J. Short. 1987. *Kangaroos—Their ecology and management on the sheep rangelands of Australia.* Cambridge U P, Cambridge. 253 pp.

Clements, F. 1916. *Plant Succession.* Carnegie Inst., Washington, Pub. 242:512.

Coppock, D. L. 1990. "The Southern Ethiopian Rangelands: Review of Vegetation and Pastoral Dynamics and Implications for Theory and Management." Paper presented at meeting on Savanna Development. ODI and Commonwealth Secretariat. London. Nov. 1990.

De Haan, C. 1990. "Changing Trends in the World Bank's Lending Program for Rangeland Development." In *Low Input Sustainable Yield System: Implications for the World's Rangelands.* R. Cincotta, G. Perrier, C. Gay, and J. Tiedeman (eds.). Range Sci. Dept., Utah Sate U, Logan. pp. 43-54.

DeAngelis, D.L., and J. C. Waterhouse. 1987. *Equilibrium and non-equilibrium concepts in ecological models*. Ecol. Monogr. 57(1):1-21.

Dyksterhuis, E. J. 1958. "Ecological principles in range evaluation." Bot. Rev. 14:253-272.

Ellis, J.E., M.B. Coughenour, and D. M. Swift. 1991. "Climate Variability, Ecosystem Stability and Implications for Range and Livestock Development." Proc. International Rangeland Symposium. Soc. Range Manage. Jan. 1991. Washington, DC.

Ellis, J.E., and D.M. Swift. 1988. "Stability of African pastoral ecosystems: Alternate paradigms and implications for development." J. Range Manage. 41(6):450-459.

Foran, B.D., G. Bastin, and K.A. Shaw. 1986. "Range assessment and monitoring in arid lands: The use of classification and ordination in range survey." J. Environ. Manage. 22:57-84.

Friedel, M. H. (in press) "Range condition assessment and the concept of thresholds." J. Range Manage. 1991.

Goldstein, M.C., C.M. Beall, and R.P. Cincotta. 1990. "Traditional Nomadic Pastoralism and Ecological Conservation on Tibet's Northern Plateau." Nat. Geog. Rev. 6(2):139-156.

Hyder, D.N., R.E. Bementt, E.E. Remmenga, and C. Terwilliger, Jr. 1966. "Vegetation soils and vegetation grazing relationships frequency data." J. Range Manage. 19:11-16.

Lamprey, H. 1983. "Pastoralism yesterday and today: The overgrazing problem." In *Ecosystems of the World 13: Tropical Savannas*. F. Bourliere, ed. Elsevier Scientific Publishing Co., Amsterdam, The Netherlands.

Laycock, W.A. (in press.) "Stable states and thresholds of range condition." J. Range Manage.

Neilson, R. P. 1986. "High Resolution Climate Analysis and S.W. Biogeography." Sci. 232:27-34.

Nicholson, S.E. 1986. "The Nature of Rainfall Variability in Africa South of the Equator." J. Climatol. 6:515-530.

Noble, I.R. 1986. "The dynamics of range ecosystems." In *Rangelands: A Resource Under Siege*. P.J. Joss, P.W. Lynch, and O.B. Williams (eds.). Aust. Acad. Sci., Canberra, p. 3-5.

Noy-Meir, I. 1975. "Stability of grazing systems: an application of predator prey graphs." J. Ecol. 63:459-481.

—-. 1978. "Stability in simple grazing models: effects of explicit functions." J. Theor. Biol. 71:347-380.

—-. 1982. "Stability of plant-herbivore models and possible applications to savanna." in *Ecology of Tropical Savannas*. B.J. Huntley and B.H. Walker (eds.). Springer-Verlag, Berlin, p. 571-609.

Sampson, A.W. 1919. *Plant Succession in Relation to Range Management*. Bulletin 791, U.S. Dept. of Agriculture, Washington, DC.

Sandford, S. 1983. *Management of pastoral development in the Third World*. Overseas Development Institute. John Wiley, 316 pp.

Schlesinger, W.H., J.F. Reynolds, G.C Cunningham, L.F. Huenneke, W.M. Jarrell, R.A. Virginia, and W.G. Whitford. 1990. "Biological Feedbacks in Global Desertification." Sci. 247:1043-1048.

Sinclair, A.R.E. and J.M. Fryxell. 1985. "The Sahel of Africa: ecology of a disaster." Can. J. Zool. 63:987-994.

Smith, E.L. 1989. "Range Condition and Secondary Succession: A Critique." In *Secondary Succession and the Evaluation of Rangeland Condition*. W.K. Lauenroth and W.A. Laycock (eds.). Westview Press, Boulder, p. 103-142.

Stafford-Smith, M. and B.J. Foran. (in press.) "An approach to assessing the economic risk of different drought management tactics on a South Australian pastoral sheep station." Ag. Systems. (1991.)

Stafford-Smith, D.M. and S.R. Morton. 1990. "A framework for the ecology of arid Australia." J. Arid Environ. 18:255-278.

Stebbings, E.P. 1935. "The encroaching Sahara." Geo. J. 86:510.

Stiles, D.N. 1983. *Camel pastoralism and desertification in Northern Kenya*. Desert. Control Bulletin 8:2-8.

Tyson, P.D. 1986. *Climate Change and Variability in Southern Africa*. Oxford U P, Capetown. 220 pp.

Walker, B.H. 1989. "Diversity and Stability in Ecosystem Conservation." In *Conservation for the Twenty-first Century*. D. Western and M. Pearl (eds.). Oxford U P.

Walker, B.H., and I. Noy-Meir. 1982. "Aspects of stability and resilience of savanna ecosystems." pp. 556-590. In *Ecology of Tropical Savannas*. B.J. Huntley and B.H. Walker, eds. Ecological Studies 42. Springer-Verlag, NY.

Westoby, M., B. Walker, and I. Noy-Meir. 1989. "Opportunistic management for rangelands not at equilibrium." J. Range Manage. 42(4):266-274.

Wiens, J.A. 1977. "On Competition and Variable Environments." Amer. Sci. 65:590-597.

Wilson, A.D. 1989. "The Development of Systems of Assessing the Condition of Rangelands in Australia." In *Secondary Succession and the Evaluation of Rangeland Condition*. W.K. Lauenroth and W.A. Laycock (eds.). Westview Press, Boulder, p. 77-102.

World Resources Institute. 1990-91. *World Resources*. Oxford U P.

CHAPTER 2

Agroecological Perspectives on Agricultural Research and Development

Thurman L. Grove
Winrock International Institute for Agricultural Development
and
Clive A. Edwards
Ohio State University

BACKGROUND AND CONCEPTS

The principal concerns of traditional agricultural science are cause-effect relationships between components of agricultural systems. Typically these relationships are measured in terms of yield or related to yield. Of lesser concern are the relationships among soils, animals, vegetation, and management practices. The conceptual reduction of agricultural systems to a series of cause-effect relationships leads to simplistic and disciplinary experiments (Altieri 1983). As a result agronomic recommendations are often based upon single cause-and-effect relationships e.g., fertilizer recommendations are typically based upon bioassays in which all nutrients other than that being tested are supplied in excess.

This reductionist approach works well when maximum yield is the principal objective. It falls short, however, in identifying the interactions that are important for the fulfillment of other objectives such as productivity, optimization of yield, stability, resilience, risk reduction, or environmental protection. The development of management strategies for such objectives requires understanding of the interactions among components and the processes by which the agricultural system functions. The concept of an agroecosystem emerged as a framework for studying the complexity of such interrelationships (Altieri 1983). Agroecology is the study of such ecosystems.

In developed and developing countries, there is a general perception that many agricultural practices are leading to degradation of natural resources through soil erosion, water contamination, deforestation, desertification, and loss of productivity (Dover et al. 1987). These trends are most evident in developing countries of the tropics where soils commonly are highly weathered, low in fertility, shallow, or susceptible to erosion (Jacobson 1988). Additionally, agricultural ecosystems in the tropics are subjected to greater numbers and intensity of pests, diseases, and weeds than in the temperate zones (Dover et al. 1987). There is concern that increased yields

from high chemical inputs may not be sustainable over the long term on many tropical soils. Currently, even on many prime lands yields are decreasing, and the rural poor who are typically subsisting on marginal natural resources rarely have adequate or secure access to chemical inputs (Francis et al. 1986; Lal 1990).

The development of the concept of sustainable agriculture is a relatively recent response to concerns about degradation of natural resources. Harwood (1990) suggests that the concept of sustainable agriculture was first articulated by Jackson (1980) and by Rodale (1983), who outlined a concept of regenerative agriculture which renewed natural resources. These early discussions emphasized the importance of maintaining the renewal capabilities of agricultural ecosystems and claimed that many conventional agricultural practices were deleterious to renewal. This concept has promoted much discussion and has evolved into a framework for a more sustainable agriculture that integrates principles of ecology and that emphasizes interactions among and within the biological components of agricultural ecosystems.

GOALS OF SUSTAINABLE AGRICULTURAL SYSTEMS

Sustainable agricultural systems should maintain or increase biological and economic productivity. Biological productivity is required to feed individual farm families and the population of non-farm people. Economic productivity is required to provide income for farmers. They should enhance the efficiency of use of inputs. Increased efficiency leads to greater economic productivity, because it lowers the input requirements; it also lessens adverse environmental impacts both on and off the farm. Sustainable agricultural systems should be both stable and resilient. Stability reduces risk and leads to continuity in income and food supply by fulfilling the short-term needs of farmers without endangering natural resources. Resilience permits adaptation to changes in the biophysical and socioeconomic environments. They should be environmentally compatible to avoid contamination and to minimize adverse environmental impact on adjacent and downstream environments. Finally, they should be socially compatible with local people and political economies.

INTEGRATED FARMING SYSTEMS

The components of a farm must be integrated for it to persist (Grove et al 1991). A dynamic conceptual model for a farm (Figure 1) is a simple mass flow model, which consists of two parallel paths of flow through the farm. One pathway is a socio-economic flow which has inputs of land, labor, capital, culture, and knowledge or information. Land, labor, and capital are the traditional inputs of economic models, and labor and capital-based inputs are often considered interchangeable; e.g., herbicides are substitutes for hand weeding or cultivation (NRC 1989). Tradition, information, and knowledge can also be substituted for labor and capital, e.g. appropriate intercropping can minimize weed problems.

Outputs of the socio-economic pathway are fulfillment of livelihood needs and include income, health, knowledge, social stability, and a sense of community. Income is the most commonly recognized output of a farm. But livelihood goes well beyond income, because farming is also a lifestyle. The formulation and perpetuation of values and the persistence of a community sense are probably equally important outputs.

The importance of internal socio-economic processes on a farm are often overshadowed by the inputs from which they develop and the outputs they produce. The farm provides collateral for loans to cover capital expenditures and operating costs. Land appreciation is a hedge against inflation, money in the bank, and a retirement account. Farming provides a lifestyle that binds a household together and is a heritage that can be passed among generations through inheritance of the farm. Indigenous knowledge is typically a product of generations of adaptation of farming practices to local environments. Family, tradition, and formulation of values are all processes that are facilitated on the farm.

The biophysical flows run in parallel with the socio-economic flows. Physico-chemical inputs include energy for operations such as tillage, harvest, and storage, and agrochemicals for fertilization and pest control. Biological inputs include organic matter such as crop residues, animal manure, legume nitrogen, cover crops, rotations, and cropping patterns. Physico-chemical and biological inputs are familiar components of conventional agriculture, but their values have not usually been optimized or integrated. Less obvious but of great importance is knowledge, or information. Use of genetically improved varieties of crops and animals, management of farming practices, and biological pest control are examples of information. These inputs often provide substitutes that are both cost-effective and environmentally benign for inputs of labor, energy, or chemicals. For example, seeds for a pest-resistant line of crop costs a farmer little more than for those without resistance but eliminate the need for pesticides and the labor to apply them and stabilize production.

The internal processes occurring within the farm are important in maintaining the natural resource base and its ability to support continued production. Nutrients are recycled and made available for plant growth through the soil decomposer community (Wild 1973). The combined activities of the soil fauna and flora stabilize soil structure and increase the permeability, long-term fertility, and resilience of the soil (Coleman 1984). Nitrogen-fixing bacteria increase the soil stock of nitrogen (Miller 1990). Soil organisms assist in control of pests through various mechanisms including competition, antagonism, predation, and allelopathy (Baker 1974). Soil microbes can metabolize toxic organic compounds (Edwards 1966). The maintenance of a healthy soil ecosystem provides for evolution and adaptation of the soil biota and community to changing conditions. Sustainable systems add greater biological diversity to nutrient cycles, thereby increasing their longevity and interactions between the decomposer and consumer communities.

The socio-economic and biophysical flows run in parallel and are interdependent. The ability of a farmer to produce food and income is tied directly to internal biological processes. Adoption of the best farm management practices and indigenous knowledge depend upon natural resources and are the results of interactions between farmers and their biophysical and socio-economic environments. Socio-economic and biophysical inputs can often substitute for one another. For example, weeds can be controlled by herbicides or by cover crops, rotations, hand-weeding or cultivations (NRC 1989). It is the understanding of the model of parallel flows and the interdependence among the flows that defines an integrated farm or farming system. For a farm to be sustainable, the flows must be coupled (Harwood 1991). When either flow or the interaction between them is sufficiently disrupted, the system becomes unsustainable. Consequently, intervention by science and technology in an integrated farm requires consideration of the whole system and the socio-economic and biophysical flows within and through the system.

Such an integrated farm model defines an agroecosystem. Both agricultural sciences and ecology have contributed to our knowledge of agroecosystems. The traditional agricultural sciences have developed a large body of information on the components of agroecosystems. Many of the current ecological theories were developed in agroecosystems. For example, much of the literature on insect ecology (e.g., Andrewartha 1954) resulted from work done in agricultural systems with a goal of pest control. Agroecology is a relatively new discipline that integrates the techniques and paradigms of ecology with agricultural sciences for the study of agroecosystems.

The farm is only one level of agroecosystem. The farm sits within a hierarchy of levels that includes fields, farms, households, watersheds, regions, etc. (Conway 1985; Lowrance, Hendrix, and Odum 1986). In the interest of simplicity, we have restricted our discussion to the farm level, but many of the concepts apply equally to other subsystems and levels of the hierarchy.

ECOLOGICAL PRINCIPLES

Ecologists usually consider three levels of organization: populations, communities, and ecosystems. Populations are groups of organisms belonging to the same species, occupying a contiguous area and defined in terms of reproduction, birth rates, mortality rates, and immigration and emigration rates (Smith 1990). Species live in complex associations or communities controlled by interactions among their members. A community is linked closely to its environment. Both climate and soil affect a community, and a community in turn affects the soil and its own internal climate or microclimate (Whittaker 1975). Energy and matter are taken from the environment to run dynamic processes, transferred from one organism to another in the community and released back into the environment. A community and its environment, when they are treated as a functional system of complementary relationships and transfer and circulation of energy and matter, are called an ecosystem (Whittaker 1975).

Undisturbed ecosystems mature with time. Biomass, species diversity, and spatial heterogeneity (canopy layers) typically increase (Dover 1987). Trophic interactions are generally more complex in mature systems, and there is a higher degree of organization (Odum and Margalef 1969).

Ecosystems function through the capture of solar energy and production of biomass by plants (primary production) and consumption of plant material by other organisms (secondary production) to produce secondary biomass. The ratio of productivity to biomass decreases with increasing maturity and the captured energy is more fully used within ecosystems as they mature (Dover 1987). In mature ecosystems, energy is used more for maintenance than for production of additional biomass (Dover 1987). Immature ecosystems have high production to biomass ratios, and living material accumulates (Dover 1987). Most agroecosystems are maintained at early successional stages to exploit this production.

A mature ecosystem is relatively closed; i.e., essential minerals and other nutrients stay within it (Odum 1971; Miller 1990). Ecosystems become more efficient at trapping and holding nutrients as they mature. In contrast, an agroecosystem does not hold nutrients tightly, and they leak readily from the system (Dover 1987).

Mature natural ecosystems have a diverse flora and fauna, whereas immature ones are less diverse. Agroecosystems, particularly those that do not involve crop rotations, tend to have a much less diverse flora, and the populations and interactions of the invertebrates and soil microorganisms also tend to be much less complex. These tendencies have strong implications for pest, disease, and weed control and for the decomposition of organic matter in soil. The maintenance of stable communities depends upon the diversity of competitors and predators that prevent explosions of populations of pest species. When diversity of plants and animals is decreased, pest populations have greater opportunity for rapid growth (NRC 1989). Decomposition of organic matter depends upon a diverse community of plants, animals, and microbes (Tivy 1990), and when any component of the community is eliminated, there are effects upon rates of decomposition.

Some ecosystem functions are common to all ecosystems whether natural or agricultural. These are biodiversity of plants and animals and biological recycling of nutrients from plant and animal organic matter, which is mediated by complex interactions among soil organisms (Grove, Edwards, Harwood, and Colfer 1991). In a natural ecosystem, the nutrient supply is ensured by the strength and diversity of the biological recycling of nutrients from the soil surface where organic matter is deposited. Leakage from the ecosystem is rare. The diversity of plants and animals results in stability and spatial heterogeneity (Weil 1990), which protects the agroecosystem from adverse environmental shocks and stresses.

In a traditional agroecosystem that involves rotations and other polycultures, there is still a reasonable degree of biological recycling of nutrients, although these are often supplemented by inorganic inputs (Tivy 1990). The supplements reduce the resilience as dependence upon external inputs exposes the system to risks of their unavailability. Leakage of nutrients from such systems are limited. The biodiversity is less, the system is thus more susceptible to shocks and stresses than a natural ecosystem, but there is still sufficient diversity for reasonable protection from shocks and stresses (Conway 1985).

A conventional monocultural agroecosystem is much more dependent upon inorganic supplements (Francis et al. 1986). The nutrient pool needs continual replenishment. Leakage from such systems is often great. The biodiversity is less and provides less protection from shocks and stresses.

The differences among the three ecosystems is greater on the poorer or more fragile soils that have fewer biological resources and reserves. The monocultural agroecosystem often has a greater carrying capacity than its traditional counterparts, but the sustainability of the monoculture is much less stable because it rests on a more fragile foundation.

COMMONALITIES AND DIFFERENCES AMONG AGROECOSYSTEMS

TRADITIONAL AGROECOSYSTEMS

There are many inputs into farming systems, all of which can be related to cropping or stocking patterns, soils, cultivations, supply of nutrients, or pest control. When planning research on integrated sustainable agricultural systems, it is important to differentiate between those processes that are common to all agroecosystems and the inputs, factors, and processes of a more regional and specific nature. Commonalities are appropriate for basic research with broad application. Regional and specific differences are appropriate for applied research and development. We suggest that biological diversity and nutrient cycling mechanisms are the key factors or common processes in the function and persistence of traditional agroecosystems (Figure 2) which are based on relatively low inorganic supplements and depend upon rotations and cultural practices. Biodiversity of plants, animals, and microbes supports production of crops and stock in such traditional agroecosystems. The specific biological components that contribute to biodiversity and the capacities, rates, and patterns of nutrient cycling vary among agroecosystems, but biodiversity and nutrient cycling are common to all. By contrast, soil types, climate, and farming practices are regional in nature and differ considerably among agroecosystems. Production, rates of recycling, and constituents of the biological community vary regionally with climate and edaphic characteristics. Different political economies and cultural histories result in different farming practices. In traditional systems the biological community and the farming practices are generally well adapted to local conditions (Logsdon 1984). It is this adaptation to local environments that is termed site specificity.

The specific functions of the commonalities of biological diversity and nutrient cycling are further subdivided in Figure 3. Biodiversity, which may be spatial (e.g., the soil biota and cropping patterns), or temporal (e.g., rotations, control of pests, weeds, and diseases through mechanisms such as competition, predation, shading, allelopathy, antagonism, and antibiotics). Biological diversity of soil organisms supports nutrient cycling, because decomposition of organic matter is a biotic process. Plants and animals are

the sources of organic matter (Brady 1990); invertebrate animals, such as earthworms, physically disrupt and mix the organic matter (Brady 1990), and microbes mineralize nutrients (Brady 1990). Biodiversity is relatively easily manipulated by farming practice. The regional soil physical characteristics and climate are much more difficult to manipulate other than by cultivations or additions of organic matter or both. Similarly, the only component of climate that can be manipulated is water availability through irrigation. Productive potential and specific farming practices vary regionally and are related to the cultural and economic characteristics of farmers (Logsdon 1984).

CONVENTIONAL MONOCULTURAL AGROECOSYSTEMS

In high-input or conventional agriculture (Figure 4), pesticides typically replace many of the functions of biodiversity as controls of pests, weeds, and diseases. Inorganic fertilizers substitute for biological nutrient cycles that are based on biological decomposition and mineralization of organic matter. These practices may destabilize agroecosystems and create increasing dependence upon chemical inputs (Edwards 1990). Pesticides often kill beneficial organisms that control pests biologically through antagonism, competition, or predation (Thibodeaux 1985). Fertilizers suppress microbial populations and the enzymes that they produce, which are key factors in nutrient cycling (Fukuaka 1985); thus the biologically-based commonalities are replaced by chemicals. The biological productivity of the agroecosystem thus becomes dependent upon chemical inputs, and alternatives for manipulating the system to provide sustainability are reduced.

SUSTAINABLE AGROECOSYSTEMS

An alternative to this chemical dependence (Figure 5), which is becoming popular in developed countries is to maximize the contributions of biodiversity to pest control and nutrient cycling and to supplement this technique with agrochemicals only as necessary to attain optimal productivity with minimal inputs (NRC 1989). Such practices of pest control are termed integrated pest management. Edwards and Grove (1991) have proposed an analogous term for management of nutrients: integrated nutrient management. This approach capitalizes on the adaptive features of traditional systems and incorporates additional advantages of conventional and innovative technology. It is important to recognize a strong link (Figure 5) between the availability of organic matter and both biodiversity and nutrient cycling (Palm et al. 1987). The practice in many developing countries of removing organic matter from the land for fuel and other purposes is a serious constraint to long-term sustainability (Oram 1988). The most sustain-

able farming practices and components of the managed biodiversity can be developed only by understanding the functioning of the agroecosystem and how social and economic conditions of farmers and their climatic and edaphic environments impact upon overall crop and animal productivity (Figure 6). No matter how well the agroecosystem functions biologically, it will only be sustainable if it is socially and economically sound (Altieri et al. 1987).

PRACTICAL TOOLS FOR DEVELOPING SUSTAINABLE AGRICULTURAL SYSTEMS

MANIPULATION OF INPUTS

The concept of two global commonalities—biological diversity and nutrient cycling—among agroecosystems is supported by the ecological literature, anecdotal accounts of indigenous practices, and the rapidly emerging literature of agroecology. The basic research challenges are to understand these main commonalities, to focus research responses upon them, and to capitalize upon our knowledge of these principles in designing productive, stable, and equitable sustainable agricultural systems for general application to all regions.

Questions concerning biodiversity are both quantitative and qualitative. We have little understanding of how much and what kinds of biodiversity are required; we have only a limited understanding of the mechanisms by which biodiversity stabilizes ecosystems. While we understand many of the principles of nutrient cycling, there are many gaps in our knowledge. Fundamental questions—such as which fractions of organic matter are labile and active in recycling and which factors control the rates of mineralization of plant organic matter (Edwards 1987)—are as yet unanswered and need resolution by research to provide the basis for better management of nutrient recycling.

Organic matter is the foundation of all nutrient cycles. The labile and available nutrients within an ecosystem are largely contained in organic matter (Tivy 1990). They depend upon a community of producer and decomposer organisms. The producers are typically well-managed, since they are the crops and animals that are produced by the farm and have economic value. The decomposer organisms in soils are less obvious, and their importance is often ignored (Coleman et al. 1984). The fundamental issues concerning efficient use of organic matter are leakage of nutrients from agroecosystems and the rates of decomposition. Organic matter and the nutrients it contains are lost from soils by runoff and mineralization (Tivy 1990), both of which can be controlled by appropriate tillage practices. Loss

of nutrients to mineralization is also controlled by assuring sufficient inputs of plant or animal material to maintain the soil organic matter reserves (Woodmansee 1984).

Legumes are important in maintaining soil organic matter and increasing the soil nitrogen supply. They are components of virtually all native terrestrial ecosystems and are typical of traditional agroecosystems (Powers 1987). Legumes can be used as food or forage crops and managed as intercrops or fallows. In addition, they protect the soil from runoff, wind, and water erosion and frequently improve infiltration.

Agroforestry systems use leguminous and other trees to provide alternative crops (Steppler et al., 1988), produce animal forage and fuel (Spears 1988), recycle nutrients for crop use (Altieri 1987), and protect soil from wind and water erosion (Altieri 1987). Traditional agricultural systems often contain trees (Farrell 1987). Some of the higher-value products of small farmers in developing countries are tree crops, e.g., coconut, papaya, coffee, tea, and cloves (Altieri 1987). Many staples are also tree crops, e.g., bananas. Leguminous trees provide nitrogen and recycle other nutrients when grown as alley crops with field crops between (Wilson et al. 1986). There is a need to design appropriate mixes and patterns of trees and to integrate animals into agroforestry systems to optimize productivity and sustainability (Baker et al. 1989).

Plant biodiversity plays an important role in pest, disease, and weed management. Rotations and various forms of polyculture are effective in controlling pests, diseases, and weeds (Altieri 1987). The control of weeds by rotation of crops in traditional agroecosystems is well known in principle, but practical recommendations are poorly documented. Living mulches control weeds and minimize the need for herbicides (Regnier 1990). Invertebrate animal pests such as insects are also controlled by rotations (Altieri 1987); in the U.S.A., for instance, the life cycle of the corn borer is sufficiently disrupted by rotations to eliminate the need for insecticides (Pimentel 1990).

Polycultures and other management patterns that increase biological diversity control pests (Altieri 1987). Increases in structural diversity within the crop canopy leads to greater diversity in insects and less damage from insect pests (Stinner and Blair 1990).

Integration of animals into agroecosystems offers further diversity and stability. Rarely is the role of animals considered in the development of integrated farming systems (McIntire and Gryzeels 1987; Harwood 1987). Yet the opportunities for and benefits of integrating crop and animal agriculture seem great. The need for integrated farming systems is especially great in the humid tropics. These ecosystems are fragile and of limited productive poten-

tial. Productivity and environmental stability are enhanced in closed agroecosystems that operate at high efficiency. Integration is fundamental to design and implementation of such closed agroecosystems.

McIntire and Gryseels (1987) summarized potential benefits of integration of crops and animals. Animals can provide direct physical contributions to crop production via draft power and manure. Infrastructure within the humid tropics typically limits availability of off-farm inputs. Animals provide on-farm alternatives for providing draft power and soil nutrients from manure. The availability of manure is especially important on these nutrient-deficient soils.

Animals can serve as a "bank account" for small farmers. Lack of infrastructure limits the availability of markets for sales of perishable plant products. Animals are potentially better sources of cash, since they are less seasonal and can be transported to market alive.

Cropping systems can be developed to make more effective direct contributions to animal production. Crop residues, forage, and browse can be incorporated into integrated farming systems and increase overall productivity. The most common domestic animals in the humid forests are chickens, pigs, and goats, which can utilize a broad range of plants as food. Developmental efforts should probably focus on these species.

Harwood (1987) identified further advantages of incorporating animals into integrated farming systems. Animals facilitate nutrient movement and increase the opportunities for nutrient management across the whole farm system. The integration of crops and animals influences nutrient flows in several ways. Farmers are encouraged to grow high-protein crops such as grain legumes, leguminous cover crops, or leguminous trees. The overall nitrogen balance is thus improved. Animals concentrate nutrients, which makes nutrient mobilization and movement on the farm more effective. Manures can be applied where and when they are needed. There is a net movement of nutrients to the farm when animals feed off the farm during the day and are housed on the farm at night. Cut-and-carry feeding systems also move nutrients to the farm.

Animals increase overall net productivity and reduce environmental degradation by serving as alternatives to crops on the marginal areas of farms and by utilizing crop residues as feed. The need for animal feed often broadens the crop base to include crops that prevent soil erosion.

In summary, the integration of crops and animals within farming systems offers a management tool for improving net production, stabilizing the farming system, and protecting the environment. Net production results from improved nutrient management and utilization of additional biological resources. Moreover, the farming system is stabilized by an increased diversi-

ty of management options. Environmental protection is enhanced by the increased productivity that reduces needs for clearing more land and by the greater stability and diversity of management options that offer long-term protection of the natural resource base.

Development of Integrated Systems

The challenge is to design practical integrated systems of crops and animals that can be adapted to regions, minimize energy-based inputs, and have long-term sustainability. The tools described above are examples of alternatives which can be integrated into systems to meet the challenges. With suitable integration of such tools, the low productivity of traditional systems can be greatly improved.

Design and implementation of integrated farming systems require collaboration among agricultural, social, economic, and ecological disciplines. They also depend upon the full participation of farmers. Examples of successful interdisciplinary agricultural research and development are rare, in part because current institutional structures mitigate against interdisciplinarity. However, it is probably impossible to develop integrated systems without interdisciplinary planning and implementation. A major challenge to agricultural research and development is the need for modifying institutional structures and research and development methodologies to allow such collaboration.

Implementation of Sustainable Agricultural Systems Research

A major objective of sustainable agricultural systems research is the integration of available information to solve complex problems of agricultural development. The lack of systems research has been identified (NRC 1989) as a major constraint to adoption of alternative farming practices and as a necessity for development of an alternative and more sustainable agriculture. While the value of systems approaches has been increasingly recognized over the past decade, few crop and livestock production systems have been studied in detail. Because of the extreme variability among agroecosystems, it is important to identify the major components of any agroecosystem and the regional factors that are constraints.

We propose a simple conceptual framework for the conduct of integrated agricultural systems research, to include the following steps:

(1) description of the target agroecosystem, including its goals, boundaries, components, functioning, interactions among components, and interactions across its boundaries;

(2) detailed analysis of the agroecosystem to determine factors which limit or could contribute to attainment of productive and sociological goals;
(3) design of interventions and identification of actions to overcome the constraints;
(4) on-farm experimental evaluation of interventions;
(5) effectiveness review of newly designed system; and
(6) redesign as necessary.

We believe that all steps should be conducted on farms by an interdisciplinary team of agricultural, social, and ecological scientists and with the full participation of farmers.

The description of the agroecosystem must be based upon discussions with farmers and upon recommendations of the disciplinary specialists. Techniques for describing agroecosystems have been reported in the literature (e.g., Altieri 1987; Harwood 1987; Conway 1985). Understanding the farmer's goals is especially important, since the role of the proposed interventions is to help the farmer attain these goals. Description of the boundaries and limitations of the agroecosystem is essential in providing focus for study but should not limit understanding of its interactions with adjacent ecosystems or with local, regional, national, and international political economies. Description of the components of the system is the traditional occupation of many agricultural scientists, but a description and analysis of interactions among components requires farmer participation as well as interdisciplinarity.

Although the descriptive phase is largely qualitative, the analytical stage takes maximal advantage of quantitative information. The proposed descriptions may lead to development of hypotheses that require experimental study for resolution and quantification. For example, if nitrogen is suspected to be a limiting factor, then nutrient response studies may be required. If losses to pests are hypothesized as a key factor, they can be quantified experimentally, and integrated management measures can be recommended for the pests identified. The result of the analytical phase is to approach a more detailed understanding of the limitations to the attainment of the farmer's goals.

The design phase involves forming hypotheses about appropriate interventions that will contribute to farmers' goals. It is a deductive process based upon the description and analysis of the system, and the final design represents the best collective judgments of the study team and the participating farmers.

The evaluation phase tests the proposed interventions empirically. Effects must be measured in terms of the goals of the system, and tradeoffs among goals must be determined for any proposed intervention. Interdisciplinary involvement and participation are essential in a successful evaluation phase.

We hypothesize that if a similar descriptive and analytical process is employed for the study of different agroecosystems in a number of agroecological zones, the commonalities among them will emerge. Furthermore, if the commonalities identified are verified by further experimentation in farmer's fields, they become, in essence, global principles. We contend that there is currently sufficient evidence to suggest that maintenance of biological diversity and nutrient cycling mechanisms are likely to be global principles and worthy of hypothesis status in the design of sustainable agricultural systems. The regional influences may differ greatly among agroecosystems and may assume major importance in some. However, action on the commonalities will be of value in most agroecosystems. Interdisciplinarity is fundamental to such action.

BIBLIOGRAPHY

Altieri, M. 1987. *Agroecology*. Westview Press, Boulder, Colorado.

Altieri, M., and L. Merrick. 1988. "Agroecology and *In-Situ* conservation of native crop diversity in the Third World." In E. O. Wilson (ed.). *Biodiversity*. National Academy Press, Washington, D. C. Pp. 361-368.

Andrewartha, H. 1954. *The Distribution and Abundance of Animals*. U of Chicago P, Chicago.

Baker, K. F., and R. J. Cook. 1974. *Biological Control of Plant Pathogens*. W. H. Freeman.

Brady, N. 1990. *The Nature and Property of Soils*. MacMillan, New York.

Coleman, D. C., C. V. Cole, and E. T. Elliott. 1984. "Decomposition, organic matter turnover, and nutrient dynamics in agroecosystems." In R. Lowrence, B. Stinner, and G. House (eds.). *Agricultural Ecosystems: Unifying Concepts*. John Wiley and Sons, New York. Pp. 83-104.

Conway, G.R., 1985. "Agroecosystem analysis." Agricultural Administration. 20: 31-55.

Dover, M., and L. Talbot. 1987. *To Feed the Earth—Agro-Ecology for Sustainability in a Changing World Order*. World Resources Institute. June.

Edwards, C. 1966. "Pesticide residues in soils." Residue Reviews. 13: 83-132.

—. 1987. "The concept of integrated systems in lower input/sustainable agriculture." American Journal of Alternative Agriculture. 2(4): 148-152.

—-. 1990. "The importance of integration in sustainable agriculture systems." In Edwards et al. (Eds.). *Sustainable Agriculture Systems*. Soil and Water Conservation Society, Ankeny, Iowa. Pp. 249-264.

Edwards, C. A., and T. L. Grove. Submitted for publication. "Integrated nutrient management for crop production." Agric., Ecosys. and Environ.

Francis, C., R. Harwood, and J. Par. 1986. "Potential for regenerative agriculture in developing world." American Journal of Alternative Agriculture. 1(2): 65-73. Spring.

Fukuaka, M. 1985. *The Natural Way of Farming*. Japan Publications, Tokyo, Japan.

Grove, T. L., C. A. Edwards, R. R. Harwood, and C. Colfer. Submitted for publication. "The role of agroecology and integrated farming systems in agricultural sustainability." Agric., Ecosys. and Environ.

Hart, R. D. 1987. "Ecological framework for multiple cropping research." In C. A. Francis (Ed.). *Multiple Cropping Systems*. MacMillan, New York.

Harwood, R. R. In press. "The farming systems uncoupling /integration cycle as a determinant of research approach." Journal of Farming Systems Research-Extension 2.

—-. 1987. "Agroforestry and mixed farming systems." In A. E. Lugo, J. R. Clark, and R. D. Child (eds.). *Ecological Development in the Humid Tropics: Guidelines for Planners*. Morrilton, Arkansas: Winrock International.

Jackson, W. 1980. *New Roots for Agriculture*. Friends of the Earth, San Francisco.

Jacobson, J. L. 1988. *Environmental Refuges Yardstick of Habitability*. Worldwatch Paper #86. Worldwatch Institute, Washington, D.C.

Lal, R. 1990. *Soil research for agricultural sustainability in the tropics*. Department of Agronomy, Ohio State University.

Logsdon, G., 1984. "The importance of traditional farming practices for a sustainable modern agriculture." In W. Jackson et al. (Eds.). *Meeting the Expectations of the Land*. San Francisco, North Point Press. Pp. 3-18.

Lowrance, R., P. F. Hendrix, and E. P. Odum. 1986. "A hierarchical approach to sustainable agriculture." American Journal of Alternative Agriculture 1: 169-173.

McIntire, J., and G. Gryseels. 1987. "Crop-livestock interactions in Sub-Saharan Africa and their implications for farming systems research." Experimental Agriculture 23: 235-243.

Miller, R. H., 1990. "Soil microbiological inputs." In Edwards et al. (Eds.). *Sustainable Agricultural Systems*. Soil and Water Conservation Society, Ankeny, Iowa. Pp. 614-623.

National Research Council. 1989. *Alternative Agriculture*. National Academy Press, Washington, D.C.

Odum, E. 1971. *Fundamentals of Ecology*. W. B. Sounders Company, Philadelphia.

Odum, E., and Margalef. 1969. "The strategy of ecosystem development." Science. 164: 262-70.

Oram, P., 1988. "Building the agro-ecological framework." Environment. Pp. 14-34. November.

Palm, O., A. de Silva, and M. Guildford, M., 1987. "Nutrient cycling in paddy rice of a traditional farming system." Tropical Agriculture. 87: 129-133. April.

Pimentel, D. In press. "Environmental and economic benefits of sustainable agriculture." In Paoletti, M. G., et al. (eds.) *Proceeding of the International Conference on Agroecology and Conservation Issues in Temperate and Tropical Regions*. Elsevier, Amsterdam.

Powers, J. 1987. "Legumes: their potential role in agricultural production." American Journal of Alternative Agriculture, 2(2). Spring.

Regnier, E., and R. Jahnke. 1990. "Evolving strategies for managing weeds." In C. A. Edwards et al. (eds.). *Sustainable Agricultural Systems*. Pp. 174-202. Soil and Water Conservation Society. Ankeny, Iowa.

Rodale, R. 1983. "Breaking new ground: the search for sustainable agriculture." The Futurist. 17(1): 15-20.

Russel, E. W. 1973. *Soil Conditions and Plant Growth*. Longman, London.

Smith, R. L. 1990. *Ecology and Field Biology*. Harper & Row, New York.

Spears, J. 1988. "Preserving biological diversity in the tropical rain forests of the Asian region." In E. O. Wilson (Ed.). *Biodiversity*. National Academy Press, Washington, D.C. Pp. 393-402.

Steppler, H., and B. Lundgren. 1988. "Agro-forestry: now and in the future." Outlook on Agriculture. 17(4): 146-151.

Stinner, B., and J. Blair. 1990. "Ecological and agronomic characteristics of innovative cropping systems." In Edwards et al. (Eds.). *Sustainable Agriculture Systems*. Soil and Water Conservation Society, Ankeny, Iowa. Pp. 123-140.

Thibodeaux, F., and H. F. Field. (Eds.). 1985. *Sustaining Tomorrow*. Hanover, U P of New England.

Tivy, J., 1990. *Agricultural Ecology*. Longman Scientific and Technical, Essex, United Kingdom.

Weil, R. 1990. "Defining and using the concept of sustainable agriculture." J. Agron. Educ. 19(2): 126-130.

Whittaker, R. H. 1975. *Communities and Ecosystems*. 2nd Ed. MacMillan, New York.

Wilson, G. F., B. T. Keng, and K. Mulongoy. 1986. "Alley cropping: Trees as sources of green manure and mulch in the tropics." In J. M. Lopez-Real et al. (eds.). *The Role of Microorganisms in a Sustainable Agriculture*. AB Academic Publishers, Great Britain.

FIGURES

Source: Grove et al. 1991.

1. Conceptual model of a farm
2. Key factors and relationships in the management of a traditional agroecosystem
3. Key processes and functional relationships in a traditional agroecosystem
4. Key factors and relationships in the management of a conventional monocultural agroecosystem
5. Key processes and functional relationships in a sustainable agricultural agroecosystem
6. Social and economic processes and functional relationships in a sustainable agroecosystem

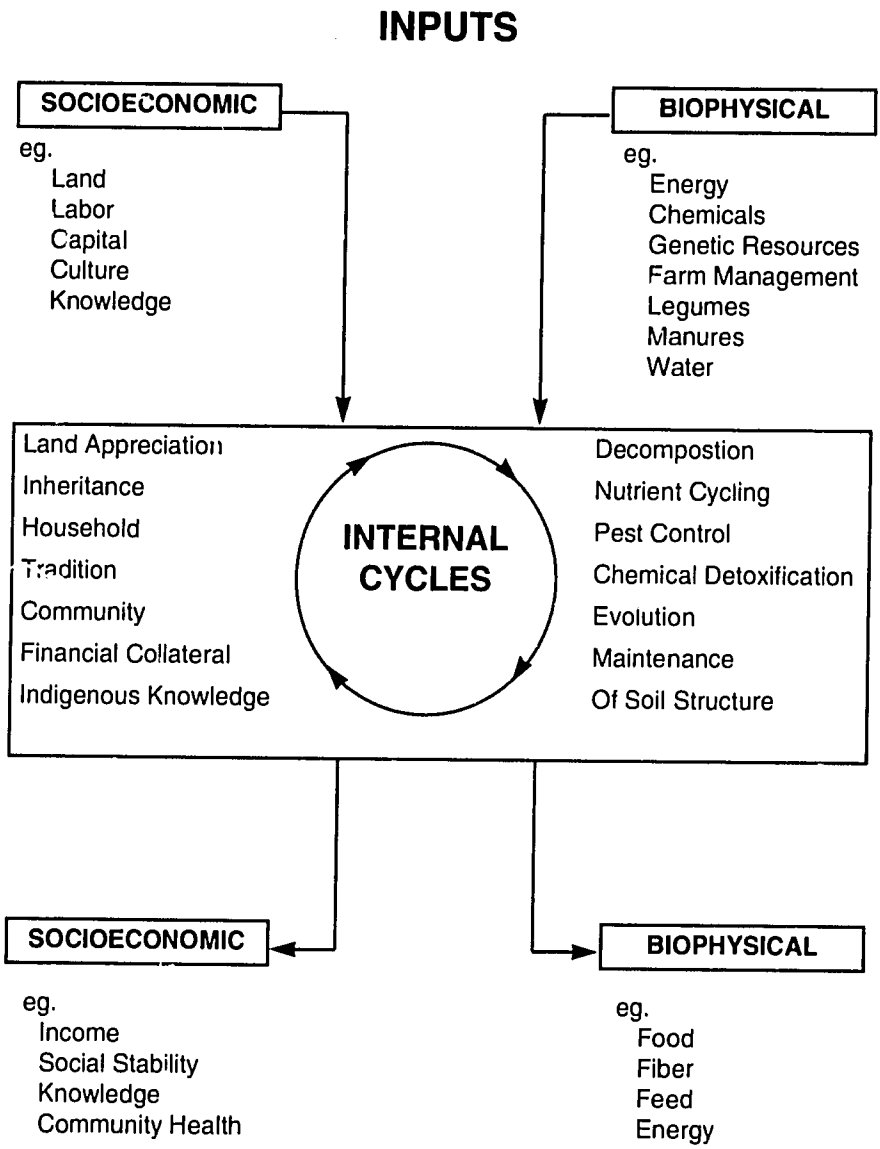

INPUTS
SOCIOECONOMIC
eg.
Land
Labor
Capital
Culture
Knowledge
BIOPHYSICAL
eg.
Energy
Chemicals
Genetic Resources
Farm Management
Legumes
Manures
Water
Land Appreciation
Inheritance
Household
Tradition
Community
Financial Collateral
Indigenous Knowledge
INTERNAL CYCLES
Decompostion
Nutrient Cycling
Pest Control
Chemical Detoxification
Evolution
Maintenance
Of Soil Structure
SOCIOECONOMIC
eg.
Income
Social Stability
Knowledge
Community Health
BIOPHYSICAL
eg.
Food
Fiber
Feed
Energy
Outputs

FIGURE 1

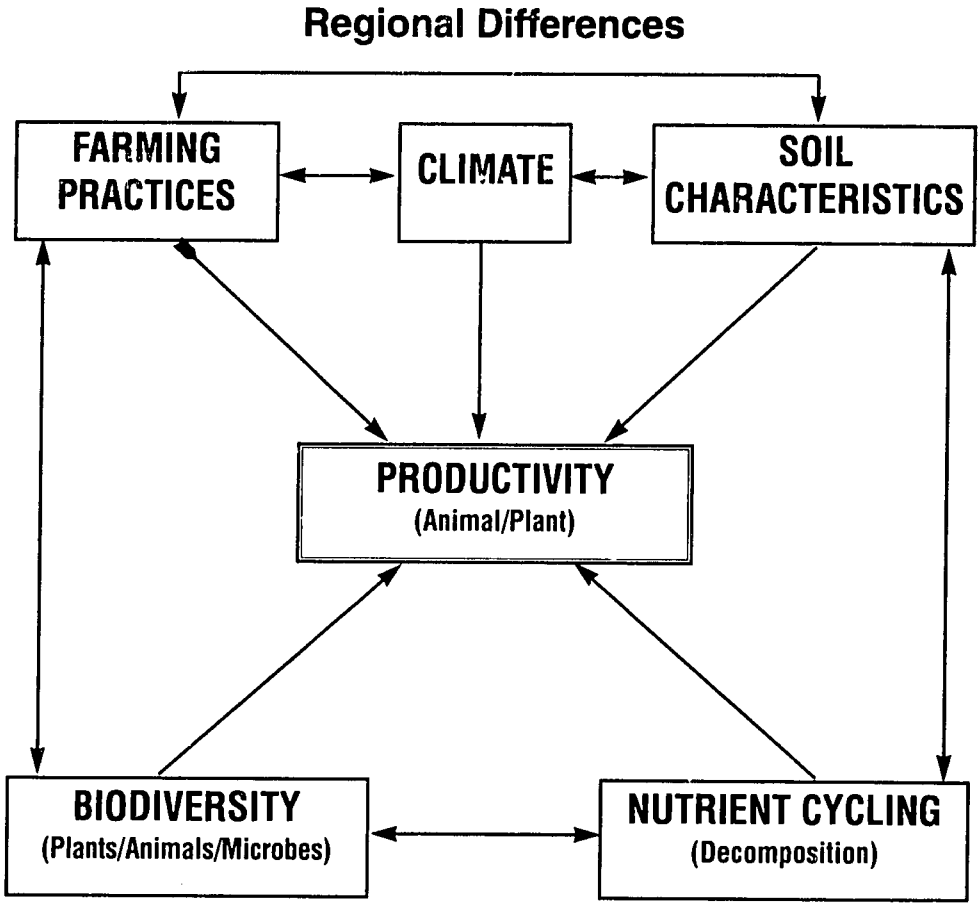
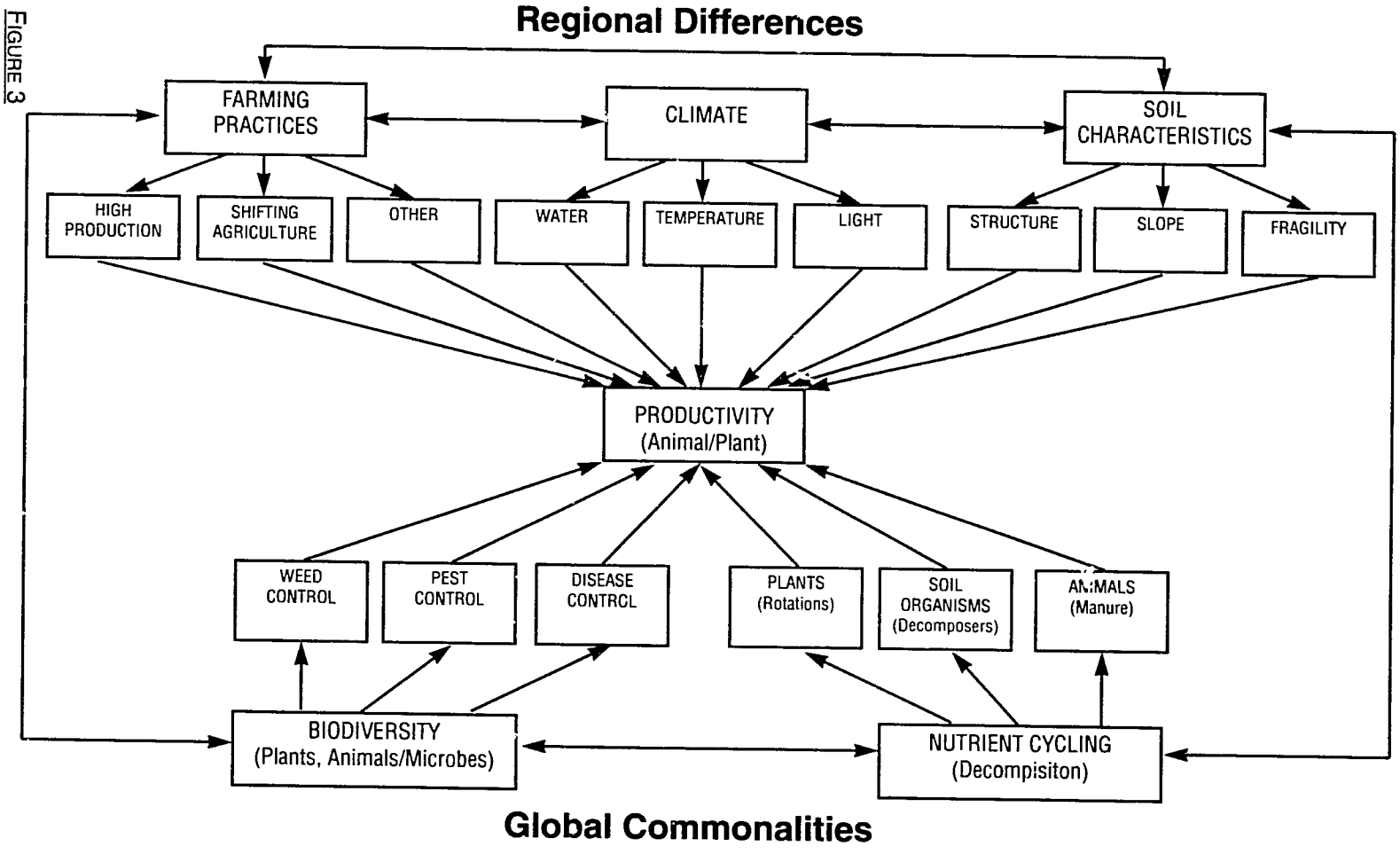
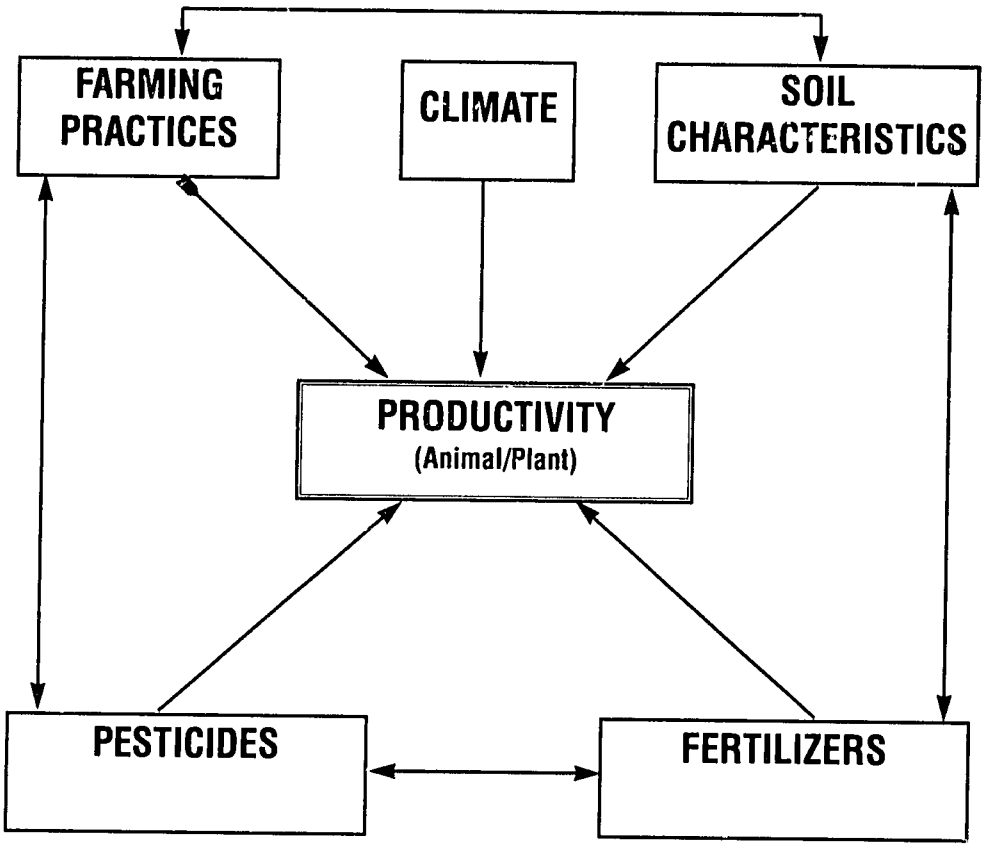

Regional Differences
FARMING PRACTICES
CLIMATE
SOIL CHARACTERISTICS
PRODUCTIVITY
(Animal/Plant)
BIODIVERSITY
(Plants/Animals/Microbes)
NUTRIENT CYCLING
(Decomposition)
Global Commonalities

FIGURE 2

FIGURE 3

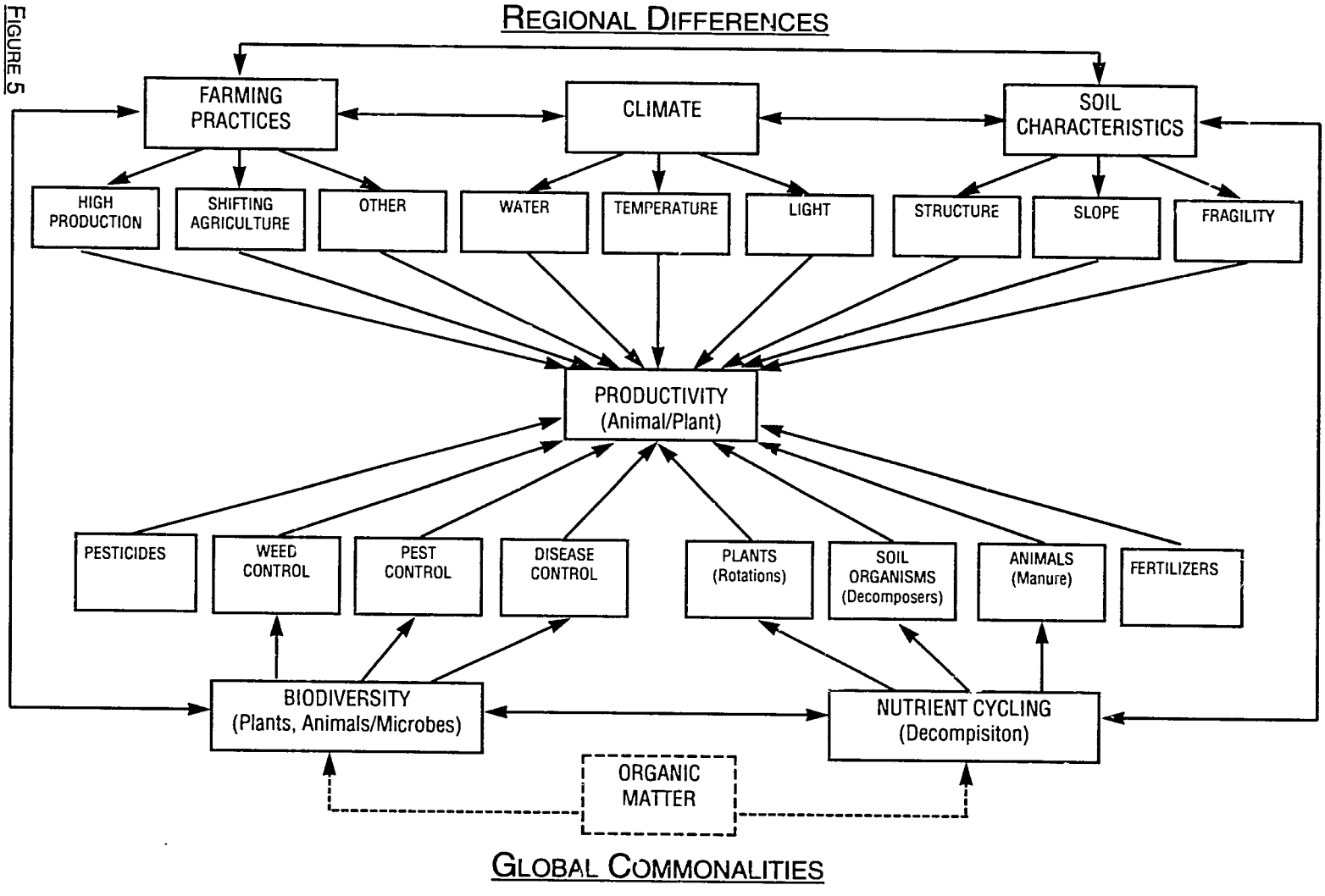

Regional Differences
FARMING PRACTICES
CLIMATE
SOIL CHARACTERISTICS
HIGH PRODUCTION
SHIFTING AGRICULTURE
OTHER
WATER
TEMPERATURE
LIGHT
STRUCTURE
SLOPE
FRAGILITY
PRODUCTIVITY (Animal/Plant)
WEED CONTROL
PEST CONTROL
DISEASE CONTROL
PLANTS (Rotations)
SOIL ORGANISMS (Decomposers)
ANIMALS (Manure)
BIODIVERSITY (Plants, Animals/Microbes)
NUTRIENT CYCLING (Decompisiton)
Global Commonalities



Conventional Agriculture

FIGURE 4

FIGURE 5


REGIONAL DIFFERENCES
FARMING PRACTICES
CLIMATE
SOIL CHARACTERISTICS
HIGH PRODUCTION
SHIFTING AGRICULTURE
OTHER
WATER
TEMPERATURE
LIGHT
STRUCTURE
SLOPE
FRAGILITY
PRODUCTIVITY (Animal/Plant)
PESTICIDES
WEED CONTROL
PEST CONTROL
DISEASE CONTROL
PLANTS (Rotations)
SOIL ORGANISMS (Decomposers)
ANIMALS (Manure)
FERTILIZERS
BIODIVERSITY (Plants, Animals/Microbes)
NUTRIENT CYCLING (Decompisiton)
ORGANIC MATTER
GLOBAL COMMONALITIES

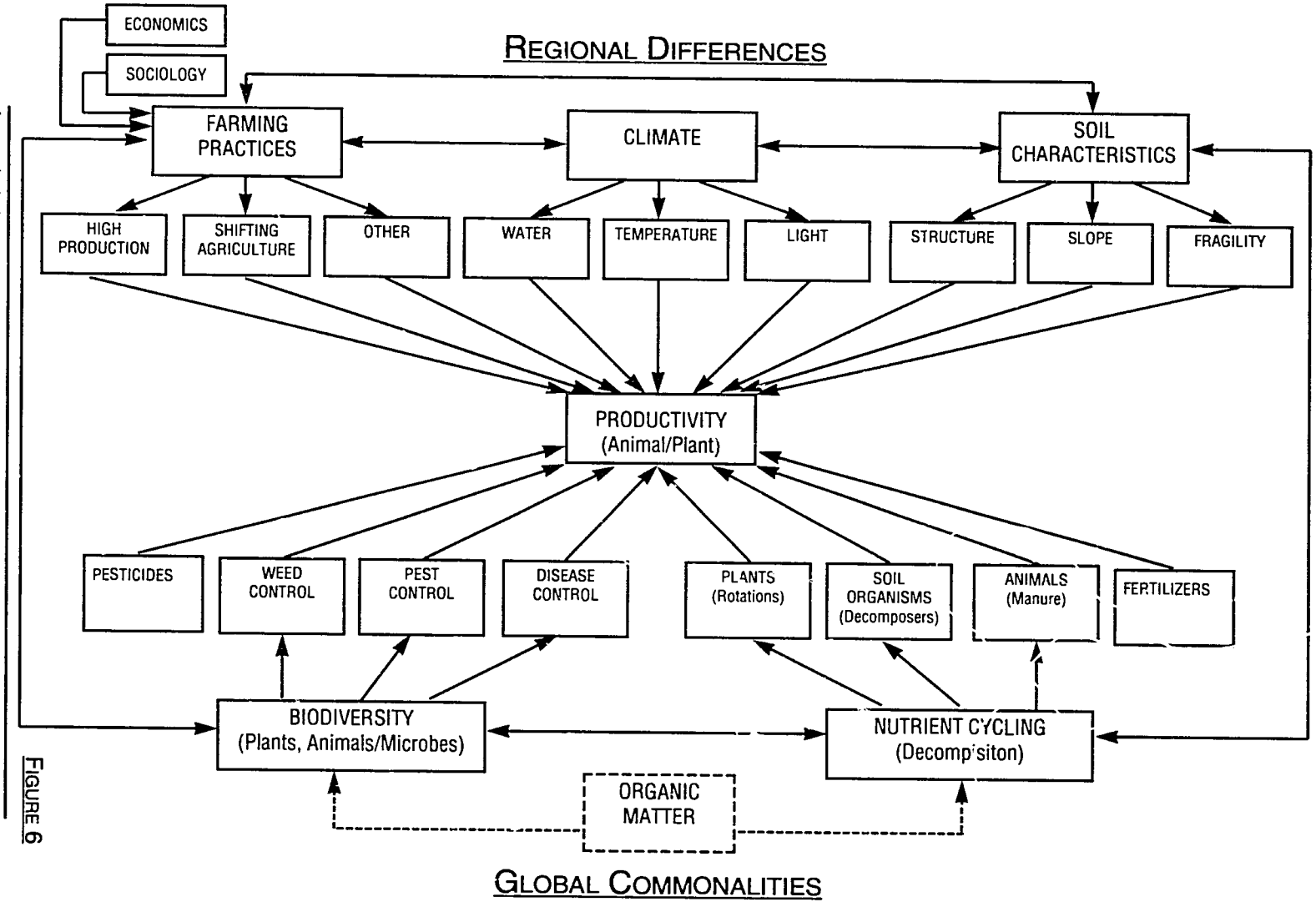

ECONOMICS
SOCIOLOGY
REGIONAL DIFFERENCES
FARMING PRACTICES
CLIMATE
SOIL CHARACTERISTICS
HIGH PRODUCTION
SHIFTING AGRICULTURE
OTHER
WATER
TEMPERATURE
LIGHT
STRUCTURE
SLOPE
FRAGILITY
PRODUCTIVITY (Animal/Plant)
PESTICIDES
WEED CONTROL
PEST CONTROL
DISEASE CONTROL
PLANTS (Rotations)
SOIL ORGANISMS (Decomposers)
ANIMALS (Manure)
FERTILIZERS
BIODIVERSITY (Plants, Animals/Microbes)
NUTRIENT CYCLING (Decomposition)
ORGANIC MATTER
GLOBAL COMMONALITIES

FIGURE 6

Household Economics and Community Dynamics[1]

D. W. Norman
Kansas State University

INTRODUCTION

The objective of this symposium is to plan a research program that will result in the development and dissemination of recommendations for improved production systems, practices and land use programs relating specifically to small ruminants (sheep and goats) and camelids (llama and alpaca) kept by agro-pastoralist households in the Bolivian altiplano.[2] Recognition of the importance of the socio-economic dimension in contributing to this objective obviously provides the justification for this paper. Therefore, the objective of this paper is to justify why this socio-economic perspective is important. At the same time I give some examples of the socio-economic factors that might need to be taken into account if technologies and support systems for sustained small ruminant and camelid production are to be relevant, that is, adopted by the agro-pastoralists. In raising these issues, I feel a sense of inadequacy, because many socio-economic characteristics are location-specific. Unfortunately, my exposure to the Andean agricultural systems is limited, and the apparent dearth of literature on the farming systems of the Bolivian altiplano has not helped matters. Thus, there is a possibility that the socio-economic factors discussed in this paper may not be complete or indeed be the most important ones. However, I hope they will provoke some discussion.

To provide a backdrop for the above discussion, the paper begins with a brief historical review of the development of the socio-economic dimension in the design, testing, and evaluation of technologies. It then moves to a more theoretical discussion in order to place the role of the household into perspective—both in its interaction with the surrounding environment and in its internal dynamics. The paper finishes with a few comments on techniques for including the socio-economic dimension.

Previous Page Blank

HISTORICAL PERSPECTIVE

EVOLUTION OF THE SOCIO-ECONOMIC DIMENSION

In the low-income countries, until the mid-1960s, most work undertaken at the micro- or farming-household level relating to the socio-economic dimension was carried out by sociologists/anthropologists. Usually these people originated in academia and were independently funded. Their approach usually involved case studies and relied on informal unstructured survey and interviewing techniques for collecting data, supplemented by direct observation. In Africa, starting in the mid-1960s—earlier in parts of Asia and later perhaps in Latin America[3]—agricultural economists started undertaking detailed micro-level studies of farming households. These agricultural economists came not only from academia but also sometimes from national and international agricultural research institutions. In such studies, the researchers usually selected stratified random samples. The techniques of data collection involved frequent interviewing—often twice a week over a one year period—using formal structured and often closed-ended survey techniques. These interviews were supplemented with direct measurement on certain variables (e.g., estimation of yields and areas). Such types of studies had a positive orientation (i.e., what farmers are doing), later leading to a normative orientation (i.e., what farmers ought to do). The normative orientation naturally led in academia to the application of linear programming techniques to assess constraints and to evaluate how efficiently farming households were allocating their resources to fulfill their goal(s). In agricultural research institutions the micro-level studies stimulated the testing, with farmers, of technological packages already assembled by technical scientists. In general, results from this testing were not particularly promising. They often showed some incompatibility with the socio-economic environment — and sometimes even with the natural environment—within which farmers were operating.

Consequently, in the mid-1970s, the farming systems research (FSR) approach evolved, particularly in resource-poor agricultural systems.[4] In such areas least success had been obtained with respect to the adoption of improved technologies. This result enabled social scientists to play a constructive ex ante role, along with technical scientists, in diagnosing farmers' problems. Also, to an increasing extent social scientists began to help designing and testing technological solutions.

The evolution of techniques for undertaking FSR is continuing. Underlying these techniques is a particularly important theme: treating the farmer as a person whom researchers can interact with on a collegiate basis. As a result, a melding occurred of techniques used by both sociologists/anthropologists and agricultural economists. Also considerable expertise developed in

involving farmers in the experimental process—for example, through researcher-managed and farmer-implemented (RMFI) and farmer-managed and-implemented (FMFI) trials. An interdisciplinary approach developed, using cost- and time-efficient techniques and solutions that:

1) Reduce the time period to move through the four research stages (description/diagnosis, design, testing and dissemination). The methodologies evolved ensured a fast turnaround and have been practical, flexible and inexpensive.
2) Maximize the returns from such research through working with representative farmers. This technique enabled results to be disseminated to other farmers with similar characteristics and problems.
3) Recognize the heterogeneity in the farming population, thereby involving development of better rather than unobtainable best solutions.

In the context of this symposium, three current shortcomings in FSR are as follows:

1) There has been more success in applying the FSR approach to the crop rather than to the livestock area. For example, a particular problem of the latter is the difficulty of undertaking RMFI, which are very important in the testing stage of FSR.[5]
2) Perhaps because of its institutional home in technical research institutions, FSR is often perceived as having only a technological mandate. So there has been a tendency—at least until recently—to accept policy/support systems as given (i.e., parameters). Thus opportunities to exploit the complementariness between the equally important strategies of disseminating relevant improved technologies and implementing relevant policy/support systems have been very limited.[6] Very likely, given the expressed purpose of developing improved sustainable small ruminant production systems in the altiplano, policy/support systems will play a critical role.
3) Much FSR work has considered the farming household as an undifferentiated unit with a single decision maker. In fact, intra-household characteristics can be very influential in deciding who are decision makers, who undertakes the various activities of the household, and who benefits from the activities. As discussed later in the paper, methodologies have recently been developed to address such issues.

THE NEED FOR A FARMING SYSTEMS PERSPECTIVE

As the earlier discussion implies, in order to design appropriate ways of helping farmers, it is essential to understand the conditions under which farmers are operating. They have, in fact, very complicated farming systems. Figure 1 shows some of the factors that have an influence on what the farming system will be. The operator of the farming system is the farming, or agro-pastoralist, household. For such households, the way in which they earn their living and their economic, social and cultural well-being cannot be separated. In other words they are both a production and a consumption unit.

The members of the farming household have three basic types of inputs: land, labor and capital. They use their managerial ability to assign these inputs to three different processes: crops, livestock, and off-farm enterprises. In assigning their inputs to producing one or more products, farming households often have to make difficult decisions. An important consideration in this decision-making process will involve using their knowledge to come as close as possible to fulfilling the goal(s) they are striving for. These goal(s), to be discussed shortly, provide the basic driving force for the presence of a particular farming system. The combination of products (crop, livestock and off-farm enterprises) resulting from the use of the inputs is the farming system. However, the extent to which the farming system fulfills the goal(s) the household has chosen will depend on the managerial skills of the agro-pastoralist households. It will also depend on their ability to make appropriate decisions in the allocation of inputs in a very uncertain agricultural environment.

Some parts of the environment that influence what the farming system will be are, however, outside the control of the individual household, contributing to the uncertainty felt by its members. The 'total' environment in which such households operate consists of two parts: the technical (natural) element, and the human (socio-economic) element. These parts are as follows:

1) The technical (natural) element determines the types of, and physical potential of, livestock and crop enterprises. Parts of the technical element include physical and biological factors. Some modifications to these factors sometimes occur through technological developments such as increasing water availability through more than one cultivation to allow water into the soil profile, improving soil quality by adding fertilizer, growing forage to feed livestock during the dry season, etc.
2) The farming system that actually evolves, however, is only part of what is potentially possible. The human element is important in determining what the actual farming system will be. It consists of two types of factors: exogenous and endogenous.

a. Exogenous factors are largely out of the control of the individual household but will influence what the household can do. These factors are divided into three broad groups:

- Community structures, norms and beliefs.
- External institutions (i.e., policy/support systems). On the input side these include extension, credit and input distribution systems. On the output side they include markets, plus other institutional arrangements such as the land tenure system.
- Other influences, such as population density and location.

b. Endogenous factors, on the other hand, are those the individual household controls to some degree; they include the three types of inputs mentioned earlier: land, labor, and capital. It is important to recognize that the quantity and quality of these resources vary among households and in different parts of the Altiplano.[7] Both quantity and quality influence the performance and the potential of the system. In addition, these inputs or resources may or may not be owned by the household. Access to one or more of these resources may be on another basis of use (e.g., borrowing draught animals, obtaining usufructuary rights to land through working part time on the landlord's own farm, etc.). This additional basis may limit or restrict the ease or intensity of use and thus in turn affect the performance of the household.

Nevertheless, it is the household which decides on the farming system that will emerge. The technical element and exogenous factors will, however, influence and sometimes constrain that farming system. Thus in calculus terminology, the technical element provides the necessary condition for the presence of a farming system, while the human element provides the sufficient condition for its presence.

The above discussion has a static connotation; however, it is not difficult to visualize it in dynamic terms. For example, the current farming systems reflect in part the cumulative interaction of the technical and human elements over time. Also, the interaction of the technical and human elements during the current time period will partially determine what will exist in the future.

The farming system is obviously complex, and the results can vary due to differences in the 'total' environment. These facts help explain why some technology, thought to be appropriate, is not adopted, or when it is, why the degree of adoption varies widely. Not considering the human (socio-economic) element in agricultural research contributes to many so-called 'improved' technologies being irrelevant. Therefore, in order to develop improved technologies appropriate to agro-pastoralist households in the Bolivian altiplano, a systems perspective is critically important. Issues of

both ability and willingness to adopt proposed improved technologies enter into the decision-making process of such households:

1) Ability to adopt is determined by such factors as:

a. **Technical feasibility** (i.e., whether the necessary inputs are readily available).

b. **Economic viability** (i.e., profitable and dependable at the levels farmers are likely to adopt).

c. **Social acceptability**.

2) Willingness to adopt is decided in part by whether farmers will be better able to achieve their goal(s) by using the improved technology. However, criteria on which they will decide their willingness to adopt are often difficult to determine.

The primary objective of agricultural research is obviously to improve the well-being of individual farming households. This improvement is achieved through increasing the overall productivity of the farming system in the context of both the private and societal goals. This increase, however, has to be done within the constraints and potentials imposed by determinants of the existing farming system. The above rather lengthy discussion shows what a complex and challenging task this is, just on the level of farming households themselves. Incorporating societal goal(s) of equitability and sustainability obviously makes the task even more difficult and challenging.

DEFINING THE AGRO-PASTORALIST HOUSEHOLD AND ITS GOAL(S)

It would appear that typical agro-pastoralist households in the Bolivian Altiplano are synonymous with what Ellis [1988; p. 12] defines as peasant households: "Farm households, with access to their means of livelihood in land, utilizing mainly labor in farm production, always located in a larger economic system, but fundamentally characterized by partial engagement in markets which tend to function with a high degree of imperfection."

With reference to the above definition, important points to note are the following:

1) Such households are often subordinate to some other external forces. That is, they do not have complete control over their own destiny and are in a process of transition, because they are not fully integrated into the market economy.

2) Such households have access to land to pursue their livelihood. They cultivate the land largely with family labor, in conjunction with only small amounts of capital.

3) The factor markets work poorly. Concerning land, non-market rights of access or non-price forms of tenure are more likely to operate than a freehold market. The capital markets usually are poorly developed, and variable production inputs are often not available. As a result "credit and interest rates may be tied to other factor prices like land and labor within a dependent economic relationship. Thus factor markets may be locked together contractually rather than being independent" [Ellis 1988: p. 12]. Also, market information may be highly imperfect. Thus it is not surprising that sharing and reciprocity often exist between households. In these non-market transactions, not valued by market prices, exchange of unlike goods and services take place.[8] Sometimes such relationships exist between households within the same general family.[9]
4) Another reason why such households are only partially integrated into the market economy is that they consume a proportion of the product they produce. This consumption enables them to have some ability to survive independent of the larger system; this procedure may be important in explaining their economic behavior.

A number of farm household microeconomic theories have been developed in an effort to explain the economic behavior of such households. These theories are based upon various assumptions about household goals and the characteristics of the markets within which households make their decisions. Ellis [1988: p. 234] notes that these theories are not mutually exclusive, sharing as they do certain key assumptions such as the following:

1) The household is a single decision-making unit for economic analysis purposes. As a result it maximizes a single utility (satisfaction) function which represents the joint welfare of its members.
2) Profit maximization and utility maximization coincide where income is the only variable in the utility function. Profit maximization is always one of the components of utility maximization[10] when all the input and output markets are fully formed and competitive.

Ellis [1988] suggests that these theories predict different results because of different assumptions about the working of the factor and product markets, rather than because of differences in assumptions about household goal(s). In fact an important characteristic distinguishing many of the theories results from different assumptions about labor markets and the allocation of household labor time. In support of these assertions Ellis [1988] then discusses a number of these theories of economic behavior, which he calls profit maximization, risk aversion, drudgery aversion, farm household theories, and share tenancy. In doing so, he recognizes the impossibility of separating

short-run household decisions from the wider social relations of production. Therefore such microeconomic theories do not operate independent of particular social relationships, the focal point of much Marxian political economy work.[11]

Consequently there is likely to be a certain universality in the aspirations of farming households, similar to those in the Bolivian altiplano. These aspirations include as the most important elements income, effort avoidance, and risk avoidance. In economic terms, such households try to increase their utility, which increases with income but decreases with greater effort or higher levels of risk. In other words, such household try to maximize income for any given level of effort or risk, or to reduce risk, or effort, for a given level of income [Norman 1982].

Attempts to maximize utility take place within a set of constraints. As implied above, differences in the constraints, rather than the aspirations, lead to the most important differences in farming systems. As earlier discussed, Figure 1 indicates some of the determinants of the farming system. It is easy to visualize constraints relating to the technical element causing differences in the type and productivity of farming systems. However, also important in the differentiation process are the factors relating to the human element. The quantity, quality, and ratios (particularly between land and labor) of the endogenous factors (factors of production—land, labor, and capital) play an important role in further differentiating farming systems. The extent to which they can be modified will depend on the degree of integration into the factor markets (i.e., input markets). Also, the resulting products will be influenced to some extent by community norms and beliefs and by the degree of integration into the product market.

The above discussion has important implications for what is appropriate technological change. The levels, qualities, and relative proportions of the factors of production are also, according to the induced innovation theory [Hayami and Ruttan 1971; Binswanger and Ruttan 1978], important in indicating the most appropriate route for improving the productivity of the farming systems—which is maximizing the return to the most limiting factor. For example, in areas of high land/labor ratios labor-saving (e.g., mechanical, extensive livestock production) types of technology/systems are likely to be most appropriate. In contrast, in areas of low land/resident ratios (i.e., high population density) land-saving technologies/systems (e.g., biological and some chemical, intensive livestock production) will likely be more appropriate. However, as Table 1 shows, increasing the return to the most limiting factor can have an indirect positive or negative impact on the use and productivity of other inputs. Thus in view of the imperfect operation of the factor markets, care has to be taken in evaluating what would be

the most relevant technologies. For example, for the agro-pastoralist household on the Bolivian altiplano, initial superficial examination indicates that because of the high population densities, strategies designed to increase the productivity of land would be most important. However, given the seasonal nature of agriculture in the area, there will be periods of intense labor activity during the year. These will create labor bottleneck periods, followed by periods of underemployment. Thus land augmenting strategies using labor at critical labor bottleneck periods—when the opportunity cost of labor is high—could make such strategies unattractive to the household. This scenario is likely if adoption of such a strategy involves the use of more labor at such labor bottleneck periods. It will also be likely if the productivity per unit of labor applied at that time is higher in alternative uses. Also, as the next section shows, further complications can arise because of differentiation in the types of labor available from household sources.

TABLE 1: RELATIONSHIP BETWEEN TYPES OF REQUIRED TECHNOLOGY AND LAND/LABOR RATIOS

Land/labor ratio	Technology required	Productivity of[a] Land	Labor
High	Labor saving	I+ or I-	D+
Low	Yield increasing	D+	I+ or I-

[a] D = Direct impact I = Indirect impact
+ = Positive impact - = Negative impact

INCORPORATING THE INTRA-HOUSEHOLD DIMENSION

As mentioned earlier, existing microeconomic theories make simplistic assumptions about farming households. For example, they assume a single decision-making unit and a single utility function representing the joint welfare of its members. Also, perceived practical problems often prevented FSR practitioners taking intra-household considerations into account to the extent that would be desirable. The 1980s saw increased donor interest in the role of women in development and increasing concern about reduced effectiveness of FSR techniques because intra-household considerations were not always included [Low, No Date]. This interest and concern stimulated increased discussion on intra-household issues and the development of techniques for addressing them [Feldstein et al. 1988; Feldstein and Poats

1990]. It is thus increasingly recognized that intra-household relationships can have an important impact on economic behavior.

Some important points to note about intra-household relationships are as follows [Ellis 1988; Feldstein et al. 1988]:

1) Such relationships are of particular importance in situations with a high degree of congruence between the production and consumption units. They are also important where there is some imperfection in integration with the factor and product markets.
2) The economic situation of individuals within households is influenced by the social norms of behavior of the society within which they reside. Therefore, specific economic roles are socially assigned to men, women, and children. Also, division of property, labor, and income within households is socially, not biologically, determined. Sometimes, as a result, males and females within households may have different income streams, with different sources and different destinations.
3) It is wrong to assume that male and female labor can substitute for each other across the range of household activities. As a result rigidities in time allocation may reduce the ability of households to respond to market signals. Therefore, such division of labor can impose constraints on seasonal labor inputs and ability to respond to price changes. As a result it can have a major impact on the composition and level of farm output.
4) Because of the above points, it is unlikely that increases in household income will benefit all members equally. This disparity is often exacerbated by the social subordination of women in many societies. Also, agricultural policies and projects have often ignored the role of women in agricultural production—not only as operators but also as decision makers. As a result, it is not surprising that technological innovations have tended to disadvantage women.

INFLUENCE OF THE COMMUNITY

A definitive relationship often exists between the various exogenous factors in Figure 1. The more isolated or inaccessible communities and their households are, and the less integrated they are with the factor and product markets, the greater is the influence of community structures, norms, and beliefs [Norman et al. 1981]. Some differentiation between households in such communities will occur, based on resources controlled and status enjoyed. Thus patron-client relationships still exist but often are not unduly exploitive, because of the interdependent and self-contained nature of such communities. Such communities often have a sense of common responsibility resulting in an incipient welfare state (i.e., helping others when they are

in trouble). In addition, sanctions are placed on extreme individualistic behavior (i.e., so people exhibiting such behavior do not become a burden on others when things go wrong), while community-wide strategies are enforced which are designed to preserve the environment (e.g., community management of pastures for the benefit of current and future generations).[12]

Unfortunately such relationships tend to rapidly break down with increased accessibility of the community to the influence of external institutions (i.e., increasing integration with the factor and product markets).[13] Thus, sanctions against more individualistic behavior on the part of households crumble, the probability of increased differentiation and exploitation in the society increases, and the potential of community-inspired systems to monitor and control progress declines [Jodha 1990].

Unless government makes explicit efforts, it is increasingly unlikely that community resources will be managed for the benefit of the community as a whole. Thus social relations of production, instead of being geared towards the benefit of all, tend to be more exploitive, benefiting a few at the expense of many.

SOME SOCIO-ECONOMIC ISSUES TO CONSIDER WITH REFERENCE TO SMALL RUMINANTS[14]

To develop strategies designed to improve the productivity of small ruminant systems, it is initially necessary to examine the heterogeneity in the agro-pastoralist households. The objective of this examination is to determine whether there is a need to stratify them into more than one research or recommendation domain. The stratification provides researchers with information on the constraints or issues which need addressing to improve the productivity of the small ruminant production system. Such an activity also indicates what resources, constraints, and other characteristics of the households need to be taken into account to develop an acceptable strategy for improvement. As a result, all households in one recommendation domain face the same constraints to improving small ruminant productivity and the same potential solutions.[15]

In order to derive the recommendation domains, descriptive/diagnostic work is necessary, which involves developing an understanding of the existing farming system, in turn eliciting information on the constraints and ideas on the appropriate route for productivity improvement. Types of information required in this exercise include the following:

1) A good understanding of the small ruminant production and management system is required to obtain an idea of the technical constraints

that require addressing to improve productivity.[16] However, socio-economic factors will likely play an important role in determining the characteristics of the current system. They will also certainly be important in determining appropriate solutions. Therefore the following activities help in explaining the current situation and aid in developing relevant solutions to the identified constraints. Before looking at these activities, it is important to determine whether researcher plans for improving the productivity of small ruminant production systems are likely to be acceptable to the agro-pastoralist households. For example, are they interested in a higher slaughter weight per animal (i.e., would it be reflected in a higher market price if sold), or are they more interested in numbers of animals to provide more manure for the cultivated fields? If there is not a congruence between the researchers and producers as to what constitutes the productivity criteria, then there will be problems in convincing producers to adopt the strategies when they have been developed (i.e., they will be inappropriate or irrelevant).

2) It is important to identify who in the household is the decision-maker with reference to the small ruminants, who controls the resources assigned to them, and who reaps the benefit [Feldstein and Poats 1990]. If at least one person is not connected with all three, then complications will arise in designing attractive and hence relevant strategies for improving the small ruminant production system. For example, in Bolivian agro-pastoralist families, are the men and women joint decision-makers? Do women concentrate on household activities and looking after the livestock? Are men mainly responsible for the crops and working in off-farm occupations?[17] If so, are any benefits from the small ruminant production system shared?

3) It is necessary to obtain some understanding of the quantity, quality, and use of the factors of production (i.e., land, labor, and capital) throughout the year in the current farming system. Such information is critically important in delineating further constraints in the farming system—often socio-economic in nature.

   Particularly important in this exercise is the need to obtain a good understanding of the amount, composition, and disposition of labor—mostly family—to different areas (i.e., crops, livestock, and off-farm and household activities) throughout the year. Are there, for example, seasonal labor bottleneck periods in any of the areas? If so, do they occur at the same time or different times of the year? It is very likely, given the seasonality of rainfall and its low level and unreliable nature, that at least one seasonal labor bottleneck will exist in crop cultivation. If one assumes that time assigned to household and off-farm activities does not

have a seasonal characteristic, does the seasonal bottleneck in crop cultivation result in problems of providing adequate labor for operation of the small ruminant enterprise? It is likely that some seasonality in labor requirements for small livestock exists, particularly if breeding times are regulated, through separate management of male and female animals, and if shearing of sheep and llamas is done. Do peak periods for births and shearing[18] occur during the cropping cycle when the opportunity cost of labor is already fairly high? Such seasonal labor bottlenecks and opportunity costs could be further accentuated if there is gender specificity to the tasks undertaken at those critical times.

The land available, its spatial distribution, and the use to which it put is another critical area to evaluate. Bolivian agro-pastoralist households probably give considerable priority to food crops (e.g., potatoes, barley, quinua, etc) which are also cash crops. Given this situation, what priorities are given to feeding small ruminants? Do they feed crop residues (e.g., barley and quinua), and in terms of cultivatable land, do they have sufficient land to fallow to provide some supplemental feed for the small ruminants?[19] What about growing forage crops for small ruminants? If this is not a practice, then there will be greater difficulties in getting it into the system, especially if it involves labor in cutting and storage. Whether households are likely to adopt such a strategy will depend upon the perceived value they are likely to place on such forage. The following are two factors that may positively influence such an evaluation:

a. **Growing special forage** is more attractive if benefits from feeding can result in some tangible benefits in the near future. An obvious example is improving marketability of the animals. Given the multiple purposes for keeping small ruminants (e.g., food plus a walking bank, wool, cheese, transport, manure, etc.), it is unlikely to be very attractive unless programs to encourage higher offtake rates were successful.
b. **Increasing shortage of other methods of feeding** the small ruminants, particularly during the dry season, when food supplies are shortest [Orlove 1980]. However, the attractiveness of this method is likely to be lower if the dry season pastures are some distance from the cultivated areas—which is true in the vertical farming system common in many parts of the Andes.

Improvement in the productivity of any system usually means the commitment of more of at least one input, although at the same time it can lead to less use of another input. Capital in the form of cash or credit, involving the purchase of improved inputs, often constitutes this increasing input and is thus usually in high demand. It is therefore important to obtain some

understanding of the availability and seasonal flow of cash and credit. The next two points address this issue:

4) Because of the close relationship between consumption and production in households like the Bolivian agro-pastoralists, it is important to look at the products of the farming system not only in terms of cash, but also in terms of the availability of products produced and available for consumption, in relation to the needs for consumption. With respect to the production/consumption relationship, poor seasonal synchronization between the two, and the poor overall level of production, often result in seasonal hunger. This outcome in turn often results in differentiation in levels of nutrition of individuals within households, according to gender and age, in many parts of the world. The prospects of such problems, combined with the uncertainty of the climate and the general low level of living, predisposes such households to implement not only strategies to minimize production risk[20] but also closely related coping strategies of various types to maintain household security. This approach enables them to consume during periods when production is deficient [Frankenberger and Goldstein 1990; Jodha 1990].[21] Some of these strategies, however, can adversely affect future productivity.

   Obvious examples would be selling off productive assets (e.g., llamas used for transport), obtaining access to food at high rates of implicit interest (e.g., repayment in terms of labor at busy times in the farming cycle) or explicit interest. It is important to know if such coping strategies exist, since they are one of the factors determining how risk-averse such households will likely be. Such knowledge also indicates how much reliability can be placed on the availability of cash, for improving the productivity of the farming system, in contrast to buying food to ensure survival. With reference to investment, it is important to obtain an idea of the attitudes of the decision-maker(s) in the households about investing in different areas of the farming system. For example, what area do they view as the best for investment? Their answer is, in part, influenced by their assessment of the probability and level of return. If they do not view investments in improving the productivity of small ruminants as high priority, it will be difficult to convince them of the value of strategies to increase their productivity. This is particularly likely to be the case when it involves greater commitment of resources, including capital. One final point relating to this issue is an assessment of whether cash resulting from another part of the farming system (e.g., sale of crops) is likely to be available for investment in improvements in the productivity of the small ruminant production system.

5) Finally it is important to obtain an understanding of the influence of the community structures, norms, and beliefs[22]—which influence community dynamics—and the external institutions. With reference to the former, if they are still influential, they potentially have a role to play in equitable access to communally owned resources. For example, are the dry season (i.e., summer) pastures and fallow land of the Bolivian agro-pastoralists communally or individually operated?[23] If the former is the case, as often is the situation in Peru, then strategies for ensuring sustainability and productivity of such pastures need to be based on communal decision-making.[24] Strategies could either involve technologies to increase their productivity and/or various techniques to adjust numbers or length of time small ruminants have access to the pastures, according to the grazing situation.

   Some understanding is also needed of the functioning of the external institutions and the degree to which households are integrated with them. For example, is there an effective hired labor market, or should any improved small ruminant production systems be formulated with the constraints imposed by the supply of family labor? Is there an effective credit market, or will purchases of improved inputs need to be based on cash generated internally by the households from their own activities? Are improved inputs readily available that can be used for improving the productivity of the small ruminant system? If productivity is improved, is there an effective market for the products? Alternatively, in the case of both the input and product markets, what is the potential for instituting improvements when results demonstrate that technologies designed to improve the productivity of the small ruminant production system are likely to be attractive to farmers? In other words, can an interventionist approach be used to adjust policy/support systems as a result of demonstrated outcomes? The alternative is a submissive approach, which would mean accepting the policy/support system as given and not likely to change. Obviously the latter approach is less desirable in that it constrains researchers in the type of strategies they can use in improving the productivity of the small ruminant production system.

Information from the above exercise will help in putting together appropriate recommendation domains. It is of course impossible to suggest, in this paper, what these might be. Only interaction with appropriate authorities and a cross-section of households will determine what should differentiate households in terms of potential appropriate strategies. As indicated earlier, households in different recommendation domains may or may not face the same constraints to improving the productivity of small ruminant

production systems. However, households within a given recommendation domain will have the same potential solution to the identified constraint(s). For example, households may be differentiated on the basis of accessibility to summer pastures, labor available for the small ruminant production system, differences in accessibility to the external institutions, differences in composition and size of small ruminant flocks, etc.

Definition of the recommendation domains provides an entree into designing possible appropriate strategies for improving the productivity of the small ruminant production system. Strategies for improvement will likely include one or more of the following: improved health, improved management practices, and improved nutrition through provision of forage and improvement of dry-season pastures. There is of course a high degree of interdependence among these strategies. For example, the health of animals depends to some extent on management practices and nutritional level. However, the important point to note is that decision-makers from representative households in the different recommendation domains need to be consulted in the design phase and be very involved in the testing or evaluation stage. Two points with reference to involvement of such individuals are as follows:

1) It is important to determine whether the proposed strategies fit in with the priorities of the households. It is also important to know *ex ante* whether it is likely to interest them and be compatible with the rest of their farming system. Obviously it is difficult for households to relate to proposed strategies that they have never seen. However, there is value in consulting them regularly during design work, particularly when trials at the researcher managed and implemented (RMRI) level are involved. As a result, not only are they sensitized, but also because of their new knowledge and resulting comments it may be desirable to make adjustments in the trial treatments that will potentially increase their acceptability to such households.
2) A much more difficult problem pertains to the sustainability[25] issue correctly emphasized in Small Ruminant CRSP research programs. The approach suggested above emphasizes involving the appropriate decision makers from representative households. These articulated 'felt' needs are likely to be somewhat short-run in focus,[26] because the closer such households are to the survival level, the more concerned they are with needs such as producing enough food to survive until next year. Therefore, they are less concerned about environmental degradation in the long-term, which thus becomes more of a societal concern. Obviously, in such a situation, there is a need to bring about a convergence between the short-run private interests of farmers concerned about attaining an

adequate standard of living and the long-term societal interest of maintaining the environment for future generations. It is not easy, given the limited resources available to governments in countries like Bolivia, to develop practical strategies that can enable this to occur.[27] Difficulties are likely to be even greater in cases where land is communally (e.g., possibly dry-season pastures), not individually owned. In deriving strategies to bring about such a convergence, two points need consideration:

a. **To make strategies designed to improve long-term productivity more attractive**, are there ways in which they be can be mounted on the back of short-run production, so as to make them attractive in the short-run as well [Norman 1991]?[28]
b. **In the case of communally owned land**, are there ways that pressures or control, in adjusting numbers of small ruminants to the carrying capacity of land, can be implemented either within the community and/or by government? It is unlikely that there will be a payoff to the adoption of technologies required to ensure sustainability unless some practical strategy is implemented that will control access.

The testing stage of the proposed improved strategies provides an opportunity for households to verify the technical feasibility of the strategies as far as they are concerned. Also, household-level involvement in the testing level—particularly at the FMFI level—provides the best opportunity for its robustness (i.e, in terms of both the average and variability in return) to be evaluated under the type of managerial and resource conditions that will occur when, and if, it is released for general dissemination. Consequently, more realistic estimates of potential profitability and dependability are possible. At the same time 'hands-on' involvement of household members provides an opportunity for an assessment to be made of their attitudes about the strategies, including whether or not they are likely to be socially acceptable.

COMMENTS ON TECHNIQUES FOR INCORPORATING THE SOCIO-ECONOMIC DIMENSION

The previous section places considerable emphasis on the importance of the descriptive/diagnostic phase in helping to define valid recommendation domains. Such efforts contribute to giving an indication on issues to address in improving the productivity of the small ruminant production system. They also give guidelines about the resource boundaries within which they need to be developed and the appropriate criteria to apply in evaluating the

results. At first sight this appears a daunting and time-consuming task. However, as discussed earlier, the development of the FSR approach over the last fifteen years or so has emphasized increased interactive dialogue with appropriate individuals in households by interdisciplinary teams consisting of both technical and social scientists. In-depth informal interview techniques emphasizing understanding and qualitative/attitudinal data are very useful in delineating an initial understanding. If necessary, specific initial observations can be later confirmed by a more formal approach, involving some type of random sampling procedure in data collection techniques that yield quantitative/objective data on variables thought to be critically important.[29] Experience over the years has shown that, in general, delaying design and possibly testing work until such information becomes available is rarely justified. Often such studies/surveys simply provide a more scientifically accepted verification of what is already known. This is particularly the case if the initial descriptive/diagnostic work using informal interviewing techniques is well done. Rather, timely starting of experimental work can itself provide an additional opportunity for learning about technical relationships. It also provides an opportunity for farmers to observe results and possibly comment on the treatments and results.

For some it might be surprising that FSR practitioners have not advocated more reliance on formal modeling techniques to provide greater understanding of agricultural households[30] and of farming systems. Most recognize the potential value of modeling in systematizing thinking and improving understanding. However, concerns arise about the potential time in obtaining the data to validate such models and the complexities of accurately simulating the real world. Therefore, skepticism often exists as to whether the benefits of such an approach outweigh the costs of the limited research resources which have high opportunity costs.[31]

Many handbooks are now available which provide useful material not only on undertaking informal surveys,[32] but also on more formal ones. Many also contain material on designing, implementing, and evaluating farm level trials.[33] Two recent publications that are particularly noteworthy are a book by Feldstein and Poats [1989], in which they present a simple methodology for examining intra-household relationships—particularly relating to gender issues, and a handbook by Amir and Knipscheer [1989], the only one that I am aware of that concentrates on the livestock sub-system; it provides much useful information on not only the procedures for on-farm animal research but also the economic analysis of such work.

Earlier in the paper three types of trials are mentioned. The basis of the differentiation is whether the researcher (R) or farmer (F) manages (M) and implements (I) them. These trials—RMRI, RMFI and FMFI—differ in terms

of research objectives, methods, experimental designs, types of data collected, methods and analysis, and evaluation criteria [Norman and Modiakgotla 1990]. All three types of trials are important since they serve different purposes. For example, RMRI trials are best for ascertaining cause-effect relationships, and data for economic analysis are often most easily collected at the RMFI level. FMFI trials, on the other hand, provide the best mode for collecting farmers' attitudinal information. Thus all three types of trials have value in on-farm research.[34] A particularly useful method for involving farmers, increasing the multiplier effect of limited research resources, and promoting farmer-to-farmer interaction are farmer groups [Norman et al. 1988]. These groups, membership of which is voluntary and is not restricted to heads of households, meet on a regular basis to discuss progress on the implementation of trials selected and undertaken by individual households. FMFI trials are well-suited to being implemented through farmer groups.[35]

In terms of techniques for economic analysis, considerable reliance continues to be placed on relatively simple approaches. Two critical issues underlying the legitimacy of many of the results of such analysis are:

1) Placing correct values on the inputs and products that do not originate from or end up in the market place.
2) The use of evaluation criteria that reflect those experienced by the household.

Particularly challenging is valuing labor—which is likely to vary seasonally—and evaluating the results in terms of the most limiting factor, for example, return per hour used during critical bottleneck periods, rather than return per hectare. Average return and budget (i.e., partial, enterprise, and sometimes whole-farm) analytical techniques are commonly used. Marginal analysis—a more powerful technique—certainly is preferable where the technology is tested over a wide range of inputs. Such a situation more likely occurs in RMRI types of trials rather than at the RMFI and FMFI level.[36] Given the poor levels of living of the agro-pastoralist households, it is likely that dependability of return will be an important criterion for them in their assessment of the attractiveness of a technology. Yet it is perhaps in the area of risk that the greatest problems exist in easily applied techniques. Techniques such as stochastic dominance [Schurle and Worman 1990], minimum returns analysis [CIMMYT 1988], safety-first analysis [Worman et al. 1990], beta ratios, and expected value analysis [Amir and Knipscheer 1989] have all been advocated.

Such economic evaluations are important in helping appropriate authorities—researchers (the technology developers) and planners (the policy/support system developers)—decide whether efforts should be made to disseminate the technology, and how the policy/support system must be

adjusted to facilitate its adoption. For households themselves, such information is likely only one component in a series of other factors that will influence their decision whether to adopt the technology. For example, their subjective evaluation of risk of a specific new technology may be very different from that measured objectively [Guillet 1980]. To date, techniques for interpreting these attitudes have not really been used — if in fact they exist. Also, to date, in most countries, such attitudinal data—some of which may relate to whether or not the technology is socially acceptable--has generally been heavily discounted by those responsible for making decisions about whether to actively disseminate specific improved technologies.[37]

Criteria for assessing environmental sustainability is perhaps the area most poorly developed at the present time. Currently used evaluation criteria are rather unsatisfactory and are primarily technical in nature, for example, percent organic matter, changes in soil structure, etc. Benefit-cost types of analysis can be useful in assessing the rates of return on investments designed to improve or maintain environmental stability (e.g., pasture improvement). However, as mentioned earlier, agro-pastoralist households are likely to discount the future very heavily. Therefore, benefit-cost analysis is unlikely to be particularly useful in assessing the attractiveness of the proposed strategy as far as such households are concerned.[38] However, such analysis can be potentially valuable in justifying the implementation of specific policy/support systems (e.g., subsidy) to encourage its adoption.

CONCLUDING REMARK

This paper has two primary functions: to demonstrate the importance of including the socio-economic dimension in improving the productivity of small ruminant production systems, and to indicate some of the socio-economic factors that must be considered in developing improvements that will be relevant for agro-pastoralist households in the Bolivian altiplano. Moreover, improving the small ruminant production system cannot be done independent of assessing interactions with the rest of the farming system. For a number of reasons (e.g., risk management, maximizing use of factors of production available to the household, etc.) a diversified farming system will remain important to such households no matter what is done to improve the productivity of the small ruminant system [Guillet 1980].

BIBLIOGRAPHY

Amir, P., and H. Knipscheer. 1989. *Conducting On-farm Animal Research: Procedures and Economic Analysis*. Morrilton and Ottawa, Canada: Winrock International and International Development Research Center.

Anderson, J.R., J.L. Dillon, and J.B. Hardaker. 1985. "Socioeconomic Modeling of Farming Systems." In Remenyi, J.V. (ed.). *Agricultural Systems Research for Developing Countries*. Canberra: Australian Council for International Agricultural Research. Pp. 77-88.

Andrew, C.O., and P.E. Hildebrand. 1982. *Planning and Conducting Applied Agriculture Research*. Boulder, Colorado: Westview P.

Barker, R., and C. Lightfoot. 1986. Farm Experiments on Trial. A paper given at the 1985 Kansas State University Symposium on Farming Systems Research, Management and Methodology, 13th-16th October, 1985. Manhattan: Kansas State U.

Bennett, D., and D.K. Macpherson. 1985. Structuring a Successful Modelling Activity. In Remenyi, J.V. (ed.). *Agricultural Systems Research for Developing Countries*. Canberra: Australian Council for International Agricultural Research. Pp. 70-76.

Bernsten, R.H., H.A. Fitzhugh, and H.C Knipscheer. 1983. Livestock in Farming Systems Research. In KSU (eds.). *Proceedings of 1983 Kansas State's University Farming Systems Research Symposium: Animals in the Farming System*. Manhattan: Kansas State U. Pp. 64-109.

Bilinsky, P. 1986. Barter and Non-Monetary Exchanges of Labor in a Highland Peruvian Community. Technical Report Series No. 74. Columbia: U of Missouri.

Binswanger, H.P., and V.W. Ruttan. 1978. *Induced Innovation: Technology, Institutions and Development*. Baltimore: John Hopkins.

Browman, D.L. (ed). 1987. *Arid Land Use Strategies and Risk Management in the Andes*. Boulder: Westview P.

Buechler, H.C., and J.M. Buechler. 1971. *The Bolivian Aymara*. New York: Holt, Rinehart and Winston.

Caldwell, J. and L. Walecka (eds.). 1987A. "Design Techniques for On-Farm Experimentation." *FSR/E Training Units: Volume 11. Second Edition*. Gainesville: U of Florida. 1987.

Caldwell, J., D. Taylor, and L. Walecka (eds.). 1987B. "Analysis and Interpretation of On-Farm Experimentation." *FSR/E Training Units: Volume III*. Gainesville: U of Florida.

Caldwell, J., T. Frankenberger, D. Taylor, and L. Walecka (eds.). 1987C. "Diagnosis Design and Analysis in Farming Systems Research and Extension." *FSR/E Training Units: Volume I, II and III Trainer's Manual*. Gainesville: U of Florida.

CIMMYT. 1988. *From Agronomic Data to Farmer Recommendations: An Economics Training Manual*. Completely Revised Edition. Londres, Mexico: CIMMYT.

Clark, R.J.. 1968. "Land Reform and Peasant Market Participation on the Northern Highlands of Bolivia." Land Economics 44:153-172.

Caro, D. 1991. "The Socio-Economic and Cultural Context of Andean Pastoralism: Constraints and Potential for Biological Research and Interventions." Invited paper for the *Symposium on Agro-Pastoralism in the Bolivian Altiplano*, sponsored by the Small Ruminant CRSP, Texas Tech U, Lubbock, Texas, May 15th-17th, 1991.

Daniels, L., J. Howard, M. Maredia, J. Oehmke, and R. Bernstein. 1990. "The Impact of Agricultural Research: A Review of the Ex-Post Assessment Literature with Implications for Africa." East Lansing: Michigan S U. (Draft).

De Janvry, A., M. Fafchamps, and E. Sadoulet. 1990A. "Peasant Household Behavior with Missing Markets: Some Paradoxes Explained." (Draft).

De Janvry, A., M. Fafchamps, M. Raki, and E. Sadoulet. 1990B. "Structural Adjustment and the Peasantry in Morocco: A Computable Household Model Approach." (Draft).

Dillon, J.L., and J.B. Hardaker. 1980. "Farm Management Research for Small Farmer Development." *FAO Agricultural Services Bulletin No. 41*. Rome: Food and Agriculture Organization of the United Nations.

Ellis, F. 1988. *Peasant Economics*. Cambridge: Cambridge U P.

—. 1991. "New Perspectives of Arid-Lands Ecology and Implications for SR-CRSP Agro-Pastoral Research." Invited paper for the *Symposium on Agro-Pastoralism in the Bolivian Altiplano*, sponsored by the Small Ruminant CRSP, Texas Tech U, Lubbock, Texas, May 15th-17th, 1991.

Feldstein, H.S., C.B. Flora, and S.V. Poats. 1988. *The Gender Variable in Agricultural Research*. Ottawa: International Development Research Centre.

Feldstein, H.S., and S.V. Poats (eds.). 1989. *Working Together*. West Hartford: Kumarian P.

Frankenberger, T., and D. Goldstein. 1990. "Coping Strategies of Small Farm Households." AFSRE Newsletter, 1(1): 1-5.

Frankenberger, T., and L. Walecka (eds.). 1987. "Diagnosis in Farming Systems Research and Extension." FSR/E Training Units: Volume I. Second Edition. Gainesville: U of Florida.

Grove, T. 1991. "Agro-Ecological Perspective on Small Ruminant Research and Development." Invited paper for the *Symposium on Agro-Pastoralism in the Bolivian Altiplano*, sponsored by the Small Ruminant CRSP, Texas Tech U, Lubbock, Texas, May 15th-17th, 1991.

Guillet, D. 1980. "Risk Management Among Andean Peasants." In *Andean Peasant Economics and Pastoralism. Small Ruminant CRSP Publication 1*. Columbia: Department of Rural Sociology. pp. 13-44.

Harman, I.M. 1984. "Women and Cooperative Labor in the Southern Bolivian Andes." *Women in International Development Publication Series, Working Paper No. 65*. Ithaca: Cornell U.

Hatch, J.K.. 1983. *Our Knowledge, Traditional Farming Practices in Rural Bolivia*. Vol. 1. New York: Rural Development Services.

Hayami, Y., and V. Ruttan. 1971. *Agricultural Development: An International Perspective*. Baltimore: Johns Hopkins U P.

Hildebrand, P., and F. Poey. 1985. *On-Farm Agronomic Trials in Farming Systems Research and Extension*. Boulder: Lynne Rienner.

Jamtgaard, K.A. 1984. "Limits on Common Pasture Use in an Agro-Pastoral Community: The Case of Toqra, Peru." *Small Ruminant CRSP Technical Report Series No. 42*. Columbia: U of Missouri.

Jaramillo, M., J. De Boer, A. Flores, F. Bryant, and L.C. Fierro. 1985. *Economic Analysis of Range and Forage Management Strategies for Increasing Small Ruminant Productivity in the Peruvian Andes*. Morrilton: Winrock International Institute and Department of Range and Wildlife Management, Texas Tech U.

Jodha, N.S.. 1990. "Drought Management: The Farmers' Strategies and Their Policy Implications." *Dryland Networks Programme Paper No. 21*. London: International Institute for Environment and Development.

Johnsson, M.. 1986. *Food and Culture Among Bolivian Aymara*. Stockholm: Almqvist and Wiksell International.

Low, A. No Date. "On-Farm Research and Household Economics." (Draft).

Marggraf, R.. 1986. *Microeconomic Analysis of Agroeconomic Systems in Developing Countries*. Fort Lauderdale: Verlag Breitenbach.

McCorkle, C.M. (ed.). 1990. Improving Andean Sheep and Alpaca Production. Columbia: U of Missouri.

McCorkle, C.M., M.F. Nolan, K. Jamtgaard, and J.L. Gilles. 1987. "Highlights from Sociological (CRSP) Research on Small Ruminants." *Pastoral Development Network Paper No. 24d*. London: Overseas Development Institute.

Norman, D.W. 1982. "Socioeconomic Considerations in Sorghum Farming Systems." In ICRISAT (ed.). *Sorghum in the Eighties*. Andhra Pradesh: ICRISAT. Pp. 633-646.

—. 1991. "Farming Systems Research in a Declining Donor Environment." Invited opening address for CIMMYT-sponsored *Workshop for Research-Extension Administrators from East and Southern Africa*, 8th-12th April 1991, Nairobi, Kenya.

Norman, D., and E. Modiakgotla. 1990. "Ensuring Farmer Input into the Research Process within an Institutional Setting: The Case of Semi-Arid Botswana." *ODI Agricultural Administration (Research and Extension) Network Paper 16*. London: ODI.

Norman, D., D. Baker, G. Heinrich, and F. Worman. 1988. "Technology Development and Farmer Groups: Experiences from Botswana." Experimental Agriculture, 24 (3): 321-331.

Norman, D.W., M.D. Newman, and I. Ouedraogo. 1981. "Farm and Village Production Systems in the Semi-Arid Tropics of West Africa: An Interpretive Review of Research." *ICRISAT Research Bulletin No. 4, Vol 1*. Hyderabad, India: ICRISAT.

Norman, D.W., E.B. Simmons, and H.M. Hays. 1982. *Farming Systems in the Nigerian Savanna: Research and Strategies for Development*. Boulder: Westview P.

Orlove, B.. 1980. "Pastoralism in the Southern Sierra." In *Andean Peasant Economics and Pastoralism. Small Ruminant CRSP Publication 1*. Columbia: Department of Rural Sociology. pp. 87-111.

Painter, M.. 1991. "Changes in Highland Use Patterns and the Implications for Agro-Pastoral Research in Bolivia." Invited paper for the *Symposium on Agro-Pastoralism in the Bolivian Altiplano*, sponsored by the Small Ruminant CRSP, Texas Tech U, Lubbock, Texas, May 15th-17th, 1991.

Preston, D.A. *Farmers and Towns: Rural-Urban Relations in Highland Bolivia*. Norwich: Geo Abstracts Ltd.

Schurle, B., and F. Worman. 1990. "Risk Analysis in the Farming Systems Approach to Research." ATIP MP 90-4. Gaborone, Botswana: DAR, Ministry of Agriculture.

Shaner, W. W., P. F. Philipp, and W. R. Schmehl. 1982. *Farming Systems Research and Development: Guidelines for Developing Countries*. Boulder: Westview P.

Singh, I., L. Squire, J. Strauss. (eds.). 1986. *Agricultural Household Models*. Baltimore: The Johns Hopkins U P.

Worman, F., D. Norman, and J. Ware-Snyder (eds.). 1990. *Farming Systems Research Handbook for Botswana*. ATIP RP 3. Gaborone, Botswana: DAR, Ministry of Agriculture.

Zandstra, H., E. Price, J. Litsinger, and R. Morris. 1981. *A Methodology for On-Farm Cropping Systems Research*. Los Banos, Philippines: International Rice Research

ENDNOTES

[1]I appreciate the constructive comments of B. Schurle, KSU, on an earlier draft of this paper. C. Flora, VPI, C. Valdivia, UM, A. Hansen, UF, and C. Bussing, N. Donaghue and T. Meyn, all of KSU, were very helpful in providing information and papers on Bolivia.

[2]For the sake of brevity, the term 'small ruminant production systems' will refer to all types of technology relating to the improved productivity of small ruminants. Also, the term 'small ruminants' will include camelids.

[3]In fact, I cannot find any Bolivian material on micro-level studies undertaken by agricultural economists. This lack may be due to the more Marzian orientation of agricultural economists in Latin America concerned with social relations of production among different groups on the society. This finding contrasts with the more individualistic approach implied in the neoclassical orientation of agricultural economists in Africa, and often in Asia.

[4]These systems are characterized by a lack of production stability or high risk. This situation occurs partly because of the environmentally diverse conditions under which such farmers operate, which in turn usually result in relatively complex farming systems.

[5]Amir and Knipscheer [1989:13], using as their source Bernsten et. al. [1983], provide a useful comparison of characteristics of crops and animals and implications for using animals in on-farm testing.

[6]This lack of opportunity is particularly disturbing since the lack of impact of much research has been blamed on the lack of, or poorly developed/inefficient, policy/support systems [Daniels et al. 1990]

[7]Managerial ability also obviously varies among households.

[8]For an example of such relationships in a Peruvian highland community, see Bilinsky [1986].

[9]Ellis [1988: p. 13] defines a family as a "social unit defined by the kinship relations between people." In contrast, a household is defined as a group of people who live together and eat from the same pot, i.e., share the same hearth.

[10]Others could include food self-sufficiency, leisure time, etc.

[11]As suggested earlier, in much of Latin America this aspect appears to have received much emphasis, in contrast to the type of micro-economic studies that would occur based on the micro-economic theories.

[12]McCorkle et al [1987] indicate examples abound of indigenous farming communities that have successfully sustained the productivity of their rangelands over hundreds of years. One important conclusion arising out of work in Morocco was that traditional systems rely on regulating the length of the grazing season, use socially flexible and/or hierarchical rights to rangelands, and control use of wells. In contrast, most Western practices and range management projects rely on fixed stocking rates, rigid control of herd movements, and privatization of pasture rights. One of the other speakers at the symposium [Ellis 1991] argued convincingly that in a highly variable climate — characteristic of many semi-arid and arid areas of the world — the optimal strategy will involve opportunistic management, namely adjusting stocking rates according to the situation.

[13]High population growth rates, placing pressure on the land resource base, also have an influence. These rates increase also as a result of improved accessibility to medical facilities.

[14]McCorkle [1990] and Browman [1987] provide some useful insights on the socio-economic dimension for improving production systems of agro-pastoralist households in the Andes. Papers with useful information on Bolivian altiplano households include Hatch [1983], Preston [1978], Johnson [1986], and Buechler and Buechler [1971]. Also, two particularly useful papers that were given at the symposium but were not available when this paper was written were Painter [1991] and Caro [1991].

[15]It is also possible for all households to face the same constraints to improving small ruminant productivity, but because of differences among some households, there may well be different relevant solutions. In such cases, there will still be more than one recommendation domain.

[16]An important component in obtaining this understanding involves getting information on the indigenous knowledge systems possessed by the households. Such information is very useful in developing appropriate methods for improving and implementing strategies to improve the productivity of small ruminant production systems [McCorkle et al. 1987].

[17]Harman [1984] in her study in the Potosi region concluded egalitarian relationships do exist between men and women. She also found that in recent years, young women are increasingly leaving for seasonal work in the eastern lowlands and cities. Finally, in Peru the women are responsible for the small ruminants [McCorkle et al. 1987].

[18]Orlave [1980] indicated that in the Andes, the peak labor period for small ruminants occurs for shearing and slaughter.

[19]That is, in addition to that for draught animals which are cattle [Hatch, 1980]. Browman [1987] mentions the increasing shortage of land leading to priority being given to food crops at the expense of hay. Also related to this issue is a reduction in the length of the fallow period reducing grazing potential while at the same time increasing the need for manure to maintain soil fertility.

[20]Guillet [1980] provides some interesting insights on risk management strategies of Andean households.

[21]Coping strategies, in a sense, involve a flexible response to the need to maintain consumption levels. However, as just indicated in the text, the seasonal variability and uncertainty in the weather conditions, particularly rainfall, also means that such households will maintain a flexible response to variations in production conditions. This is likely to exist, particularly during the cropping season, when sequential decision-making (i.e., a decision-tree type of strategy) is likely to occur based on what happens as the season unfolds.

[22]I am unclear about the current strength of these as a result of the land reform program of 1952 [Clark 1968]. This obviously had a dramatic impact on communities and production practices. On the other hand, Browman [1987] observes that agrarian reforms did focus on re-establishing specific social institutions to enhance economic productivity.

[23]For example, in some areas of Peru, when cropping activity stops in a field, the land passes from individual to communal tenure until they cultivate the land again [Jamtgaard 1984].

[24]Apparently in parts of Peru, coordination occurs among several households in daily cropping and herding activities. although each household has its own plots and animals [McCorkle et al. 1987].

[25]In the context of this paragraph, sustainability is discussed in terms of ecological stability. Much of the preceding discussion in this paper is implicitly concerned with developing strategies that are sustainable as far as the individual household and exogenous factors are concerned. Another paper given at the symposium addressed the issue of sustainability in some detail [Grove, 1991].

[26]Responding to the 'felt' needs of farmers is one of the important characteristics of FSR.

[27]In the high-income countries such a convergence occurred through combining the implementation of technologies designed to ensure environmental stability with strong policy/support systems involving a heavy degree of subsidization to encourage their adoption.

[28]Possible strategies include: ex ante screening of all technologies to ensure they will have no negative environmental impact; developing technologies that have both a production and conservation impact (e.g., agroforestry); and bringing about a convergence between policy/support systems designed to promote production and those designed to promote conservation, through improving the potential for a carrot-and-stick approach.

[29]Because of the time-consuming nature of data collection followed by delays in analysis and writing, multi-purpose farm management surveys are no longer so popular. Instead, special studies and surveys that have more limited objectives, which are implemented and processed fairly rapidly, are becoming more popular [Worman et al. 1990]. These studies/surveys sometimes explicitly try to relate technical and socio-economic variables.

[30]In some circles, these techniques have received some emphasis in recent years, particularly in assessing the potential impact of policies. See, for example, Singh et al. [1986], Maggraf [1986], and De Janvry et al. [1990A: 1990B].

[31]With respect to this, Anderson et al. [1985] review the role, contributions, and limitations of socio-economic modeling of farming systems. Bennett and Macpherson [1985] provide an even more skeptical view of its value.

[32]Sometimes called sondeos or rapid rural appraisal.

[33]These works tend to concentrate on the crop sub-system. Nevertheless, they do contain much information on techniques that could be applied to the livestock sub-system as well. Useful references are Andrew and Hildebrand [1982], Caldwell et al. [1987A: 1987B: 1987C], CIMMYT [1988A], Frankenberger and Walecka [1987], Hildebrand and Poey [1985], Shaner et al. [1981], and Zandstra et al.[1981].

[34]Surprisingly, however, a few years ago, a survey of 41 FSR-type projects revealed that only 12% undertook RMRI trials, while only 46% undertook FMFI trials [Barker and Lightfoot, 1986]. Thus in many cases farmers are not well integrated into the research process. The results of the same survey also revealed only 32% of the FSR projects undertook all three types of trials.

[35]Siebert also found those groups of farmers useful who offered their opinions on possible treatments in design RMRI trials [Worman et al. 1990].

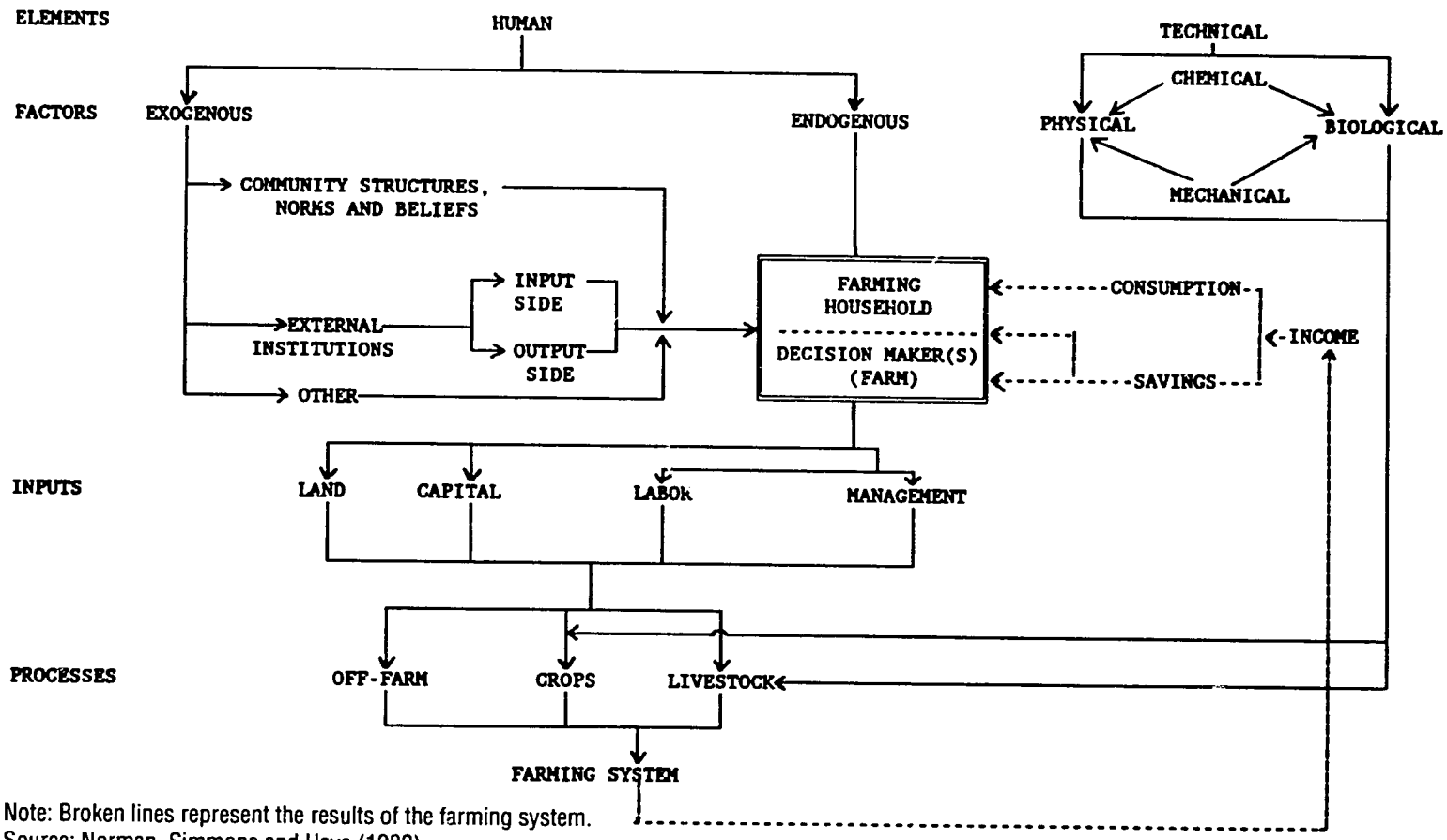
[36]Worman et al. [1990] provide a general review of the techniques, while Amir and Knipscheer [1989] provide more specific information on specific techniques. For example, they discuss partial-farm techniques of various sorts, including partial-budget analysis, gross-margin analysis and bread-even analysis. CIMMYT [1988] provides a clear description of marginal analysis using on-farm trial data. Another useful reference on the techniques of economic analysis is Dillon and Hardaker [1980].

[37]Unfortunately greater incorporation of the household — the ultimate customer of trial work — in the evaluation process results in more qualitative 'softer' type of data, usually less acceptable to those responsible for such decisions. Related to the issue of these consumers is the need to include in any recommendation produced specific information that will enable it to be successfully adopted by more farmers. In this regard, targeting information (i.e., stating under what technical and socio-economic conditions the proposed strategy would be most applicable) and conditional clauses (i.e., stating what to do under circumstances different from those originally envisioned in the recommendation) are particularly useful {Norman 1991}.

[38]One possible way to partially compensate for this factor is to assume that a high financial internal rate of return (IRR) is necessary to attract producers. For example, in work on improved grazing management strategies and forages in Peru, Jaramillo et al. [1985] assumed a minimal IRR of 25% was necessary to attract producers.

FIGURE 1

SCHEMATIC REPRESENTATION OF SOME FARMING SYSTEM DETERMINANTS



Note: Broken lines represent the results of the farming system.
Source: Norman, Simmons and Hays (1982)

The Socioeconomic and Cultural Context of Andean Pastoralism

Constraints and Potential for Biological Research and Interventions

Deborah A. Caro
The Futures Group, Washington, D.C.

INTRODUCTION

In 1988, Jorge Flores Ochoa threw down a gauntlet to researchers and developers interested in Andean pastoral systems. He chastised foreign researchers and developers for promoting European animal species at the expense of an ecosystem to which camelids are peculiarly adapted. He challenged us, instead, to look for a sustainable pastoral system in native Andean animals and technology rather than in improving conditions that favor the production of sheep and goats—conditions which he perceives to be ultimately destructive to the Andean ecology (Flores 1988).

Flores argues that camelid pastoralism offers a comparative advantage for Andean countries due to native Andean camelids' adaptation to the altitude, climate, and flora of the altiplano and cordillera, the relatively high price of alpaca fiber, and the excellent source of protein provided by camelid meat.

This paper presents an overview of some relatively recent changes in agropastoral and pastoral production systems in the Andean highlands of Bolivia. It takes Flores' challenge seriously in examining the socioeconomic conditions which have increasingly undermined the importance of Andean camelids in pastoral and agropastoral communities and have promoted what Flores has termed the "ovinization" of the Altiplano. It argues for an alternative research strategy focused on Andean camelids, the means of improving the marketability of their products, and developing approaches to land management which will encourage agropastoralists and pastoralists to increase the numbers of these animals in their herds. The point of departure of this research would be the expertise of Andean herders and the problems they confront in trying to improve their animal production and management systems. The focus would be on the recuperation and wider dissemination of local management practices, interactive problem-solving among researchers and herders, financial, infrastructural and technical support for implement-

Previous Page Blank

ing those solutions, and on-farm/on-ranch research that responds to the herders' concerns. This argument is not based on some romantic notion of an idyllic Andean past, but rather on a belief that Andean animals managed under improved Andean technology is the most efficient means of reestablishing sustainable agropastoral production systems in the Altiplano.

Overview of Agropastoral and Pastoral Production Systems in the Bolivian Highlands

There is considerable variability among agropastoral and pastoral production systems in Bolivia. Therefore it is difficult to describe one set of constraints and opportunities which will guide research. Nevertheless, a few trends can be discerned which allow us to speak broadly of three types of community-based pastoral production which are either complementary to or complemented by agricultural production: 1) an agropastoral system where agriculture and herding are fairly equal and complementary activities—sheep are the most important animals both numerically and commercially; 2) a pastoral system complemented by agricultural production—llamas predominate in importance culturally and for interzonal trade, but sheep have become increasingly important as a source of cash; 3) camelid pastoralism, occasionally supplemented by direct agricultural production in adjacent ecological zones—herds are chiefly composed of alpacas, llamas and sheep, in that order of importance. The sale of alpaca fiber is the principal source of cash income for this last group of herders. I will summarize the annual calendar of productive and exchange activities, the land tenure patterns extant in each type of production system, labor requirements and constraints, and sources of cash and in-kind income for households in each of the three regimes.

Type I: Agropastoral communities in Pacajes[1]

The agropastoral communities described by Birbuet in the Pacajes Province of the Department of La Paz span an altitude of 3,820 to 4,000 meters above sea level. The climate is cold and dry, with an annual precipitation of 400 mm per year. Low temperatures and lack of rainfall make agriculture an extremely risky endeavor (Birbuet 1989:10).

Description of production system

Pastoral production is the principal mechanism through which herders attempt to compensate for the uncertainty of agricultural production. Agropastoralists in Pacajes invest income derived from the sale of agricultural products in the purchase of animals during the rainy season (November to March). Over the course of the dry season (April to October) agropastoralists decapitalize their herds to cover their cash and subsistence needs. Barley cultivated by the agropastoralists supplements native forage during the lean months of the dry season.

Herd size and composition

A sample of 10 households studied by Birbuet demonstrates that sheep herds range in size from 20 to almost 200. Sheep represent 86.5% of the animals in family herds. Other animals include cattle (5%), llamas (.5%), and pigs (4%). The predominance of sheep in the herds and the absence of Andean camelids is due to the following factors: 1) Individualized land holdings and the consequent parcelization of lands discourages llama pastoralism. It is easier to contain sheep in a smaller area than llamas who move gradually all day while nibbling daintily. Their tendency to wander across property boundaries creates conflicts over land among households (Birbuet 1989:13). Parcelization of land holdings has also resulted in a haphazard distribution of agricultural and pasture lands. When communities conformed to the discipline of an aynoka system, pasturelands were usually not contiguous with agricultural plots. Therefore, animals could wander while grazing without endangering cultivated fields. 2) Cattle owners reserve pasture for their cattle for use during the dry season. This practice further restricts pasture available for llamas. 3) There is no tradition of alpaca herding in the communities studied by Birbuet, although neighboring communities do herd alpacas despite the paucity of bofedales. Those alpacas have adapted to dry pasture year round (Birbuet 1989:14).

Herd size varies over the year. Between January and June, herders invest agricultural surpluses in increasing their herds. Animal numbers decrease between July and December due to scarcity of forage, increased susceptibility to disease, and increased sales to cover household subsistence needs (Birbuet 1989:16).

Land tenure

Agropastoral households in the Caquiaviri and Comanche areas of Pacajes own individual plots of land which they designate for both herding and agriculture. The Agrarian Reform imposed a system of individual land holding which was contrary to the system of communal land management extant in these areas prior to the reform (Birbuet 1989:39). This change in tenancy patterns has likely undermined one of the most effective means of achieving a sustainable agropastoral system in the Andean highlands. Joint management of communal resources favors an effective distribution of different types of productive resources among community members according to household size and needs. It also allows the community households to rotate pastures and to protect crops from animals (Birbuet 1989:39-40).

Herding practices

While the most concentrated period of activity related to the herds is during the rainy season, there is considerable variability among households in the timing of these activities. For example some families mate sheep in August, while others do it in January. Similarly, three different families cited widely divergent dates for when they clip tails and castrate their sheep (January, April, and September). Different families also chose quite diverse times of the year to shear their sheep. The diversity of individual choice exercised by the different households in timing these various activities contrasts greatly with the disciplined scheduling of activities in communities where camelid pastoralism predominates.

Labor Use and Availability

There is a notable difference in the division of labor by gender with regard to the number of labor days dedicated to different activities. Over 70% of men's time is dedicated to agriculture, while over 80% of women's time is invested in the herding and care of animals, particularly small animals such as sheep and pigs (Birbuet 1989). Cattle, however, are chiefly but not exclusively the responsibility of men. The demand for pastoral labor for both sexes is highest during the rainy season between January and March.

Young children of both sexes, under the tutelage of their mothers, are a vital source of herding labor in the household. Thus, one consequence of school attendance has been to severely restrict the pool of herders. Adult women compensate for this labor shortage by herding more animals on

smaller amounts of land and by forgoing other complementary economic activities, such as weaving. Labor is a key constraint in permitting agropastoral households to utilize the lands available to them.[2]

Market relations

Animals in agropastoral communities are principally a source of cash and savings. Agropastoralists invest monetary income from agricultural products in animals. When households find themselves short of cash, they sell animals. Most weekly markets and fairs in agropastoral areas are animal markets (Birbuet 1989:21).

Women are the principal buyers and sellers of butchered animals (mostly sheep) in the regional markets. Women also make most of the decisions with regard to which and how many sheep to sell at any particular time (Birbuet 1989:24). The sale of meat and animals on the hoof is more common in these areas than the sale of wool and skins. Most wool is used for domestic consumption, but occasionally women will sell wool for petty cash to purchase food in a weekly market (Birbuet 1989:28).

Increasingly, a common economic strategy in these communities is a dual residence pattern, whereby husbands reside the majority of the year in La Paz, while wives and young children remain behind to care for the animals and agricultural fields (Birbuet 1986:55). This shift is a response to increased pressure on land in the area.

Major trends and implications

Birbuet draws several salient conclusions about the current situation in agropastoral communities (Birbuet 1989:106-112):

1) Differences in herd size and composition among households are as much a function of the economic strategies by which households are articulated with the market as they are a factor of families' access to pastures.
2) The decline in the llama population in these communities is due to the waning importance of llamas as pack animals, legal restrictions and urban prejudices against the sale and consumption of llama meat, difficulties of herding llamas on small individualized parcels of land, and incompatibility of herding llamas and cattle because of their conflicting pasture needs.
3) Household consumption needs, rather than herd size, are key in determining the number of animals particular families sacrifice for sale—wealthier herders do not necessarily sell more sheep.

4) There is a clear division of labor by gender: men dedicate most of their time to agriculture and the care and marketing of cattle, while women, aided by their young children, manage all aspects of sheep production and commerce. Formal schooling of children has created a serious labor shortage within these communities.[3] This shortage of labor affects the care of the animals and increases, along with the parcelization of land holdings, the tendency toward overgrazing.

Despite the high incidence of individual land holding in Type I communities, labor availability, not land, is the key indicator of economic well-being among different households. Extended families that manage their resources in common can achieve a more efficient allocation of productive resources than can nuclear families.

Type II: Llama pastoralism in Pampa Aullagas, Oruro; Laguna Colorado, Potosi; Macha, Northern Potosi

The difference between Type I and Type II communities has less to do with ecology and altitude than with proximity to urban markets, labor availability, land tenure, and regional histories. Type II communities are characteristic of the southern altiplano (the south of the Department of La Paz, Oruro, and Potosi). In the 19th Century and up until quite recently these llama-producing areas were instrumental in moving large quantities of agropastoral products between diverse ecological zones. Llama transport was critical to assuring the subsistence of indigenous communities in the altiplano and intermontane valleys as well as essential for the commerce of minerals and manufactured goods in the vicinity of mining centers (Torrico 1990:9).

Many of the trends discernable in Type I communities, such as increased parcelization of land, gender polarization of herding activities, and an increase in sheep herds at the expense of camelids are also evident in Llama herding communities (Molina 1983). Torrico discusses increased agricultural production in the highland fields which formerly were used exclusively for pastures as a consequence of the waning importance of llamas as beasts of burden. This shift has put additional pressure on scarce pasture resources (Torrico 1990: 33).

Description of production system

The primary subsistence and commercial activities of these communities are derived from llama and sheep production. Llama transport and llama products such as wool, meat, and dung are the principal source of income

(Liberman 1990:210). Agriculture in these communities, principally the cultivation of potatoes and quinua, also provides a partial yet important source of household food but contributes little in terms of cash income (Liberman 1990; Molina 1983). All households in Type II communities are dependent on barter or market exchange for providing a significant portion of their subsistence food needs. The herders obtain maize, a major component of their diet, exclusively through barter exchange or market purchase. Most households must also supplement their own production of potatoes through barter or purchase.

Herd size and composition

Herd size and composition varies considerably from place to place and among households within the same communities. A census of animals in Pampa Aullagas during the drought year of 1983 revealed 13 families with no llamas at all to llama herds ranging in number to more than 31 (8 families). Most families (50%) owned between 6 and 30 llamas. A surprising 32%, however, owned 5 llamas or less. Forty-six percent of the 50 households surveyed owned 31 or more sheep (Molina 1983:18-19).[4]

Liberman cites considerably higher figures in the Sud Lipez, where llama herds average 100 head. Households with 60 or less animals are considered poor, while those with 400 or more are regarded as wealthy (Liberman 1990:211). Households own additional sheep and goat stock of undetermined numbers. In Macha, household herds range in size from 75 to 240 llamas and 30 to 300 sheep. Additionally, families own up to 20 cows and as many as 10 pigs or donkeys (Torrico 1990: 65). Alzerreca and Jerez report much smaller herds, averaging 12 llamas and 30 sheep, for the community of Japo in the highland area of the Department of Cochabamba (Alzérreca and Jerez 1989: 11).

Land tenure

Generally, land titles in Type II areas are communal, with each household or groups of related households having usufructuary rights to specific areas of the community. Two common misconceptions about land tenure are common in Type II communities: 1) that communal tenure means free access by all households to all pastures in the community, and 2) that communal tenure combined with individual ownership of animals provokes a tragedy of the commons, resulting in severe overgrazing in these communities (Alzérreca and Jerez 1989:9).[5] Despite communal titles, each household has specific and recognized usufructuary rights which are inherited from

their ancestors. Contrary to provoking a tragedy of the commons, several authors have argued that the great flexibility in communal land tenure systems with recognized usufructuary rights allows herders to redistribute pasture resources among households according to relative changes in their herd sizes and labor pool (Caro 1985, 1989, Molina 1983, Torrico 1990).[6] Torrico presents a compelling comparison of two communities in the Macha ayllu, one of which opted for individual land holding, while the other maintained communal rights. Overgrazing and land shortages are much more severe in the first community (Torrico 1990).

Herding Practices

There is considerable variation in herd management practices among these communities. Some common elements, however, are evident. Women are chiefly responsible for the daily herding and management of the animals. They take the female llamas and sheep to pasture early in the morning, often walking several kilometers to grazing sites, and return late in the afternoon leading the herd into a corral for the night. Male household members are usually responsible for the care of male llamas who are left to graze alone on hillsides or in more distant pastures. Every few days a male member of the household checks on the herd to make sure that the animals have not strayed too far, are healthy, and have not fallen victim to predators.

Labor Use and Availability

The most intense period for activities related to the care of the herd is in the rainy season from November to March. This is the period during which the animals are shorn, mated, born, and marked (branded) and during which the demand for labor is greatest. In addition to these special activities, Torrico describes the following daily labor needs in Macha: one herder to pasture the female llamas and sheep, one herder to oversee the male sheep, and one man to check on the male llamas (Torrico 1990:69).

The declining importance of llamas as pack animals for interzonal trade and the consequent increased cash needs of herding households to replace items formerly acquired through barter has prompted household members (mostly men) to seek temporary and occasionally permanent employment outside their communities (Liberman 1990; Molina 1983; Torrico 1990). In addition to covering the subsistence needs of the household, herders in some communities invest income from wage-labor employment in repopulating their herds.[7] Molina estimates that income in cash and in-kind are derived fairly equally from wage-labor and barter. He argues that the decision to

work for wages outside the community hinges on the availability of labor within the household. There is a clear, direct relationship between the number of economically active household members and income (Molina 1983:34).

The trend toward increased dependence on income from wage-labor activities has also had an impact on the division of labor within herding communities. Pastoralism has become virtually the exclusive domain of women and their young children of both sexes (Liberman 1990:203; Molina 1983:14; Torrico 1990:33). Nevertheless, this trend has not been accompanied by a cultural depreciation of the importance of herding, contrary to the usual assumption that tasks that are identified as female are somehow inferior. Women's management and administration of the herds accords them a particularly high status and a great deal of economic power and political influence in Andean herding communities.[8]

Market relations

The major source of subsistence in Type II communities is pastoral products such as meat, wool, skins, dung (for fuel and fertilizer), and textiles, whether for barter or sale. Meat is the most important of these products in both exchange systems (Liberman 1990:219-220; Molina 1983:28). Animals are sold either butchered or on the hoof. Barter and market exchange are by no means closed and separate circuits of exchange. The herders move products between the two types of exchange systems with great versatility. A transaction might begin in the market with the sale of wool or meat and the purchase of manufactured goods which are then bartered in intermontane valleys for agricultural products.

Major trends and implications

Two apparently contradictory trends emerge out of the literature on Type II communities. Molina notes a decrease in barter and agricultural activities with a consequent increase in pastoral activities and wage labor. Torrico notes an increase in agricultural activities and wage labor on the part of men as a consequence of demise of llama transport in rural areas surrounding the mines. Women seem to dedicate most of their time to herding, while men allocate most of their labor to agriculture and income-generating activities outside the community. Due to a decrease in herd size, women's labor employed in the care of the animals is less intensive than in the past and can be simultaneously invested in weaving. In both cases an increase in wage-labor outside the community is due to a reduction in herd size and a

decrease in the importance of llama transport. In Pampa Aullagas during the drought of 1983, men opted for investing their time in wage-labor activities, forgoing agricultural tasks which promised meager returns. In Macha, men withdrew from herding tasks in order to invest their labor in agricultural production and wage employment outside the community. Liberman reports similar trends in Sud Lipez, where she noted a high incidence of temporary male out-migration especially to neighboring mines and to Chile and Argentina. Barter exchange, however, has by no means disappeared in any of the three areas. The herders in all of these regions continue to barter with agricultural communities, a system which continues to offer them options to unfavorable terms of exchange in the market.

Type III: Alpaca pastoralism in the Ulla Ulla Region, La Paz

Description of production system

The Ulla Ulla region in the Franz Tamayo Province of the Department of La Paz is the largest area of alpaca production in Bolivia, with an estimated 75 percent of the alpaca population of the country.

The altitude and low diurnal temperatures preclude crop production in the herding area. The primary occupation of approximately 600 Aymara-speaking families is herding alpaca, llama, and some sheep. Ulla Ulla herders practice a transhumant form of pastoralism, moving their flocks between *bofedales* in the dry season and dry rangelands during the rainy season. Some families also cultivate potatoes in the intermontane valleys to the east. All herders barter with valley agricultural producers for potatoes, corn, and wheat. Some travel with their llamas on trips lasting up to one month, while others travel by truck on shorter trips of one or two days' duration. Alpaca and sheep wool is sold for cash or woven into textiles. Llama wool is mostly left on the animal, especially on males, where it serves as a protective mat between the animal and its cargo.

The herders live in dispersed hamlets (*estancias*) usually composed of four to ten households, although they can be as large as thirty and as small as one. The *estancias* are loosely grouped into ten communities called *nucleos agrarios*, which were formed by the Agrarian Reform in 1953. Prior to the Agrarian Reform, these communities were part of larger social groups called *ayllus*.

HERD SIZE AND COMPOSITION

Herds range in size from as few as 10 or 15 animals to as many as 2000. Most families have herds composed of about 100 alpacas, 30 sheep, and 40 llamas. Female animals outnumber males in a ratio of approximately 2 to 1.

Production yields from mating are very low. A little over half the females of a given herd are bred each year; the remainder either give birth too late in the rainy season to mate for the following year, or are too old, too young, or barren. Only about 50 percent of the new offspring survive each year. The rest commonly die of disease, of lack of nutrients (especially in very dry or cold years), or at the hands of predators (foxes and condors).

The yearly growth rate varies with the size of the herd. For example, in a herd of three hundred alpacas, two hundred would be female. Only one hundred of those would produce offspring in a given year, and of those half would die. Approximately 12 animals would be consumed by the household over the course of the same year. Thus, the net yield would be 38 animals or a growth rate of about 13 percent. In a herd of one hundred, in contrast, only about 34 females (to use an even number) would produce young, and of those, about 17 would survive. Assuming that this family would also consume 12 alpacas, the increment to their herd would be only five animals, or a growth rate of 5 percent.

Thus, many poor herders attempt to acquire additional animals through the exchange of their labor or through marriage. At the other end of the spectrum—a herd of one thousand or more—the growth rate is obviously greater, though probably limited somewhat by the quality of care which the animals receive. Wealthy herders employ more non-family labor than other herders. Non-family herders do not attend the animals with the same care they would extend to their own. Thus wealthy herders lose a greater percentage of their animals to disease and predators than do middle herders who intensify the care given to the animals in order to increase their yields.

Herders can manipulate the expansion of their herds by intensifying labor and expanding pasture area, but they are limited in doing so by similar actions among competing households. The level of herd viability, culturally defined as 50 animals, is tantamount to the ability of the household to retain control over its own labor.[9] Growth of the herd allows the household to control labor beyond the domestic unit and to employ household labor freed from herding chores in the production of textiles and in commercial and non-commercial exchange. Increased production of textiles and wool can be converted in turn into a wider network of social relations. Often the ques-

tion of optimal ratios of humans to animals in pastoral societies is framed in terms of the number of herders needed to herd a certain number of animals. In the Andes, it seems more appropriate to ask how many animals are needed to retain a certain number of herders.

LAND TENURE

In 1976, the *nucleos agrarios* of the Ulla Ulla region received legal titles to their lands from the Agrarian Reform office. The herders were given communal titles establishing all pastures as common for use by members of the community. The herders, however, follow other norms which regulate the division and distribution of pastures among families. A temporary visitor to the region would be hard pressed to find discernable signs of any social or territorial boundaries delimiting social groups larger than the *estancias*. Individual *estancias* function quite autonomously, although they are loosely connected through kinship and marriage ties.

In contrast to agropastoralists in many parts of the altiplano, the herders are not property owners in the sense of exercising exclusive and individual rights of possession. Consequently, the herding communities of Ulla Ulla have not suffered from the division of communal lands into *minifundios* (small peasant landholdings) as has occurred in many agricultural areas of the Andes.

The division of pasturelands among herders is based on a delicate balance between the control of family and extra-family labor and the number of animals possessed by *estancia* households. A family with a large herd and available labor, for instance, can control more pastureland than a herder with fewer animals. Wealthier herders commonly recruit labor from poor families as a means of dispersing their herds over greater territory. Even within an *estancia*—generally composed of a group of siblings and/or cousins, their spouses, children, and parents—the household which takes its herd out earliest in the morning can take advantage of the best pastures. Those who follow later necessarily pasture their animals in areas with sparse or inferior vegetation. Most families in an *estancia*, however, cooperate in the administration of pastures and thus rotate the herds of different households among pastures of varying quality and distance from the homesteads.

Many factors condition the relative wealth among community members. The wealth of a particular family in land and animals can change radically from generation to generation. The herders recount endless stories about families who were once rich but whose descendants are now poor. The explanation they offer for such changes is that families suffer alterations in fate due to rustling, epidemics, bad luck, and/or natural disasters. In the

instances where people have suffered such a radical change in fate so as to lose their animals and lands, they have been absorbed into other families through marriage or as herders for rich families, thus losing (at least temporarily) their active rights to lands in their natal *estancias*.

Herders inherit usufructuary rights to pastures by virtue of being born into a particular *estancia* or through such rights transmitted to them by parents and grandparents living in different *estancias*. The ideal representation of the inheritance of grazing rights is that all children, grandchildren, and great-grandchildren who retain the paternal surname of an original male ancestor have usufructuary rights to lands pertaining to that ancestor. Preference to activate those rights inclines toward male descendants, as long as they maintain their herds on *estancia* lands. Most women lose their active rights to these lands, not because they are women, but because they remove their animals to their husbands' *estancias*. In this sense, it is a misconception to view the transmission of usufructuary rights as an inalienable inheritance of lands. Women can reactivate their own rights to their natal estancia by asking permission to herd their animals there from their fathers, brothers, or male cousins who reside on the *estancia*.

Herding practices

The one activity that is constant throughout the year is the daily tending of the animals while they graze. Typically, the herd is divided into three groups: 1) male alpacas and llamas; 2) female alpacas and llamas; and 3) sheep. The male alpacas and llamas graze separately and require a minimum of supervision. Some families even leave them out to pasture for a week at a time, checking them only periodically to make sure they have not strayed or fallen prey to predators or rustlers. In less protected estancias, the male animals are released each morning and brought back each afternoon without being tended by a herder while they graze. The female herd and the sheep need constant attention.

Alpacas and sheep are shorn every two years for both sale and domestic uses such as weaving, knitting, and barter. Llamas are shorn only for the production of ropes. Generally shearing takes place during the months of November through March, although the herders shear at any time during the year when they have an immediate need for cash. They prefer to shear in November and December, since they believe that the rain washes and irrigates the animals' wool and skin in the same way rain irrigates a field to produce a better crop the next time they shear the animal. When the National Wool Institute (INFOL) suggested that the herders shear every year in April instead of every two years in the months of November and

December, the herders objected. They contended that if they sheared their animals only one year after the previous clip, they would not be able to leave enough wool on the animals to protect them from the cold weather, which sets in at the end of April. They also emphasized that shearing at the beginning of the rainy season washes the alpacas and allows the wool to grow back more quickly; in contrast, when they shear during the dry season, they say the wool does not grow back as readily. The herders shear older animals at any time during the year to meet domestic expenses as they arise. Often they kill these animals at the same time to make *charki* to take to trade in the valleys and they use the wool from the skins for their cash needs.

In December or January, the herders separate the two-year-old male alpacas, *ankuta*, from the female herd. At this time they examine the animals to determine which will serve as studs in the future.

Herding families butcher animals throughout the year. They prefer to call older and barren females and older males just after the rainy season when the animals are fattest. Slaughtering a live alpaca or llama requires the labor of three adults.

In May, some of the young male alpacas, llamas, and sheep are castrated. For alpacas and llamas, the process requires three people. One holds the animal's ears which quiets and steadies it; a second person ties the animal's two front legs to one hind leg and holds the free leg; and a third person performs the operation with a knife.

In June and July, and again in October, the herders treat animals infected with scabies. In June and July they also treat shorn animals with lard and DDT. Three people work one hour and ten minutes per animal applying the mixture three times to each one. Three pounds of lard and one pound of DDT are used for ten animals. In October, the herders make a general review of the entire herd. An extended family works from six a.m. to six p.m. checking males, females, and calves for scabies and the females for signs of pregnancy. They treat the animals with scabies with a mixture of *maych'a*, a wild plant, and lard. Two people ascend the *cordillera* to gather one hundred pounds of *maych'a* which they mix with two pounds of lard and apply to the infected animals. The pregnant females are marked with colored yarn so that they are readily identifiable even at a distance.

Families mark (brand) their year-old animals anytime from Christmas to Easter in a ritual called *maran allpaqa senalane*. The entire extended family marks their animals together assigning distinctive ear cuts to the animals of each individual in the *estancia*, including children.

LABOR USE AND AVAILABILITY

In addition to the daily grazing activities, the household fulfills numerous specialized herding tasks over the course of the year. The labor needs for daily herding are constant, while these other activities require additional workers. Households in hamlets often exchange labor among themselves to compensate for seasonal needs. The annual calendar of work, organized primarily around the productive and reproductive cycle of the herds, includes mating, shearing, butchering, curing, calving, branding, castration and separation of male animals, and daily herding. The most intense period of pastoral activities is during the rainy season, from November through March. During the dry season, April through October, the herders engage in complementary forms of production, such as tuber cultivation (potatoes and oca) in the high valleys, weaving, and barter with people in lowland valleys.

Labor requirements for pastoral production vary over the course of the year. During the rainy season extended families and sometimes entire *estancias* work together to mate, shear, and butcher animals. Large- and medium-scale herders often must recruit additional labor during this period, especially if family members are away at school, in the army, or temporarily working outside the area.

In contrast, during the dry season most families have surfeit labor, since few people are needed to fulfill the minimum requirements of daily herding. Women weave during this time. Younger women usually combine weaving with herding by carrying their looms with them to pasture. The animals are easier to watch during the dry season, since they are grouped more closely together in a *bofedal* than when they are scattered extensively over dry pastures in the rainy season.

Even daily herding requires varied labor imputs during different seasons. *Estancias* with large *bofedales* frequently group their animals together during the dry season so that one herder can oversee the entire herd. The herd moves little and remains fairly confined within the boundaries of the *bofedal*, since the moist pasturage is rich and a small area provides for hours of grazing. During the rainy season each nuclear family separates out its own herd and pastures alone near its *jit'ina*.

Thus each smaller herd requires its own herder. Families in other *estancias* with small *bofedales* but possessing extensive flat dry pasturelands might practice the regime in reverse. They pool their animals during the rainy season and divide them up in the dry season since their *bofedales* cannot support large herds. The seasonal routines vary from *estancia* to *estancia*, not only in relation to an *estancia's* topography, but also according to the labor available and the size of the herds.

Labor inputs for each type of specialized pastoral activity vary with herd size and the number of family members available in each household during different times of the year. The amount of labor required for mating, for instance, depends upon the size of the mating cohorts. Usually, mating about ten pairs at a time requires the work of a minimum of three people. One must hold each female animal while another binds its legs, and a third person directs the mating by releasing the males one by one into the corral and guiding them to the designated females. During the two-hour mating period (not all animals mate for the entire time) the three in charge keep vigilance over the proceedings to make sure that several males do not gang up on one female and that females already mated successfully are not mounted again.

Market relations

The degree of market integration influences the amount of wool sold by a household. Herders from Hichocollo and Súchez, for example, acquire more of their food through the market than herders in Coololo who produce potatoes in Pelechuco and barter for potatoes and corn in the eastern valleys. Herders from Súchez claimed that an average family sold three to four hundred pounds of wool per year. Middle herders in Hichocollo reported a similar amount, even though most Suchez animals are fed on dry pasturage while most Hichocollo animals are grazed in *bofedales*. Herders in Coololo sold between one and two hundred pounds per year, even though their herds grazed in both *bofedales* and dry pasturelands. With the exception of poor herders (less than fifty animals) and wealthy herders (more than one thousand animals), herd size did not influence greatly the amount of wool sold in a year. Thus two families with three hundred animals might sell very different quantities of wool per year depending on their particular cash needs. Similarly, families with different size herds but with comparably sized families at the same point in the domestic cycle shear about the same number of animals. For instance, in one *estancia*, a herder with three young children sheared 32 of his 66 alpacas (48 percent), while his brother-in-law with four young children sheared 40 of his 213 alpacas (only eighteen percent). The herders prefer to retain their savings on the animals rather than in the form of stored wool, consumer goods, or cash.

Major trends and implications

Unlike many pastoral groups in other parts of the world where wealth is measured in numbers of animals, among Andean herders in Type III communities wealth is conceived of in terms of the number of laborers, both familial and extra-familial, that a household can draw into a network of reciprocal relations.[10] Labor cannot be stored, however, except in the form of products resulting from the expenditure of human energy in the transformation of resources. Ulla Ulla herders appear to make a conceptual distinction between the control over human labor as wealth and the concrete means by which wealth is stored in the form of assets which are readily convertible into labor. These products, especially animals and textiles, are the means by which Andean herders secure and increase their access to labor. In other words, wealth is stored in the form of herds, but the animals are thought of mainly as representing the number of people a particular household can potentially marshal for the care of its herd (Caro 1988).[11]

Increasing commoditization of agricultural and pastoral products in rural Bolivia has not had a major impact on relations of production in the Ulla Ulla area in the way it has in other areas of Bolivia. The herders continue to rely predominantly on family labor, and even when they recruit laborers from outside the family circle, they remunerate these workers with animals and pastoral and agricultural products rather than with cash wages. On the whole, they invest very little money in the production of their herd; most of their inputs are in the form of local resources and family labor.

Nevertheless, the herders exchange relations with agricultural trading partners in the valleys, and the wool intermediaries have been undergoing significant changes since the land reform period. The herders have tended to barter less and to buy and sell more. As their dependence on the market for provisioning their households with food, clothing, and school supplies has increased, so has their exploitation by intermediaries and the state, chiefly through a devaluation of their primary cash crop, wool.

In the last several years, the decreasing price of alpaca fiber relative to the increasing demand for gold has driven most male adult household members to prospect in the surrounding cordillera. Although they rarely leave their communities permanently in their search for other sources of income, the men's absence from herding activities on a daily basis has left women with the major herding burden. Consequently, women have less time for other activities, especially the production of cloth.[12]

CONCLUSIONS AND IMPLICATIONS

Land Tenure: Parcelization of holdings makes camelid pastoralism more difficult. But at the same time, increases in the sheep population inhibit camelid pastoralism because of competition for forage and a greater time lag in the recuperation of pastures. The usual sheep-oriented solution is to suggest fencing as a strategy for pasture rotation. But rather than improving pasture availability, this approach aggravates the trend toward parceling holdings and intensifying animal/pasture ratios. Flexibility of pasture use among households is the key to an effective camelid-based pastoral system in the Andes.

Labor: Increasing dependence on market exchange by pastoralists and agropastoralists has increased their need for cash and undermined their production system by forcing herders to seek employment outside their communities. This dependence places considerable stress on household labor reserves, resulting in poor management of animals and pastures. Women assume the major burden of the rural production system while their husbands and older sons and sometimes daughters seek employment in cities, mines, and commercial agriculture. Many economic activities that were once integral to the rural production systems—such as weaving, interzonal barter, food processing, and diversification of crop production—wane in importance to the point of disappearing. Molina has argued that these complementary economic activities provide the vehicle by which pastoral communities are integrated into the market without being destroyed by market relations (Molina 1983:11). I have argued elsewhere that the diversity of productive activities and the complex of rights and values guiding access to productive resources within pastoral communities have allowed herders to retain control over their labor while actively participating in a market-driven economy (Caro 1985).

SUGGESTED RESEARCH

- Improvement of llama fiber
- Research on the adaptability of alpacas to dry pastures
- Herder preferences on herd size and composition
- Adaptation of indigenous technology on introducing genetic variability into their herds
- Testing of biological innovations under varied conditions of land tenure and labor availability (farm modeling)
- Criteria for success should be economic and ecological sustainability and not production/yields

BIBLIOGRAPHY

Alzérreca A., Humberto, and Boris Jerez C. 1989. *Análisis y propuestas para el manejo de praderas nativas, pasturas y ganaderia en la comunidad de Japo.* Cochabama: Universidad Mayor de San Simon, AGRUCO Serie Tecnica No. 20.

Birbuet Díaz, Gustavo. 1986. *Tierra y ganado en Pacajes.* La Paz: SEMPTA.

—-. 1989. *La ganadería campesina en Pacajes: estudio en el area de Caquiaviri y Comanche.* La Paz: SEMPTA.

Caro, Deborah. 1985. *Those Who Divide Us: Resistance and Change Among Pastoral Ayllus in Ulla Ulla, Bolivia.* Ph.D. dissertation. Baltimore: The Johns Hopkins University.

—-. 1988. "Reproducing Labor: Procreative Metaphors in the Accumulation of Herds and Cloth in the Andes." Paper presented at the 87th Annual Meeting of the American Anthropological Association, Phoenix, AZ. November 16-20, 1988.

Flores Ochoa, Jorge. 1988. *Llamichos y paqocheros. pastores de llamas y alpacas.* Cuzco: CONCYTEC.

Liberman, Kitula. 1990. "Aspectos Socio-económicos." In *Diagnostico de Recursos Naturales de la Reserva de Fauna Andina Eduardo Abaroa.* La Paz: LIDEMA.

Molina Rivera, Ramiro. 1983. "Crisis económica, sequía, y estrategias de subsistencia." In *Proyecto Extrema Pobreza en Bolivia.* La Paz: Ministerio de Planeamiento y Coordinacion, Documento de Trabjo No. 5.

Torrico, Cassandra. In press. *Women in Macha Herding Societies in Northern Potosi, Bolivia.* La Paz: HISBOL.

West, Terry L. 1988. "Rebaños familiares y propietarios individuales: ritual ganadero y herencia entre los Aymara de Bolivia." In Jorge Flores Ochoa (ed.). *Llamichos y paqocheros: pastores de llamas y alpacas.* Cuzco: CONCYTEC.

ENDNOTES

[1]The discussion in this section is based principally on one source, Birbuet 1989, due to the lack of good information on pastoral production in Bolivian Agropastoral communities. Most authors who have written about these communities have focused on agricultural production.

[2]Birbuet comments that there is a fundamental contradiction in agricultural production in Caquiaviri and Comanche: when families have access to less land, in order to cover their subsistence needs, they must cultivate a larger proportion of the land than people who have access to larger areas. He attributes the fact that larger landowners cultivate a smaller proportion of their holdings to scarcity of labor within their households (Birbuet 1986:58). Thus land size in itself is not a good indicator of wealth. The agropastoralists in this area of Pacajes measure wealth according to herd size, which is a factor of available herding labor.

[3]This shortage has no doubt been aggravated by temporary and permanent outmigration by young adults to the cities.

[4]Terry West cites a number for average herd size for Pampa Aullagas which is considerably higher: 40-50 llamas and 40-50 sheep. A rich herder is someone who has 100-200 of both species (West 1988:192). The difference in herd sizes reported by West and Molina for the same area no doubt has to do with the effects of the extreme drought conditions during 1982-83.

[5]"Es necesario remarcar que la particularidad de la tenencia de la tierra de pastoreo comunal y rebaño individual hace que cada comunario o familia capitalice la intensidad de uso de la tierra de pastoreo, lo cual conduce al sobre pastoreo y consiguientemente, el deterioro de la producción forrajera y erosión y agotamiento de los recursos de pradera nativa. La tenencia a la tierra intercomunitaria es una limitante estructural, para la implementación de un plan de manejo y poder aportar la carga animal con la capacidad de sostenimiento. Sin embargo, mediante la organización comunal es necesario adminstrar y reglamentar y el uso de las tierra de pastoreo comunal bajo la misma organizacion con la que se manejan las tierras de cultivo " (Alzérreca and Jerez 1989:9).

[6]See the argument below for Type III communities where this type of land tenure system is practically universal regardless of legal titles.

[7]Torrico says that Macha herders seem to control for a stable herd size based on the consumption needs of the household and the availability of forage. If normal processes such as slaughter, natural deaths, and ritual sacrifices reduce the herd below this ideal number, Macha herders repopulate their herd through purchases (Torrico 1990:70). Herders' decisions whether or not to migrate also depend on the size of their herds. Not surprisingly, herders with large numbers of animals do not migrate, since they can cover their household expenses through the sale of their animals and derived products. Households with small herds, however, seek temporary employment in cities. Upon returning to their community, their major investment is in sheep and llamas (Torrico 1990:66).

[8]"The reproduction of the herd depends on women's llamas, and their labor, or love, for their animals which is though to be the main factor affecting the fertility and procreation of the herd. For this reason, they are granted high status within herding societies" (Torrico 1990:64). Torrico also mentions that important men within Macha herding communities are known as awatiris, or herders, an occupational category that is overwhelmingly female. She cites this term as evidence that although women do not have as public a role in politics as men do, women's occupations provide the political symbolism for power.

[9]The ideal level of herd viability has an interesting parallel in ideal consumption levels. When asked how many animals a family consumes per year, people in Ulla Ulla invariably answered about one per month. A survey of eight households revealed that actual consumption varied between 8-20 animals annually. Variation depended less on herd size than on what stage the household was at in the development of the domestic cycle. Families with young children consumed the lesser amount. Thus it appears that the ideal of a 50-animal herd, which produces about 10 new offspring per year, correlates with the number necessary to maintain a stable herd if the consumption level varies between 8-12 animal per year.

[10]Standard anthropological treatments of wealth in pastoral societies focus almost exclusively on the size of herds; nevertheless, recent unpublished research suggests that certain East African pastoralists also emphasize access to labor as an important determinant of economic status (Barbara Grandin and Angelique Haugerud, personal communication). Approaching the study of pastoral groups with a focus on accumulation from the vantage point of labor-use patterns, rather than animals, might reveal intriguing comparisons about how pastoral groups have responded to market penetration of their relations of productions.

[11]This is one of the main reasons Andean herders have not responded favorably to researchers' and developers' suggestions to reduce the number of animals in their herds in order to improve animal nutrition, meat, and wool quality. Herders prefer to have more skinnier animals which are both a hedge against risks to the herd (greater numbers allow for faster recuperation of the herd after a drought or epidemic) and allow them to call on more laborers — the true measure of wealth in Andean terms.

[12]A notable change in women's clothing took place between 1982 and 1989 when I returned to Ulla Ulla after many years' absence. Women no longer wove and wore the brightly colored textiles for which they are renowned. When asked why they had changed their form of dress, they responded that they no longer had time to weave.

Changes in Highland Land Use Patterns and Implications for Agropastoral Development

Michael Painter
Institute For Development Anthropology

[This paper is produced by the Institute for Development Anthropology and reports on work supported by the Systems Approach to Regional Income and Sustainable Resource Assistance (SARSA) Cooperative Agreement No. DHR 5452-A-00-9083-00, at Clark University, the Institute for Development Anthropology, and Virginia Polytechnic Institute and State University, funded by the U.S. Agency for International Development, Bureau for Science and Technology, Office of Rural and Institutional Development, Division of Rural and Regional Development. The views and interpretations in this publication are those of the authors and should not be attributed to the Agency for International Development or to any individual acting on its behalf.]

INTRODUCTION

Agricultural researchers have long been noted for their insensitivity to the subtleties of local production systems that are not based on knowledge generated in an experiment station setting. The horror stories of promising new technologies and techniques of production that proved to have disastrous results when subjected to the real world constraints faced by farmers, particularly less well endowed farmers in poor countries, are by now legend. Altieri and Yurjevic (1989:17) summarize the problem confronting agricultural research as follows:

> Among the lessons to be learned from decades of . . .rural development efforts in Latin America, two stand out. One is that no single discipline or methodological approach can adequately address the range of biological, cultural, and socioeconomic processes that surround rural development. The other is that the great majority of technological innovations in agriculture have bypassed the campesino sector, which is mostly confined to marginal soils, hillsides, and rainfed areas. Despite the intentions of development programs and mostly because of institutional and political-economic biases, resource-poor

campesinos are increasingly subjected to subdivision of landholdings. This process, associated with environmental degradation, leads to a progressive decline in the significance of peasant agriculture in regional markets. Curbing this systematic impoverishment is crucial if further loss of food self-sufficiency and further soil erosion, deforestation, and dependency are to be avoided in Latin America.

Farming Systems Research (FSR) and its intellectual offspring have been an effort to deal with the methodological issue of disciplinary boundaries not corresponding to the sorts of problems confronting farmers in Latin America and elsewhere. Characterized by an effort to contextualize farm families in their social and economic environment—a focus on the production goals of farm families and the constraints on meeting those goals and emphasis on the interrelationships between the different components of family farming systems (e.g., livestock and crops)—FSR pointed the way to how we can direct agricultural research to solving the kinds of on-farm problems confronting poor rural families.[1]

A second current of efforts to deal with the inability of agricultural research has been housed within the agroecology and sustainable development movement (e.g., Allen and Van Dusen, eds. 1988).[2] It focuses on the knowledge and techniques embodied in traditional agricultural production systems and seeks to build agricultural development efforts from the bottom up" by promoting technologies and practices that derive from what farmers already know and depend on resources they already have. Agroecology in its various forms is an approach particularly identified with non-governmental organizations (NGOs).[3] Several characteristics make it particularly compatible with the discourse of many NGOs, including the following: 1) emphasis on the reproduction of the household; 2) emphasis on low-input and regenerative agricultural techniques that require a high level of local participation; 3) cultural compatibility, which results from beginning with traditional farming knowledge and combining it with selected elements of modern technology; 4) the goal of enabling peasant production to produce itself more efficiently rather than attempting to transform peasant production; and 5) emphasis on reducing the costs of production (Altieri and Yurjevic 1989:17-18).

Applied agricultural research is undoubtedly much better today for the contributions of FSR and agroecology, and research projects seeking to work with local production systems can learn much from both. Indeed, it would be irresponsible to attempt to undertake research with poor farmers and fail to draw on the lessons that each experience has to offer. At the same time, both approaches have methodological limitations that should be cause for

reflection at the outset of a new research effort. FSR, for example, has had difficulty defining the spatial and conceptual boundaries of its object of study (Little 1985).[4] In some cases, aspects of the physical environment draw the boundary around a study area (e.g., University of Chiang Mai 1980), while in others the defining criterion is the homogeneity cropping systems (e.g., Hildebrand 1977:8). Norman et al. (1982:108) comment on the problem, noting that the analysis of household-level issues is often complicated by the ways in which exogenous variables impinge on them. Little (1985:332) sums up the problem as follows:

> The understanding of interrelationships between components of the system — however defined — is integral to the FSR approach. But, analysis of systemic relationships usually is limited to different dimensions of the farm itself.

For their part, agroecological approaches react to some very serious problems associated with much agricultural research and development. These difficulties include the vulnerability of production systems based on high levels of chemical inputs, the negative health consequences of the contamination of rural water supplies by agricultural runoff, and the cycle of indebtedness, impoverishment and loss of land that many rural dwellers caught in agricultural modernization schemes have experienced. However, the agroecological response to these issues also offers major pitfalls to the unwary. For example, the emphasis on working with household production systems and the reproduction of rural households can lead to problems of boundary definition similar to those experienced by FSR.

More importantly, however, agroecological approaches also share with FSR a tendency to be ahistorical. They emphasize tapping farmer knowledge to recover traditional production techniques, but they do not necessarily analyze the processes that led to those techniques being lost. People do not simply forget or abandon production techniques; they lose them because they and their production systems are subjected to a series of pressures that render the techniques untenable. Studies of agrarian change in the Andes tell us that they rarely lost without a struggle by those losing them. To adapt traditional techniques successfully to modern production systems it is necessary to understand clearly the historical processes that led to their loss in the first place and to overcome them. Depending on the particular circumstance, this adaptation will normally involve some combination of technical innovation, community organization, and policy reform.

Similarly, while it is well to examine existing production systems as a starting point of applied research, it is well to remember that they are frequently but vestiges of production systems that have been under assault for

long periods of time. For example, Deere and Wasserstram (1980) suggest that most rural smallholders in the Andes earn more than half their income off the farm. For upland families with less than five hectares of land, the figure appears to range between 60 and 90 percent in different areas of the Andean region. This off-farm earning has meant that labor scarcity for most smallholders has ceased to be a largely seasonal phenomenon associated with periods of peak agricultural activity like planting and harvesting. Instead it has become a chronic condition, obliging rural families to sacrifice medium- and long-term resource management strategies in order to satisfy immediate survival needs (Collins 1987). The resulting cycle of impoverishment and environmental destruction often weighs particularly heavily on women and small children, who, because of the hiring preferences of wage labor markets, are frequently those who must remain behind and manage family farms during the prolonged absences of most adult males. In addition, the absence of much of the population for substantial part of the year often has disastrous effects on community and syndical organization (e.g., Gisbert et al. 1991).

In such a context, development projects that equate local participation with a high contribution of labor by beneficiaries must consider very carefully their assumptions about the appropriateness of the demands they are making on a rural population, and on how such activities really do fit with their idea of traditional production systems. Similarly, despite the long tradition of strong community or syndical organization in many areas of the Andes, and their continuing formal existence, institution building to consolidate and sustain improvements in agricultural production may require considerably more thought and effort than originally appears necessary. Furthermore, focusing on how farm families can reproduce existing production systems without considering their transformation over time may perpetuate the problems that many face, even when innovations in agricultural production offer short-term improvements in the material conditions of life.

This paper offers two case studies, one from the Peruvian altiplano and the other from the high valleys of central Bolivia, to illustrate the kinds of processes that can change rural production systems. Both areas are characterized by production systems in which crops and livestock each play an important role. The livestock component of the altiplano system revolves around cattle, sheep, and camelids, while livestock production in the high valleys is based primarily on cattle and goats. Each case study illustrates the interrelationships that exist between local production systems and factors that are typically discussed, but not carefully considered, as exogenous variables. By looking at the two cases together, we see how different local situations may be linked by larger social and historical processes.

THE PERUVIAN ALTIPLANO[5]

HISTORICAL BACKGROUND

At the turn of the century, one would have noted the first signs of the economic growth that was to shape the course of change in southern Peru in the coming decades. The railroad linking the city of Puno to the coastal port of Mollendo via Arequipa had been completed 26 years previously, in 1876, opening the area up to an unprecedented flow of imported manufactured goods. With the joining of the Puno rail terminus with that of Bolivia, in Guaqui, by a steamship connection across Lake Titicaca, the departmental capital had become an important collection point for agricultural exports from the Peruvian and Bolivian areas of the Lake Titicaca basin. The rail connection linking Puno and Juliaca to the major bulking center for the wool export industry, Sicuani, had been completed just three years before.

The changes in the transport network made themselves felt in both the urban and rural areas of the region. Puno's position as the departmental capital was enhanced by rapid population growth. In 1876, Puno's population was 2,729 people, only 166 more than the second city in the department at that time, Ayaviri. By the turn of the century, Puno was growing steadily, so that by 1940, with a population of 13,786, it was over twice as large as the new second city of the department, Juliaca. Juliaca, in 1876, had not even ranked among the dozen largest towns of the department, with a population of 516. However, it contained over 3000 people by 1919, and, by 1940, it had supplanted Ayaviri as the second-largest town in the department, with 6,034 inhabitants.

In the rural areas of the department, competition for grazing land between peasant communities and large estates intensified (Orlove 1978). This competition partially was manifested itself in the growth of the number of estates in the altiplano from 696 in 1876 to 3,375 in 1915 (Appleby 1978:43). In spite of this expansion, independent peasant communities remained strong in Puno, both as wool producers and in agricultural areas. The combination of generally increasing wool prices and urban demand for food raised incomes in the countryside, allowing the rural population to begin to constitute a market for a growing range of manufactured goods. This growth provided the basis for a strong regional commercial activity, with the lacustrine ports serving as important centers. Items such as imported Scotch whiskey were reported to be in more plentiful supply in towns around Lake Titicaca than in many major cities.

The collapse of international wool prices following World War I accelerated processes of economic differentiation and intensified land conflicts in herding areas. Estates sought to counter falling prices by increasing production so that gross revenues might remain relatively stable, even as per-unit

earnings dropped. They expelled resident peasants, who had their own herds of animals and grazing rights on the estates, and attempted to expand onto the lands of peasant communities (Orlove 1977). The displacement of estate peasants and the search for ways to make up for revenue shortfalls by peasants in independent communities accelerated the process of urbanization that was already taking place. As rural dwellers moved to the towns in search of employment, the already growing urban demand for food increased, initiating fundamental changes in the social relations surrounding the marketing of agricultural products and intensifying competition in the countryside for access to the best agricultural land (Appleby 1980:43-44).

Renewed efforts to displace peasants in the herding areas and heightened competition over land in agricultural areas interacted with changes at the level of peasant production itself and led to violence in many areas of the region by the 1920s. By 1923, the peasantry of the Lake Titicaca Basin had established linkages with several institutions and interest groups outside of the region who were sympathetic to their situation and willing to be supportive to some extent of their struggle against the regional elites. One of the institutions that built strong ties to the peasantry was the Seventh Day Adventist Church, which had undertaken missionary activity in the region around 1912. The Adventists combined preaching the gospel with heavy emphasis on the value of education and the importance of economic self-improvement. As a result, they were violently repressed by the regional elites and warmly welcomed by the peasantry.[6]

The peasants of the Lake Titicaca Basin also established ties with the Tawantinsuyo Society, a Lima-based organization of intellectuals, students, and political activists. Influenced by the writings of Castro Pozo, Haya de la Torre, and Mariátegui, the organization was dedicated to improving the material conditions of Peru's Native American population, as part of a general strategy to organize the peasantry and forge an alliance between it and organized labor as a basis for political action (see Chevalier 1970; Hazen 1974).

The national government also appeared to favor the interests of the peasants over those of the regional elites. Through the early 20th century, the state was in the hands of the plantation elite of the northern coast. With their interests tied to a healthy export economy, the north coast planters sought to cement ties with the markets for sugar in industrialized countries by developing Peru as a market for the manufactured goods that these developed countries had to sell. The high labor demands of sugar cane production also predisposed the coastal planters to have an interest in increasing peasants' freedom to move about the country and sell their labor power on their own behalf, rather than having to work through members of the highland elite acting as brokers. As part of this effort, President Leguía,

for example, would ally the national government with interests attempting to undermine the authority of regional oligarchs able to oppose him (e.g., Taylor n.d.).

Uprisings of peasants in the early 1920s around issues related to access to schools and markets were repressed almost as quickly as they began by the regional elites with the assistance of the Peruvian army. While President Leguía was willing to support the peasantry in undermining the authority of the elites with respect to the national government, he was not willing to let peasants assume power in their own right.[7] Afterward, the elites conducted a series of violent reprisals against communities and individuals who had participated in the uprising.

The decades that followed witnessed frequent violence between regional elites and peasants. Changes in the position of southern Peru in the international economy continued to threaten the dominance of the elites and provide opportunities for some peasants to move into new areas of economic activity, providing the basis for a new entrepreneurial class. One important factor was continuing instability in international wool prices following World War I. In an effort to protect profits, the wool export houses entered directly into wool production. They bought out many estate owners unable or unwilling to continue producing in the newly unfavorable situation; those estates not sold suffered, since this action exacerbated their difficulties in finding a market for their wool (Appleby 1978:50-51).

Changes in the regional transportation network also unsettled regional social relations, as truck transport began to replace steamships around Lake Titicaca and began to compete with the railroad for passengers along some sections of its route. By the early 1940s, regularly scheduled steamship service to most of the ports on Lake Titicaca had ceased, with only the link between Puno and the Bolivian rail terminus of Guaqui remaining. While the possibilities for investment in the railroad and steamship transport had been limited, it was relatively easy to acquire a truck and compete for passengers and cargo, and, in fact, large numbers of people who were not members of the regional elite did so. Besides broadening participation in transport and marketing, the expansion of truck transport caused some towns strategically located along roads to grow, while some lacustrine ports suffered from economic decline.

Instability in the wool economy was a major contributor to continuing urban population growth, as increasing numbers of rural people sought employment opportunities or, failing that, joined the ranks of the petty traders purveying manufactured goods in the countryside and bulking small amounts of rural produce. The growing aggregate demand for food, combined with the increasing competition among the ever-more-numerous

urban-based merchants for access to food, eased the establishment of new rural markets, improving rural-urban terms of trade on behalf of the peasants. This situation sharpened competition for agricultural land; thus wealthy peasants bought out poorer neighbors, heightening inequalities in access to land, particularly in the best agricultural areas.

Because of continuing repression and violent reprisals against the peasantry by the elites, and the growing number of families who did not own enough land to support themselves, seasonal and long-term migration out of the region grew in importance. Wage labor on the coast, in the emerging commercial agricultural enterprises and the maritime fishing industry, became more important. In 1937, fifty people from the district of Conima established a settlement near what had been the Spanish gold mining town of San Juan del Oro, in the Tambopata Valley, on the eastern Andean slopes, some 1300 meters above sea level.

The migrants established coffee production in the region, an undertaking that was successful enough to attract the attention of the national government in the mid-1940s. The government established an Indian Migration Office in 1944 and, in 1946, decreed a process whereby migrants could claim formal title to the lands they had possessed. It also provided supplies to permit the completion of a road constructed with voluntary contributions of peasant labor to the provincial capital of Sandia, in 1945. Because of improved access to the area and a more secure tenure situation for migrants claiming land, the rate of migration to the Tambopata Valley increased sharply in the mid-1940s. It continued to increase into the early 1980s before beginning to show signs of slowing.

These changes caused the situation in southern Peru at mid-century to be highly conflictive (Bourricaud 1967:148-155). The elite classes demanded displays of ritual servitude from the peasantry whenever they could enforce it (e.g., Tschopik 1951:159). At the same time, while observers were unclear about the origins of this "caste-structured" (ibid.) social system or the reasons for its intensity, the signs of its dissolution were unmistakable. Bourricaud (1967) observed changes in Puno between visits to the area in 1952 and 1958. He noted in particular the peasantry's increased entrepreneurial activity and participation in wage labor and discussed the phenomenon in terms of the emergence of a new social class, with its roots in but distinct from the traditional peasant society of the region (pp.24-25, 221-227). Based on observations made during the 1940s (Kuczynski-Godard 1945) and in the early 1960s (Martínez 1969), researchers felt that the seasonal migration between the altiplano and the Tambopata Valley other regions was becoming a permanent population movement, which was symptomatic of the increasing landlessness of the highland peasantry. The con-

tinuing establishment of rural marketplaces and the emergence of an integrated regional market system in response to growing urban food demand meant improved conditions of sale for farmers and increasingly efficient purveyance of manufactured goods in rural areas (Appleby 1976).

Indeed, there was considerable evidence to suggest that southern Peru was undergoing a transformation of relations of production in agriculture. The rural population was becoming increasingly polarized into a class of capitalist landowners and rural proletarians. The landowners were clearly divided into two groups. On the one hand were the proprietors of the herding enterprises, whose interests were directly tied to the condition of the international wool market and who were experiencing an intense land consolidation process as the instability of that market forced the weaker enterprises out of business. On the other were agriculturalists, whose interests were tied to the growing urban demand for food within the region. The proletariat was divided into those who were hired as wage laborers on the agricultural and herding enterprises and those who were being forced to seek work outside the area as wage laborers or coffee producers. The region was also home to a growing group of merchants, who were predominantly urban-based and involved in the gathering of wool and foodstuffs from the countryside and the purveyance of manufactured goods imported into the region through the major urban centers. The merchants were internally class-stratified according to three closely interrelated factors: access to transportation facilitates, the quantities and types of goods they handled, and the physical location of their base in the regional urban hierarchy.

ECONOMIC CRISIS AND TRADITIONAL PRODUCTION SYSTEMS

However, several factors were combining to abort this transformation, and these would ultimately recreate a peasant economy in southern Peru. This reconstituted peasant economy would bear little relation to the peasant economy that existed in the region before the onset of the changes described above. Yet, it would be characterized by production relations that are not traditionally associated with capitalism and by community-based institutions operating under an ideology of reciprocity and redistribution.

The major factor underlying the recreation of peasant economy in southern Peru was national agricultural policy, which through the course of the 20th Century became increasingly oriented toward using agriculture to promote rapid industrial [illegible] ent. Since before the turn of the century, the country had purs[illegible] ral policy that promoted the production

of industrial export crops. The state also sought to promote rapid industrial development, again with a heavy export orientation. However, until the middle of the century, the weakness of the State, precluded systematic pursuit of this development model in the highlands.

With the establishment of the Ministry of Agriculture in 1943, agricultural policy was focused in two major directions: 1) the maintenance of low food prices for urban consumers, as part of an effort to keep Peru's labor force cheap and attractive to potential foreign investors, and 2) the promotion of continued development of export agriculture (Alvarez 1980, 1983; Caballero 1981, 1984; Painter 1983). The maintenance of low food prices was attempted through various measures, including a growing reliance on the subsidized importation and sale of wheat and wheat products and milk solids, and retail price controls. The state also allowed a market structure to develop that was oligopsonistic in relation to farmers and oligopolistic in relation to consumers (Esculies Larrabure et al. 1977; Figueroa 1979). The market structure exacerbated the effects of state policies in depressing producer prices and did not pass low prices paid producers on to consumers. Smallholding farmers throughout the country responded by allowing agricultural production to decline and placing greater emphasis on off-farm activities to earn an income. As domestic food production declined, the state placed even greater emphasis on food imports, making conditions even more unfavorable for domestic production.

Unassisted, this dynamic would have proven disastrous for the emerging processes of growth and accumulation. The impact on southern Peru, however, was accelerated by other events. Principal among these was the drought of 1956-58, which was reported to have destroyed 80 percent of the crops and 30 percent of the livestock in the region in the first year alone (Dew 1969:89).[8] Occurring over three agricultural cycles, the drought caused rural families to exhaust their stored supplies of food and seed, and massive numbers of people left their homes in the countryside.

Many went to the regional urban centers in search of work, and, from there, many who did not find it went to Arequipa and Lima. Schaedel (1967:109), for example, estimates that in 1958 alone, over 27,000 people left Puno and migrated to the cities of Arequipa, Cuzco, Lima, Tacna, and Moquegua. Competition for jobs in the mines and on the commercial agricultural enterprises of the coast intensified greatly. Migration to the Tambopata Valley to claim land and begin coffee production also increased sharply (Collins 1984:425-427).

The impact of the drought on the region was exacerbated by a drop in international wool prices after the Korean War (Appleby 1978:67,79,91). This drop proved fatal to many of the enterprises that had survived the pre-

vious decline in prices and market instability and contributed to the migration of rural dwellers into the cities.

The rapid expansion of the regional urban population because of these circumstances increased the demand for food at the same time that local production was effectively eliminated by the drought. This demand was met to a large degree by the imported foodstuffs that had already become staples in the diet of the urban working class. Once they had been displaced from the regional markets, the economic conditions created by national agricultural policy prevented regional agriculture from regaining its former position as a major supplier of foodstuffs in southern Peru. Between growing cash requirements and the difficulties in earning a living through agriculture, peasants continued to turn away from farming as a source of cash revenue in favor of off-farm activities. However, the revenues offered by wage labor, coffee production, and petty trade, which were the major off-farm activities, were sufficiently low to require continuing food production by farm families to subsidize their off-farm work (Painter 1986).[9]

Ironically, major aspects of the massive relief and development effort undertaken in southern Peru in response to the drought, which were intended to reestablish regional agricultural production, accelerated the recreation of the peasant economy that was underway. For example, development efforts such as the Puno-Tambopata Project sought to provide families with an alternative to migration to the cities but instead simply accelerated migration to the petty commodity production regime that was developing around coffee cultivation. As a result, it broadened participation in a pattern of seasonal migration between the highland and valley areas that arises from people not being able to cover consumption requirements in either place, and which stresses family labor resources in such as way as to promote environmentally destructive production practices in both areas. Similarly, the influx of imported foodstuffs through the retail market system, disaster relief activities, and rural development projects using a food-for-work approach purveyed vast quantities of food into all areas of the region at prices that did not reflect production and transport costs. Although responding to the need to supply the region with food during the period when there was little local production, these foodstuffs facilitated the replacement of local production in the markets of the region, and their continued purveyance as part of development activities after the drought had ended was an additional obstacle to reestablishing the position of local production in the markets.

The urban population of the region soared in the wake of the drought and the subsequent relief and development efforts. In the case of Juliaca, for example, the population increased from 6,034 in 1940 to 9,248 by 1950. By 1960, the city was home to 20,403 inhabitants (Torres Juarez 1962), and in

1972 the population was 38,475. The city of Puno increased from 13,786 people in 1940 to 44,166 in 1972. The distribution of the urban population also changed substantially, with Puno and Juliaca increasing their primacy over other urban centers in the region. In 1940, two out of five urban dwellers lived in one of these two cities; by the early 1970s, almost half did. In addition, this urban growth occurred in a period during which the department of Puno as a whole lost population. The Plan Regional de Desarrollo del Sur del Peru (PRSDP) estimated the department of Puno's population to be 812,000 people in 1958, while the population recorded by the 1972 census was 779,594 (Appleby 1978:148).

The rate of growth of rural markets also increased sharply after 1960 (Appleby 1978:188). This increase reflected the intensified competition among petty merchants to gather foodstuffs from the countryside and to purvey manufactured goods as their ranks were swelled by the large numbers of migrants to the cities unable to find formal employment. Here, too, however, opportunities were limited. In Juliaca in the mid-1970s, for example, 9.5 percent of the businesses controlled over 60 percent of legal sales, then estimated to amount to approximately $500,000 per month. At the same time, 22 percent of the businesses in the city controlled 67 percent of the total working capital (Velásquez Rodríguez 1978:50,76-77). In these circumstances, the only option for migrants-cum-petty merchants was to try to compete with others in the same situation in the countryside. This strategy involved not calculating a value on their own labor power in the transport of goods, and, as in the case of wage laborers and coffee growers, a continuing reliance upon familial agricultural production to subsidize their participation in petty trade and transport. The ability of petty merchants not to attach a cost for their labor power enabled larger areas to be incorporated into the urban hinterlands, leading to the establishment of the additional rural markets.

The agrarian reform undertaken between 1969 and 1975 by the reformist military government of General Juan Velasco Alvarado marked another phase in the recreation of the regional peasant economy. The large livestock estates were expropriated and reorganized into state cooperatives[10] worked by the peasants residing on them. The state also encouraged independent peasant communities to seek recognition as corporate landholding units to protect their access to land and receive support from the state in improving agricultural production and revenues. The reform removed the last vestiges of the landlord class from the countryside; however, it did not provide the means for the rural institutions it created or supported to accumulate capital. Patterns of state investment continued as they had before the reform, placing priority on the rapid industrialization of coastal urban

centers and developing new agricultural areas through the irrigation of the coastal desert. Thus, the coastal departments of Lima-Callao, Arequipa, Piura, and Ancash received 55 percent of all public investment under the Velasco government (Wilson and Wise 1986). The state also continued its commitment to keep urban food prices down, and it increased its reliance on subsidizing food imports to do so. The Velasco government also relied heavily upon retail price controls. Furthermore, conditions on the international wool market did not improve. As a result, neither the peasant communities nor the cooperative enterprises in the southern highlands were able to become competitive with enterprises producing similar goods on the coast or outside Peru (Rénique 1987).

Thus, by the late 1970s and early 1980s, the highlands of much of southern Peru had become a labor reserve. Agricultural products had been replaced by labor power as the principal export of the rural communities of the region (Figueroa 1982, 1984). On the north side of Lake Titicaca, for example, most of the rural population derived its cash income from off-farm activity in one of these areas. Only negligible quantities of food were sent to the urban centers of the region. The role of local markets was to redistribute products among producers of different production zones. However, agriculture remained central to the regional economy because the cost of replacing the food they grow with comparable foodstuffs purchased on the retail market would by far exceed the cash earnings of most peasants (Painter 1986).

The Upland Valleys of Central Bolivia

Historical Background

Economic stagnation of the agricultural economy of Cochabamba's upland valleys was a development problem that dated from the colonial period of Bolivian history and periodically became a source of crisis. As the colonial economy evolved, the role of the agricultural areas was to supply mining and administrative centers with food and fiber. Smallholding farmers frequently undercut large estates in this enterprise, because they did not attach a value to their labor power and could sell their produce at prices the large estates could not match if they were to be profitable. In fact, large estates could only count on making money in drought years, when smallholders were obliged to consume most of what they grew and had little left to sell. Because their landholdings were small and located in the least favorable areas for agriculture, however, many smallholders could not support themselves through farming, despite dominating the markets for agricultural products in most years. As a result, smallholding farmers became heavily

dependent on off-farm sources of income early in Bolivian history. This was an important stimulus to the growth of craft industries during the 18th century in many areas of Cochabamba, including textiles, pottery, and gunpowder in the Valle Alto, located to the southeast of the city of Cochabamba, and *charango* production further south in Aiquile, capital of Cochabamaba's Campero province. Similarly, by the end of the 18th Century, smallholders dominated the production and sale of bread in the city of Cochabamba, undercutting and eventually eliminating the established baker's guild (Larson 1988:202-205).

This social context effectively discouraged investment in agriculture and resulted in continuing deterioration in the terms of trade between the agricultural and mining sectors of the economy. For large landowners, their estates were largely collateral for investment in other economic activities. For example, owning a large estate provided the security that permitted a farmer in 18th-Century Cochabamba to become involved in "tithe farming." Under this practice farmers bid on a commission from the Catholic Church to collect tithes, in the form of grain, with their bids reflecting expectations about grain prices in the coming year. They would then collect the grain in the name of the Church and try to sell it when prices were high, with the difference between their bid for the commission and the actual price of the grain representing their profit or loss (Larson 1988:227-231). For smallholders, revenues not immediately consumed were invested in off-farm activities.

The lack of economic opportunity in the rural economy was a source of worry to government officials by the late 18th Century. Intendent Francisco Viedma proposed constructing a road linking the city of Cochabamba with the Chapare and promoting coca cultivation there as a way of infusing new life into the moribund regional economy. Although it was not built because of opposition from other regional interests, exploitation of the tropical lowlands as a way to stimulate upland economic growth was an idea that anticipated modern development strategies by 200 years (Larson 1988:253-258).

Unfavorable terms of trade between the agricultural and mining sectors of the economy was a longstanding problem which was exacerbated by several events during the 20th Century.[11] With the completion of the railroad link between Cochabamba and Oruro, linking the region with ports on the Pacific coast, centers of craft production could no longer compete with manufactured imports, and many members of freeholding communities had to seek employment in the mines. Large estates contracted labor on behalf of the mines, frequently obliging part of their resident peasant population to work there. The relationship with the mines was strongly influenced by international ore prices. During periods of high prices, the agricultural areas of central Bolivia exported large numbers of people to the mining centers

and then reabsorbed many of them when ore prices declined (Dandler 1984; Harris and Albó 1984:36-54).

The problems faced by the agricultural areas deepened with the agrarian reform implemented by the Movimiento Nacionalista Revolucionario (MNR) government, which took power in 1952 in a national revolution that wrested control of the tin mining industry from a small, entrenched elite and placed it into the hands of the state. In return for the support of Bolivia's peasantry, the MNR enacted the agrarian reform in 1953, which substantially redistributed land in the country's upland areas and released peasants from the political domination of the large estates. However, the agrarian reform did not redistribute land in the eastern portions of the country, promoting instead the development of commercial and largely export agriculture through the modernization of the large estates.[12] Similarly, the agrarian reform did nothing to improve the productivity of peasant labor. As a result, even though more rural people had land, the conditions for earning a living on that land were less favorable than before. Economic development policy focused on expanding the export enclave in Santa Cruz and on investing in modernizing the mining industry to make it more competitive internationally (e.g., Gill 1987; Gordon 1977; Heath 1969). The net result for rural smallholders in areas such as Cochabamba, however, was to recreate the unfavorable terms of trade that had characterized their relationship with the mining industry with a new sector of the economy.

While the agrarian reform did not solve, and probably contributed to, the increasing difficulties that smallholders faced in earning a living on their farms, it did allow large numbers of rural dwellers who had previously been restricted in their movements by patron-client ties with landlords to go where they wished to seek employment. Large numbers of people migrated to Bolivia's cities, dramatically swelling the urban population in a major migratory movement that continues into the present (Pérez 1991). Rural families from the upland valleys of central Bolivia also made their presence felt as construction workers and domestic servants in Buenos Aires (Balán and Dandler 1986), agricultural laborers in northern Argentina (Whiteford 1981), the Azapa Valley of northern Chile, and Santa Cruz department of Bolivia (Gill 1987; Riviere d'Arc 1980; Stearman 1976), and as settlers in the colonization areas of northern Santa Cruz (Hess 1980; Painter et al. 1984; Pérez 1987; Stearman 1985). In Santa Cruz during 1976, for example, the pool of migrant workers from upland Bolivia ranged between 19,000 in February and 96,000 in August, when agricultural labor demands are highest (Riviere d'Arc 1980:158- 159).

By the mid-1970s, before the rapid expansion of coca production, upwards of 90 percent of rural families in areas of central and southern

Bolivia earned more than half their income from off-farm sources (Riordan 1979). In addition, from their bases in rural upland areas, families maintained contact in multiple migratory destinations and rapidly changed their migration patterns in response to changing opportunities and risks in different areas (e.g., Baln and Dandler 1986; Carafa et al. 1987). Thus, as a series of natural and economic disasters dramatically worsened the conditions of rural life during the 1980s and coca-leaf production rose in response to increasing international demand for cocaine, the nearby Chapare area was incorporated into the migratory strategies of many rural families.

Three factors caused a dramatic deterioration in the living conditions of rural families during the 1980s. A severe drought began in 1983 and continued through the 1980s in much of central and southern Bolivia, pushing thousands of smallholders "over the edge" in terms of their ability to earn a living through agriculture. Thousands of families left their homes permanently as a result, and thousands more have either begun to migrate seasonally or have increased the amount of time they must spend away from home in order to earn the income needed to cover family consumption requirements.

Drought relief efforts themselves sometimes increased the pressures on people to migrate. In Mizque, for example, many farmers received agricultural credit under the *Crédito Agropecuario de Emergencia* (CAE) program, sponsored by USAID/Bolivia, with participation of P.L. 480 and some *Instituciones Crediticias Intermediarias* (ICIs). The credit program sought to speed the recovery of rural families affected by the drought. Unfortunately, in Mizque, the drought lasted longer than the CAE program. As a result, farmers had to repay their loans even though they continued to realize subnormal harvests. To repay the loans, many families sold livestock and farm implements and even tried to sell or give their land to the financial institution, efforts that were generally inadequate. When USAID/Bolivia sought money for the credit component of the CRDP, it encouraged the financial institutions involved in the CAE program to collect outstanding loans and return the money to P.L. 480. Naturally, the financial institutions increased the pressure on farmers, who responded by migrating to the Chapare to earn money. Sometimes, the loan program was responsible for families who had not previously migrated beginning to seek employment in the Chapare (Cuba 1989).

In 1985, a second disaster struck the poorest sectors of Bolivian society, as international tin prices collapsed when the London Metal Exchange stopped trading. The result of an unfavorable shift in exchange rates and the accumulated debts of the International Tin Council, this collapse brought ruin to Bolivia's principal legal export industry. Between August 1985 and August 1986 some 27,000 mine workers lost their jobs. The *Banco Central de*

Bolivia estimated the unemployment rate to be 20 percent by the end of 1985, largely because of the layoff of mineworkers, and, according to the *Central Obrera Boliviana* (COB), the figure approached 30 percent by the end of 1986 (Crabtree et al. 1987:20). The impact of the mining collapse on families not directly employed by the mining industry—but dependent upon it—has never been measured. Many families migrated to urban areas, particularly Cochabamba and La Paz, and from Cochabamba, many went to the Chapare when they were unable to find work in the city.

Finally, it is important to remember that these events took place in the context of general financial collapse. The collapse was closely related to Bolivia's inability to continue to make payments on its substantial foreign debt, most of which was incurred during the 1970s, under the Banzer regime. In addition, in 1983, the Siles government embarked on an ill-conceived attempt to unlink the exchange rate of the Bolivian peso from the U.S. dollar. The effects of this *desdolarización* on the already weakened Bolivian economy were disastrous; the annual inflation rate exceeded 14,000 percent at its peak in 1984. Even middle-class salaries evaporated, and only those with access to dollars enjoyed any protection.

The combination of historical problems of agricultural productivity and the specific jolts to rural livelihoods that occurred during the 1980s have produced a self-perpetuating spiral of rural impoverishment and environmental destruction. Rural poverty led to a historically heavy reliance on off-farm income, and farm families have increasingly turned to wage labor migration as a way of satisfying that need. Labor scarcity resulting from absences of increasing duration by family members has obliged rural families to sacrifice medium- and long-term farm management to the exigencies of satisfying immediate consumption needs. This trend has contributed to a progressive degradation of the physical environment, manifested in serious problems of erosion, declining soil fertility, deforestation, and overgrazing. Environmental destruction exacerbates existing problems of low agricultural productivity and produces additional pressures for outmigration.

The relationship between on- and off-farm income is a crucial one for understanding the dynamic between impoverishment and environmental destruction. On the one hand, historically unfavorable conditions for market-oriented agricultural production has caused the importance of migration to earn off-farm income to grow in recent decades. At the same time, low wage rates made it impossible for a family to live on off-farm earnings alone, so that food production for domestic consumption remained a crucial family production activity. The complimentary inadequacies of the production options available to rural families produced the production strategy based on male outmigration and female farm management.

LIVESTOCK AND GENDER

Two aspects of the relationship between impoverishment and environmental destruction warrant particular attention: the implications for the productive role of women in rural households, and the implications for livestock management. The continuing unfavorable environment for the sale of agricultural produce, the environmental destruction resulting from the labor scarcity associated with high rates of outmigration, and the exclusion of women from most opportunities to receive technical and organizational assistance to improve their situations have begun to alter the relationship between on- and off-farm family productive activities. Among those families where male migration is primarily to the Chapare, women report that of nearly equal importance to the cash that men earn are the foodstuffs that they bring back with them. Thus, the processes of impoverishment and environmental destruction has reached a point where domestic agricultural production does not even cover most of the family consumption requirements. Not only does it have to be supplemented with cash, but families now also rely on foodstuffs imported from other areas (Gisbert et al. 1991).

This development has important implications for rural women. First, a continuing decline in living standards increases the vulnerability of particularly at-risk groups like pregnant and lactating women and small children. Physical survival is becoming more difficult, and women are subjected to an additional source of stress that limits their ability to manage natural resources effectively or to take initiatives and risks to increase their incomes. Additionally, however, the situation creates the conditions for increased gender-based oppression of rural women. Over time, the economic importance of those activities for which women are responsible is tending to decline. This deterioration undermines women's claims to political representation in local affairs, and it creates a situation in which family responsibilities are viewed as increasingly burdensome by men, so that women are more subject to abandonment and physical abuse by their spouses.

Environmental destruction in central Bolivia is particularly associated with damage caused by livestock, which is, in turn, closely associated with gender issues. The normal pattern of livestock ownership in the area is that large livestock, primarily cattle, belong to men, while small animals, the most important of which are goats, belong to women. Considerable environmental damage is attributed to goats, resulting from the impact of their browsing on trees and shrubs in the semi-arid environment and erosion associated with the paths they create on the steep hillsides. Development specialists, concerned about the extreme environmental degradation of the area, frequently focus on the goats as the key issue to address. Often, this focus fails to consider the important role that the goats play for rural families

as a source of meat and hides and as the only form of savings available to most rural women.

In the absence of their husbands, women also assume full responsibility for the care of cattle. Except for the central Mizque valley and other areas where production revolves around irrigated agriculture, cattle are usually kept in lands, called *monte*, that belong either to the community or *sindicato*, to which community families have use rights. These areas are usually located a two- or three-hour walk from the parts of the community where people live, so that keeping track of livestock is a time-consuming task under the best of circumstances. When the men are present, they form informal groups that take turns going to the *monte* to look after one another's cattle, and the animals are checked on nearly every day. However, the task becomes particularly onerous for women, because the time required to travel to and from the *monte* combined with other tasks is prohibitive. The physical difficulties associated with simply doing all that needs to be done every day, combined with the lack of women's participation in institutions that could help coordinate individual activities, means that livestock care is less regular when men are absent.

This situation creates specific problems in cattle management which are aggravated in the context of longer term trends. Salt licks are not maintained, with negative consequences for animal health. Animals are not moved around within the *monte* as they normally are, contributing to deterioration of the community range land. Physical deterioration of the land and lack of supervision of the animals have caused cattle to wander or be driven out of the *monte* belonging to their owners' community and onto the land of neighboring communities. This movement has become a serious source of conflict and confrontation in several areas.

These problems are worsened by parallel processes of increase in the number of cattle being maintained and shrinking size of the *monte*. There is evidence that the numbers of cattle are increasing in parallel fashion to increases in family dependence on migration. Money earned through migration that is not immediately consumed by families is invested in cattle, which constitute one of the few available mechanisms for saving. In addition, in many areas the formation of new households exceeds the land resources of the communities. This disparity has obliged communities to allocate communally-held *monte* to individual families for agricultural production. Since *monte* lands were designated as such in part due to their unsuitability for agriculture, this reallocation aggravates environmental destruction in addition to reducing the area available for livestock.

The role of livestock in the rural economy poses several problems for technical specialists seeking to reduce environmental destruction through

improved herd management. With cattle, attention focuses on the increasing number of animals being maintained on a shrinking area of pasture land and on the low quality of the individual animals with respect to weight and overall health. Small livestock, particularly goats, are seen very strictly in terms of the environmental damage associated with their numbers and with their ranging freely over the hillsides. As a result, livestock development strategies have focused on improving the quality and value of cattle herds by decreasing numbers and providing the necessary elements for the remaining animals to be larger and healthier. Discussions of goats have revolved simply around how to reduce the goat population.

Such an approach overlooks the role that livestock play in family production systems as sources of savings. It also ignores the fact that for many rural families a larger number of relatively low-quality cattle is preferable to a small number of high-quality cattle, because the low-quality animals are more resistant to drought and disease and the existing strategy offers more options for managing risk. Technical specialists also fail to appreciate that efforts to reduce the goat population represents a direct assault on one of the few areas of property that women control. Additionally, they often do not realize that the lack of management so visible today results from the increasing burden borne by women as a result of the impoverishment and environmental destruction afflicting the region, and of the male outmigration that is rural families' response to these conditions.

Discussion and Conclusions

The cases of the Peruvian altiplano and the central valleys of Bolivia provide a series of parallels and contrasts in the ways that extra-local forces shape land use. During the early 20th Century, it appeared that the Peruvian altiplano would experience an almost classical transition to modern capitalist agriculture on the basis of its participation in the wool export economy and its provisioning of regional urban centers tied to the export economy with food. This transition was aborted at mid-century, however, by a combination of national agricultural policies and regional crises in production and marketing generated by drought and drought relief. Lacking opportunities to earn a living through agriculture, rural families turned to off-farm sources of income, and family agriculture subsidized participation in these. Many of the trappings associated with traditional peasant production, particularly those related to reciprocal labor exchanges, increased in importance as a way to reduce the financial cost of agricultural production by maximizing the use of unwaged labor. Central Bolivia was a provider of food and fiber from early in

its history. However, in contrast to Peru, land distribution patterns and relations between large and small landowners precluded agriculture forming the basis of the kind of capital accumulation that would transform production into a modern capitalist variety. As a result, the terms of trade with Bolivia's mining sector, which did experience several periods of capital accumulation, deteriorated over time, subjecting the region to a long-term process of impoverishment, events which have accelerated in recent decades. Thus, unlike in the Peruvian altiplano, traditional peasant production practices are longstanding, and not a response to recent economic changes.

In both cases, agricultural production has subsidized participation in off-farm income-earning activities. As these off-farm activities have become more critical to family survival, family labor resources have become increasingly stressed; farm management practices that contributed to the medium- and long-term management of soil and water resources have been abandoned if they did not also contribute to satisfying immediate consumption needs. This trend, in turn, has led to continuing environmental destruction. Thus, we need to exercise care in designing participatory rural development strategies that assume a substantial investment of time and effort by rural families.

The two case studies also raise issues about how we think about traditional household production systems. The peasant economy recreated in the Peruvian case included exchange relationships useful in mobilizing unwaged labor, because families wished to minimize the cash expenditures required by agriculture. But the management of physically dispersed production with competing labor demands precluded maintaining longstanding production practices that conserved soil and water resources. In some senses, production today is more "traditional" than it was fifty years ago, when economic growth and land consolidation was causing the importance of agricultural wage labor to expand rather than contract. However, the expansion of traditional reciprocal production relations has been directly tied to the demise of traditional conservation practices. The notion of traditional production needs to be carefully contextualized.

Similarly, the Bolivian case illustrates the limitations of thinking about production strictly in terms of household units. While all rural households have been affected by impoverishment and environmental destruction, the burden is not equally shared within those households. The physical and social condition of rural women has been particularly badly damaged, and well-intentioned but poorly conceived rural development efforts could worsen their situation. By the same token, because rural women are the ones who are managing the farms, they are the major hope for reversing the processes described. Applied research needs to be conceived and implemented with rural women defined explicitly as the major beneficiaries. Assigning

gender issues to a separate "women in development" component will not improve land use or the position of rural women and will, in fact, probably contribute to both getting worse.

Finally, the two cases clearly suggest two areas in which new knowledge from applied research is desperately needed. First, there is a need for technology that will improve the productivity of rural labor, either by allowing agricultural tasks to be accomplished more efficiently or by reducing the time that must be dedicated to the drudgery of staying alive (e.g., gathering firewood and water, cooking) so that people have more time to devote to the resource management aspects of agriculture. It is here that understanding social and institutional aspects of rural life become particularly important. For example, significant reductions in drudgery could result from implementing collective strategies for firewood and water gathering, livestock management, and child care in place of the individual household strategies that are found in most rural communities (Gisbert et al. 1991). However, this approach requires an intimate knowledge of the institutional structure and politics of power in these communities and a long-term commitment to fomenting the kind of institutional development that will permit such innovations to be accepted and sustained.

A second priority area for research is raising rural incomes. As the two cases discussed here clearly show, impoverishment is the starting point for declining agricultural production and environmental destruction. Several areas suggest themselves as points of departure for such research, including the following: 1) expanding markets for rural products; 2) improving the conditions under which rural people market their produce, particularly with respect to bulking and transport; 3) promoting agroprocessing as a source of off-farm employment that does not require migration, as a means of adding value to products, and as a strategy for permitting rural families to exercise more control over when and where they sell their produce; and 4) promoting higher wage rates and greater job security in areas that are migratory destinations so that more people who are dependent on off-farm income can actually earn a living from it.

Successful applied research on agropastoral land use relies on an understanding of local production systems and on the application of technologies whose appropriateness often derives from traditional practices. However, it is not enough to focus on local production systems as they appear to us in the present. We must also understand the history that is responsible for present appearances at the local level, and that it links local production systems to one another in regional, national, and international contexts. In applied research as in politics, there is much to be said for linking local action to global thinking.

BIBLIOGRAPHY

Allen, P., and D. Van Dusen (eds.). 1988. *Global Perspectives on Agroecology and Sustainable Agricultural Systems. Proceedings of the Sixth International Scientific Conference of the International Federation of Organic Agriculture Movements.* Two Volumes. Santa Cruz, CA, U of California Agroecology Program.

Altieri, M., and A. Yurjevic. 1989. "The Latin American Consortium on Agroecology and Development: A New Institutional Arrangement to Foster Sustainable Agriculture Among Resource-Poor Farmers." Development Anthropology Network 7(1):17-19.

Alvarez, E. 1980. *Política agraria y estancamiento de la agricultura, 1969-1977.* Lima, Instituto de Estudios Peruanos.

—-. 1983. *Política económica y agricultura en el Perú, 1969-1979.* Lima: Instituto de Estudios Peruanos.

Andrew, C. O., and P. E. Hildebrand. 1982. *Planning and Conducting Applied Agricultural Research.* Boulder, CO: Westview Press.

Appleby, G. 1976. "The Role of Urban Food Needs in the Regional Development of Puno, Peru." In *Regional Analysis. Vol. 1.* Carol A. Smith (ed.). New York: Academic Press. Pp. 147-178.

—-. 1978. *Exportation and Its Aftermath: The Spatioeconomic Evolution of the Regional Marketing System in Highland Puno, Peru.* Ph.D. dissertation. Anthropology Department. Stanford University.

—-. 1980. "Markets and the Marketing System in the Southern Sierra." Paper presented to the Symposium on Andean Peasant Economics and Pastoralism, Columbia, Missouri.

Baker, D., E. Modiakgotla, D. Norman, J. Siebert, and M. Tjirongo. 1983. "Helping the Limited Resource Farmer through the Farming Systems Approach to Research." Culture and Agriculture 19:1-8.

Baln, J., and J. Dandler. 1986. *Marriage Process and Household Formation: The Impact of Migration on a Peasant Society.* Report prepared for the Population Council. La Paz (ms.).

Bourricaud, F. 1967. *Cambios en Puno.* México, D.F.: Instituto Indigenista Interamericano.

Caballero, J. M. 1981. *Economía agraria de la sierra peruana antes de la reforma agraria de 1969.* Lima: Instituto de Estudios Peruanos.

—-. 1984. "Agriculture and the Peasantry under Industrialization Pressures: Lessons from the Peruvian Experience." Latin American Research Review 19:3-41.

Carafa, Y., S. Arellano, and M. Uribe. 1987. *Tratamiento de la temática de la mujer en los valles del sur de Cochabamba*. Report prepared for USAID/Bolivia in support of the Chapare Regional Development Project. La Paz: U.S. Agency for International Development.

Chevalier, F. 1970. "Official *Indigenismo* in Peru in 1920: Origins, Significance, and Socioeconomic Scope." In *Race and Class in Latin America*. Magnus Morner (ed.). New York: Columbia U P.

Collins, J. L. 1984. "The Maintenance of Peasant Coffee Production in a Peruvian Valley." American Ethnologist 11(3):413-438.

—-. 1987. "Labor Scarcity and Ecological Change." In *Lands at Risk in the Third World: Local Level Perspectives*. P. D. Little and M. M Horowitz (eds.). Boulder: Westview Press. Pp.19-37.

—-. 1988. *Unseasonal Migration: The Effects of Rural Labor Scarcity in Peru*. Princeton: Princeton U P.

Crabtree, J., G. Duffy, and J. Pearce. 1987. *The Great Tin Crash: Bolivia and the World Tin Market*. London: Latin America Bureau (Research and Action), Ltd.

Cuba, P. 1989. "Aspectos sociales de la provisión de servicios de crédito a pequeños agricultores en los Valles Altos Asociados." SARSA Working Paper. Binghamton, NY: Institute for Development Anthropology.

Dandler, J. 1984. "Campesinado y reforma agraria en Cochabamba (1952-1953): Dinmica de un movimiento campesino en Bolivia." In *Bolivia: la fuerza histórica del campesinado*. F. Calderón and J. Dandler (eds.). Cochabamba: CERES and UNRISD. Pp.201-239.

Deere, C. D. and R. Wasserstrom. 1980. "Ingreso familiar y trabajo no agrícola entre los pequeños productores de América Latina y el Caribe." Paper presented to the Seminario Internacional sobre la producción agropecuaria y forestal en zonas de ladera en América Latina. Turrialba, Costa Rica.

Dew, E. 1969. *Politics in the Altiplano: The Dynamics of Change in Rural Peru*. Austin: U of Texas P.

Esculies Larrabure, O., M. Rubio Correa, and V. Gonzlez del Castillo. 1977. *Comercialización de alimentos*. Lima: Desco.

Figueroa, A. 1979. "Política de precios agropecuarios e ingresos rurales en el Peru." Allpanchis Phuturinqa. 8:25-50.

—-. 1987. "Production and Market Exchange in Peasant Economies: the Case of the Southern Highlands in Peru." In *Ecology and Exchange in the Andes*. David Lehmann (ed.) Cambridge: Cambridge U P. Pp. 122-156.

—-. 1984. *Capitalist Development and the Peasant Economy in Peru*. Cambridge: Cambridge U P.

Gill, L. 1987. *Peasants, Entrepreneurs, and Social Change: Frontier Development in Lowland Bolivia*. Boulder, CO: Westview Press.

Gisbert, M. E., M. Painter, M. Quitón, and I. Zabala. 1991. *Development Issues Confronting Women in Areas of High Male Outmigration. Summary of Research Results and Guidelines for Development Projects*. Report presented to the United Nations Development Fund for Women. Binghamton, NY: Institute for Development Anthropology.

Gordon, R. F. 1977. *United States Aid to Bolivia*, 1953-1972. Ph.D. dissertation. Government and Politics Department. University of Maryland. College Park, MD.

Harris, O. and X. Albó. 1984. *Monteras y guardatojos: campesinos y mineros en el norte de Potosí*. La Paz: CIPCA (originally published 1974).

Hazen, D. 1974. *The Awakening of Puno: Government Policy and the Indian Problem in Southern Peru*. Ph.D. dissertation. History Department. Yale University. New Haven, CT.

Heath, D. B. 1969. "Land Reform and Social Revolution in Eastern Bolivia." In H. C. Beuchler, C. Erasmus, and D. B. Heath. *Land Reform and Social Revolution in Bolivia*. New York, NY: Praeger Publishers.

Hess, D. 1980. *Pioneering in San Julian: A Study of Adaptive Strategy Formation by Migrant Farmers in Eastern Bolivia*. Ph.D. dissertation. Anthropology Department. University of Pittsburgh. Pittsburgh, PA.

Hildebrand, P. E. 1977. "Generating Small Farm Technology: An Integrated Multidisciplinary Approach." Paper presented at the 12th Annual West Indian Agricultural Economics Conference. Antigua.

Kuczynski-Godard, M. 1945. *Estudios médico-sociales en las minas de Puno con anotaciones sobre las migraciones indígenas*. Lima: n.p.

Larson, B. 1988. *Colonialism and Agrarian Transformation in Bolivia: Cochabamba 1550-1900*. Princeton: Princeton U P.

Lewellen, T. 1978. *Peasants in Transition. The Changing Economy of the Peruvian Aymara: General Systems Approach*. Boulder: Westview Press.

Little, P. D. 1985. "Adding a Regional Perspective to Farming Systems Research: Concepts and Analysis." Human Organization 44(4):331-338.

Martínez, H. 1969. *Las migraciones altiplánicas y la colonización del Tambopata*. Lima: Centro de Estudios de Población y Desarrollo.

—-. 1980. "Las empresas asociativas agrícolas peruanas." In *Realidad del campo peruano después de la reforma agraria*. Centro de Investigación y Capacitación y Editora Ital Peru (eds.). Lima: Centro de Investigación y Capacitación y Editora Ital Peru. Pp. 105-153.

Norman, D. W., E. B. Simmons, and H. M. Hays. 1982. *Farming Systems in the Nigerian Savanna: Research and Strategies for Development*. Boulder: Westview Press.

Orlove, B. S. 1977. *Alpacas, Sheep, and Men*. New York: Academic Press.

—-. 1978. "Systems of Production and Indian Peasant Insurrections: A General Discussion of Three Specific Cases." Actes du XLII Congrés des Americanistes, Paris 3.

Painter, M. 1983. "The Political Economy of Food Production in Peru." Studies in Comparative International Development 18(4):34-52.

—-. 1986. "The Value of Peasant Labour Power in a Prolonged Transition to Capitalism." Journal of Peasant Studies 13(4):221-239.

—-. 1991. "Re-creating Peasant Economy in Southern Peru." In *Golden Ages, Dark Ages: Imagining the Past in Anthropology and History*. J. O'Brien and W. Roseberry (eds.) Berkeley, CA: U of California P. Pp. 147-188.

Painter, M., C. A. Pérez C., M. Llanos A., S. Hamilton, and W. Partridge. 1984. "New Lands Settlement and Regional Development: The Case of San Julian, Bolivia." Working Paper. Cooperative Agreement on Settlement and Natural Resource Systems Analysis. Binghamton, NY: Institute for Development Anthropology.

Pérez Crespo, C. A. 1987. "San Julián: balance y desafíos." In *Desarrollo Amazónico: una perspectiva latinoamericano*. Centro de Investigación y Promoción Amazónica and Instituto Andino de Estudios de Población (eds.). Lima: CIPA and INANDEP.

—-. 1991. "Why Do People Migrate? Internal Migration and the Pattern of Capital Accumulation in Bolivia." Working Paper. Cooperative Agreement on Settlement and Natural Resource Systems Analysis. Binghamton, NY: Institute for Development Anthropology.

Rénique, J. L. 1987. "Estado, partidos políticos y lucha por la tierra en Puno." Debate Agrario 1(1):55-76.

Riordan, J. 1979. *An Assessment of the Southern Valley Region of Bolivia.* Farm Policy Study Analytical Document No. 1A. La Paz: U.S. Agency for International Development.

Riviere d'Arc, H. 1980. "Public and Private Agricultural Policies in Santa Cruz (Bolivia)." In *Land, People and Planning in Contemporary Amazonia.* Occasional Publication No. 3. F. Barbira- Scazzocchio (ed.). Cambridge: Cambridge University Centre of Latin American Studies. Pp.154-170.

Schaedel, R. P. 1967. *La demografía y los recursos humanos del sur del Perú.* México, D.F.: Instituto Indigenista Interamericano.

Shaner, W., P. Philipp, and W. Schemhl. 1982. *Farming Systems Research and Development: Guidelines for Developing Countries.* Boulder, CO: Westview Press.

Stearman, A. M. 1976. *The Highland Migrant in Lowland Bolivia: Regional Migration and the Department of Santa Cruz.* Ph.D. dissertation. Anthropology Department. University of Florida. Gainesville, FL.

—-. 1985. *Camba and Kolla: Migration and Development in Santa Cruz,* Bolivia. Orlando, FL: U P of Florida.

Taylor, L. n.d. *Bandits and Politics in Peru: Landlord and Peasant Violence in Hualgayoc, 1900-30.* Cambridge: Centre of Latin American Studies, University of Cambridg e.

Torres Juarez, D. 1962. *Monografía de la provincia de San Román.* Arequipa: Offset Acosta.

Tschopik, H. 1951. "The Aymara of Chucuito, Peru." New York: Anthropological Papers of the American Museum of Natural History, Vol. 44, Pt. 2.

University of Chiang Mai. 1980. *An Interdisciplinary Perspective on Cropping Systems in the Chiang Mai Valley: Key Questions for Research.* Chiang Mai, Thailand: University of Chiang Mai.

Urioste, M. 1987. *Segunda reforma agraria: campesinos, tierra y educación popular.* La Paz: Talleres CEDLA.

Velsquez Rodríguez, M. G. 1978. *Análisis de la estructura comercial de la ciudad de Juliaca*. Tesis para optar el título de Ingeniero Economista. Programa Académico de Ingenería Económica, Universidad Nacional Técnica del Altiplano, Puno, Peru.

Whiteford, M. 1981. *Workers from the North: Plantations, Bolivian Labor, and the City in Northwest Argentina*. Austin: U of Texas P.

Wilson, P., and P. Wise. 1986. "The Regional Implications of Public Investment in Peru, 1968-1983." Latin American Research Review 21(2):93-116.

ENDNOTES

[1]The Farming Systems literature is far too extensive to review here. Readers interested in more information on the basic elements of the approach may wish to consult Baker et al. (1983) or Shaner et al. (1982). Andrew and Hildebrand (1982) provide a "nuts and bolts" discussion of how to conduct multidisciplinary agricultural research.

[2]Readers of this paper will probably be especially interested in Part 8, "Traditional Farming Systems in Latin America" (Volume 2, Pp. 433-473).

[3]Several Bolivian NGOs have made an agroecological approach to agricultural production systems a central element of their programs. These include SEMTA (Sevicios Múltiples de Tecnologías Apropriadas, Casilla 15041, La Paz), CENDA (Centro de Comunicación y Desarrollo Andino, Casilla 540, Cochabamba), and PROBIOMA (Casilla 5559, Cochabamba). Each has a particular focus with respect to geographic area of interest and technical speciality.

[4]This entire paragraph draws heavily on Little's (1985) discussion. Interested readers should refer to his article.

[5]The Peruvian case presented here summarizes part of a longer critical discussion published elsewhere (Painter 1991), to which readers interested in more detail may wish to refer.

[6]For accounts of the activities of the Adventist Church in the region during this period, see Hazen (1974) and Lewellen (1978).

[7]Fort a description of the 1923 uprising and a discussion of its significance in terms of regional class formation, see Collins (1988:51-61).

[8]Droughts are endemic in the region, and localized droughts are a frequent occurrence. At irregular intervals, however, the entire region is afflicted by a major drought that lasts through more than a single growing season. For example, a drought similar in severity, although less dramatic in its social and economic impacts, struck southern Peru in 1940. More recently, the altiplano was hit by a severe region-wide drought during the 1982-83 and 1983-84 growing seasons.

[9]Collins (1984) discusses how possibilities for coffee production in the Tambopata Valley to serve as a basis for capital accumulation were cut off (see especially pp. 430-31).

[10]A number of different state cooperative organizations were created under the agrarian reform, with administrative structures varying according to the role they were envisioned as playing in the economy. Most of the coastal plantations, for example, were organized as Cooperativas Agrarias de Producción. The estates in highland southern Peru became Sociedades Agrícolas de Interés Social (Martínez 1980).

[11]Due to space limitations, this discussion refers generically to "the mining economy" or the "mining sector." From the beginning of the colonial period through most of the 19th century the mining industry revolved around silver and was geographically centered in Potosí. Beginning in the last quarter of the 19th century, tin grew in importance and became Bolivia's major mineral export, and the center of Bolivia's mining industry shed northward to Oruro. Tin dominated the mining industry until 1985, with the crash in international tin prices and the bankruptcy of the London Metal Exchange.

[12]This practice led to a process of land concentration related to the economic growth of the new export agriculture sector, so that today land distribution is more unequal than it was prior to the agrarian reform (Urioste 1987).

CHAPTER 6

Agroecological Characterization of the Bolivian Altiplano

Ing. Juan Carlos Quiroga M.
Executive Director, CUMAT

PRELIMINARY CONSIDERATIONS

One of the biggest problems in Third World countries is that on one hand they have the weight of the national debt (external) and on the other hand they have a gross mismanagement of their natural resources. This misapplication of natural resources has caused great ecological problems with irrigation in newly established agriculture frontiers and the hydroelectric projects have caused a variety of environmental problems to the region. These countries along with international financial organizations can share in the blame for the financial and environmental situations that exist in third world countries today.

There is an urgent need in Bolivia to take actions in developments that would create jobs for the large peasant population while at the same time developing projects that are compatible with the ecology while causing a minimum impact on the environment. The experience gained in developed countries can aid in solving the environmental problems while using mass human and economic resources to improve the havoc that presently exist.

Because of these considerations, this paper will try to do a characterization of the agro-ecosystems of the Bolivian Altiplano showing the physical aspects, actual land use and the socio-economic indicators.

GENERAL ECOLOGY OF BOLIVIA

Bolivia has an area of 1,098,000 km^2 occupied by nine major physical regions. Each region presents a complex group of conditions distinct from the others in its physical environment.

Basically these regions are the result of the overlap of three latitudinal bioclimatic regions: tropical, subtropical, and template. They are located over four major physiographic areas: the altiplano, surrounded by the Cordilleras Andinas; the Andean (Eastern) zone, deeply divided from altiplano; the Lowlands; and the Low Plateaus of the East. Since these areas have a tendency to run at opposed angles, nine combined areas are the result (Fig. 1).

Previous Page Blank

MOSAICO
SEMICONTROLADO, DE LA REPUBLICA DE
BOLIVIA

Escala Aprox. 1:9,000,000

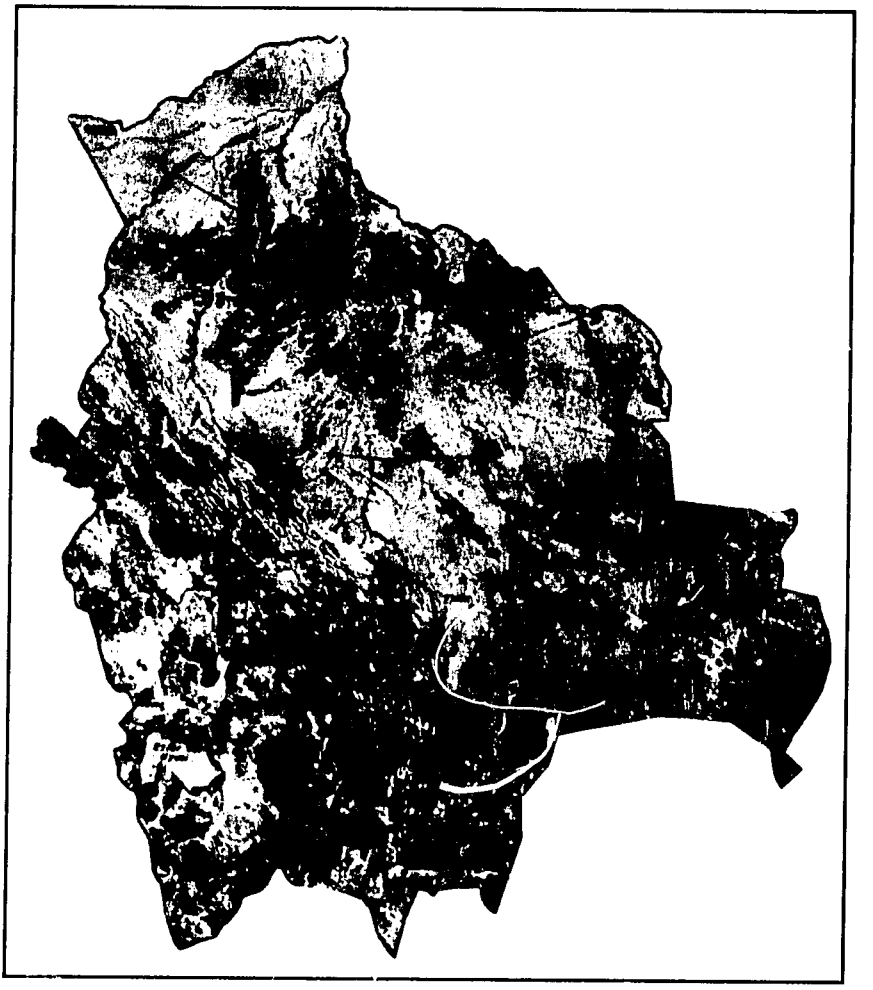
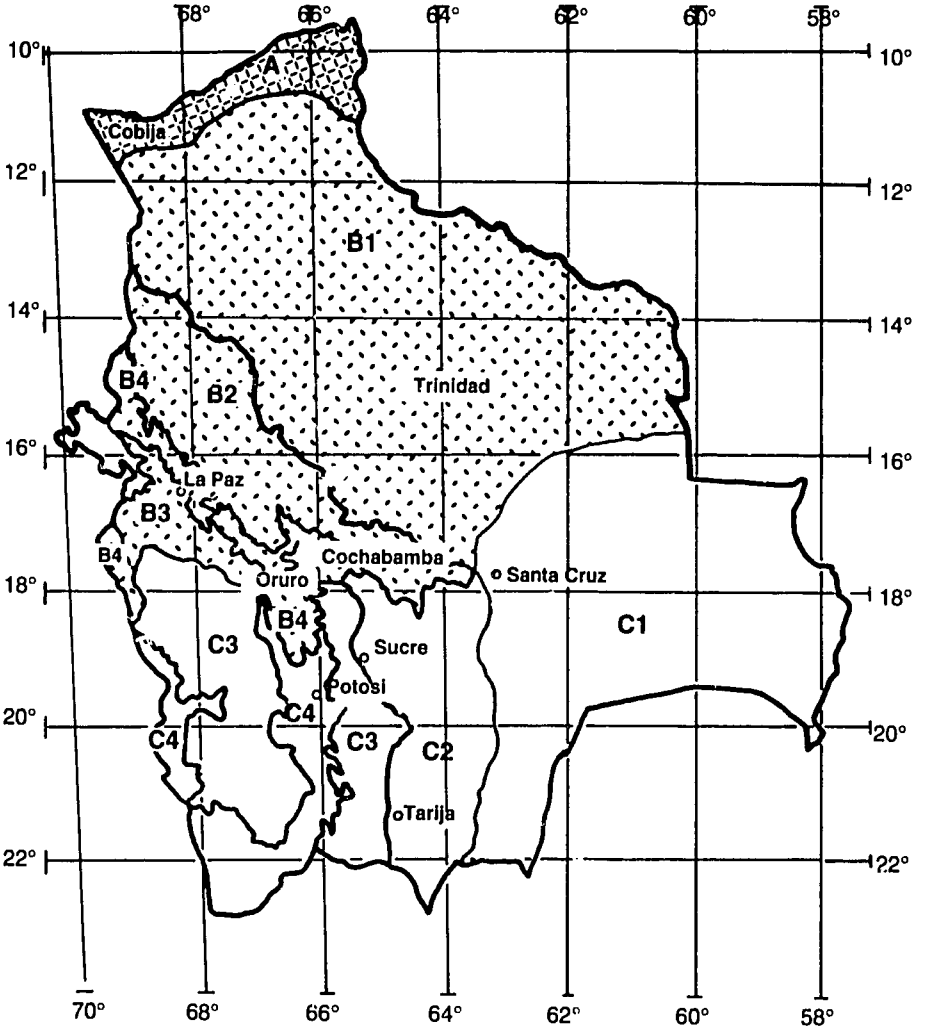


FIGURA 1



REFERENCIAS

A. REGION TROPICAL

A. Region tropical de tierras bajas

B. REGION SUB TROPICAL

B1. Region subtropical de tierras bajas
B2. Region subtropical de tierras de valle
B3. Region subtropical de tierras altos
B4. Region subtropical andine

C. REGION TEMPLADA

C1. Region templada de tierras bajas
C2. Region templada de tierras de valle
C3. Region templada de tieras altos
C4. Region templada andine

REGIONES LATITUDINALES

Region tropical
Region subtropical
Region templada

MAPA ECOLOGICO GENERALIZADO DE BOLIVIA

FIGURA 2

In Bolivia, the isothermal bio-temperature corresponding to the division between the latitudinal region of the Tropical and Subtropical, with an average of 24°C. (Fig. 2), is located at the north of the country varying between 11° and 12° of latitude South. In other words, with the exception of about 37,680 km^2 (3.42% of the national territory) to the extreme north, the country does not have truly tropical areas in any elevation above sea level. However, a total area of almost equivalent size (34,500 km^2) of tropical life zones (humid and very humid) extends as a strip across the deep eastern watershed of the Andes to 17° South; nevertheless, these bio-climes with mean annual bio-temperatures a little below 24°C. are transitional to the subtropical and are considered to be within the same subtropical region (Fig. 3, approximated profile).

In total, about 545,275 km^2, or almost 50% of the national territory, are within the limits of the subtropical region, including 34,500 km^2 of tropical life zones in transition to the subtropical and 515,405 km^2, or almost 47% of the national territory, in the temperate region. The generalized ecological map of Bolivia elaborated by Leslie Holdridge and Joseph Tosi took as a base the three latitudinal regions present in the territory, combined with the major physiographic divisions.

PHYSIOGRAPHY OF BOLIVIA

Considering the big morphological factors, climatology of fauna and flora, and the variety of soils, the country can be divided into two major units: the elevated and cold Andean block and the hot lowlands; these units are subdivided into other minor areas characterized by their own properties.

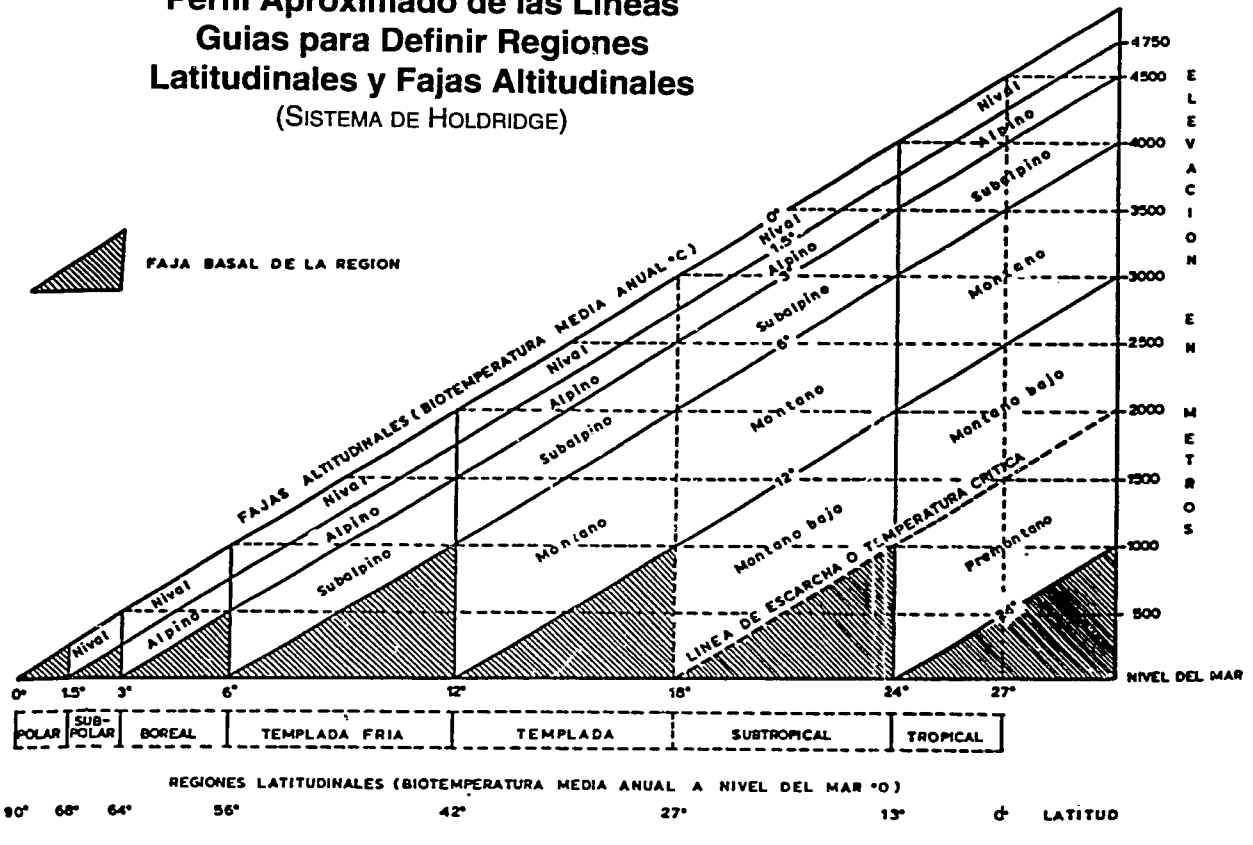
Bolivia has seven physiographic provinces (Fig. 4) from West to East:

A-1 .....Cordillera Occidental o Volcanica
A-2 .....Cordillera Central-Oriental
B .....Altiplano
C.....Subandino
D.....Llanuras
E .....Escudo Brasilero
F.....Serranias Chiquitanas

FIGURA 3

Perfil Aproximado de las Lineas Guias para Definir Regiones Latitudinales y Fajas Altitudinales

(SISTEMA DE HOLDRIDGE)



REPUBLICA DE BOLIVIA
MAPA DE UNIDADES
MORFOESTRUCTURALES

Con las subdivisiones consideradas
en el cuadro estratigráfico

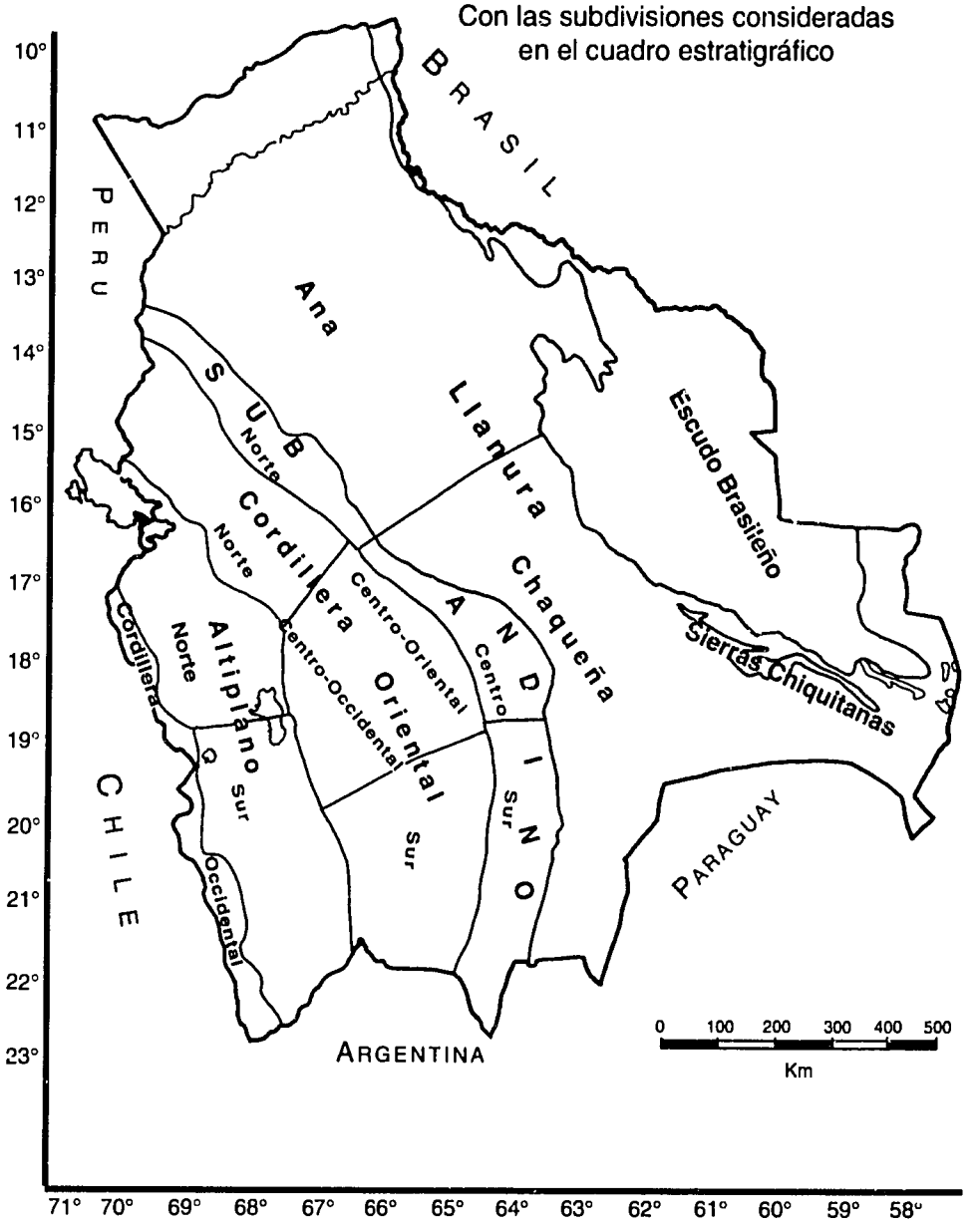


FIGURA 4

ALTIPLANO BOLIVIANO

LOCATION AND EXTENSION

The Bolivian altiplano is the physiographic unit located between the eastern and western mountains that starts in the Abra de la Raya in the south of Peru and continues to the 22°50' parallel to then enter the Puna of Atacama in Chile. It is 149,980 km^2, representing 14% of the total national territory.

Traditionally, the altiplano was considered to be a series of plains with various ridges of mountains, isolated mountains, and a plain denominated "Puna" that has the characteristics of a closed basin. However, it was considered convenient to subdivide this unit into two: the part of the plains keeping the name altiplano, and all the morphological formations with reliefs over-passing in the plains called serranias interaltiplanicas.

The whole altiplano could be said to be a very big basin, probably originating from the compound fracture in blocks during the raising of the Andes, currently covered with disappeared lake sediments (Ballivian, Minchin, Tauca), partially dried lakes (Titicaca and Poopo), and residues of the big salt lakes Uyuni and Coipasa.

The altiplano could be divided into a sub-humid part and another dry. It is evident that the humidity decreases from north to south, changing its dryness into lake, lagoon, and salt lake. Lake Titicaca, with 1 gr./lt. of salinity, constitutes a sweet-water lake and generates a humid zone. The Poopo, with 25 gr./lt. of salinity, has not yet reached the salt lake state, because it is permanently fed with sweet water from the Desaguadero River and forms a semidry zone.

PHYSICAL CHARACTERISTICS OF THE ALTIPLANO

GEOLOGY

Following is a brief description of the most important geological characteristics of the altiplano according to a chronology of the geological periods:

- Precambrian

  There are data of the precambric base at 2.800 of depth in an oil well drilled by Y.P.F.B. (Yacimientos Petroliferos Fiscales Bolivianos) in La Paz.

- Cambrian

  It is not present.

- Ordovician

  Non-differentiated Ordovician rocks are found at the south end of the altiplano with outcroppings routing NE-SW and are disposed in a discontinuous linear form.

- Silurian
  Small outcroppings are shown.
- Devonian
  Isolated small prolongations of Devonic outcroppings that correspond to the main outcroppings of the Cordillera Oriental.
- Carbonian
  Sedimentites of this system crop out in lesser extent in the Lake Titicaca area.
- Permian
  It is shown in the Northern Altiplano and represented by two formations: Copacabana of petrified limestones and Tiquina of calcareous sandstones, reddish and pink in thin banks.
- Triassic
  It is not present.
- Jurassic
  It is not present.
- Cretaceous
  This system is found vastly distributed in the Altiplano. The Meridional Altiplano presents large bodies of gypsum deposits.
- Tertiary
  This system is widely found and is a sequence of the continental type with possible marine influence of shallow waters.
- Quaternary
  Recent climatic characteristics have permitted a good sedimentation from the mid to the top Quaternary in almost all the altiplano where there is a lot of accumulated volcanic material, ignimbrites, tuffs, and lava flows of all kinds.

The Bolivian Altiplano is an endoreic group of quaternary basins occupied by the Titicaca and Poopo lakes and by the Uyuni and Coipasa salt lakes. In earlier times, there were various quaternary lacustrian extensions known under the names of Ballivian (Bowman 1909), Minchin (Steiman 1906), and Tauca (Servant 1977). Older lakes existed in other regions such as the basin of Chara:a.

In the northeast of the altiplano, the region of La Paz, four glacial formations are distinguished and are from the oldest to newest Calvario (Dobrovolny 1962), Kaluyo Sorata (Servant 1977), and Choqueyapu (Troll 1929). The lowest moraines are located between 3,000 and 3,800 m. of altitude, or 1,000 m. below the actual glacials.

HYDROGRAPHY

The hydrography consists of two zones:

A. Northern Altiplano

This is the plain zone between the Titicaca and Poopo lakes that cover four hydrographic basins (Fig. 5).

A.1. The Basin of Lake Titicaca, with its sub-basins

- Suches, near the border with Peru, with an important and abundant flow, however with a tight valley where agricultural practices are very limited.
- Achacachi, which collects a large portion of the water from the Cordillera Real.
- Catari, which collects water from El Alto-Viacha-Comanche-Alturas de Tiwanacu and Guaqui. It is the most extended of the sub-basins that flows to the lake. It is the watershed of the waters flowing to Titicaca and Poopo.

Lake Titicaca has a drainage area of approximately 56,000 km^2 for an extension of 8,440 km^2 of the top layer of the lake.

A.2. Desaguadero-Santiago de Machaca-Calacoto

- The Desaguadero River, which carries an average of 20 cubic meter/sec. from the Lake Titicaca to Poopo, creates various sub-basins when it crosses the northern altiplano and part of the interaltiplanian mountain belts.

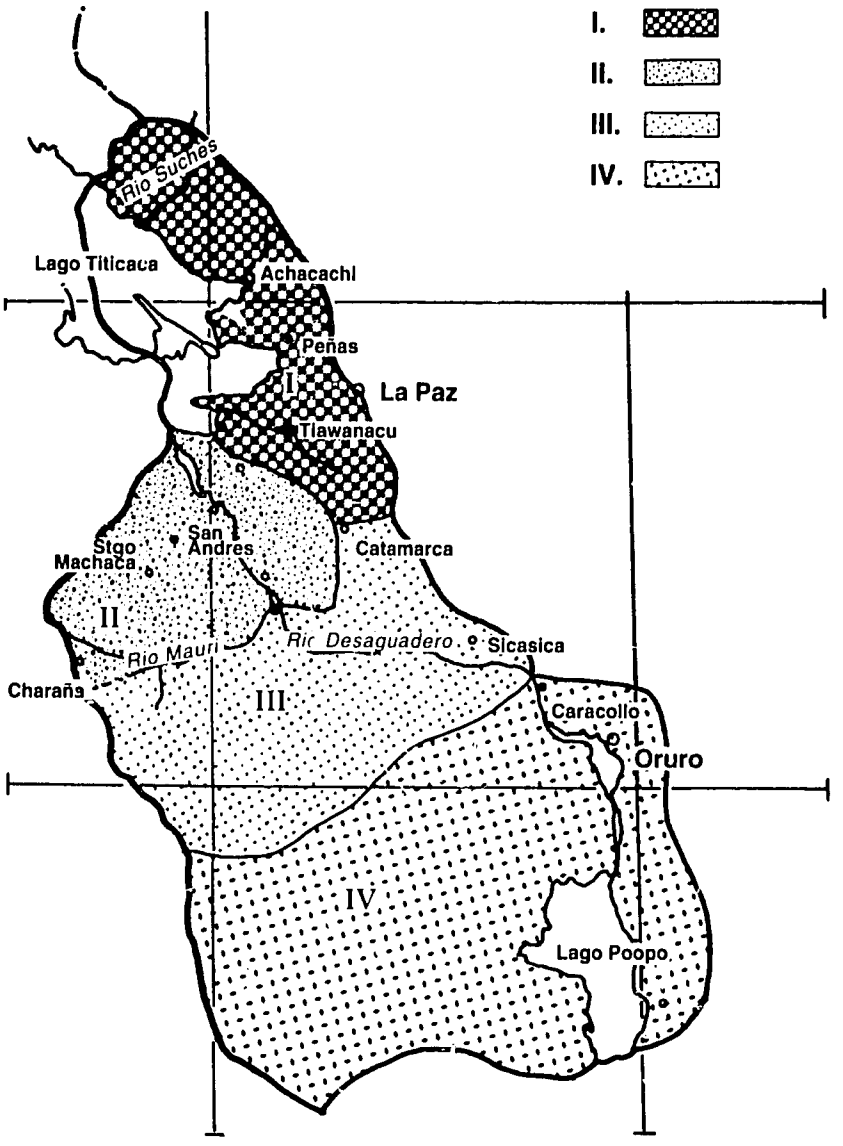
The drainage area of the Desaguadero River until it joins the Mauri River has an extension of 9,000 km^2. The Mauri River is the main tributary of the Desaguadero and the only one that provides sweet water with a flow of 5 cubic meter/sec. in the lower period.

A. 3. Calamarca-Sicasica

- To the south of the Catari sub-basin and from Calamarca, there is a plain that covers Calamarca-Patacamaya-Sicasica. To the east, it is bounded by the Eastern Cordillera, and it runs to the West to Umala and the Desaguadero Rivers.

A.4. Caracollo-Oruro-Lago Poopo

- The northern altiplano ends in a very extended plain about 200 km. long, a continuation of the previous sub-basin, and it reaches to the south of the Lake Poopo. The Desaguadero River ends its path at the Lake Poopo. The carried sediments and salted materials are deposited at the lake, raising its salinity to 25 gms./lt. The size and shape of Lake Poopo and the delta of the Desaguadero, including its flooded areas, are changing con-



ALTIPLANO NORTE

ESCALA APROXIMADA 1:2,500,000

I. Cuenca del Lago Titicaca
   Subcuencas: Suches, Achacachi, Catari

II. Cuenca Desaguadero-Stgo. Machaca

III. Cuenca Calamarca Sicasica

IV. Cuenca Caracollo-Oruro-Lago Poopo

FIGURA 5

stantly. During recent years, they formed new flooded areas, thus increasing the size of the Uru Uru lake that is getting dangerously closer and closer to the city of Oruro. Back in 1970, the level of this lake was at 3,697 meters, or 1 meter below the lowest part of the city.

B. Southern Altiplano

At the south end of Lake Poopo begins a different region characterized by the appearance of big salted bodies and desertified pampas formed by clay, limestone, and gravel. It is the most arid region of the country, with less than 100 mm. per year of rain, and sometimes none.

There are rivers that stay dry for years, and when an occasional rain occurs, they could carry lots of water, but it is absorbed very quickly by the soil. The dry conditions and the lack of resources are so extreme that human life is non-existent there.

Underground Hydric Resources

The hydrogeological basin of the altiplano is located between 3,000 and more than 4,000 m. above sea level, forming a series of irregular underground pockets of water flowing and emptying to Lakes Titicaca, Poopo, and Uyuni. It is evident that from the quality point of view of those waters, the ones to the Titicaca lake have better hydrogeological conditions and contain important quantities of underground water of good chemical quality. These characteristics decrease in the region of Lakes Oruro and Poopo and become even less in the sale lake Uyuni.

Physiography

The Altiplano has three well-defined zones:

A. Northern Altiplano, an area located between Lakes Titicaca and Poopo, covers four hydrographic basins already described.

B. Southern Altiplano is a different area from the previous one, starts at Lake Poopo and is characterized by the presence of salted bodies and desertified plains (pampas); it is the arid region of the country, with less than 100 mm. of rain per year and sometimes more.

C. Interaltiplanian Belts, in the middle of the northern Altiplano is a chain of mountains that starts at the south of Lake Titicaca and continues south-southeast near Lake Poopo. They are outcroppings of sedimentary tertiary rocks.

The peculiarity of this physiographic sub-unit is that it breaks the continuity of the plateau of the altiplano with hills that raise to 60 m.

THE ECOLOGICAL REGION OF THE ALTIPLANO

The altiplano is the intermountain region located between the eastern and western peaks of the Andes at an average height of 4,000 m., with their highest peaks over 6,500 m. above sea level. In this extended region are various scenarios; the most important are the interandean valleys, plains, and low depressions with outcroppings such as salted bodies, plateaus, alluvial slopes, fan-shaped bodies, and volcanic and colluvial-alluvial groups mostly in the west and south of the altiplano. It is also important to note the presence of deep valleys and a chain of mountains, the majority of which are covered with year-round snow that form big glacial lakes and numerous rivers and streams where the majority of the agricultural activities are concentrated.

Because of its environmental characteristics, this region had numerous animal and vegetal species of its own, natural resources that were utilized through time at diverse states and intensities.

The introduction of the usage of burning materials as an auxiliary tool began the long and continuous process of reducing the extension and variety of original forests and almost causing the extinction of numerous animal species, altering negatively the vegetation of the altiplano.

The arrival of the Spanish Conquistadores to this highly and well-conserved and developed cultural region had a strong impact and harmful consequences not only for the landscape and for the native inhabitants, but for the new institutional and political structure that was imposed and the mining activity to which they were dedicated.

The uncontrolled firewood exploitation, plus burning and overgrazing for the new animals that were introduced caused the Andean forests to virtually disappear. The Andean fauna, not permitted its necessary habitat, was drastically reduced, resulting in the extinction of many valuable species.

The newly introduced livestock were sheep, goats, and horses, all of which had a decisive impact on the natural resources and the economy of the region. Because of the inadaptability of the horses and goats, it was necessary to establish pastures at lower altitudes, between 2,000 and 3,500 m. above sea level on soils with strong slopes inside the valleys of the Andes. Through yearly burns, they replaced the natural forests with pastures, and overgrazing was generalized, having constantly a negative impact on secondary forests.

The erosion problem is variable, and it depends mainly on climate, topography, human activity, and soil. Throughout the years and because of human activity, these soils were degraded, becoming skeletical soils with outcroppings of bedrock in some areas.

The most notable aspect of the overgrazing is the negative alteration of the pastures, reducing its size and density, and as a result invaded by other unusable species such as "paja brava" (Stipa ichu), thola, spiny shrubs, and cactus replacing the climax vegetation.

LIFE ZONES, LOCATION, VEGETATION, PHYSIOGRAPHY AND SOILS, LAND USE, LAND CAPABILITY

Subtropical Region: Lower Montane Belt
Thorn Steppe Lower Montane,
Transition to Montane Subtropical

- Location. It is located throughout the Desaguadero River from the junction with the Mauri River to its flow to Lake Poopo. It is a strip of land with an average width of 30 km. and with an extension of 5,800 km^2.
- Climate. A range of bio-temperatures from 10.5°C to 12°C and a total annual precipitation between 250 and 350 mm. In ecological terms, despite being transitional to two bio-climates, it has both colder and very dry conditions and even marginal to proper species in the life zone. Since it borders the Desaguadero River, it gets the benefits of irrigation for existing productive Alluvial soils.
- Vegetation. The dominant natural vegetation is formed by dispersed grasses and shrubs. The last part of this paper lists a few typical examples of vegetation of the altiplano.
- Physiography and soils. The Desaguadero River, because of its relatively high fall, does not meander with the exception of few sectors. There are two well-differentiated scenarios:

  A. High dissected terraces formed by tertiary rocks, lithosolics and very well dissected.

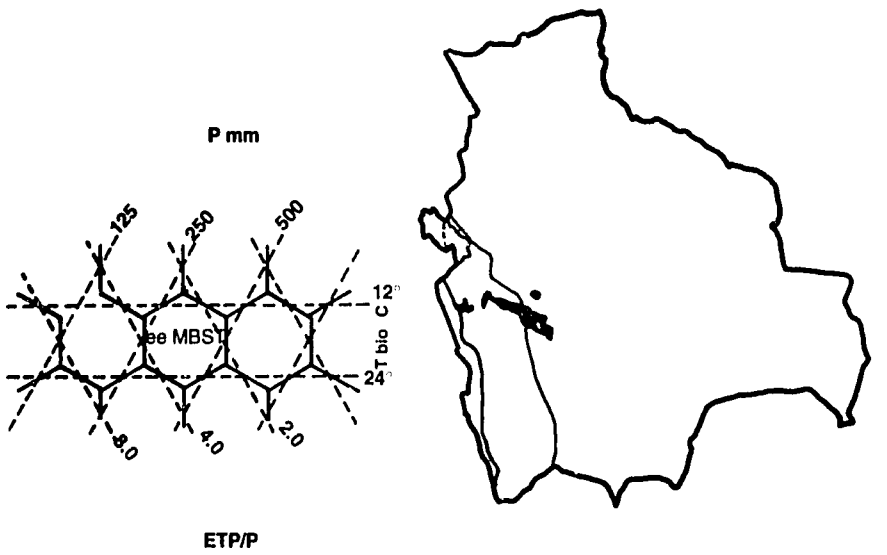
  B. Alluvial plains with bad drainage and flooded areas, deep with salinity problems.

  The chemical characteristics of these soils show that they are weakly lixiviated and with a very high base of saturation.

  The reaction varies from moderated alkaline to weak acid.

  The phosphorous is low, varying the potassium from moderated low to high, and the contents of minor nutrients such as calcium and magnesium vary from low to moderated.

THORN STEPPE LOWER MONTANE TRANSITION TO MONTANE SUBTROPICAL



Distribución y límites climáticos de la estepa espinosa montaño bajo subtropical

FIGURA 6

- Land use. A big part of this area is overgrazed because of the large number of sheep overcoming to the receptive capacity of the natural vegetation of this life zone. There are a few annual crops, such as barley (Hordeum Vulgare), quinua (Chenopodium Quinoa), and potato (Solanum Andigenum).
- Land capability. There is special interest in this area because of the irrigation possibilities, using water pumps and dirt dams to stop the inundation. This way, alfalfa (Medicago Sativa) and principally wheat could be planted, along with other horticultural species.

STEPPE MONTANE SUBTROPICAL

- Location. Located between coordinates 17° and 19° latitude South, it has an area of 15,200 km^2 and is mostly represented at the north-central sector of the altiplano, forming part of the hydrographic basin of the Desaguadero River, with its south and west limit bounding with the formation Thorn Steppe Lower Montane Transition to Montane Subtropical.
- Climate. The precipitation in a big part of this area is between 300 and 500 mm. per year, elevations are between 3,500 and 4,200 m. above sea level, and bio-temperatures are between 10°C and 6°C.

  The months of summer are hotter than those in winter, and since summer coincides with the months of rain, growth conditions are good for natural vegetation such as pastures and shrubs from mid-September to mid-May; the rest of the year is dry. Freezing is common during winter and frequent in the months of summer.
- Physiography and soils. The area has well-drained alluvial plains, alluvial fluvial-lacustrian plains with drainage problems, pockets with salty outcroppings, etc.; the soils of these plains are generally deep with permeability that varies from slow to very slow in all the profile. Because of their chemical characteristics, they are considered as weakly lixiviated and with very high base saturation. The soil's reaction varies from low to high alkaline. Phosphorus is low, and Potassium varies from high to moderate. Secondary nutrients such as calcium, magnesium, etc., are in quantities that vary from moderate to high due to the alkaline nature of the soils.

STEPPE MONTANE SUBTROPICAL

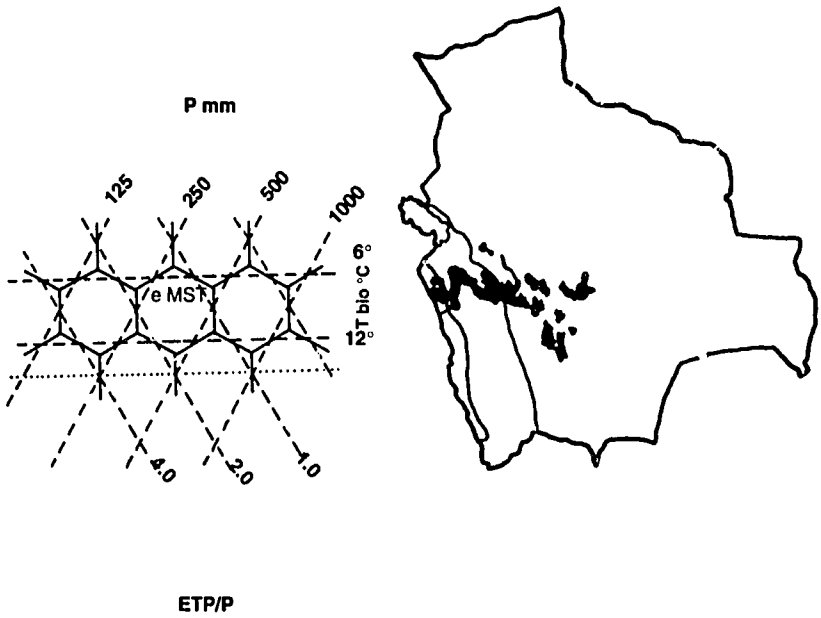


Fig. N. 41. Distribución y límites climáticos de la estepa montano subtropical.

FIGURA 7

- Vegetation. The dominant vegetation in this area is the perennial gramineous kind, mainly those that are presented in bundles with dispersed shrubs that grow during the rainy period. In sectors forming almost a blanket shape are the "tholares" which are shrubs from 50 to 100 cm. high, covering extensive areas of the plains.
- Land use. With the exception of small areas where bitter potatoes are planted, as well as barley, quinua, and cañahua, a big portion of this area is dedicated to pastures mainly for ovine species.
- Land capability. Agricultural activities could have a substantial increment if the rivers were utilized, such as the Desaguadero and few other affluents, for irrigation purposes based on water pumps.

MOIST FOREST MONTANE SUBTROPICAL

- Location. This is one of the most important formations and is one of the most densely populated in the country. It has an area of 27,700 km^2, partly belonging to the northern altiplano.
- Climate. It is the most favorable for agriculture and cattle raising and for ages was densely populated. Pre-Colombian cultures were born and grew here with high levels of civilization, reaching the point of domesticating native plants such as potato, quinua, oca, cañahua, and many more. For the same reasons, there are not even traces of the original forest that existed before agriculture.

  The temperatures of 6°C and 12°C correspond to elevations between 2,150 to 4,150 m. They could be higher in those areas where there is a notable difference in the relationship between bio-temperature and precipitation. In some areas, this forestation can be found as high as 4,300 m. above sea level, with an annual mean temperature of 8.8°C and a precipitation of 553 mm.
- Physiography and soils. The landscape has a smooth, wavy topography, with valleys and rivers not too deep. There are extensive deposits of moraines, alluvial and fan-shaped. The alluvial plain is drained by numerous small rivers. The monotony of the landscape is broken thanks to the appearance of elevations from isolated hills.

  Soils normally are very deep with permeability that varies from moderate to very little in all the profile. Chemically the soils are weakly lixiviated with a base saturation that varies from high to very high, with a soil reaction from neutral to strongly alkaline. The contents of organic material is low and decreases much more in function of depthness. Phosphorus is absent in almost all soils, and potassium exists in moderate quantities. Secondary elements such as calcium, magnesium, and sodium

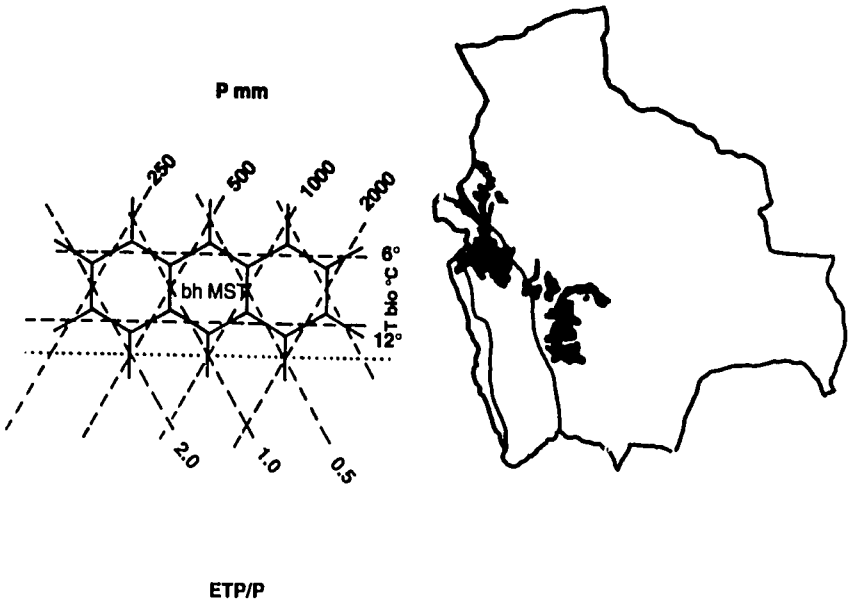


Fig. N°45. Distribución y límites climáticos del bosque húmedo montano subtropical

FIGURA 8

are in moderate to high quantities, which explains the alkaline nature of these soils.

- Land use. These soils were exploited before the coming of the Spanish Conquistadores due to their moisture and crops of notable nutritive value such as potato, oca, tarhui, cañahua, and quinua.

  There are many land tenure systems, although the mini-fundia is the one creating major problems in the improvement of agricultural activity due to the alarming rate of population. Consequently, the problems are in essence socio-cultural rather than technical.
- Land capability. The climate is favorable for the growing of cultivated forests where many problems of erosion could be solved mainly in those areas where irregular agricultural practices are performed. The following species of eucaliptus are recommended: E. bicostata, E. gunnii, pine varieties such as P. insignis, P. rudis, and native species such as Quishuara o Kolli (Buddleia coriacea Remy) and Kenua or Kehuina (Polylepis incana HBK).

TEMPLATE REGION: MONTANE BELT

DESERT MONTANE TEMPLATE

- Location. This area occupies a big part of the South of the altiplano, including Uyuni, Empexa, Coipasa, etc. It covers an area of 37,930 km^2, which is 3.47% of the total area of the country. The annual average temperature varies between 6°C and 12°C. Nights are very cold with a high incidence of nocturnal radiation. Days are fresh, with a high incidence of direct solar radiation. In general, the rain that falls is scarce or null except in those years during the months of summer that it rains very short and fast.
- Physiography and soils. Volcanic and sedimentary rocks dominate the area where the topography is very rough, alternating with plains, where superficial and salted soils were formed. Most of those plains are covered with salt.
- Vegetation. The quick rain (yearly average) of less than 100 mm. clearly explains the scarce vegetation.
- Land use. Little land is cultivated due to the extreme arid conditions. There is some agricultural activity in the small valleys, with planted quinua combined with the raising of camelids on a small scale.

DESERT SHRUB MONTANE TEMPLATE

- Location. This area occupies 52,890 km^2.
- Climate. Because of the conditions imposed by cold temperatures and the lack of humidity, vegetation is reduced in its growth rate as well as in its density. Other limitations are the extreme arid conditions and the soil moisture, with yearly rain not over 200 mm.
- Vegetation. What calls the attention in this life zone is the xerophytic vegetation, since it is a very dry zone. Grasses are fibrous, and feeding capacity is very limited, even for those domestic and habituated animals such as the camelids. To prevent overgrazing, the carrying capacity in these areas has to be considered; many experts say there should be one animal per 12 hectares.
- Physiography and soils. There is a complex physiographic landscape where wavy and rugged landscapes dominate, composed of old and hard sediments which are strongly folded. In general it has high elevations and rough topography and is very dissected, forming small valleys where agricultural activity is developed for subsistence purposes.

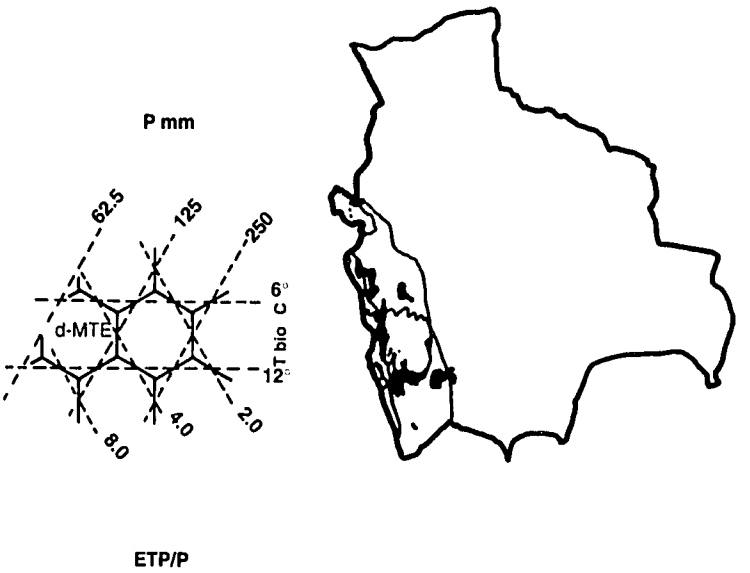
  In this formation, there is a depression occupied by the Colorado Lagoon that is important to be mentioned, located at 4,200 m. above seal level; it is a closed basin surrounded by volcanic structures. It was mentioned because of its impressive beauty and the need to conserve it for tourism and wildlife. It is the home of a variety of birds with aquatic habitat such as flamingos, ducks, ostriches, and others. The importance of this lagoon is that it constitutes a center for natural reproduction of these many migratory birds.

  There is almost nothing to be done to improve agricultural activities in this area.

THORN STEPPE MONTANE TEMPLATE

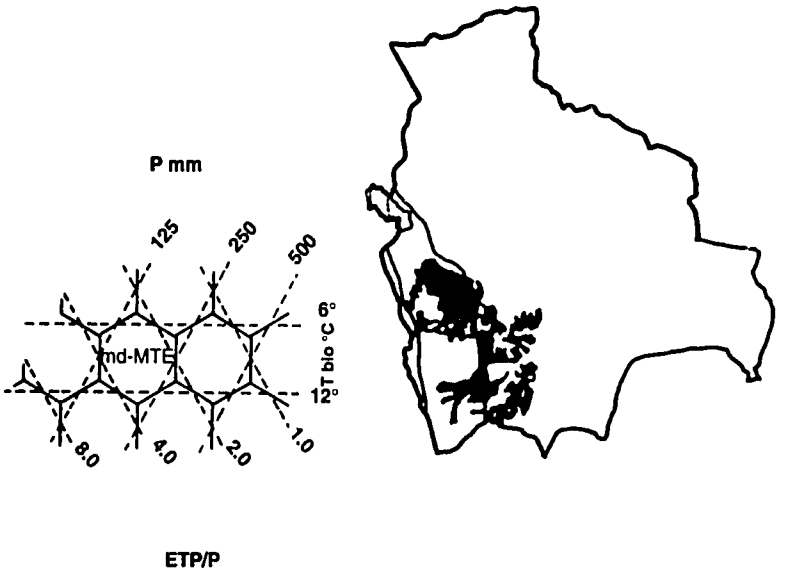
- Location and area. It is an extension of 12,850 km^2. Its population density is low.
- Climate. This area is located in between 3,800 and 4,100 m. above sea level and as low as 3,400 m. high and has very low temperatures at night between April and September, with 0°C. With respect to cattle raising, the species suffer a lot because of the cold weather and the lack of forage, especially during autumn, winter and spring. This bio-climate has no future for greater development, except as an experiment where overgrazing occurs and erosion exists in many places.

DESERT MONTANE TEMPERATE



Distribución y límites climáticos del desierto montano templado.

FIGURA 9



Distribución y límites climáticos del matorral desértico montano templado.

FIGURA 10

- Vegetation. The vegetation in this life zone is special with respect to the density factor and the composition of its species with low gramineous grass and some shrubs 3 m. high.
- Land use. A big part of this area is dedicated to livestock, especially sheep, camelids, and cattle. The agricultural activity is limited to small valleys normally close to the rivers and hillsides but only for subsistence. Little can be done to improve the agricultural activities because of the limiting factors of soil and climate. Nevertheless, the potential productivity of this area could be a lot more than at present, it is the consequence of bad management of the area and overgrazing. It is recommendable to have a correspondence between the number of heads and unit area per hectare. Profits for the peasants could be increased by introducing improved ovine species instead of the present ones and by rotating the pasture areas.

The following, in a general way, are some typical vegetation elements of the altiplano or Puna:

The climax vegetation consists of:

Stipa ichu
Calamagrostis spp.
Nasella sp.
Baccharis incarum
Baccharis boliviensis
Parastrephia lepidophylla

The distribution of the species are dependent on the edaphological variables, such as the following:

<u>Soils of humid plains</u>

Muhlenbergia fastigiata
Haffmannseggia sp.
Boutelova simplex

<u>Soils of dry plains and salted</u>

Anthobryum triandrum
Suaeda fruticosa

<u>Sandy dry soils</u>

Junellia seriphioides
Lampaija medicinalis

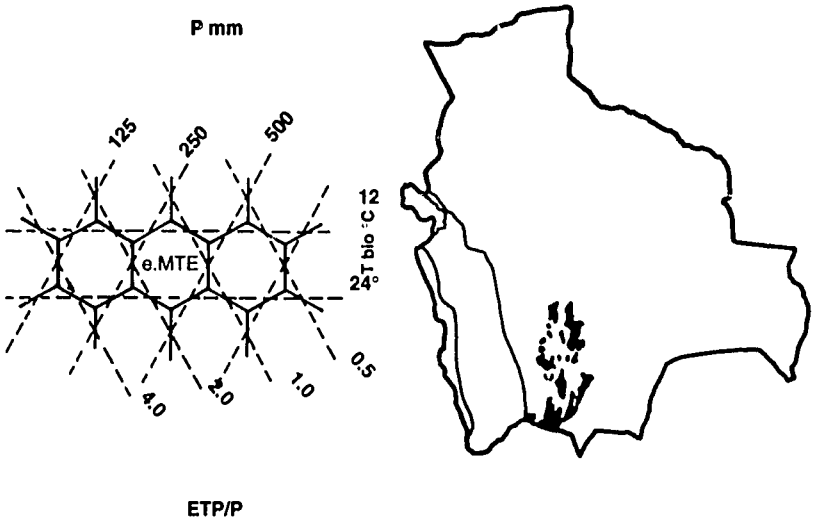


Fig. N°71. Distribución y límites climáticos del monte espinoso Montano templado.

FIGURA 11

Stony dry soils
Fabiana densa
Tetraglochin cristatum
Adesmia spp.

Stony and humid plain soils
Psila boliviensis

Salty soils
Distichlis humilis

Humid soils close to small streams
Festuca dolichophylla

River sandy boarders and depressions with low depthness of water
Parastrephia phylicaeeformis

LIVESTOCK OF THE ALTIPLANO

Livestock covers all the plateau of the altiplano in the departments of La Paz, Oruro, and Potosí It is characterized by its cold climate and frequent freezing. There are natural prairies called "prairie of the heights" where native forage is grown. These prairies in the altiplano are degraded, since there is no conservation practice that would limit overgrazing.

EXTENSION OF NATURAL AND CULTIVATED PRAIRIES

Prairies	Natural sq. km.	Cultivated for year 1974 sq. km.
Altiplano	93,037	3.7

OTHER PASTURES AND FORAGE

The natural prairies of the altiplano are sufficiently poor and do not represent an important nutritive value for the ovine and bovine species raised there. Only camels make good use of them. That is why the Agricultural Experimental Stations of the area recommend the plantation of artificial prairies based on alfalfa (Medicago sativa), festucas (Festuca arundinacea), pasto ovillo (Dactylis glomerata), oats elatior (Arrbenatherum elatius), agropiro (Agropyron elongatum), and fleo (Phleum pratense), especially for

NATIVE FORAGE OF THE ALTIPLANO

Scientific name	Common name
Picnophyllum molle	Coca de vicuña huari coca
Parastrephia lepidophylla	Thola
Baccharis microphylla	Kerhua thola
Carex nebularum	Ajsa
Carex sp.	Sercipasto
Atriplex cristata	Ullpuyuyo
Suaeda fructicosa	Cauchi
Erodium cicutarium	Alfilerillo, reloj, reloj
Ephedra americana	Sanu Sanu
Aciachne pulvinata	Paco Paco
Agropyron attenuatum	Toja
Aristida adscencionis	Caballo huchinca
Aristida asplundii	Yawarilla
Bouteloua simplex	Llapa
Bromus lanatus	Cebadilla
Bromus unioloides	Cebadilla
Calamagrostis heterophylla	Konkor-kara
Calamagrostis vicunarum	Crespillo
Distichlis humilis	Orko-chiji
Eragrostis sp.	Tonko-tonko
Festuca dolichophylla	Chillihua
Festuca orthopylla	Paja Brava
Festuca rigescens	Paja Brava
Hordeum muticum	Cola de ratón
Muhlembergia fastigiata	Cachu chiji
Muhlembergia peruviana	Napa
Nasella mayeniana	Pasto pluma, Yawara
Paspalum pygmaeum	Cachu chiji
Poa candamoana	Ckachu
Poa gymantha	Grama
Stipa ichu	Ichu
Stipa sp.	Yawara
Trifolium amabile	Layu
Medicago denticulata	Carretilla
Astragalus garbancillo	Garbancillo
Lachemilla pinnata	Sillo-Sillo

the northern zone of the altiplano influenced by Lake Titicaca. For drier zones, central and southern altiplano alfalfa and pasto llorón are recommended.

For annual forage there are newly selected varieties of barley (Hordeum vulgare), especially Bolivia and E.E.A. No. 46. For oats (Avena sativa), the varieties of Rotemburger, Bannoch, and E.E.A. No. 18 are equally recommended.

■ **Bovine.** In the altiplano, this practice is closely related to the agricultural activity in the best areas for both activities. The objective of bovine raising is the use of male animals as working beasts (yuntas) in all kinds of hard labor such as harvesting, pulling or pushing materials, ploughing, seeding, and others. The useful life of these animals is around seven years; after that they are used for meat. Consequently bovine raising is not necessary for meat or milk production, and the peasant owner of the land reduces to one to three heads of these animals to satisfy his needs. In the northern altiplano influenced by Lake Titicaca and the city of La Paz, there is a tendency to have small milk farms that technically are unsophisticated compared to a fairly modern reproductive farm of Brown-Swiss species adapted for high elevation areas owned by CORDEPAZ (Corporacion de Desarrollo de La Paz) near by the city of El Alto in La Paz.

■ **Sheep.** This practice has a double purpose: to obtain meat and wool. It was introduced in Bolivia by the Spanish and actually uses domestic species based in Merino, Churra, and Manchega and other races adapted to the regions of the country. The next chart shows the sheep population by regions in the altiplano.

SHEEP PER REGION (1972)

Regions	Population (Heads)	%
Northern Altiplano	1,500,000	36
Central Altiplano	2,400,000	57
Southern Altiplano	300,000	7
TOTAL	4,200,000	100

Sheep raising keeps a big number of peasants busy as an important way of subsistence mainly obtaining the wool to weave their clothing and meat for their diet but used also for income and for exchange. Nevertheless, the yield of the wool (approx. 800 grs. per head) and the meat are lower than the standard international average, making this activity less profitable and secondary. The overgrazing activity in these natural prairies does not allow

recuperation of usable vegetal species. Consequences of such bad management are high mortality rate of the baby animals genetically deformed, and as a result low yields of wool and meat.

■ **Camelids.** These animals (llama, alpaca, vicuña) in Bolivia have special importance, because they originated in the Andean Mountains and because, since their domestication in prehistory, they accompanied the campesinos in the altiplano plains, giving them meat, wool, leather skins, fertilizer (manure), and combustible dung, as well as representing until recently most efficient transportation for carrying loads.

The habitat for these South American animals is between 3,800 and 4,200 meters above sea level in the ecological regions of the altiplano and high valleys.

Management of the animals did not reach modern techniques. Raising of llamas and alpacas is traditional and extensive. Insufficient and small corrals exist where normally llamas, alpacas, and sheep are mixed.

The main characteristic of this activity is in the first place the low yield of wool and meat, secondly the high mortality rate related directly to insufficient feeding with lactation problems and bad post-natal care, the lack of control during mating, and infections, illnesses, etc.

■ **Llama.** This animal is very important for Bolivia because of its large population. There are more than 2,500,000 distributed in the departments of Oruro, Potosí, La Paz, and Cochabamba (in order of importance).

The wool produced by the llama contains very fine fibers, probably more fine than from the alpaca, but with a coverage of bristly hair that lowers the quality of their wool.

The llama also produces meat of excellent quality, richer in proteins and energy than from bovine species. One llama weighs 60 kg. and produces after removing other materials (bones, skin, etc.) about 30 kg. of meat. The skin is of high quality, thin and resistant. A llama can carry up to 75 lbs. of load.

■ **Alpaca.** In Bolivia about 330,000 exist. They are mostly concentrated in specific areas with "bofedales." These are prairies irrigated by permanent flows of defrosted waters from the mountains and with short pastures.

Its fiber or wool is the most internally and externally commercialized. Bolivia produces about 300 tons of alpaca fiber. Its meat and skin are of high quality.

The Bolivian law declared these species "in process of being extinguished," and the national organization called INFOL is responsible for the production and conservation of these species by protecting and conserving the present nucleus of these animals.

■ Vicuña. This wild species lives in the altiplano from Ulla Ulla to Lipez. Unfortunately, they were used by bad merchants to make profits and now are almost extinct, although they are Bolivia's patrimony. Even with special controls in Ulla Ulla, as of June 1981, the population of these species is only 2,150. The Bolivian government established park reserves in Ulla Ulla, Sajama, Eduardo Avaroa of Lipez, and Altamachi in Cochabamba for their conservation. It is necessary to mention Dr. Armando Cardozo as a prominent Bolivian scientist who is very knowledgeable about the camelid species (South American Camelids).

PROTECTION AREAS OF THE VICUÑAS

No.	Denomination	Verified Census I	Non Verified Census II	Estimated III
1.	Reserva Nacional de Fauna "Ulla Ulla"	2.150	-.-	-.-
2.	Reserva Nacional de Fauna "Eduardo Avaroa"	12	-.-	500
3.	Area de Protección Mauri-Desaguadero	920	312	-.-
4.	Area de Protección Laruta-Charaña	207	-.-	-.-
5.	Area de Protección de Anallajchi	-.-	72	-.-
6.	Area de Procección Altamachi-Morochata	426	-.-	-.-
7.	Estación Experimental de Patacamaya	30	-.-	-.-
8.	Area de Protección Belén-Andamarca	252	-.-	-.-
9.	Area de Protección Chijmuni	28	-.-	-.-
10.	Area de Protección de Tomave	-.-	146	-.-
11.	Area de Protección San Pablo de Lipez	-.-	1.132	-.-
12.	Refugio de Vida Silvestre Huancaroma	228	-.-	-.-
13.	Otras áreas	-.-	-.-	1.000
14.	Guanacos-Cordillera de Mochará	-.-	-.-	Pocas
15.	Guanacos-Zona Estancia Perforación-Chaco	-.-	-.-	Pocas
Totals		**4.253**	**1.162**	**1.5000**

Totals I + II = 5.650

Totals I + II + III = 7.150

Source: Infol

SOCIO-ECONOMIC ASPECTS

INTRODUCTION

An analysis of the economic behavior of the people in the altiplano becomes more complex as the communities of campesinos, towns or microregions go through deep changing processes and in different directions depending upon specific factors that will influence them. Density in population, closeness to markets, roads for communication, and microclimes are some of these factors that differentiate the economic behavior of the campesino family into the Aymara world with the rest of the national society.

In the economic aspect, there are marked differences among these families specially with the lack of cultivable land. Consequently, it forces to classify the population universe in two stratums:

a) Influenced area of the Titicaca lake, communities that are very close and far away from the lake but affected by the microclime of the lake that generates major population density.

b) With less population density, non lacustrian areas or communities and towns that are not benefited with better temperatures and more humidity as a result of the evapo-transpiration.

THE PHYSICAL MEDIA: NON AND LACUSTRIAN AREAS

The obtained data is the result of a sampling study (Urioste, 1989) that covers five provinces of the department of La Paz and constitute the Northern altiplano that surrounds the Bolivian coast of the Titicaca Lake. Only campesino communities that qualify to be typical and characteristic of the altiplano were included in the mentioned study.

Good and critical aspects justified the choice of this region to be studied. Those aspects mainly were the population density, but most of all their socioeconomic specific characteristics and their more and more intense relationship and dependence on the economy of the national market.

The number of inhabitants in the Northern altiplano, based on preliminary data, was of 329,166.

Practically along the coast of the Titicaca lake, are located many campesino communities forming a kind of over-populated belt in contrast to those regions that are little far away. This situation created the two stratums for the study.

Despite the low rate of growing population in Bolivia and mostly in the altiplano (Censo de Población y Vivienda 1976), this region is one with the highest in the country.

EXTENSION, POPULATION AND POPULATION DENSITY OF THE AREA OF STUDY

	Extension km^2	Population census 1976. Preliminary results	Number Inhabitants km^2
Camacho	2.80	73,016	35.10
Omasuyos	2.065	83,621	40.49
Manco Kapac	.367	23,561	64.19
Los Andes	1.658	62,779	37.86
Ingavi	5.410	86,189	15.93
Totals	**11.580**	**329,166**	**28.42**

Unit of measure: simple density: 38.71 inhabitants per sq. km.
Source: Instituto Nacional de Estadistica.

In the Northern altiplano, the collected data based on questionaires show different use of the land: in the lacustrian areas, the population density is lower and consequently land use is less intensive. The quality of soils, frequency of rain, humidity, and less intense in freezing, increases the demand of lands nearby the Titicaca lake. Therefore, there are different and very significant productive aspects compared to the non lacustrian areas where cultivation is less intense.

The five provinces, cover an extension of 11,580 kms^2 and are 1% of the total of the whole country. Although, the 329,166 inhabitants of the Northern altiplano are equivalent to 7% of the country's population.

In general, the Northern altiplano based in this study, only 25% of the land have some kind of irrigation. Almost half of the cultivated parcels of land are located on slopes (45%), and a higher proportion on plains (55%).

POPULATION SURPLUS

Approximately 35% of the population of the Northern altiplano, are living on the coast of the lake. This means that around 115,208 campesinos are beneficiaries of the clime of the Titicaca lake, but at the same time they produce a population density of approximately 99.5 inhabitants per square kilometer. Now, if we consider that only 10% of the total area of the North-

ern altiplano corresponds to the one we classified as lacustrian then, 115,208 campesino farmers only occupy 1,158 km^2.

Using the same source of data the relation between man and land in non lacustrian areas is very different: there are 213, 958 inhabitants dispersed on 10,442 kms^2 of land of poor quality in nutrients and dry. The population density in this non lacustrian area of the Northern altiplano is approximately 20.5 inhabitants per square kilometer.

The marked difference on the population density between the non and the lacustrian areas explains itself the need to get a universal population stratum for a more differentiated analysis of the productive behaviors dependent upon the availability or scarcity of the most important productive factor in agriculture: the land.

TYPES OF LAND IN THE NORTHERN ALTIPLANO*

	Lacustrian area		Non Lacustrian area		Total	
	No.	%	No.	%	No.	%
With irrigation	33	27	40	24	73	25
Without irrigation	89	73	130	76	219	75
On hillsides	51	43	80	47	131	45
On plains	69	57	89	53	158	55

**In many charts, the totals do not exactly coincide with each other. This is due to some unanswered questions in the questionaires.*

TRADITIONAL CROPS

The traditional dominant crops in the Northern altiplano are: potato, barley, oca, haba, and other less important crops such as quinua, and in some special cases vegetables. The yields of these crops are very low, but a lot better from those other regions in the altiplano. A big number of these crops are for home eating, which explains the little importance to the economy of the campesino family to commerce with. As we will see ahead, other are the productive activities that provide to the campesino families with the minimum cash capital.

A family that has a regular size of land will always plant various products to assure their basic diet. If they would have bigger, they would select one or two products that later they will commerce with them. In the Northern altiplano, this will not happen, instead they will plant a big variety of products mainly to satisfy the diet needs of the family.

The following chart shows the distribution of the land based on cultivation. In the lacustrian Northern Altiplano, 32% of the area is with potato while in non lacustrian areas 36%. The 96% of the questioned families plant potato, and the 4% left correspond to exclusively cattle raising families in the province of Ingavi.

The crops of barley and oats in the non lacustrian area have an important effect in the general averages of the Northern Altiplano. 43% of the total cultivated area is dedicated to barley mainly to feed cattle. In those communities away from the lake the average cultivated extension with barley per family is of 0.62 has. while in those lacustrian communities only 0.31 has. In both regions the number of families that plant barley is less than those that plant potato. 85% of the campesinos of both regions plant barley or oats to feed cattle, and few plant barley as grain.

In the lacustrian area, the climatological conditions help the cultivation of lima beans with very good yields. 83% of the families plant lima beans in an average extension per family of 0.21 has. On the other hand, in the nonlacustrian altiplano, only 55% of the families do it in an average extension of 0.17 has.

In relation to the total family cultivation in the lacustrian are, lima beans occupy 21% of the total cultivated extension, in the non lacustrian only 8%. Quinua presents a similar situation in both regions; 9% of the total extension for quinua with 0.22 has. per family, although the number of cases are greater at the non lacustrian areas that cultivate this product (only 32% in lacustrian areas and 52% in the non lacustrian).

Onions are cultivated using seed beds, the extension used for transplantation is really insignificant. More and more this last product is cultivated by the campesinos of the Northern Altiplano mainly to trade.

CULTIVATED EXTENSION BY PRODUCTS

A) LACUSTRIAN AREA

	Potato	Barley	Lima Bean	Quinua	Onion	Others	Totals
Number of cases (families)	120	107	103	40	17	75	-.-
Cultivated extension (has.)	34.12	32.91	22.08	9.91	1.00	7.89	107.93
Average cultivated extension	0.29	0.31	0.21	0.25	0.06	0.11	1.22
Cultivated extension (% of total)	32	30	21	9	1	7	100

B) NON LACUSTRIAN AREAS

Number of cases(families)	163	146	95	89	16	68	-.-
Cultivated extension(has.)	77.05	91.01	16.50	18.86	1.03	7.81	212.26
Average cultivated extension	0.47	0.62	0.17	0.21	0.06	0.12	1.66
Cultivated extension (% of total)	36	43	8	9	0	4	100

C) TOTALS

Number of cases (families)	283	253	198	129	33	143	
Cultivated extension (has.)	111.19	123.92	38.58	28.77	2.03	15.70	320.19
Average cultivated extension	0.39	0.49	0.19	0.22	0.06	0.11	1.46
Cultivated extension (% of total)	35	39	11	9	1	5	100

CAMPESINO EMIGRATION

Where do campesinos of the altiplano temporarily emigrate?

The proximity to roads, and other attractive conditions and mainly the important economy of the city of La Paz makes it the most important center of temporal emigration. 77% of the campesinos travel in variable time periods to La Paz. The percentage gives us an idea of the urban influence in the campesino activity.

TEMPORAL EMIGRANTS

Number of emigrants (persons)	Lacustrian area			Non lacustrian area			Total		
	NºCases	%	Persons	NºCases	%	Persons	NºCases	%	Persons
One	61	59	61	78	63	78	139	61	139
Two	24	23	48	34	27	68	58	26	116
Three	12	12	36	7i	6	21	19	8	57
to Five	6	6	27	5	4	20	11	5	47
Total	103	100	172	124	100	187	227	100	359
Average (number of persons)	-.-	-.-	1.7	-.-	-.-	1.5	-.-	-.-	1.6
Number of inquiries	121			171			292		1.2

In second place of importance, is the traveling they make to areas of colonization, could be Caranavi, Alto Beni and in some cases to more far away areas (Chapare, Santa Cruz). Those that move to Yungas or Alto Beni, mainly do to work on their own land or their relatives', or as labormen. Since the agricultural periods of these subtropical zones don't always coincide with those from the altiplano, they can combine the cultivation of products of different ecological areas. They alternate two productive agricultural activities in areas of different clime.

MAIN OCCUPATION, EXTENSION, PRODUCTIVE TECHNOLOGY AND LEVEL OF INCOME

The next chart shows these relationships for both the lacustrian and non lacustrian areas.

MAIN OCCUPATION, EXTENSION, PRODUCTIVE TECHNOLOGY AND LEVEL OF INCOME

LACUSTRIAN AREA (NUMBER OF CASES AND PERCENTAGE)

	(56%) Agricultural		(7%) Cattle raising		(25%) Both		(12%) Other activities		(100%) Totals	
	Nº Cases	%	Nº Cases	%	Nº Cases	%	Nº Cases	%	Nº Cases	%
Extensions										
Extension I	40	(57)	0	-.-	14	(45)	10	(67)	64	(52)
Extension II	24	(34)	4	(57)	12	(39)	4	(27)	44	(36)
Extension III	6	(9)	3	(43)	5	(16)	1	(6)	15	(12)
Totals	70	(100)	7	(100)	31	(100)	15	(100)	124	(100)
Productive Technology										
Traditional	26	(38)	2	(25)	12	(39)	4	(27)	44	(36)
In transition	29	(42)	2	(25)	5	(16)	8	(53)	44	(36)
Non traditional	14	(20)	4	(50)	14	(45)	3	(20)	35	(28)
Totals	69	(100)	8	(100)	31	(100)	15	(100)	124	(100)
Income level										
Level I	43	(61)	2	(25)	5	(16)	2	(13)	52	(42)
Level II	23	(33)	5	(63)	18	(58)	5	(33)	51	(41)
Level III	4	(6)	1	(12)	8	(26)	8	(54)	21	(17)
Totals	70	(100)	8	(100)	31	(100)	15	(100)	124	(100)

RELATION OF MAN/DAYS WORKING IN AGRICULTURAL ACTIVITIES

A) LACUSTRIAN AREA

	Potato	Barley	Lima Bean	Quinua	Onion	Others	Totals
Man/days seeding	29.6	8.2	13.8	5.3	17.5	12.0	86.4
Man/days cultural care	25.9	18.9	16.8	16.8	18.2	18.2	114.8
Man/days harvesting	29.6	11.4	13.7	8.1	7.4	14.2	84.4
Total	85.1	38.5	44.3	30.2	43.1	44.4	285.6
Average cultivation extension	0.29	0.31	0.21	0.25	0.06	0.11	1.22

B) NON LACUSTRIAN AREA

	Potato	Barley	Lima Bean	Quinua	Onion	Others	Totals
Man/days seeding	49.4	11.5	9.9	4.8	12.9	12.0	101.0
Man/days cultural care	29.4	28.7	15.4	9.8	16.8	18.9	119.0
Man/days harvesting	60.6	21.4	10.5	7.0	6.7	20.5	126.7
Total	139.9	61.1	35.8	21.6	36.4	51.4	346.7
Average cultivation extension	0.47	0.62	0.17	0.21	0.06	0.12	1.66

C) NORTHERN ALTIPLANO

	Potato	Barley	Lima Bean	Quinua	Onion	Others	Totals
Man/days seeding	41.3	10.0	11.0	4.8	17.0	12.0	96.1
Man/days cultural care	28.0	25.9	16.1	13.3	17.5	18.2	119.0
Man/days harvesting	46.0	16.6	11.8	7.3	6.9	16.8	105.4
Total	115.3	52.5	38.9	25.4	41.4	47.0	320.5
Average cultivation extension	0.39	0.49	0.19	0.22	0.06	0.11	1.46

Relation of man/days working in agricultural activities, continued

D) NON LACUSTRIAN AREA

	Potato	Barley	Lima Bean	Quinua	Onion	Others	Totals
Harvest time in days	14.1	6.3	3.5	2.5	1.9	5.4	-.-
Nº of persons working in harvest	4.3	3.4	3.0	2.8	3.5	3.8	-.-
Man/days in harvest	60.6	21.4	10.5	7.0	6.7	20.5	126.7

E) TOTAL NORTHERN ALTIPLANO

	Potato	Barley	Lima Bean	Quinua	Onion	Others	Totals
Harvest time in days	11.5	5.2	3.7	2.6	2.1	4.9	-.-
Nº of persons working in harvest	4.0	3.2	3.2	2.8	3.3	3.5	-.-
Man/days in harvest	46.0	16.6	11.8	7.3	6.9	16.8	105.4

IMPORTANT ASPECTS ABOUT THE ECONOMY OF THE CAMPESINO OF THE ALTIPLANO

Based on the presented previous information, following are some important aspects of the economy of the campesino:

a. In the Northern altiplano, there are rich and poor campesinos. This unequal situation is probably due to multiple factors such as: social level or of authority in each community along with the education of each family. The current formal and informal education gives to the campesino few instruments so that he can reach by his own merits higher levels in his economy.

There are also other factors that are influential such as the size and fertility of the soils.

b. At the border of the Titicaca lake where the population density is three times higher than the rest of the Northern altiplano, in general terms the families are of older age than those in the non lacustrian areas (there are younger).

c. From each family in the Northern altiplano, an average of one person emigrated definitely. The real size of each family is reduced to five persons.

d. 36% of the questioned families cultivates the totality of their land as owners, meaning that they do not have unused land. They abandoned the practice of land repose.

e. Independent from definite emigration, an average of 1.2 persons per family of the Northern altiplano, leaves temporarily the altiplano for periods from two weeks to three months. This temporal emigration is more important in the lacustrian altiplano.

f. The most important center for temporal emigration is the city of La Paz. Less people temporarily go to areas of colonization (Caranavi, Alto Beni, Chapare, Santa Cruz) or to Yungas.

g. The fundamental reasons for temporal emigration are: commerce, work, and to visit relatives. When it is for work, their main activities are: bricklayer helper, gardener, know how of agricultural activities, load carrier, and as servants.

h. The less advanced or traditional is the used agricultural technology, the bigger is the proportion of emigrants that leave the altiplano looking for work.

i. For 13% of the campesinos of the Northern altiplano, the agricultural activity, fishing, cattle raising are not the main productive activities. From other activities they obtain higher income than from those who dedicate exclusively to the agricultural activity.

j. A family dedicates only three and a half months per year to an intense agricultural activity, mainly potato.

k. The incorporation of marginal lands to family agriculture seems that the extreme maximum limits was reached mainly in the lacustrian areas. These produces a structural unbalance between men and land with no possible solution in the region.

l. It is not the Reforma Agraria (Agrarian Reform) that created the structural unbalance, but the growing population. Land is a fixed factor and scarce while the population increases at a very fast rate.

m. The use of relatively modern technology is for potato cultivation and almost none for other products. Almost half of the campesinos are in the traditional technological level considering the rest of the crops of the area.

n. Cattle raising is a complement to the agricultural subsistence; few are the families that do not raise some animals. Cattle constitutes a way of savings and an assurance for those years of bad harvest.

o. In those economic units with very small parcels of land, it seems that they are in the typical phase of decreasing yields. The average productivity for the work in these cases, is very low.

p. The typical dispersion of the cultivation in various lots not only responds to the equal distribution of the land in different ecological belts, but to a rationalized economy that prevents them from the dangers and disadvantages of an extensive productive activity and therefore closely tied to the market.

q. Families with high education level commercialize a big part of their products. while those of a lower level consume theirs in very high proportions.

r. 34% of the questioned campesinos from the Northern altiplano, assure that the most profitable productive activity is not the combined cultivation and animals activity. They get the most important part of their income via other sources.

s. It is estimated that the yearly gross income per capita is of $us. 269. Families from lacustrian areas have more money than those non lacustrians.

SOME PROPOSED IDEAS ABOUT THE WORK TO BE DONE IN THE BOLIVIAN ALTIPLANO

The proposed ideas for the Bolivian Altiplano consists in a series of suggestions that are the result of an analysis of what was exposed previously. Some considerations about the socioeconomic factors that show the campesino's resources, way of life that only are some indicators for orientation.

Following are the proposed suggestions for the Bolivian Altiplano presented and rounded to gross themes:

■ The main problem to solve is how to revert the deterioration of the soils and the resource water, promoting an increment of the agricultural activity, and of the income of the campesinos from the Altiplano.

It is known that there exists an extensive erosion on the soils, nevertheless, the nature and extension of it is not well documented. It is not clear about how much of the erosion is to be blamed on geological processes and how much is induced by men.

Research and analysis is necessary to determine the reasons and the extension of this erosion, as well as to determine what to do to prevent and face the problem, urgent priorities and immediate actions.

■ Other reasons for the degradation and erosion of the Altiplano is caused by the use of manure and wood, particularly thola used for energy. There are no studies that estimate the cost of opportunity of manure as a fertilizer versus thola and other vegetation for combustion energy.

■ Another reason for erosion in the Altiplano is that there is no adecuated watershed management, in a way to control the overgrazing activity of ovines, cattle and camelids, and also to control the loss of soils and water.

■ Away from this serious degradation problem of the resources of the Altiplano, there is a reason to believe that some of these resources are over utilized where they could be more productive with appropriate technology and supporting services.

There are methods to control pastures, crops rotation, management of pastures, small irrigation and drainage project, increase the productivity with conservation of water and the use of adecuated fertilizers, and the increase of cattle raising production.

■ A financial investment, for research on agricultural and cattle raising activity for the Altiplano, is indispensable in order to provide the campesino the opportunity to face its limitations in production.

■ It is important and necessary to do an Institutional Analysis to determine the impact of the actions of the so many public, private, national and international organizations working in the Altiplano. There are dispersed technical and economical efforts by them, but without any real benefit for the campesinos.

■ It is mandatory to do an Agroecological Zoning of the Altiplano where technically is to be determined which areas are potentially appropriate for agricultural production, which for pasture production, which areas would be susceptible for extensive forestation, and which to be maintained under protection. This way, it could be done a territorial ordering which will give clues for a distinct distribution of the land based in demographic factors about the demand and land capability.

■ The recapturing of the traditional technologies that were in effect for ages, for example the use of *camellones* for water handling, soils, and cultivation, which were totally optimum in the improvement of the micro-environment, diminishing the freezing effects thanks to the thermo regulator aspect of existent water in those channels, conserving the humidity and water in those channels and renovating the fertility with the concentration of organic materials.

■ A final recommendation: for the Altiplano, high priority should be given to identify options and priorities on investment to manage soil and the load capacity, creating scenarios for the future based on different options related to erosion, land capability and its relation to the growing population and migration.

BIBLIOGRAPHY

Ahlfeld, Branisa, L.; 1960. Geología de Bolivia. La Paz-Bolivia.

Araca Quispe, R.; 1987. Universidad del Altiplano. Los Waru-Waru. Puno-Perú.

Beek, K.J.;1978. Land Evaluation for Agricultural Development-Wageningen, The Netherlands.

Cochrane, T.; 1973. Mapa Sistema de Tierras. La Paz-Bolivia.

CUMAT, 1985. Manual de Levantamientos Semidetallados de Clasificación y Metodoligía de la Capacidad de Uso Mayor de la Tierra. La Paz-Bolivia.

CUMAT, 1987. Clasificación de Uso Mayor de la Tierra. Región Achacachi. La Paz-Bolivia.

GEOBOL, 1978. Mapa Geológico de Bolivia. La Paz-Bolivia.

Holdridge, L.R. y Tosi, J.A.; 1975. Ecología Basado en Zonas de Vida. San José-Costa Rica.

Lara Rico, Raul; 1988. Estado Actual de las Especies con Necesidades de Protección en la Flora de Bolivia-CUMAT. La Paz. 6p.

Montes de Oca, I.; 1989. Geografía y Recursos Naturales de Bolivia. La Paz-Bolivia.

Quiroga, J.C.; 1984. Estudio de los Recursos Naturales del Corredor Central de Desarrollo. La Paz-Bolivia.

Tosi, Jr. J.; 1975. Mapa Ecológico de Bolivia. La Paz-Bolivia.

Tosi, Jr. J.; 1981. Una Clasificación y Metodología para la Determinación y Levantamiento de Mapas de la Capacidad de Uso Mayor de la Tierra. San José-Costa Rica.

Urioste, M., 1989. CEDLA: La Economía del Campesino Altiplánico en 1976.

Overview of Small Ruminant Research in the Bolivian Andean Zone

Humberto Alzérreca Angelo
Bolivian Institute Of Agriculture Technology

BOLIVIA ANDEAN ZONE AGRO-ECOSYSTEMS

The Bolivian andean zone is located to the west and southwest of the country and has an area of 292,952 km^2, equal to 26.6% of the total of 1,098,581 km^2 (Table 1).

The Puna—high mountains and the tableland (altiplano)—represent 84.1% (246,253 km^2) of the total and the remaining 15.9% (46,699 km^2) is intermontane valleys and a low mountain chain. Eighty percent (3.6 million) of the country's population is located in the Andean Zone (Map 1).

TABLE 1. BOLIVIAN ANDEAN ZONE IN KM^2

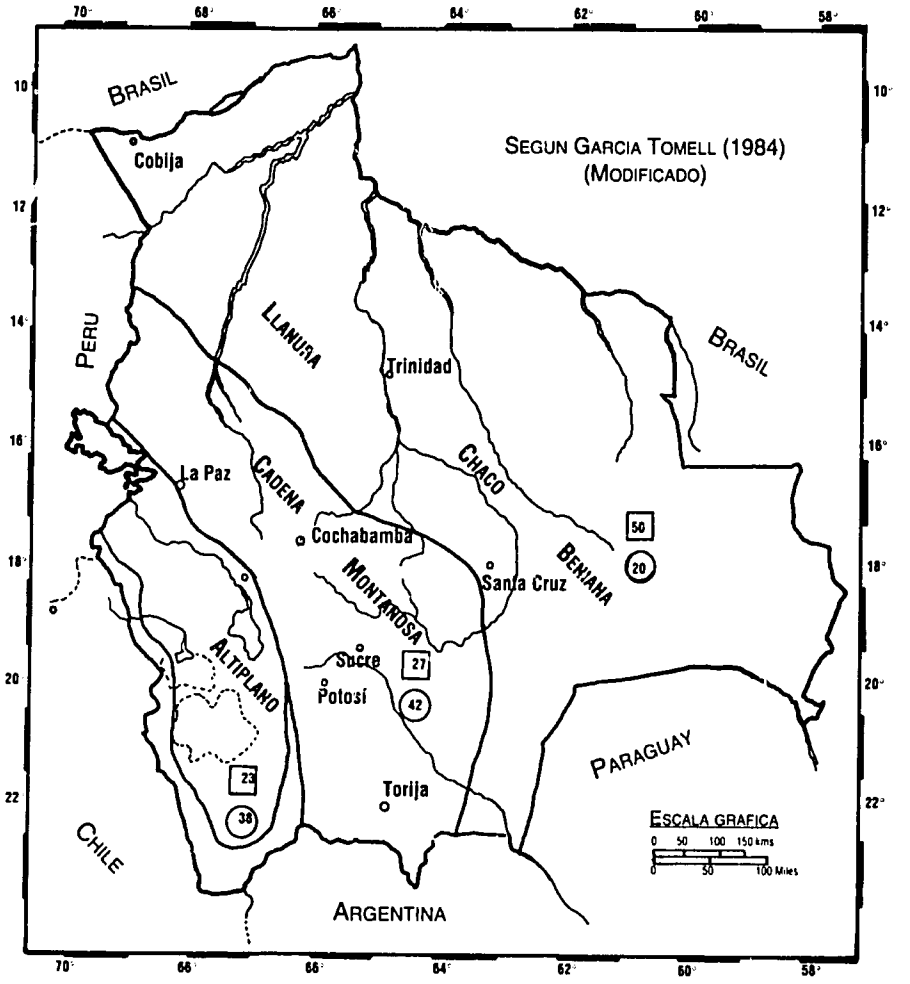
Total	
High Andes and the tableland (Puna)	246,253.0
%	84.1
Valleys and low mountain chains	46,699.0
%	15.9
Total	**292,952.0**

Source: Alzérreca, 1990

This area contains the following large agroecosystems (Map 2):

- Semihumid high andes, no cultivation
- Semiarid and arid high andes
- Semihumid tableland (altiplano)
- Semiarid and arid tableland (altiplano)
- Semiarid and semihumid valleys and mountains

DISTRIBUCION PORCENTUAL
DEL TERRITORIO Y LA POBLACION POR REGIONES



REFERENCIAS

○ % DEL TERRITORIO

□ % DE LA POBLACION

Map Nº1

PRINCIPAL CLIMATIC ECOLOGICAL REGIONS CHARACTERISTICS OF THE BOLIVIAN ANDEAN ZONE

(The ecoregion identification number of Table 2. matches Map 2.)

TABLE 2. PRINCIPAL CLIMATIC CHARACTERISTICS OF THE ECOLOGICAL REGIONS OF THE BOLIVIAN ANDEAN ZONE (RANGES)

Ecoregion	Temper. °C	Precipita. mm Humid months	Altitude m.s.n.m	Principal activity
Semihumid high andes No. 12 in Map 2.	2.5-10	550-1.200 6-7	4,100 5,000 3,000	Camelids Sheep Cattle
Semiarid and arid high andes No. 11 en Map 2.	2.5-10	100-500 1-5	4,100 5,000 3,000	Camelid Sheep Cattle
Semihumid tableland (altiplano) No. 8 in Map 2.	6-10	520-650 6-7	3,810 4,100	Agriculture Cattle Sheep
Semiarid and arid tableland (altiplano) No. 9 in Map 2.	2.5-10	300-400 1-5	3,660 4,100	Sheep Agriculture Camelids Cattle
Semiarid and semihumid valleys and mountains No. 7 in Map 2.	10-17	320-1,200 1-7	2,000 3,000	Agriculture Sheep Goat Cattle

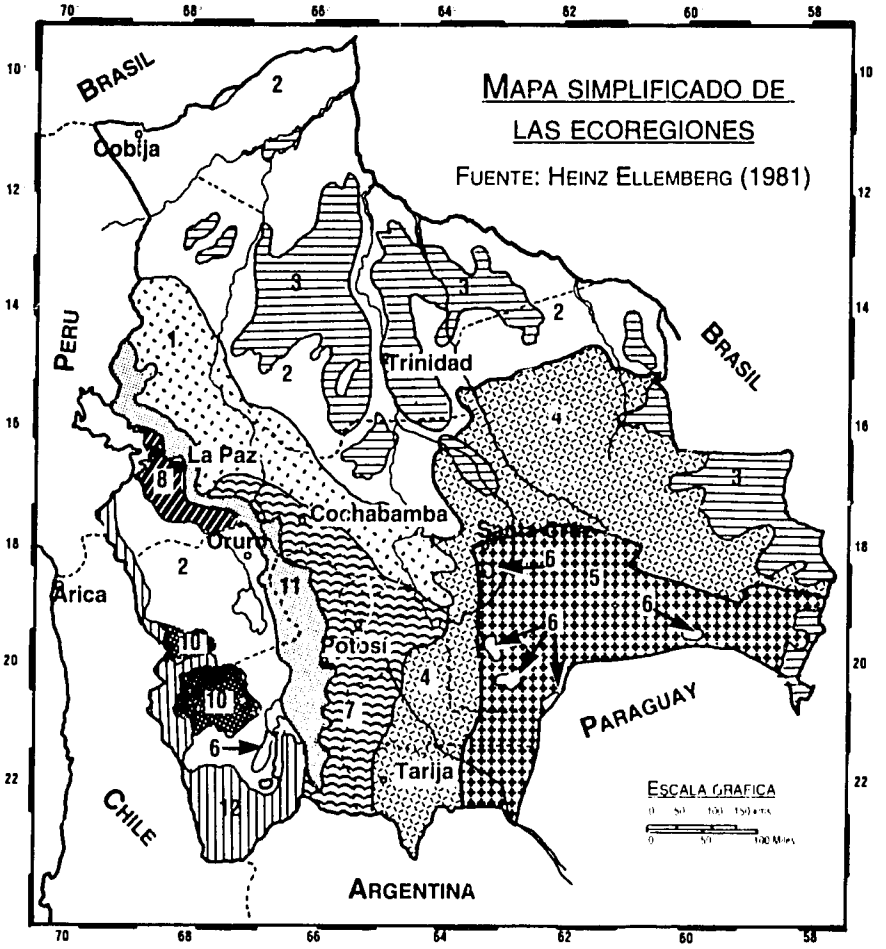
FORAGE RESOURCES

THE RANGELAND

General characteristics

Animal production in the Bolivian Andes is based on the alimentation of forage resources provided by rangelands. It is estimated that more than 98% of the forage comes from rangelands. The difference is provided by agricultural byproducts, weeds, cultivated annual and perennial forage crops, and others.

Table 3 presents condensed data on the sources of forage for the Bolivian Andean zone.



REFERENCIAS

- Selva húmeda montañosa
- Selva subhúmed, baja, con unos meses más secos
- Sabana 5-7 meses (o más) con islas de bosque en parte, tenipre verde
- Bosque semi húmedo bajo y montaños
- Monte semiáride bajo
- Territoriode dumas en Nº 5 y 9
- Valles y montañas semiáridas (hasta semi húmedos)
- Puna semihúmeda con árboles
- Puna semiárida y árida
- Salar (más pequeños salares no distinguidos)
- Piso alto andino semihúmedo, sin cultivos
- Piso alto andino semiárido y árido, sin cultivos

MAP Nº 2

TABLE 3. USE OF LAND AS A SOURCE OF FORAGE RESOURCES

	Andean zone km^2	Canapa* km^2	Pastures** km^2	Annuals*** km^2	Other km^2
Km^2	292,952	241,832	281.7	975.0	49,863
%	100.0	82.55	0.096	0.403	17.0

*Canapa = Rangeland (Campo Nativo de Pastoreo).

**Pastures, mainly alfa

***Annual cultivated forages, mainly barley

Because of the evident importance of the rangeland area in the Bolivian Andean zone, Table 4 presents additional information at the departmental level.

TABLE 4. RANGELAND AREA OF THE BOLIVIAN ANDEAN ZONE BY DEPARTMENTS IN KM^2

Altiplano and high Andes

	Potosí	La Paz	Oruro	Cochaba.	Chuquisa.	Tarija	Total
Range	88991.0	40689.0	47465.0	12342.0	9696.0	2741.0	201924.0
%	44.1	20.2	23.5	6.1	4.8	1.4	00.0

Valleys and mountains

	Potosí	La Paz	Oruro	Cochaba.	Chuquisa.	Tarija	Total
Range	6918.0	924.0	0.0	9242.0	19939.0	2885.0	39908.0
%	17.3	2.3	0.0	23.2	50.2	7.2	00.0
T. Range	95909.0	41613.0	47465.0	21584.0	29635.0	5626.0	241832.0
%	39.7	17.2	19.6	8.9	12.3	2.3	100.0

Source: Alzérreca, 1990

The Potosí Department has the most rangeland area with 39.7% (95,909 km^2), and Tarija the least with only 2.3% (5,626 km^2).

Table 5. shows some important range types and the dominant species.

TABLE 5. PRINCIPAL RANGE SITES OF THE BOLIVIAN ANDEAN ZONE

RANGE TYPE	IMPORTANT SPECIES
1. **Bofedales:**	Distichia muscoides, Oxichloe andina, Plantago, tubulosa, Carex sp, Ranunculus spp, Calamagrostis spp, Poa spp, Juncus spp.
2. **Chillihuares:**	Festuca dolichophylla, Lachemilla spp., Trifolium amabile.
3. **Pajonales de Iru ichu:**	Festuca ortophylla, Stipa spp. y Calamagrostis spp.
4. **Tholares:**	Parasthrephia spp., Baccharis spp, Senecio spp., Adesmia spp.
5. **Pajonales de Ichu:**	Stipa ichu, Stipa spp. Erodium cicutarium, Aristida sp.
6. **Tholar-pajonal:**	Parasthrephia spp, Baccharis spp, Festuca, spp, Stipa spp. y Nasella sp.
7. **Matorrales de Polylepis:**	Polylepis tomentella, P. tarapacana, Stipa ssp. y Festuca spp.
8. **Pajonales de Kheña:**	Calamagrostis vicunarum, C. curvula, C. heterophylla
9. **Gramadales:**	Distichlis humilis, Muhlenbergia fastigiata
10. **Arbustales de Kauchi:**	Suaeda foliosa, Atriplex spp. Salicornia peruviana.

LIMITATIONS AND ADVANTAGES OF THE ANDEAN RANGELAND

NEGATIVE FACTORS:

■ Natural.

✔ Natural low production potential in the majority of the range sites

✔ Climatic and edaphic production limitations for introduced forage species

✔ Seasonal production

✔ Dry-season low nutritive forage value

◪ Anthropic.

✔ Overgrazing: specific and scattered data indicate that overgrazing could be general.

✔ Itinerant Agriculture

- ✔ Use of the shrub and grass vegetation for fuel, construction, and uncontrolled burning of the range
- ✔ Danger of extinction of native forage plants (decreasers)

POSITIVE FACTORS:

- ✔ The extensive rangeland area
- ✔ The admirable adaptation of native plants and their capacity to adapt to the extreme edaphic and climatic highland constraints
- ✔ The presence, even sporadic, of high quality native forage
- ✔ The high recuperation potential of some rangelands
- ✔ The availability, not very well evaluated yet, of surface and underground water resources for range irrigation.
- ✔ The traditional range science knowledge that campesinos have could be important for improving range management.
- ✔ The rustic quality of camelids and criollo sheep, goats, and cattle, and their adaptation to a difficult situation that allows for flexibility in identifying management range systems with low technological inputs.

ECOLOGICAL CONDITION OF THE RANGELAND

The overgrazing of the rangeland is an evident phenomenon but is not a consequence, as is generally assumed, of small andean farmers the lack of knowledge. In fact, it is a result of a complex mixture of exogenous factors to the nature of the rangeland that have to do with land tenure, population growth, and dynamics (LeBaron 1979). The lack of information about range conditions and trends prevent a generalization of the magnitude of range overgrazing, but some data show that this can be the situation (Table 6).

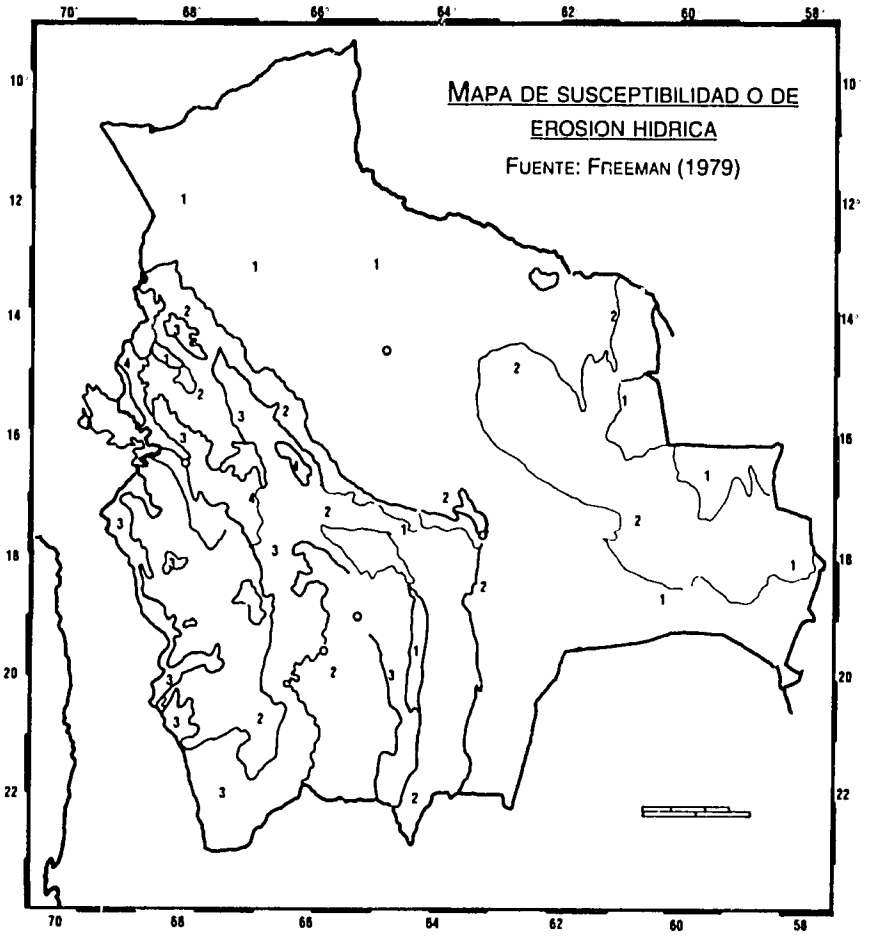
In addition to overgrazing, there is extensive over-cropping that has depleted the natural soil fertility, especially nitrogen and phosphorus. Use of dung and wood from tholabushes, utilization of other vegetation resources for fuel, and construction on a large scale have contributed to soil erosion and a decrease in soil fertility. Under these conditions even minor amounts of rainfall run off the surface soil, and the result is a serious erosion problem. It is estimated that more than 30 million ha could be affected by erosion in the altiplano and valley regions (Map 3).

TABLE 6. COMPARISON BETWEEN STOCKING RATE AND CARRYING CAPACITY IN SOME RANGELANDS OF THE BOLIVIAN HIGHLANDS*

Ecoregion	Stocking rate and condition	Carrying capacity	Balance	Source
Semiarid Tableland	0.45 U.O.(Poor)	3.8 U.O.	3.35 U.O.	Cardozo y Riera, 1972
Semiarid Tableland	2.00 U.O.(Good)	4.8 U.O.	-2.00 U.O.	Bellour, 1980
Arid Tableland	0.30 U.LL.(Poor)	0.48 U.LL.	-0.18 U.LL.	Alzérreca e Izco, 1987
High Andes Subhumid	0.90 U.AL.	3.06 U.AL	-2.15 U.AL.	La Fuente et al., 1987

* Estimated data of specific studies.
U.O. = Sheep unit; U.LL = Llama unit; U.AL.= Alpaca unit.

Source: Alzérreca, 1988.



REFERENCIAS

Niveles de susceptibilidad de erosion hidrica

1. Ninguna a ligera susceptibilidad
2. Moderada susceptibilidad
3. Alta susceptibilidad
4. Muy alta susceptibilidad

Map Nº 3

It is estimated that only about 2% (2,038 km2) of the native rangeland located over 2,000 m. above sea level were evaluated and classified (Table 7).

TABLE 7. CONDITION AND AREA OF THE EVALUATED RANGELANDS UP UNTIL 1990

Condition	Range sites	Grazing area ha*	%
Excellent	2, 17	1,857	0.8
Good	5, 12, 13, 14, 15, 2	73,973	33.2
Regular	11, 6	1,431	0.6
Poor	1, 3, 4, 7, 8, 9, 10, 16, 18	144,295	64.9
Very poor	9	1,155	0.5
Total		222,714	100.0

1=pajonal de Stipa spp.
2=pajonal de Festuca dolichophylla
3=tholar de Parastrephia
4=arbustal de Frankenia
5=Muhlenbergia y Distichlis
6=Parastrephia y Muhlenbergia
7=arbustal de Parastrephia
15=bofedal de Calamagrostis
17=bofedal altoandino
8=pajonal de Stipa ichu
9=arbustal de Tetraglochin
10=paj. Festuca orthophylla
11=pradera de Bromus unioloides
12=pradera en descanso
13=pradera inundadiza
14=Festuca orthophylla y gramas
16=Festuca ort. y Parastrephia
18=gramadal de Achiane

Good conditions represent 33.2%, and poor range conditions are the most common, with 64.9%.

In general in the tableland and valleys, the main environmental issue is how to reverse the deterioration of land and water resources and at the same time promote growth in agricultural output and increase income of subsistence farmers.

The conclusion about range conditions will be that highland range is actually producing far below its natural potential. There is serious evidence of range degradation. Nevertheless, there are still native and adapted forage germoplams that can be used for range revegetation and for forage production.

CULTIVATED FORAGE RESOURCES

Cultivated forages in the highlands and valleys are of little importance, because of different limiting factors such as: lack of irrigation, limited availability of agricultural land for forage production and edaphic and climatic constraints. The principal sources of cultivated forage are as follows:

TABLE 8. SOURCES OF CULTIVATED FORAGE RESOURCES — ANDEAN ZONE

Sources	Highland ha	Valley	Total	Production ton/D.M.
Stubble	86,942	347,724	434,666	1'746,013 *
Alfa	14,525	10,162	24,687	98,748
Barley	59,993	15,652	75,645	163,564
Oats	13,090	3,430	16,520	55,342
Corn	—	5,300	5,300	84,800
Total	174,550	382,268	556,818	2'148,467
%	31.34	68.65	100	—

* Estimated of andean crops
Source: Alzérreca, 1990

By extension and production the most important source of forage, even of low quality, are the stubble, 81.2% (1,746,013 ton/D.M.), which in this case came from cultivated potatoes, quinua, beans, barley grain, corn grain, cañahua and other less important andean crops. The major part of the 24,687 ha of alfa and the 5,300 of forage corn are produced under irrigation. On the other hand, most of the 92,126 ha of annual forage crops are produced under dry (rain-fed) farming. Almost all this forage production comes from the agropastoral production systems of small holder farmers.

It is clear that the potential of alfa and forage corn production depends on the availability of new areas under irrigation or on favorable rainfall. Actually, the growing rate of cultivated area with alfa is about 1,427 ha annually, and only 377 ha for forage corn (Table 9).

A modest annual increment is reported for oats and barley; with good production in favorable years and low yields in bad years, such as the severe drought in 1983-84. The farmer's preference to grow grain barley for the beer industry and for consumption also influences the increment of barley forage cultivated area. The area cultivated with other introduced perennial forages is very low and restricted to irrigated and subhumid zones.

TABLE 9. CULTIVATED FORAGE PRODUCTION TENDENCY 1980-1988

	Alfa		Oat		Barley		Forage corn	
Year	ha	t/ha	ha	t/ha	ha	t/ha	ha	t/ha
1980	15330	19.4	2075	11.9	66325	2.8	1900	39.9
1981	16350	19.5	2000	8.6	65615	2.7	4005	24.8
1982	16311	19.6	11740	4.5	62260	2.7	4240	26.9
1983	15147	11.4	16500	3.3	75645	2.1	2200	14.5
1984	24985	8.0	6358	2.7	42397	1.9	3200	14.6
1985	27735	7.9	6770	2.5	67330	2.1	4955	11.9
1986	28440	7.1	6800	2.2	69950	2.2	5000	14.0
1987	27680	7.4	6880	2.2	74840	2.5	5200	15.0
1988	28175	7.6	7150	2.3	79300	2.5	5300	16.0

Source: Office of Statistics, MACA, 1989.

With reference to yields, it can be observed that oats cultivated in dry conditions were more affected by drought than the barley. This is a result of the higher water requirements of oats in relation to barley and is an indicator of why the barley is widely used in Bolivian highland agropastoral systems of the semiarid and arid climatic zones.

SEASONAL OFFER OF FORAGE

The marked seasonality of the rainy season also defines a seasonality of the supply of forage and the characteristic of animal production in two different typical periods: the weight-gaining period during the rainy season (3-4 months) and the weight-loss period during the long dry season (8-9 months). The seasonal variation in the amount of the forage depends upon the types of rangeland.

In this case farmers have developed some strategies to overcame the situation, such as the following:

1) Reserving range segments for grazing during the dry season; the forage quality in dry ranges is very low under this conservation system; the opposite occurs in irrigated ranges (Bofedales).
2) Forage conservation practices such as hay, using as source of forage primarily barley, oat, weeds, and agricultural by-products. Silage is partially utilized in a few medium- and large-sized milk cow farms. Hay utilization is mainly for milk and work cattle, followed by sheep, burros, goats, and, to a small degree, camelids.

During October and November, the feeding situation becomes critical, and it is quite common in this period to notice increased animal mortality because of starvation and related problems.

In conclusion, on an annual basis it can be said that the animal feeding is deficient and constitutes an important limiting factor for the development of animal production in the andean zone of Bolivia. Animal health practices or genetic improvements in the herd are not relevant if animals are malnourished. Research is urgently needed in this direction.

ANIMAL RESOURCES

As we can see in Table 10, almost all of the sheep, camelid, and goat population are located in the andean zone.

TABLE 10. ANIMAL POPULATION OF THE ANDEAN ZONE

Highland					
Department	Cattle	Sheep	Llama	Alpaca	Goat
Oruro	49,037	1,949,586	739,823	86,040	——
La Paz	198,900	2,263,487	426,034	233,138	——
Potosí	48,048	1,009,742	819,029	1,009	——
Cochab.	37,102	275,891	37,240	4,139	——
Others	124,370		443	10	——
Total	457,493	5,498,706	2,022,569	324,336	——

Valley and mountain					
Department	Cattle	Sheep	Llama	Alpaca	Goat
La Paz	9,240	49,896	—	—	26,200
Potosí	69,180	368,172	—	—	963,000
Cochab.	92,420	499,068	—	—	93,400
Chuquis.	199,390	1,068,468	—	—	500,500
Tarija	28,850	155,790	—	—	90,900
Total	399,080	2,141,394	—	—	1,974,000
Andes	856,573	7,640,100	2,022,569	324,336	1,974,000
Bolivia	5,515,100	7,803,600	2,022,569	324,336	2,190,700

Source: USAID/Bolivia Mission, 1988.
Office of Statistics, MACA, 1985.
Rodriguez y Cardozo, 1989.

The cattle population belongs to the local andean criollo brand, an ecotype that is adapted to poor forage and management conditions. Small ruminants, sheep, and goats are also of the criollo brand. It is estimated that only 5% of the sheep herd has been improved mainly by crossbreeding with Corriedale sheep.

In the market, sheep meat (Table 11) has a better price than camelid meat as a consequence of some legal, social, sanitary, and cultural factors that are not favorable to llama meat marketing. Goats are reported to provide 1,888 ton/year of meat.

TABLE 11. MEAT PRODUCTION OF THE BOLIVIAN ANDEAN ZONE

References	Sheep	Cattle	Llamas	Alpacas
Population	7,640,100	856,573	2,022,569	324,336
Extraction %	22.0	18.7	10.0-21.6	10.0-16.8
Extraction No.	1,680,822	160,198	100,000	16,217
Yield kg.	7.1	165.0	32.9	23.0
Production ton.	11,934	26,433	3,290	373

Source: Rodriguez y Cardozo, 1989; Office of Statistics, MACA, 1985

The llama population sheared annually for wool production is very low, even if the length of the fiber is appropriate for shearing. In sheep the sheared population is higher than in llama, and in alpaca it is much higher than in either llama or sheep. This situation has to do with the dynamics of the wool market and alpaca wool quality (Table 12).

TABLE 12. WOOL PRODUCTION OF SMALL RUMINANTS

References	Sheep	Llamas	Alpacas
Sheared populat.	2,139,228.0	404,514.0	113,518.0
%	28.0	20.0	35.0
Yield kg.	0.9	1.0	1.8
Production t.	1,925(173) **	404.0	204.0

*Sheared animals annually **Improved animals

Source: Rodriguez y Cardozo, 1989; Office of Statistics, MACA,1985

In sheep and llama the quality of the wool is low because of the high presence of medullated fibre (hair) product that is not accepted by the wool industry. Once the medullated fiber of llama wool is eliminated, the resulting product is comparable in quality to Alpaca wool (Table 12).

In the fleece color, the llama and alpaca present some variability. In alpaca, as demanded by the wool market, 91.6% of animals are pure color; the dominant color is brown, with 32.0%, while black has 23.0% of the total population. In llamas the proportion of spotted fleeces is higher than in alpaca.

The above situation suggests a need for research on genetic improvement and selection in alpaca, llama, and sheep wool by quality, color, and production.

On population dynamics, the data are diverse, but in general there is agreement that the population has been growing steadily since 1983-84, years in which the animal population went down because of the lack of forage and water, due to a severe drought.

Other animal species of minor interest, but present in the agropastoral production systems of the small holder farmers, are pork, poultry, rabbit, and guinea pig. All of them are bred with traditional technology.

RESEARCH

IN ANIMAL PRODUCTION

In general the producers have a mixed animal exploitation in order to utilize all the available forage resources (complementary and competitive grazing is common), and because the animals are also a rural savings bank for small farmers. In addition, the animals supplement agriculture in years with drought or severe frost. This is a common phenomenon in the Bolivian highlands.

It can be said that the major part of the Bolivian highland ecosystems is suited for animal production and not for agriculture. Usually a typical family owns in order of importance: one or two oxen, a cow, 15 to 30 sheep, a burro as a pack animal, one or two pigs, some chickens, and a few rabbits. If we go to the high andes and marginal areas, included in the inventory are some llamas in dry rangeland and alpaca in humid environments.

SHEEP

The criollo sheep breed in the experimental station has superior zootechnical indices over the ones raised on farms. This situation is an indicator that improvements in production are due to better management and feeding. For this reason it can be said that there exists an unutilized potential for the increase of criollo sheep production. This conclusion is especially

interesting for poor range conditions where improved breeds or crossbreeding have low possibilities of good performance.

The introduction of new sheep breeds, especially Corriedale, made an important contribution to raising the productive indices, as can be seen in Table 13. But when the improvement program does not include a strong effort to develop additional sources of forage and improve management, usually the programs fail. There are several examples of this situation scattered through out the andean region.

TABLE 13. PRODUCTION INDICES OF CRIOLLO AND CORRIEDALE SHEEP UNDER DIFFERENT MANAGEMENT CONDITIONS

	Criollo		Corriedale
Character	Country	R.Station	R. Station
Fertility %	50.0	80.6	66.6
Prolificity %	—	101.0	103.0
Offspring Mortality %	21.7	8.8	15.9
Weaning weight kg	—	18.3	18.5
Winning weight g/day	—	131.0	136.0
Adult weight kg	20.0	22.9-25.5	42.9
Fleece weight kg	0.5-0.8	1.4	2.9-3.1-3.2
Fleece yield %	—	67.4	60.9
Fiber length cm	4.6	7.2	6.0-7.9
Fineness counts	60.0	54.0	58.0
Canal weight kg	7.0-10.0	9.0-11.5	21.0
Adult mortality %	15.0	—	—

Source: Rodriguez, 1985., Cardozo, 1970.

The mortality coefficient of lambs and adults of introduced sheep is superior to the criollo sheep under the same management conditions. Fleece length is less in Criollo than in Corriedale sheep, but in fineness the situation is the reverse.

Research on sheep has been conducted since 1950 in the Belen, Patacamaya, and Chinoli Experimental Stations. Some of the outstanding research results in sheep are as follows (Rodriguez, 1981):

Reproduction

Iñiguez et al. (1974) pointed out a greater production stability in Corriedale sheep than in other introduced breeds, because the Corriedale breed—at least at the Experimental Station level—is the introduced animal that adapted best.

Choque et al. (1974) pointed out that there is no difference in birth weight among Corriedale, Targhee, and Ramboullet sheep breeds. On the other hand, the percentage of surviving lambs was superior in Corriedale. Chumacero (1977) reported significant differences in different lambing seasons in birth weights, weaning survival, and weight gain between Corriedale and Targhee breeds; the March to May period was superior.

Under altiplano agroclimatic conditions there are two lambing periods at the farm level: June-August and December-January. Under controlled conditions the fertility of Corriedale and Targhee were compared for these two mentioned periods; the result showed greater Corriedale sheep fertility for the winter lambing period.

During the dry season (June-December), criollo sheep were more sexually active ($P>0.01$) than introduced sheep. Anestri was not detected in either group. For interestrual intervals and number of services during the year, there were no differences between groups. Finally, two periods of sexual activity were determined: June to December revealed minimum sexual activity, and December to May showed maximum.

In other studies, the effects of weight in the ovulation rate of Corriedale (high body volume) and Criollo (low body volume) were compared. The animals were divided into groups that were receiving high and low levels of protein. The result showed that in both groups high protein supplements induce a greater presence of estrus (80% and 90%) and as a consequence a greater number of ovulations per animal. On the other hand, sheep under traditional grazing systems and with low protein levels showed low sexual activity throughout the year. At the same time, it was demonstrated that sheep with higher body weights require higher supplemental levels of protein to maximize fertility.

Alimentation

Feeding research was done using Corriedale, Targhee, Criollo, and Criollo/Corriedale sheep. The animals were provided the same fat regime which have to do with grazing and supplemental food. The result shows sim-

ilar weight increments for introduced and half-breeds; but the Criollo show inferior weight gains, and its performance was not adequate under this fat system (P<0.01).

■ Animal health

Rodriguez (1982) reports the results of a study of sarnic infestation in two zones of the central altiplano.

The following parasites were identified: *Psaroptes communis*, *Sarcoptes scabieri*, *Melophagus ovinos*, and *Bovicola ovis*; the first one was most abundant. It was determined that there was greater infestation under mountainous conditions than in tableland conditions (P<0.01). The dry seasons are more favorable for external parasites (P<0.01).

In another study, in order to determine lethal dosages and to identify the critical growth period, criollo sheep were fed rations containing 0, 5, 10 and 15% of the toxen *Astragalus garbancillo*. After 40 days the animals did not show any symptoms of intoxication, while the results showed a slight weight increment (85 and 91 g/day) (Riera 1964, cited by Rodriguez 1981). These results were expected, because criollo sheep have a long history of small amounts of *Astragalus* consumption and probably have developed a tolerance to the toxic ingredients of this plant. With introduced animals or criollo sheep from zones free of *Astragalus*, the results could be different.

■ Genetics

Studies of hemoglobin show a higher frequency of an allele that controls hemoglobin type (B) in Corriedale sheep than in other introduced sheep breeds. The carrier individuals of this kind of hemoglobin seem to have greater fertility and more surviving lambs than the other breeds. These data are an indicator of the greater adaptative advantage of the Corriedale sheep than the altiplano than the other introduced sheep.

In studies about heredity and the environment, it has been reported that the genetic heredity is masked by the environmental effects. A greater adaptative flexibility is reported for Corriedale sheep, which can be in the physiological adaptation process to the restrictive highland agroecological conditions.

Another study, intended to determine the correlation coefficients between different production parameters, shows that birth weights are highly correlated with sheep mating weight for Corriedale and Rambouillet sheep. Ramboulliet sheep do not show a stable association for birth weight and weaning weight. Fleece weight and fiber lengths were positively correlated for Corriedale and Ramboullet sheep, but not for the Thargee breed.

CAMELIDS

Low camelid fertility rates reported at the farm level (35-45%) are indicators of deficiencies in one or more production factors. But this reproductive capacity is seriously affected by post-fertilization factors such as abortions, malnutrition in offspring and mothers, and deficient sanitary care (Table 14).

TABLE 14. SOME CAMELIDS BIOECONOMICAL PRODUCTION COEFFICIENTS

	Llama		Alpaca	
Character	Farm	Expe. C.	Farm	Expe. C.
Fertility %	35-45	61-70	35-41	66
Offspring mortality %	26-30	6.5	32	25
Weaning weight kg	--	53.9	—	28
Winning weight g/day	—	181.0	—	120
Adult weight kg	70-75	84.1	—	55
Fleece weight kg	1-0.7	1.1-1.2	1.1-1.2	1.8
Yield %	—	80.0	—	—
Fleece length cm	—	8.3	6.3	8.9
Fineness counts	—	53.2	—	—
Canal weight kg	35.0	—	25.0	—
Adult mortality %	3.0	—	3.0	—
Mud kg/fresh/day	0.65	—	—	—

Source: Rodriguez, 1985., Alzérreca, 1988.

The high alpaca offspring mortality is mostly a consequence of enterotoxemia, because of deficient management.

Recent research reports in nutrition, such as San Martín and Bryant (1987) and Cardozo (1989), confirm the general hypothesis that llamas have a greater digestion capacity than the other domestic andean ruminants and that this difference is increasing along with increases in the quality of the diet.

The ramifications of this conclusion are of interest for guiding research in feeding and grazing of camelids. Some of the implications could be as follows:

✔ Greater productivity than sheep and cattle
✔ Complementary grazing, cattle-alpaca, cattle-sheep
✔ Competitive grazing, llama-sheep
✔ Range recuperation based on camelid grazing
✔ Greater possibilities of surviving under stress conditions, such as drought, for example
✔ Camelid wool receive higher prices than sheep wool

Disadvantages:

✔ Low availability of llama production technology
✔ Low demand for camelid meat
✔ Grazing management problems because of the fractioning of rangeland and land tenure problems

Some of the more important camelids research conclusions are the following (Martinez 1991):

■ Reproduction

- The llama does not have reproductive seasonality. The llama is of induced reproduction and there is no pseudopregnancy.
- The body luteo is maintained from 19 to 20 days, and the LH (loutinizant hormone) hormonal secretion occurs posterior to coitus and prior to ovulation.
- The body luteo is formed 4 days after the mating or induction and is functional until day 16.
- No method to collect semen was successful, even with electra ejaculation methods.
- The llama does not seem to have a cyclical estrus; the average duration of the coitus was 24 minutes.
- The gestation period is between 345 to 366 days.
- The llama's sexual receptivity is the same with or without the presence of body luteo.
- Rectal palpation to detect pregnancy is possible in llamas.
- The male llama's sexual maturity is from 22 to 24 months; phimosis disappears at about 18 months. The spermatogenesis in the testicles is initiated about the 6 months of age, and the sperm is ready at about 22 months of age.

- It is possible to get significant increments in fertility using the complementary service method 30 days after the first service, increasing the fertility up to 81%. The total mating period should not be more than 3 months, preferably with a 20-day interval between services.
- The llama can reproduce in both dry and humid seasons, assuming that males and females are being managed separately.
- The high mortality, low fertility, and low birth and weaning weights registered in the dry season are attributed to the poor nutritional conditions.
- The general interval between births was 618 days, between two consecutive births 398 days. The observance of discontinuous births is high, almost 45%.

■ Management

- The fastest growth period is compressed between 400 to 600 days of age; after that period growth is slower. The protein requirement is superior for the fastest growth period. The daily weight gain for males was 117 g/day and for females 97 g/day.
- Llamas' productive lifetimes are determined to be 8 years, and reportedly age is more important to reproduction than environmental factors.
- The annual shearing, usually with 7 cm of length in the Tampully ecotype (llama wool), should be done in springtime, because the high temperatures are present at this time. With the Kara ecotype (llama meat) it is preferable to shear every two years, time that is needed to reach 8 cm of fiber length.
- The weaning period in llamas was established between 4 to 6 months of age but for alpacas could be between 5 to 9 months of age.
- Castration can be done at two years of age, because by that time testicles have completely fallen.
- Carcass meat yield production of llamas is reported to be 52.1%, corresponding to 27.8% to the vicera; the ratio of meat/bond is 3.6 to 1. Llama meat has 25% of D.M., 21.06% of Protein and 1.1% of ash. For alpaca it is reported that a cold meat carcass yields 46.4%.
- The meat which comes from castrated llamas shows better tenderness than meat from whole animals, but in palatability the opposite situation occurs.
- The relation of fine fleece with respect to the total fleece is highly influenced by the sex; total fleece production shows a incremental tendency with the animal's age, but the quality goes down.
- It is reported that the first shearing and fleece weight of the animal can be used for selection, because the data show a positive correlation with the productive value and the future performance of the animal.

- The body weight can be used also as a selection parameter, because it is highly correlated with the majority of the important economic characteristics.
- So far two llama phenotype have been classified: the Tamphully (wool producer) and the K'ara (meat and pack animal).

Animal health

- Enterotoxemia is reported to be the major cause of mortality in alpaca offspring in the subhumid high andes (Ulla-Ulla 4.500 m.o.s.l., Sajama, etc.). Sarcosystis is also a major health problem in adult camelids, but there is still little known about the disease.
- Vaccination, pasture rotation, corral rotation, and moving the lambing season are the practices recommended to overcame the situation.
- Actually, the camelid's genetic resources are in the process of erosion, mostly because the selection and selling of the high-quality animals for illegal exportation to more developed countries. As a consequence, the andean countries are in danger of losing their monopoly on camelid production.

GOATS

The goat production zone is located generally in marginal rangelands of the slopes of the eastern Andes. At present, there are some promising perspectives for goat development as an economic activity. The basis for this development could be the use of adapted improved foreign technologies. Improvements should be based on improved utilization of agricultural byproducts and production of forages of high quality involving the agropastoral systems under irrigation.

Under dry conditions, there is an urgent need for a strong research program in range management and related subjects. The same thing has to be done with goat management, because they are located in areas under severe soil erosion and there is a danger of losing the natural base for range and water production.

Usually, highly degraded ranges are associated with goat utilization, but the truth is that the management is wrong and not the goats themselves. This situation is becoming critical mainly because there is not a solid goat research program in Bolivia; but there is an evident need, if we want to preserve the fragile ecosystems where the goats are bred.

TABLE 15. SAME BIOECONOMICAL INDICES FOR CRIOLLO AND SAANEN GOATS IN THE BOLIVIAN ANDEAN ZONE

Character	Farm Criollo	Research - Station Saanen	1/2 blood
Fertility %	59.0	37.4	32.6
Offspring mortality %	36.6	—	—
Adult weight kg	18-24	42.0	39.0
Milk production lt/day	0.20-0.30	0.52-0.86	0.64-0.92
Lactation days	120-150	240	210-300
Live weight male 4 year kg	30-40	60	—
Extraction	20.0		

Source: Proyecto San Juan del Oro, 1990; Est. Exp. Chinoli-IBTA, 1979.

Table 15 evidences the high fertility of the criollo goat in relation to the introduced goat, and it could be higher under better nutrition and management conditions. But in milk production introduced Saanen and 1/2 blood (Criollo/Saanen) show better performance than Criollo goats.

OTHER SPECIES

Usually the small producer has small animals for subsistence and sometimes for cash. They primarily are chickens, rabbits, pigs, and guinea pigs. These animals feed on vegetable residues from humans and plants that are available in the range. The development of guinea pigs and rabbit is limited because of the scarcity of forage. Intensive forage production systems, such as those under greenhouses or similar constructions, can provide green forage year round to feed these animals.

IN RANGE AND FORAGE PRODUCTION

Usually both range and forage production, in addition to agriculture, are the components of the agropastoral small holder farmer production systems of the Bolivian Andean region.

RANGELAND RECUPERATION

Cardozo (1970) reports forage yield increments of: **Hordeum muticum** 2.320 kg/ha, **Nasella pubiflora** 4.820 kg/ha, **Bromus unioloides** 2.630 kg/ha and **Calamagrostis** sp. 3.100 kg/ha, respectively, under irrigation and fertilization treatments.

In the same area Alzérreca and Román (1987) worked with recuperation treatments for 8 years in a degraded **Parastrephya lepidhophylla-Stipa ichu** range site. The results show that no treatments are significant under drought conditions for recuperation (211 mm) but under favorable situations offer a better response to treatments of irrigation-sedimentation (174% yield increment), followed by the subsoil-seeding and contour furrows-seeding treatments, with 76 and 71% of yield increment, respectively, in relation to the control (189 kg/ha).

Similar research was done in three range sites of the high andes subhumid zone: I. tableland, II. intermediate, and III. mountainous. Seventeen treatments of recuperation were probed. At the three areas second year evaluation, the better treatment is pitting—manure (12 t/ha of alpaca manure)—leveling out with increments in forage yield of more than 800% over the control (97 kg/ha/D.M.).

Small programs in range inventory and evaluation, key forage plant seed production, and native and introduced forage plant collection and evaluation are under way. There is already a germoplasm bank of criollo alfalfa adapted to the severe agroclimatic andean zone conditions (drought, cool, low fertility of soils, soil with high contents of soluble salts, and so forth). Native species were collected for about 30 accessions of promising forage plants, especially halophytes. This material is to be used for classification, evaluation, selection and eventually seed production for range revegetation.

Preliminary conclusions about rangelands are the following:

- Most of the rangelands have a natural low production potential
- The rangelands are producing below their natural potential
- Overgrazing and intensive use of the other range resources are the biological cause of the range degradation.

The original source of the rangeland mismanagement situation has to do with social and economic problems such as increment of population density, increase of pressure over range land for agriculture, subsistence economical system, lack of opportunity, etc.

On the other hand, it is recommended that much research on range recuperation be undertaken, emphasizing efficient utilization of water, identification and seed production of selected native forage species, seeding of

key native forage and introduced adapted species, grazing management, and production of supplementary forage to feed the animals during the long dry season.

INTRODUCED FORAGES

■ Annual species

As a result of the research work of the Altiplano experiment stations, several species and varieties of annual forages have been selected and recommended. The more important material is shown in Table 16.

TABLE 16. AVERAGE YIELD IN TON/D.M./HA OF SELECTED ANNUAL FORAGES FOR TWO AGROCLIMATIC ZONES OF THE BOLIVIAN ALTIPLANO

Species and varieties	Semihumid 560 mm	Semiarid 350 mm
Barley — IBTA-80	7.60	3.49
Barley — LUCHA	7.39	2.87
Barley — L-154	7.65	2.60
Criollo barley — (control)	1.0-3.00	0.6-1.50
Oat — SEFO-1	8.63	2.49
Oat — GAVIOTA	7.83	1.66
Oat — TEXAS	6.67	2.30
Oat — (control)	4.00	1.00
Triticale — RENACER	8.56	2.61
Triticale — CAUTIVADOR	8.50	2.33
Triticale — ERONGA	8.56	3.22

Source: Prieto and Alzérreca 1989

Forage corn is produced under irrigation, usually in association with **Vicia villosa** and **V. sativa** in the valleys zone. There are proven varieties available (Delgadillo 1985).

As a preliminary conclusion we can say that there is proven annual forage material available for the altiplano and irrigated valley zone, but none for the dry rangelands. The yields are variable according the interaction of several factors, especially the amount and distribution of rainfall and the fertility of the soil. In dryer areas the performance of improved species is not appropriate and criollo material should be used, especially barley, which is the most important annual forage cultivated in the zone. Finally, annuals (barley) are quite important, because, preserved, they are the major animal forage source during the dry season.

Associations between annuals and **Vicia sativa** or **Vicia villosa** for hay or silage have good results in subhumid deep soil zones, but not in dryer areas.

PERENNIAL SPECIES

■ Legumes

Forty research years with introduced forage trials have identified alfa as the most appropriate introduced forage for cultivation in the Bolivian Altiplano. Currently varieties are available for the different ecologies of the Andean zone where water is available. Usually the producers have a small protected patch of Alfa. Under dry cultivation there is not very much alfa. Table 17 shows the principal results of alfa trials researched under irrigated and dry cultivation.

The availability and prohibitive cost of selected seeds are the limiting factor for their utilization. Local alfa criollo seeds are extensively used, and some Bolivia 2000 and Riviera local certified seeds are also used. The most widely introduced Alfa varieties are Ranger and Moapa.

In lower regions such as the valleys, the most widely varieties used are Bolivia 2000, Arminda, Sabina, Matador, Punatena, Africana, Ranger, and Moapa. The work of introducing, evaluating, improving, and agronomically testing the varieties are permanent activities with alfa and associations, especially alfa/Festuca and alfa/Dactilis (Delgadillo 1985).

TABLE 17. DRY MATTER ALFA YIELDS UNDER IRRIGATION AND DRY CULTIVATION IN TON/D.M./HA.

Variety	Irrigated	Variety	Dry cultivati.
Uinta	7.75	Vernal Idaho	1.75
Saranac	7.69	California Common	1.52
Saranac N.York	7.56	Sud Cinti	1.51
Atlantic	7.45	MSB - IIG2	1.50
California Common	7.06	W.L. - 202	1.46
Cherokee	6.96	California Province	1.40
Ranger	6.95	Cherokee	1.30
Riviera*			3.44
Bolivia 2000*			2.96
Maxidor*			2.20
Africana*			1.98
Moapa*			1.75
Producer			
(Farm level)	3.50		0.8-1.20

Source: Mendieta 1985; 7-year average
*Source: Prieto and Alzérreca 1989; 2-year average

In pasture fertilization, phosphorus has been identified as the most important limiting mineral. In other species of forage legumes and grasses the following are recommended for use: **Trifolium pratense** cv. Kenland and Violeta, **Trifolium repens** cv. Ladino, **Trifolium alexandrinum** cv. Cornnel and Chile, and in association with **Dactylis** and **Lolium.**

■ Perennial grasses

Under irrigation and nitrogen fertilization good results have been obtained with the following varieties: **Dactylis glomerata, Festuca arundinacea, Lolium multiflorum, L. perenne**, and a hybrid from **Phalaris canariencis x P. tuberosa**, in dry conditions **Agropyron elongatum** and **Eragrostis curvula**. A summary of forage yields are shown in Table 18.

TABLE 18. FORAGE YIELD OF PERENNIAL FORAGES IN KG/D.M./HA — SEMIARID ZONE, PATACAMAYA

Name	Treatment	Dry Condition	Irrigated	Source
Weeping lovegrass	——	235	520	Mendieta 1982
Weeping lovegrass	50 kg/N/ha	1,550	1,940	" "
Weeping lovegrass	50 kg/NFK/ha	1,740	1,833	" "
Phalaris tuberocanariencis	75 kg/N/ha	1,338	3,070	Mendieta 1983
"	50 kg/N/ha	1,366	2,870	" "
"	——	1,180	2,113	" "
"	50 kg/N/ha	——	2,327	Alzérreca 1979
"	——	813	1,210	" "
"				
Phalaris/Alfa		3,608	8,695	" "
Alfa/Dactilis/Fes.	——	——	6,704	Durán 1983

SEED PRODUCTION

Barley, oats, and now triticale produce seeds in protected areas; the quality depends upon the amount of rainfall and its distribution and on the soil quality. Many farmers have small cultivated areas of barley and produce their own seed. In dryer areas seed production is uncertain in bad years. Drought and freeze are the climatic limiting factors for producing seeds in the altiplano.

Of introduced adapted grasses it is possible to produce seed from weeping lovegrass (about 50 kg/ha) under irrigation and nitrogen fertilization. The amount and quality can be significant.

In the valley zones, there are no seed production problems. Only soil availability is a limiting factor.

NUTRITION

Riera (1964), Riera and Cardozo (1970), Camargo and Cardozo (1971), Quispe and Cardozo (1988), Zegada, Cardozo and López (1972), Flores and Cardozo (1988), Maiza and Cardozo (1988), Dennis and Kucera (1988), etc. show that the camelids, in particular and the llamas have higher coefficients

of digestibility than sheep, and there are variation according the quality of the forage. In general, llamas are much more efficient users of forage than sheep.

■ Nutritive rangeland forage value

Numerous authors (McKell 1975; Rocha 1983; Alzérreca 1975; Manrique 1981; Alzérreca and Lara 1987; Prieto 1988; and others) report on forage plant proximal analysis (Wende). This information is compiled by Alzérreca and Cardozo (1991), and so far there are reports on about 400 analyses for 65 forage species. Some data show protein content as high as 24% in **Suaeda foliosa**, for example, and as low as 1% of protein content in bad quality barley hay (Figure 1). Obviously a modernization of forage quality evaluation methods is needed.

There is little information on forage mineral content, but Espinoza, et al. (1982) indicate that the deficient minerals in llama grazing areas are P, Ca, Na, Zn and Se. Phosphorus is in general reported as the most deficient mineral in native forages.

The majority of reported analyses show appropriate levels of nutrient contents during the humid season, although the availability is limited. But during the dry season the nutritional content of native forages, with the exception of the ones from shrubs and irrigated ranges (Bofedales), is low enough to be inadequate to meet the animals' requirements.

SOME CASES OF TECHNOLOGY ADOPTION

Currently technology adoption is of minor magnitude and is limited to the cultivation of improved forage species and varieties, especially alfa. Areas with perennial species usually are cultivated on small protected patches of land, and more commonly under irrigation. Lately the Phalaris sp. is being adopted in areas with acidic and humid soils.

Cultivation and preservation of annual forages is common, especially for cattle raisers, because it is used to feed these animals during the dry season.

Some practices for recuperating pastures, especially those related to more efficient utilization of water, are being employed on irrigated rangelands near a source of water.

Under traditional technology, some important management practices are as follows: primitive rotational grazing systems, moving animals to saline natural sites for mineral supplementation, barley hay, utilization of agricultural by-products, and preservation of parts of rangeland to feed animals during the dry season. Range seeding with native forage species and range irrigation are the practices most commonly used.

INSTITUTIONAL AND HUMAN RESOURCES

NATIONAL GOVERNMENT SECTOR

The public sector research in small ruminants, particularly in the last decade, have been almost nil, (universities, state research agencies, and others). Progressively lower budgets and a general economic crisis seriously affected the performance in quality and efficiency of the state research institutions.

On the other hand, the reorganization of research under way (financed by the World Bank Sector Adjustment) only affects the major agricultural research institution in Bolivia (IBTA), but will not help other research institutions, such as universities and related organizations.

NON GOVERNMENTAL SECTOR (NGOS)

Non-governmental institutions so far do not contribute significantly to the generation of animal production technology. Most of the research has been done on social topics, but actually there is some work on technological research that is not being carried out by state agencies.

RESEARCH INSTITUTIONS IN THE BOLIVIAN ANDEAN ZONE

Table 19 shows a list of institutions that are working in animal production research in the Bolivian Andean zone. It includes the major areas of work and the number of technicians for each activity.

TABLE 19. NATIONAL RESEARCH STATIONS IN THE BOLIVIAN ANDEAN ZONE

Institutions	Research	Subject	Technicians
1. Ulla Res. Station Subhumid highland IBTA-La Paz. 4000 ha. 650 mm, 4.480 m.o.s.l RESEARCH	Alpaca Vicuña Llama	Native Annual —	2
2. Patacamaya Res. Station Semiarid puna. IBTA* La Paz. 900 ha. 400 mm, 3.879 m.o.s.l RESEARCH	Sheep Llama Vicuña Cattle	Perennial Annual Native	5
3. Turco Camelids Project Semiarid puna. CORDEOR-Oruro. 300 mm, 3.950 m.o.s.l. PRODUCTION-RESEARCH	Llama	Native Annual	2
4. Tomave Camelid Center Semiarid puna, Potosí 250 mm, 3.900 m.o.s.l PRODUCTION-RESEARCH	Llama	Native Annual Perennial	s/t
5. Cosapa Alpaca Center Highandes, semiarid CORDEOR, Oruro 60 ha. 300 mm 4.050 m.o.s.l	Alpaca	Native	1
6. Belén Research Station Subhumed Altiplano UMSA, La Paz. 90 ha. 514 mm 3.815 m.o.s.l RESEARCH-PRODUCTION	Cattle	Perennial Annual	2
7. Puna Cattle Center Semiarid Altiplano UMTF, Potosí 50 ha. 504 mm, 3.420 m.o.s.l PRODUCTION AND RESEARCH	Cattle	Perennial Annual	2

Institutions	Research	Subject	Technicians
8. Chinoli Research Station Semiarid Altiplano IBTA, Potosí. 344 mm 3.450 m.o.s.l RESEARCH	Sheep Goats	Perennial Annual	3
9. Iscayachi Res. Station Semiarid Altiplano IBTA, Tarija 290 ha. 380 mm, 3.360 m.o.s.l RESEARCH	Sheep	Perennial Annual	1
10. Forages Research Center CIF. Valley semiarid UMSS-Cochabamba 20 ha. 400 mm, 2.600 m.o.s.l RESEARCH	—	Perennial Annual Native	5
11. La Tamborada Res. Station Semiarid valley UMSS, Cochabamba 400 mm, 2.600 m.o.s.l RESEARCH AND PRODUCTION	Cattle Cuy	Perennial	4
12. Condoriri Res. Station Semiarido Altiplano UTO-Oruro. 390 mm, 3.780 m.o.s.l RESEARCH AND PRODUCTION	Cattle Sheep	Perennial Annual Native	3
13. CADEA Center Semiarid Altiplano CORDEOR-Oruro. 600 ha. 390 mm, 3.780 m.o.s.l PRODUCTION AND RESEARCH	Cattle Sheep	Perennial Annual	3
14. Calcha Goat Center Valley semiarid IBTA-Potosí 5 ha. 280 mm, 2.800 m.o.s.l PRODUCTION AND RESEARCH	Goat	Perennial Annual	s/t

Institutions	Research	Subject	Technicians
15.Rio Mulato, Animal Production Center Arid puna, CORDEPO 4.035 ha. 245 mm 3.790 m.o.s.l. PRODUCTION AND RESEARCH	Sheep Alpaca Llama	Native Annual	1
16.PDAR-Small Ruminant Research Program Component Semiarid valley. SUBDESAL, Cochabamba Different areas, 2.000 to 3.000 m.o.s.l. RESEARCH	Sheep Goat	Perennial Native Annual	2

*Institutional symbols are shown at the end of the researchers' list.

Turco, La Tamborada, and CIF have some financial support from international agencies. Of the 6 research institutions working with camelids, only 3 are doing very limited work. In research with goats the situation is even worse: there is only one station with very little possibility for doing significant research on goats.

In general the personel are not well qualified (7 B. Sc., 2 M. Sc., and 1 Ph. D.) to do significant research work, and on the other hand, the infrastructure and limited scientific and economic capacity have a negative influence on the efficiency of research technology transfer.

RESEARCHERS LIST — ANDEAN ZONE

The names include technicians who dedicate partial time to research work and some who have aptitude and potential to do research.

1. Armando Cardozo	Ph.D.	IBTA	Nutrition-reproduction (I)
2. Teddy Monasterios	Ph.D.	IBTA	Plant improvement (I)
3. Edmundo Espinosa	Ph.D.	IBTA	Nutrition (Tropical)(I)
4. Humberto Alzérreca	M.Sc.	IBTA	Range and pasture (I)
5. Tito Rodríguez	M.Sc.	UMSA	Nutrition and genetics
6. Carlos Salinas	M.Sc.	UMSA	Alimentation

7. Hugo Mendieta	M.Sc.	UMSA	Pasture (I)
8. Rafael Vera	M.Sc.	IICA	Statistic (I)
9. Einstein Tejada	M.Sc.	UMSS	Animal production (I)
10. Edwin Roman	M.Sc.	——	Pasture and range (I)
11. Jorge Delgadillo	B.Sc.	UMSS	Pasture and range
12. Ladislao Lazarte	B.Sc.	UMSS	Pasture and range
13. Fimo Alemn	B.Sc.	UMSS	Pasture and range (I)
14. Zenón Martínez	B.Sc.	CORDEPAZ	Alimentation
15. Dino Rocha	B.Sc.	PAC	Grazing
16. Guillermo Prieto	B.Sc.	IBTA	Range and pastures
17. Máximo Flores	B.Sc.	IBTA	Nutrition
18. Raúl Lara	B.Sc.	CUMAT	Botany
19. Jorge Laura*	B.Sc.	IBTA	Range and pasture
20. Eduardo Chumacero	B.Sc.	IBTA	Nutrition
21. Félix Martínez	B.Sc.	PAC	Management and production
22. Humberto Vilela*	B.Sc.	PAC	Animal health
23. Victor Rivero	B.Sc.	CORDECH	Alimentation
24. Boris Jeres*	B.Sc.	UMSS	Range evaluation
25. Alejandro LaFuente*	B.Sc.	ONG	Range and pasture
26. Jorge Portugal*	B.Sc.	PAC	Range management
27. Celso Ayala*	B.Sc.	IBTA	Animal health
28. Rodolfo Puch	B.Sc.	UTF	Range and pasture
29. Adolfo Flores	B.Sc.	UTF	Animal production
30. Rene Baptista*	B.Sc.	ONG	Animal production
31. Hugo Baptista	B.Sc.	UTF	Forage production
32. Máximo Liberman	B.Sc.	UMSA	Fitosociology
33. Eusebio Calle	B.Sc.	UTO	Range and botany

* Working on B.Sc. degree thesis.

The institutional symbols belong to:

IBTA=Bolivian Institute of Agriculture Technology

UMSA=University of San Andrés

UMSS=University of San Simón

CORDEPAZ=Development Corporation of La Paz

PAC=Peasant Self Development Program

CORDECH=Development Corporation of Chuquisaca

CORDEOR=Development Corporation of Oruro

CORDEPO=Development Corporation of Potosí

ONG=Non Governmental Organization

IICA=International Institute of Agriculture Cooperation

CUMAT=Mayor Use of the Land Capacity

UTO=Technical University of Oruro

UMTF=Tomás Frías Mayor University

I=English

POLICIES

The research activities in the Bolivian Andean zone, according to IBTA, the state organization that represents the official voice of the country in research subjects, are based on realistic policies directed to develop an animal production industry with appropriate technology.

The major objectives are as follows:

- To develop research activities to strengthen production basically for the country's self-sufficiency in food production and security
- To develop research activities to strengthen production of exportable products and transference and substitution for imported products
- In general, the main view is to apply a technological generation policy that can save capital, support greater economic independence, and can generate autonomous development at the same time.

It is also necessary to say that research and technology transfer are only some of the important points in Andean rural development. They must be correlated through coherent policies with other social factors (land tenure, proper utilization of the natural resources, population density, etc.) and with economic production factors (profit, market, marketing, prices, credit, services, etc.).

CONCLUSIONS AND RECOMMENDATIONS IN SMALL RUMINANTS RESEARCH

ALIMENTATION

It can be said that among the different production factors, the alimentation and management problems are most critical for the initial development of a small ruminant industry in the Bolivian highlands. Any other factors are less important under subalimentation conditions. Additional recommendations follow:

- A program to prove and select introduced forages under irrigated and dry conditions for the different agroecosystems and production systems must be maintained.
- The availability of native forage species that have development potential is not very well known. Because of that fact, it is important to develop a strong program in collection, on-site evaluation, agronomic evaluation, and, eventually, evaluation with animals and seed production. It is an urgent need to investigate seed production of native and introduced adapted forages to support range revegetation programs.
- Because of the availability and limited use of hydric resources with high salts content, it is important to develop research for the efficient utilization of these water resources, especially with native tolerant forage plants (halophytes). In addition, it is important to explore the increase of irrigated native pastoral ecosystems, looking for an appropriate botanical composition in response to the differences in quality and quantity of water resources.
- There is also promising research on developing technology to increase the amount of water infiltration as one of the better short- or medium-term range recuperation alternatives. Because of the short time and high intensity of rainfall and extensive amount of bare ground in the rangelands, runoff is quite common, and there is an urgent need to reverse this situation if we want to maintain the natural productive base.
- There is practically no information on animal and plant reactions to grazing:
  - traditional grazing systems
  - complementary grazing
  - defoliation intensity related to grazing
  - palatability and grazing
  - trampling related to animal species, plant cover carrying capacity, and kind of soil

— grazing and water management of irrigated native ranges
— integrated agropastoral production systems studies
— identification of native key forages
— range inventory and evaluation
—range condition and trend
—native seed production technology

NUTRITION

The seasonality of the forage range and pasture production have a definite negative influence on sustaining productivity of the animals. For this reason it is important to develop research programs in:

- developing a reliable and rapid methodology to understand the annual nutrition dynamics of small ruminants. Proper alimentation strategies such as maximizing the utilization of forage resources by adequate storage strategies during the rainy season.
- Alternative sources of forage for supplementation; cultivated forages, use of weeds, stubble, agricultural and agroindustry byproducts, grazing systems, native irrigated plants, high fiber forage transformation, etc.
- Identify macro, micro, and vitamin deficiencies and develop cheap supplementary technology, especially important for the intensive production systems that could be proposed.

GENETIC IMPROVEMENT

Some recommendations are as follows:

- To incorporate better production genes in criollo sheep and goat flocks, it is important to determine the most convenient degree of crossbreeding, according to the local production systems and agroecological conditions in order to develop several valid technological alternatives for the small holder farmers.
- There is a need to develop classification and selection programs for small criollo and native ruminants, identifying superior animals to form and maintain and utilize flocks with good adaptation and productivity characteristics.
- A llama animal breeding program through the identification and selection of superior ecotypes for meat and for wool production. In wool llama ecotypes, the selection has to be focused on the following characteristics: entire color fleece, low presence of hair, and high fleece weight. It is also important to reintroduce camelids into areas that they occupied formerly.

- In alpacas, entire color fleece selection (different colors) and greater productivity should be the principal topics for selection work. Conduct research on selection and adaptation of alpacas to dry rangeland conditions and to intensive alpaca production systems.

Production

The following are the main recommendations:

- It is important to go ahead with research on shearing periods and height of shearing according to differences in climate and in animal husbandry practices used by small holder farmers.
- In vicuñas, because of the positive results in preservation, it is important to have a research line in order to develop proper management technology to support a future rational utilization of this wild camelid.
- It has been concluded that the major characteristic of the agropastoral production system of small holder farmers is essentially a multispecies exploitation based on the full use of the soil, water, and forage resources. For this reason, it is important to focus research on describing, analyzing, and identifying the problems in order to develop improved technological alternatives from a production system point of view.

Animal health

Needs in this area include the following:

- So far, the magnitude and distribution of zoonotic diseases need to clarified.
- Toxic plants: identification, problems, importance, and control methods.
- Research to overcome the enterotoxemia problem must be done, because it constitutes the major cause of mortality in alpaca and llama offspring.

Reproduction

The following are important recommendations:

- The low fertility observed in camelids has to be studied to develop practical solutions to this situation.
- There is an excess of males, and usually they are in the sheep flocks all the time, resulting in inbreeding problems and in uncontrolled spreading of reproduction throughout the year. For that reason it is necessary to determine the optimum mating and lambing season to avoid production risks.

BIBLIOGRAPHY

Alzérreca A,. H. Y Jerez C,. B. 1989. Análisis y propuestas para el manejo de praderas nativas, pasturas y ganadería en la comunidad de Japo. UMSS-AGRUCO. Serie técnica No. 20. Cochabamba, Bolivia. 37 p.

Alzérreca A,. H. 1975. Evaluación de la pradera nativa en el altiplano central de Bolivia. Tesis Ing. Agr. UMSS-FCAP Cochabamba, Bolivia. 81 p.

Alzérreca A., H. et al. 1983. Ensayo de recuperación de la pradera nativa para camélidos en Ulla Ulla. Reunión Nacional de Pastos y Forrajes, Quinta y Reunión Nacional de Ganadería, Séptima. ABOPA-IBTA-INFOL. Potosí, Mayo 1983. pp. 169-184.

Alzérreca A,. H. 1988. Diagnóstico y prioridades de investigación en praderas y pasturas del Altiplano y Altoandino de Bolivia. Proyecto Piloto de Ecosistemas Andinos. Cajamarca, Peru. 51 p.

Alzérreca A., H. Y Román, E. 1987. Ensayo de recuperación de una pradera nativa degradada en el altiplano central de Bolivia. Reunión Nacional de ABOPA, Octava. ABOPA-CORDECH. Sucre, Septiembre 11-15, 1985. La Paz, Bolivia. pp. 107 - 114.

Alzérreca A,. H. Y Lara, R. 1988. Evaluación de praderas nativas en el Altiplano Central y Oeste del departamento de Oruro. Primera Reunión Nacional en Praderas Nativas de Bolivia. Oruro, Agosto 26-29 de 1987. PAC-CORDEOR-CEE. Oruro, Bolivia pp. 3-11.

Alzérreca A,. H. 1986. Campos Nativos de Pastoreo de la Zona Altiplánica y Altoandina de Bolivia. In Primera Convención Nacional en Producción de Camélidos Sudamericanos. Oruro, Julio 2-4. PMPR-CORDEOR-CEE-INFOL-IBTA-ABOPA. Oruro, Bolivia. pp. 155-191.

Alzérreca A,. H. et al. 1983. Ensayo de recuperación de la pradera nativa para Camélidos en Ulla Ulla. Quinta Reunión Nacional de Pastos y Forrajes y Séptima Reunión Nacional de Ganadería. ABOPA-IBTA-INFOL. Potosí, Mayo 1983 pp. 169 - 184.

Alzérreca A,. H. Y Cardozo G,. A. 1990. El valor nutritivo de las especies forrajeras nativas e introducidas en la zona alta de Bolivia. En preparación.

Beck, S. 1985. Florúla ecológica de Bolivia. In Ecología en Bolivia. Nº. 6. La Paz, Bolivia. 1-41 pp.

Blanco, C. 1973. Zonificación de la comunidad vegetativa del rea del Desaguadero. In III Reunión de Agrostólogos y Zootecnístas de Los Andes Altos. IICA. Jujuy, Argentina. pp. 38-44.

Bolivia. 1989. Estadísticas Agropecuarias 1980 - 1988. Ministerio de AA. CC. y Agropecuarios. Departamento de Estadísticas. La Paz, Bolivia.

Braun, O. 1964. Forrajeras del altiplano. Bolivia, MACA. Servicio Agrícola Interamericano. Boletín Experimental No. 30. La Paz, Bolivia. 19 p.

Camargo, R. Y Cardozo G., A. 1971. Ensayo comparativo de la capacidad de digestión de la llama y la oveja. In Reunión Latinoamericana de Producción Animal, Tercera. Resúmenes Bogotá, Colombia. R18:46

Cárdenas, M. 1970. El altiplano como un sistema ecológico. Reunión proyecto de pasturas de los Andes Altos, primera. MACA-IICA, Zona Andina. La Paz, Bolivia. pp. 58-65.

Cardozo, A. 1989. Estudios sobre consumo y digestibilidad aparente de la Llama en Bolivia. La Paz, Bolivia 9 p.

—-. 1970. El altiplano de Bolivia y la cría de ovejas. Edit. Universitaria. UMSS. Cochabamba, Bolivia. 165 p.

Choque H., Cardozo A. Y Riera S. Pesos al nacer y sobrevivencia de corderos de tres razas. In. Reunión Nacional de Investigadores en Ganadería, Segunda. pp. 31-39. Ministerio de Asuntos Campesinos, Instituto Boliviano deTecnología Agropecuaria, Instituto Interamericano de Ciencias Agrícolas. Serie: 51. IICA. La Paz, Bolivia. 218 p.

Cumacero E. 1977. Crecimiento comparativo de corderos. In.Reunión Nacional de Ganadería, Tercera. pp. 82-87. Ministerio de Asuntos Campesinos, Instituto Boliviano de Tecnología Agropecuaria. La Paz, Bolivia. 283 p.

Delgadillo, J. 1985. Seminario sobre la situación actual de la producción ganadera en pastos y forrajes en Bolivia. Asociación Boliviana de Producción Animal. Santa Cruz, Bolivia. 97 p.

Dennis, A. Y Kucera, E. T. 1988 A comparison of the diets of sympatric vicuñas and alpacas in Bolivia. Department of Forestry and Resource Management. University of California. Berkeley, USA. 10 p.

Espinoza E., Mcdowell L., Rodriguez J., Loosli J., Conrad J., and Martin F. 1982. General status of llamas and sheep in the Bolivian Altiplano. Journal of Nutrition. Reprinted. Vol. 112. No. 12. pp. 2286-2292.

Flores L, M., Y Cardozo, A. 1988. Evaluación de la broza de quinua, afrechillo y harina de tarwi en la alimentación de ovinos y llamas. Tésis de Grado. Facultad de Ciencias Agrícolas y Pecuarias, UMSS. Cochabamba, Bolivia. 65 p.

Iñiguez L., Riera S., Rodriguez J. Y Rodriguez T. 1974. Efectividad de diferentes métodos de cruzamientos y el comportamiento reproductivo en tres razas ovinas. In. Reunión Nacional de Investigadores en Ganadería, Segunda. pp. 40-58. Ministerio de Asuntos Campesinos, Instituto Boliviano de Tecnología Agropecuaria, Instituto Interamericano de Ciencias Agrícolas. Serie: 51. IICA. La Paz, Bolivia. 213 p.

La Fuente, R. et al. 1987. Evaluación de la productividad de campos nativos de pastoreo en Ulla Ulla. Primera Reunión Nacional en Praderas Nativas de Bolivia. CORDEOR-CEE-PAC. Oruro 1987. pp. 56-64.

Lara, R. Y Alzerreca A,. H. 1976. Forrajes nativos del altiplano. MACA-IBTA. La Paz, Bolivia. Boletín Experimental No. 57.

Lara, R. 1982. Estudio sistemático descriptivo de las Poaceae nativas del altiplano. Contribuciones al conocimiento de la vegetación de las tierras altas de Bolivia. MACA-INFOL. Estudios Especiales EE 32. La Paz, Bolivia. pp. 1-53.

LeBaron, A. 1979. An Explanation of the Bolivian Highlands Grazing; Erosion Syndrome. Journal of Range Management. Publication of the Society for Range Management. Vol. 32 No.3. pp. 201-208.

McKell M., C. 1975. Shrubs-a neglected resource of arid lands. Science. USA. Vol. 187, pp. 803-809.

Maiza, R. Y Cardozo, A. 1988. Digestibilidad del ichu (**Stipa ichu**) en ovinos, llamas y vicuñas. Est. Experimental de Patacamaya. Informe 1987-1988. La Paz, Bolivia. 8 p.

Manrique, R. 1981. Análisis químicos bromatológicos de forrajeras nativas y estiércol de Alpacas y Ovinos de Ulla Ulla. INFOL. Estudios Especializados EE: 12. 9 p.

Mendieta, H. 1985. Seminario sobre la situación actual de la producción ganadera y de pastos y forrajes en Bolivia. ABOPA - CORDECRUZ. Santa Cruz, Bolivia. pp. 8-20.

—-. 1982. Informes anuales 1981-1982. Estación Experimental Patacamaya. MACA-IBTA. La Paz, Bolivia.

MENDIETA, H. 1983. Asociación de pasto brasilero (**Phalaris sp.**) y alfalfa (**Medicago sativa**) bajo condiciones de riego y secano. ABOPA-IBTA-INFOL-BCB. Potosí Mayo 1983. pp. 127-132.

Martínez F. Z. 1991. Avances de la investigación sobre la producción de la ganadería camélida en Bolivia. Instituto Boliviano de Tecnología Agropecuaria. La Paz, Bolivia. 38 p. (Mimeo).

Miranda, L. 1990. Estado de situación de la producción de cultivos agrícolas en la región andina de Bolivia. Andean Development Thrust. Centro Internacional de Investigaciones para el Desarrollo (CIID). La Paz, Bolivia.

Quispe, E. Y Cardozo G., A. 1988. Prueba de valor forrajero y digestibilidad de la quinua henificada en llamas y ovejas. Convención Internacional sobre camélidos, Sexta. Febrero, 8-12. Oruro, Bolivia.

San Martin, F. Y Bryant C., F. 1987. Nutrición de los Camélidos Sudamericanos: Estado de nuestro conocimiento. Texas Tech. University, Artículo Técnico T-9-505. 67 p.

Prieto, G. Y Alzerreca A., H. 1989. Diagnóstico de las actividades forrajeras en el altiplano y altoandino de Bolivia. Reunión de la Red de Pastizales Andinos de los Andes Altos. Cochabamba, Bolivia. 20 p.

Prieto, G. 1988. Evaluación agrostológica y mapeo de una pradera nativa en el altiplano semiárido de la provincia Ingavi. Tesis Ing. Agr. UMSS-FCAP. Cochabamba, Bolivia. 93 p.

Riera G,. S. 1964. Camélidos. Estación Experimental de Patacamaya, Boletín Informativo 4. MACA. La Paz, Bolivia 8 p.

Riera G,. S. Y Cardozo G,. A. 1970. Consumo de ensilaje de alfalfa y agua en llamas y ovinos. Asociación Latinoamericana de Producción Animal. Memorias, México 5:49-54.

Rocha, E. 1983. Estudio agronómico, nutritivo y análisis de semilla del Cauchi (**Suaeda foliosa**) en dos épocas de siembra. Quinta Reunión Nacional de Pastos y Forrajes y Séptima Reunión Nacional de Ganadería, Potosí Mayo 1983. IBTA-INFOL-BCB. Potosí, Bolivia. pp. 205-209.

Rodriguez C. J. 1981. Investigación en ovinos de altura. Instituto Boliviano de Tecnología Agropecuaria. Estación Experimental de Patacamaya. La Paz, Bolivia. 25 p.

—-. 1982. Estudio de la infestación sárnica en ovinos a través del año. In. Reunión Nacional de Ganadería, Cuarta. pp. 27-32. Asociación Boliviana de Producción Animal. Edit. CRISOL. La Paz, Bolivia. 440 p.

Rodriguez, T. 1985. Situación de la ganadería en el Altiplano de Bolivia. In Seminario sobre la Situación Actual de la Producción Ganadera de Pastos y Forrajes en Bolivia. ABOPA. Santa Cruz, Bolivia.

Rodriguez, T. Y Cardozo, A. 1989. Situación Actual de la Producción Ganadera en la Zona Andina de Bolivia. PROCADE-UNITAS. La Paz, Bolivia. 99 p.

Tapia, M. 1971. Pastos naturales del altiplano del Perú y Bolivia. Programa de Investigación Zona Andina IICA. Publicación Miscelánea No. 58. Quito, Ecuador. 200 p.

USAID/Bolivia Mission. 1988. Agriculture Sector Assesment Office. Office USAID/BOLIVIA MISSION. Chemonics International Consulting Division. Washington, D. C. USA. 247 p.

Zegada, L., Cardozo, A. Y Lopez, J. 1972. Ensayo de digestibilidad aparente de tres forrajes en alpacas. In Reunión Nacional de Investigadores de Ganadería, Primera. Sept. 12-14. Memorias. La Paz, Bolivia 137 p.