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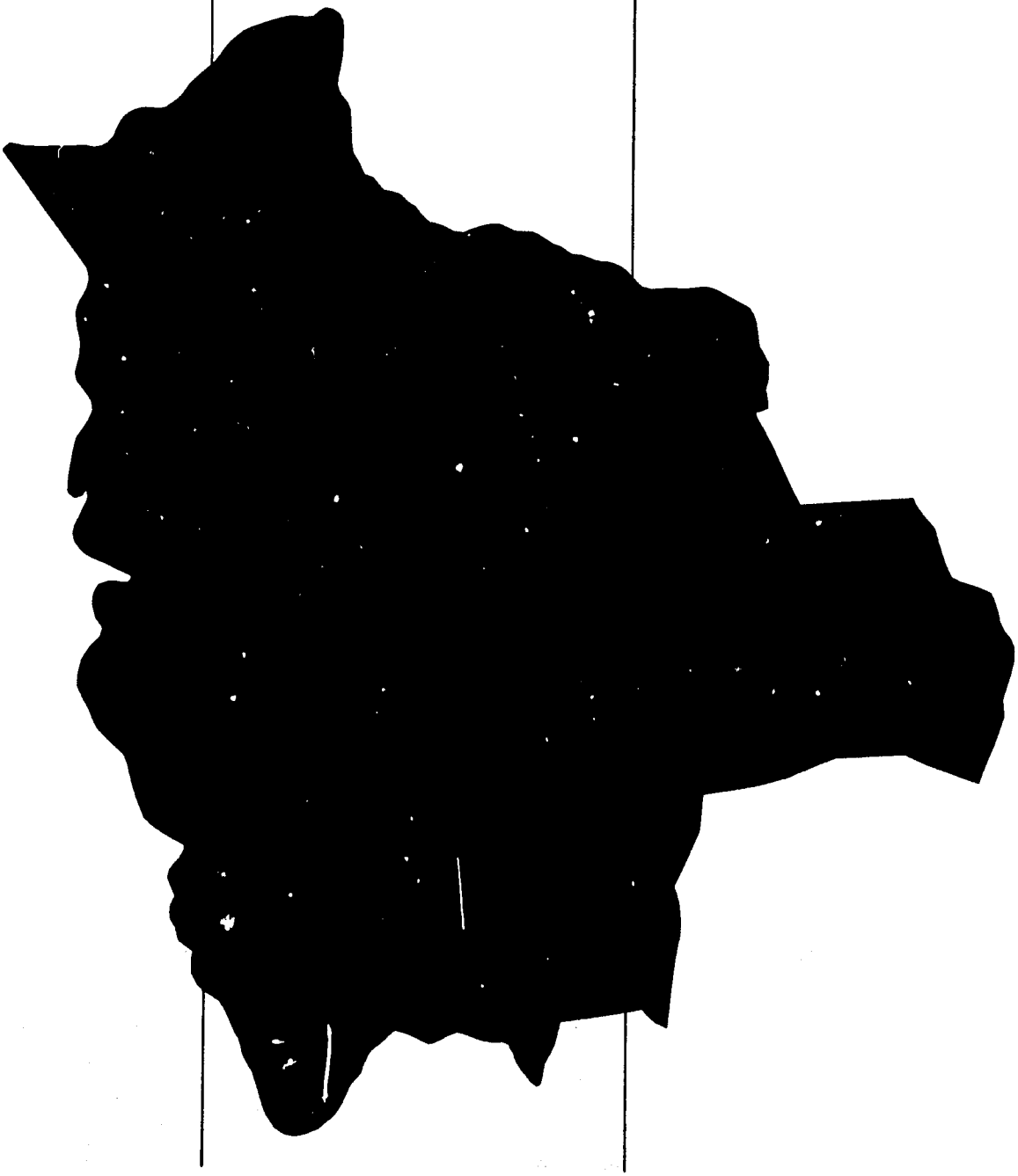
A Field Study



Bolivia

State of the Environment
and Natural Resources

A Field Study

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Preface

This environmental profile of Bolivia is the first field study of a series that AID is commissioning for the AID-receiving countries. In a process termed environmental profiling and similar in many ways to sector assessments, initial desk studies are followed by field reconnaissances of the kind that are reported in this document. The companion desk study titled *Draft Environmental Report on Bolivia*, was prepared for AID in June 1979, by the Library of Congress. That study is for the most part superceded by the present report, however it contains a useful and detailed compendium in English of laws and legislation concerning natural resources and the environment, which complement the present report.

The scope of work for this study was developed jointly by the AID Mission in Bolivia and the Environmental Coordinator for the Bureau for Latin America and the Caribbean. The need within the Bolivian government for a comprehensive review of the state of the environment and natural resources was anticipated, however. It is hoped that this report therefore will assist in furthering policies and actions on these fronts, as well as in orienting AID's work in Bolivia. This profile was prepared by the following persons:

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The reporting team wishes to express its appreciation to the Bolivian government, especially the Ministerio de Planificacion y Coordinacion Economica's Oficina de Ciencia y Tecnologia, for its support and cooperation, and to all of the individuals with whom contact was made. They are too numerous to list here, but all appear in the appendix.

A warm vote of thanks goes to the AID Mission in Bolivia, especially to Mr. Michael Deal, Mr. Peter Bittner, and Mr. Malcolm Butler.

Table of Contents

	Page
List of Tables	vii
List of Figures	viii
Summary and Recommendations	x
Summary	x
Summary of Recommendations	xi
Recommendations to AID	xiii
Chapter 1 – Introduction	1-1
Objectives and Scope	1-1
Methods	1-1
General Environmental Characteristics and Problems	1-1
Chapter 2 – Wildlands and Wildlife	2-1
Introduction	2-1
Wildlife in Bolivia	2-1
Parks and Equivalent Reserves	2-5
Evaluation	2-11
Foreign Assistance and Cooperation	2-12
Recommendations	2-12
Chapter 3 – Natural Forests	3-1
Introduction	3-1
Generalized Forest Descriptions	3-1
Forests by Life Zone	3-1
Estimates of Total Area in Forest	3-5
Demands Upon Forest Lands and Resources	3-7
Forest Management	3-9
Foreign Assistance	3-12
Principal Forest Management Problems	3-13
Recommendations	3-16
Chapter 4 – Plantation Forests	4-1
The Status of Plantation Forestry	4-1
The Need for Forest Plantations	4-5
Constraints on Progress	4-6
Recommendations	4-7
Chapter 5 – Soil Erosion and Watershed Conditions	5-1
Introduction	5-1
Knowledge of the Soils Resource	5-1
Extent and Nature of Erosion	5-2
Governmental Actions to Control Erosion	5-6
Watershed Conditions and Watershed Management	5-8
Recommendations	5-9

Table of Contents (continued)

Chapter 6 – Altiplano Range 6-1
Introduction 6-1
Range Characteristics and Potential in the Altiplano 6-1
Present Situation of the Altiplano Range 6-8
Recommendations 6-9

Chapter 7 – Pollution and Health Impacts 7-1
Introduction 7-1
Institutional Framework 7-1
Principal Problems and Their Health Consequences 7-2
Recommendations 7-6

Chapter 8 – Institutional Perspective 8-1
Introduction 8-1
Institutions Concerned with Pollution 8-1
Institutions Concerned with Natural Resources 8-2
Environmental Policy and Planning Institutions 8-4
Evaluation 8-5

Acronyms A-1

List of Persons Interviewed B-1

Bibliography C-1

List of Tables

Table		Page
2-1	Endangered Species in Bolivia	2-2
2-2	Primates Shipped Live to the United States from Bolivia, 1978	2-4
2-3	National Parks and Wildlife Conservation Areas	2-6
3-1	Potential Forest Lands of Bolivia	3-5
3-2	Areal Extent of Forest Vegetation Types by Departments as Determined by GEOBOL's Interpretation of Recent Satellite Images	3-6
3-3	Timber Products in Quantities Harvested and Produced and Their Values for the Year 1976	3-8
3-4	Secondary Forest Products in Quantities Harvested and Produced and Their Values for the Year 1976	3-8
3-5	Professional and Technical Forestry Personnel in Bolivia	3-10
3-6	Forest Reserves in Bolivia	3-11
4-1	Hectares of Forest Plantations Established from 1960 Through 1975	4-1
4-2	Hectares of Forest Plantations Required Annually to Meet the Demands for Wood Products	4-6
5-1	Conversion of Land System Units to Levels of Erosion Susceptibility	5-2
5-2	Evaluation of Watersheds with Hydropower Plants	5-9
6-1	Characteristics de Algunas Forrajeras-Nativas del Altiplano	6-3
6-2	Composition and Production of Three Grasses at Tiwanaku (15-year Enclosure)	6-8
7-1	Incidence of Eleven Transmissible Diseases, 1978	7-2
7-2	Levels of Sewer and Sanitation Services in 1976	7-2

List of Figures

Figure		Page
1-1	Geographic Profile of Bolivia	1-3
2-1	Organization of CDF	2-3
3-1	Diagram for the Classification of World Life Zones or Plant Formations	3-2
3-2	General Ecologic Map of Bolivia (Source: Unzueta, 1975)	3-3
3-3	National Forests, Parks, and Wildlife Reserves	3-12
3-4	Land Settlement Areas and Protected Areas	3-14
5-1	Susceptibility to Water Erosion	5-4
6-1	General Climatic Zones	6-2

SUMMARY
&
RECOMMENDATIONS

Summary and Recommendations

Summary

Methods and Purpose

During four weeks in September and October, 1979, a multidisciplinary team of seven experts in environmental and renewable natural resources undertook a general review in Bolivia of the following topics: wildlands and wildlife, natural forests, plantation forests, soil erosion and watershed management, high altitude range management and condition, and industrial and urban pollution and its health impacts. Individual reports were compiled and edited into the present report. The purpose of the review was to orient future efforts by AID, the Government of Bolivia and the international assistance community in environmental and natural resources work.

The Most Serious Problems Affecting Bolivia's Renewable Natural Resources

- **Soil erosion.** Eighty percent of Bolivia's farmlands and grazing areas are eroded in varying degrees. Except for a small program in Tarija, there is no work or program for combatting soil erosion and no institution charged with this task.

- **Range degradation.** In the 210,000 km^2 Altiplano all of the range is overgrazed and degraded, so that present productivity is as little as 10% of potential. Measurements of potential productivity vary from 6.6 mt of forage per hectare near Lake Titicaca to slightly less than 1.0 mt/ha at Patacamaya on severely eroded sites. Sheep are a major factor in range degradation; overgrazing is general.

- **Illegal settlement, hunting, and logging.** These activities are threatening the integrity of Bolivia's park and forest reserve system. Strong markets in Brazil for mahogany, and internationally for animal skins and live animals, as well as ease of circumventing laws and customs checkpoints, are major factors. Lack of coordination in MACA between the Instituto Nacional de Colonizacion and the Centro de Desarrollo Forestal, and no effective management of forest reserves and parks are also underlying problems.

- **Deforestation and destruction of woody vegetation.** Deforestation in the tropical lowlands, especially the Yungas, is destabilizing easily degraded soils and is occurring along newly constructed roads. Loss of tropical forests is relatively recent; 12,000 km^2 of forests are estimated to have been cut down. Approximately 560,000 km^2 of natural forest remains. In the Altiplano 24,700 km^2 of low forests have been destroyed over the centuries. Woody bushes are being cut and burned now for fuel. Reforestation efforts are in their infancy, except for relatively old plantations in Cochabamba. About 11,000 hectares of plantations, mostly eucalypts, were established by 1979.

The Most Serious Pollution and Related Health Problems

- **Water pollution.** Pollution by human wastes is associated with high incidences of gastroenteritis and typhoid fever (18,326 cases and 55 cases per 100,000 respectively). Twelve percent of the total number of deaths for all ages are related to water pollution and unsanitary conditions.

- **Pesticides pollution.** Pesticides intoxication is causing sickness and some deaths, particularly in cotton-growing areas in Santa Cruz. There is no control on the use of pesticides. Ignorance and carelessness characterize distribution and application. Measurements of pesticides in the environment or food chains have not been made.

- **Water pollution by industry.** ENAF and YPFB, the state mining and oil/gas industries, are principal polluters, according to persons interviewed. Industrial pollution has not been documented, however.

Constraints on Action

The principal constraints on solving Bolivia's principal environmental and pollution problems are:

- **Weakness of CDF.** The Centro de Desarrollo Forestal, which is charged with implementing the legislation concerning forests, wildlife and parks, is

presently a weak institution, with insufficient and inadequately trained staff, poorly executed programs, and little power relative to the importance of the resources it manages.

- **Lack of official perception of soil erosion and range degradation.** Absence of programs or even legislation aimed at these problems is testimony of a lack of awareness. There is no obvious explanation for this situation, especially since private individuals, including government employees, acknowledge the existence of soil erosion and range degradation.

- **Lack of regulations for the 1978 Health Code.** Regulations and related administrative or other measures are the next important step in controlling air, water, and land pollution. Without them authoritative programs cannot be developed.

- **Lack of a wider context for pollution control.** Emphasis on human health limits the scope of effective action and the definition of important environmental impacts which are not necessarily of immediate consequence to human health. A more comprehensive policy for environmental protection is needed.

- **Current development strategies.** Emphasis at the national level on settling and developing the forested lowlands of the Oriente (which amount to about half the national territory), has diverted attention from the potentials of the Altiplano, which is generally considered to be overpopulated. In general, the productivity of the Oriente seems overrated and that of the Altiplano underrated, leading to the perpetuation of erosion and range degradation problems in the Altiplano and the ill-advised settlement of poor areas in the Oriente, resulting in fertility loss and invasion of weedy species. The vision that Bolivia's future is in the Oriente also weakens those who counsel conservation of forests and protection of wildlife.

Foreign Assistance

Foreign assistance concerned with Bolivia's environmental and natural resources management problems as exemplified in the table below, has been relatively modest.

Project title	Source	Total Amount (US$)	Duration
Inventory and management of forest resources (BOL/74/031)	UNDP/FAO	$ 699,215	1976-1979
Feasibility study of Hichukhota-Penas fisheries complex.	UNDP/FAO	9,700	1978
Programa de rehabilitacion de Tierras en el Valle de Taria (8/BOL/C2/I)	FAO/TCP	90,000	1980
Plantacion de coniferas de crecimiento rapido (study only)	Corporacion Andino de Fomento	38,000	1977-1978
Mision Forestal Alemana	Fed. Rep. Germany	1,164,135	1973-1978
Escuela Forestal	idem	1,544,341	1978-
Saneamiento Ambiental	OMS/OPS	46,800	1975-1980
Saneamiento Ambiental	UNICEF/ CIDA	1,058,000	1976-1980
Regulation of Pirai River	Fed. Rep. Germany	708,229	1977-1980
Inundaciones (study, R. Mamore)	BID	20,000	1977-1978
Apoyo al Sistema Nacional de Dessarrollo Cientifico y Tecnologico y Politicas Ambientales (BOL/79/008)	UNESCO/ UNEP	168,000	1980
Manejo y conservacion de suelos en zonas aridas y semiaridas	UNDP/FAO	80,000	1979-1980*
Forest nurseries and erosion control in the La Paz Department	UNDP/FAO	150,000	1980-1982

*Pending government approval.

Additional assistance is being provided or has recently been provided as follows:

- **IDRC.** Trials in the Altiplano with forest species.
- **CIFCA.** 1979 seminar and short course on mining pollution
- **U. of Goettingen.** $3.0 million, 4-year project to support development of the Instituto de Ecologia, affiliated with the Universidad Mayor de San Andres.
- **OSTROM (France).** Scientific support for studies of Altiplano lakes, especially Lake Titicaca, to the Instituto de Geodinamica y Limnologia (U. Mayor de San Andres).
- **IUCN.** 1978 survey of Bolivia's parks and wildlife preserves.

Summary of Recommendations

The following recommendations are presented in greater detail in the corresponding chapters.

Renewable Natural Resources Management

Wildlands and wildlife

- Review illegal wildlife trade and find ways to enforce the Convention on International Trade in Endangered Species, to which Bolivia is a signatory.
- Train a cadre of Bolivians in the philosophy and methods of wildlands and wildlife management.
- Prepare a national plan and strategy for wildlands and wildlife management using the exercise as an in-service training opportunity. This would be a 2-year effort.
- Delineate and protect the homelands of Indian forest tribes.
- Relocate the squatters (about 70) from Isiboro-Secure National Park, north of Cochabamba.
- Initiate popular environmental education programs at the Santa Cruz Zoo (municipality of Santa Cruz) and Tarila Regional Park (La Paz Department, CORDEPAZ project).
- Study the possibility of two new parks: (1) MAB reserve linking Ulla Ulla National Park with Caquiahuaca Regional Park, and (2) Tariquia Podocarp Park.

Forest resources

- Undertake a field evaluation of GEOBOL's land capability classification for the Oriente (recently published).
- Provide 3-4 years of technical assistance to the Chore Forest Reserve facility set up by the Programa de Plantaciones Forestales and expand the facility to carry out training and research on natural forest regeneration and management as well as plantation forestry. (Combines recommendations concerning natural forest and plantation forests.)
- Technical and financial assistance to CDF for its forest plantation program. Three to four years of assistance is recommended; co-direction of the proposed PL 480/WFP reforestation project would be a major portion of the work.
- Undertake national educational campaign to promote forest plantings. Formal as well as informal means are needed for communicating information on the need for and values of trees.

Soils and watersheds

- Carry out a national survey of erosion and sedimentation. About 30 person-months of technical assistance would be required in addition to field, office, and laboratory support.
- Undertake a national education effort on soil erosion and conservation. (The outline of a curriculum was provided to the Direccion de Ciencia y Tecnologia, Min. de Planificacion y Coordinacion Economica).
- Train technical personnel in MACA in erosion control and watershed management.
- Establish soil conservation/land rehabilitation demonstration centers in a number of communities in the Altiplano and Valleys area.
- Develop work plans for the management of two important watersheds, one in the Altiplano, and one in the Valleys (or Yungas) region.

Range resources

- Undertake practical trials in a number of ayllus in range regeneration and management.
- Carry out research and development with native forage species, with the aim of improving their productivity.
- Map the range potential of the Altiplano.
- Carry out research and development on range management and regeneration techniques.

Pollution and Health

- Reduce pesticides hazards, through the enforcement of regulations, educational programs, and improved medical services.
- Institute a program of industrial pollution control.
- Develop small-scale technological alternatives to sewage treatment and safe water in communities.
- Draft regulations for the 1978 Codigo de Salud.
- Strengthen the Instituto de Salud Ocupacional.

Other Recommendations

Comprehensive planning for environmental conservation

All the team members commented upon the need for a focused effort to develop a comprehensive plan for conserving environmental quality and natural resources. The Direccion de Ciencia y Tecnologia was about to initiate such an effort in late 1979, with assistance from UNESCO and UNEP. However, Dr. Carlos Aguirre, the director of the Direccion (who has since left this post), emphasized the desirability of undertaking well-defined, specific studies that would establish the scientific and technical bases for conservation and pollution control. The Direccion de Ciencia y Tecnologia could coordinate such studies by governmental agencies, while the Academia Boliviana de Ciencias could provide a link between government and the universities, which has not been well utilized in the past.

In essence, the informational base for comprehensive planning of environmental quality and natural resources conservation is very weak, and must be built up by means of a number of specific actions and studies. Ultimately, also, some form of public dialogue must be undertaken in order to establish a democratic base and public acceptance for achieving goals of environmental quality and conservation of soils, forests, waters, and wildlife.

Non-governmental groups in conservation and pollution control

Non-governmental groups such as the Sociedad Boliviana de Ecologia (SOBE) in La Paz could undertake important work in surveys, research, and education, given the needed resources. SOBE's planned seminar on environmental problems in Bolivia is an example of an event that constitutes a public dialogue on these problems.

The Aymara language radio, Radio San Gabriel, located in La Paz, is another example. That radio is interested in broadcasting programs on ecology and resource conservation to its listeners throughout the Altiplano, as part of its formal and informal education program. Another radio, ACLO (Accion Loyola), broadcasts in Quechua and reaches Altiplano as well as Oriente residents.

Appropriate technology and natural resources conservation

AID support of projects which introduce appropriate technologies and of projects for natural resources conservation should be integrated to the extent possible. In the Altiplano, the reduction of grazing and cutting pressures on scant vegetation as well as the improvement of soils, could be greatly assisted by the development of alternatives to organic fuel (solar, wind). Also land use patterns that hedge against climatic vicissitudes, but also prevent innovations for resource regeneration, could be more easily modified by such introductions as home or village level greenhouses for food or cash crop production, or other changes that assure food availability.

Demonstrations at the village level of soil erosion control, range regeneration and management, and watershed management could well be fortified or integrated with appropriate technologies which ease the pressure on renewable resources.

Integration of natural resources conservation and community development

Especially in the Altiplano, community development must be the matrix for introducing measures to

renew soils and range and to conserve their productivity. A number of circumstances supports this recommendation: (1) communal ownership or cooperation in the use of farmland and rangeland, (2) the fact that resource degradation is a symptom of underdevelopment, (3) the fragmented nature of properties, largely as a hedge against climatic variability, and (4) the imperative for treatment of soils and range over continuous surfaces, dictated by physical conditions.

Recommendations to AID

The following recommendations are consistent with congressional authorizations under the Foreign Assistance Act, namely Sections 102, 103, 103b, 118 and 119, relating to assistance in institutional strengthening as well as direct assistance in environmental and natural resources, including forestry, agroforestry, soil conservation, and watershed management.

An attempt to prioritize the recommendations has not been made. The initiation of projects or actions with long term payoffs, such as planning a strategy for national wildlands conservation, or drafting regulations for the Health Code should not be delayed. Neither should efforts be delayed to resolve the very immediate problem of pesticides intoxication. Since Bolivian endorsement is, in any case, essential for the implementation of the recommendations, it is suggested that the project possibilities be ranked after a review by the Bolivian government.

1. Support the national reforestation program proposed for PL 480 funding, as outlined in a memo from the team's forest plantation consultant (October 14, 1979, David A. Harcharik to Ken Johnson, Title III Officer, AID/Bolivia).

2. Provide technical assistance in forestry as follows:

- Three to four person-years to assist CDF in executing a national forestation program, and related silvicultural work.

- Two years of technical assistance to the Programa de Plantaciones Forestales (PPF) center in the Chore Forest Reserve, to assist in the design and execution of research and education programs in forest management and agroforestry. This technical assistance could be routed through CDF who is a partner with PPF in the Chore Forest Reserve Center.

3. Provide financial and technical support through AID/Bolivia or AID/LAC/ Washington for a wildlands and wildlife planning effort. Work would be undertaken under arrangements with World Wildlife Fund, IUCN, the University of Michigan, or the Department of Interior, who would coordinate technical expertise and provide project management. A 2-year effort would be needed, and should be designed with CDF's Departamento de Vida Silvestre and with the Departmental Development Corporations. This effort should also integrate training in wildlands management and the delineation of Indian homelands in the Oriente. A commitment at the level of the Minister in MACA is needed to obtain maximum results from this work.

4. Design a 3 or 4 year program (1) to support research and development under the auspices of IBTA on range improvement with native forage species for different kinds of range, and (2) to develop a range potential map.

5. Design and support a number of community level resources conservation and management projects, which would seek ways to regenerate and manage range land and to rehabilitate and conserve soils so as to increase their productivity. These projects could integrate AID support of appropriate technologies aimed at rural communities. Approximately 10 soil and range conservation/improvement projects are recommended for different environments in the Altiplano and the Valleys.

6. Design and support a long term (3 to 5 years) land rehabilitation and rural development project in the San Jacinto sub-watershed of the Tarija Valley, in cooperation with PERTT. Per hectare costs could be as much as $1000, exclusive of technical assistance. Approximately 5,000 hectares need treatment. Because soils are relatively productive, reclaimed areas could be settled by small farmers. Probable construction of the San Jacinto dam and power project makes this a priority project for PERTT.

7. Support advisory services for the design of research and development in integrated pest management for cotton production, as well as horticultural crop growing.

8. Provide technical and financial assistance for educational projects or programs concerned with natural resources conservation and pollution, for different levels in both formal and informal settings, and through governmental as well as non-governmental channels. Technical assistance in project or program design is needed. A small grant project in support of non-governmental organizations working in conservation education is suggested.

An educational effort to reduce pesticides pollution and intoxication is urgently needed and should be considered.

9. Provide technical assistance for the development of air and water quality standards and the preparation of regulations for the Codigo de Salud, of 1978.

10. Through meetings with other members of the development assistance community in Bolivia, seek to coordinate projects concerned with renewable natural resources, or which impinge indirectly upon these. Greater coordination between AID and the World Food Program in rural conservation works would be very desirable.

I. INTRODUCTION

Introduction

Objectives and Scope

The broad aim of this reconnaissance environmental profile is to orient future actions by AID and the government of Bolivia, directed at solving problems of degradation of environmental quality and renewable natural resources. More specifically the survey was to:

- Identify major existing and potential problems and areas of concern for natural resources and environmental management, including an analysis of the impact of these problems on the Bolivian society and economy.
- Develop an overview of Bolivian institutions, policies, and resources as related to natural resource conservation and environmental management.

Specific tasks undertaken included:

- Review of forestation projects in Bolivia
- Recommendations for a PL 480 Title III Reforestation Project proposed to AID by the Bolivian government
- Recommendations for future forestation projects
- Assessment of the severity of erosion problems
- Review of range management actvities and recommendations for range management programs in the Bolivian Altiplano
- Review of watershed management activities
- Review of national parks and forests and wildlife preservation activities
- Review of solid waste, air, and water pollution problems in Bolivia
- Review of manpower
- Review of current and proposed environmental activities
- Suggestions for action.

Methods

An environmental team visited Bolivia during September 16 to October 13. It consisted of a geographer (Mr. Peter H. Freeman), a tropical ecologist (Dr. Gary Hartshorn), a forester (Mr. David A. Harcharik), wildlands planning and management expert (Mr. Bradley Cross), soil and watershed management expert (Mr. Robert Flannery), a high altitude range expert (Mr. Greg Simmonds), and an environmental health specialist (Mr. James Williams).

Following planning sessions with AID and the Direccion de Ciencia y Tecnologia of the Ministerio de Planificacion y Coordinacion Economica, field trips and interviews were carried out in different parts of Bolivia. Two reconnaissance overflights were made: one from La Paz, northeast over the Yungas, south to Cochabamba and west to La Paz; and one south over the western Altiplano, east to Tarija, and north to La Paz over the eastern Altiplano. Land trips were made to Caranavi, Parque Nacional Isiboro-Secure, Reserva Forestal Chore, to Ulla Ulla, to Oruro and Cochabamba, and in Tarija Valley.

A list of persons interviewed is appended.

Reports of individual team members were edited into the present full report.

General Environmental Characteristics and Problems

Physiography

Bolivia is a landlocked state in Western South America lying between latitudes 10°S and 22°S. Thus, its territory embraces the sea level climate of the tropics, the subtropics, and the warm temperate region. The great elevation and mass of the Andean Cordillera, which attains over 6,000 meters in Bolivia, exert a major influence on the climate and consequently the ecological conditions. Thus, in Bolivia can be found perennial snows, Amazonian wet forest, deserts at high and low elevations, and intermediate variations of temperature and moisture, resulting in a total of 48 ecological Life Zones (as defined by the Holdridge system of ecological classification [Holdridge, 1947]).

Three major geographic regions are commonly used to describe Bolivia: the Altiplano, the Valleys, and the

tropical lowlands of the Oriente (Fig. 1-1). This terminology is used throughout this report; however, it is an excessive generalization of the great ecological diversity that is found, particularly in the valleys that sweep from snow-capped Eastern Cordillera down to the lowlands of the Amazon or Plate River Basin.

The Altiplano, which historically has been densely populated, especially in the more humid northern sections, is an internal drainage. All rivers flow into Lake Titicaca or Lake Poopo, or the salt flats to the south. The susceptibility of these water bodies to pollution is therefore great, and they are in fact being polluted now by minerals concentrating plants and foundries.

The Altiplano is probably over-populated by people in terms of the present traditional production technologies, and it is obviously overgrazed. The Altiplano soils and range are in general, overused and degraded, and no longer sustaining the vegetation (grasses, crops, trees) that are potentially possible in this environment. Restoration of the altiplano's productivity should be a national commitment.

The lower elevation Valleys region is in general steep, except for the actual river valleys, and also drier, because of the rain shadow effect of the mountain ranges that block westward moving moist air, and force precipitation on the windward slopes. Although their climates are more hospitable than those of the Altiplano, much of the Valleys areas (sloping soils) are geomorphologically unstable, and susceptible to quick degradation following removal of vegetation. The Yungas consist of a relatively narrow belt at the foothills of the Andean Cordillera subject to very high orographic rainfall and catastrophic erosion on slopes stripped of vegetation.

The Oriente is by no means homogeneous, as the chapter on natural forests demonstrates. With almost 561,000 km^2 of different kinds of forest, the Oriente is seen as the frontier of Bolivia, and the area that can absorb future population growth. Experiences with colonizaciones have not yet fulfilled this promise, since many soils once cleared of forest quickly lose fertility. Extensive cattle raising, hardly an economic base for population increases, has tended to develop in areas where fertility declined. A critical review of the premise that the Oriente can absorb Bolivia's additional population in coming years is needed.

Population, Development, and the Environment

Bolivia's population numbers 4.65 million (1976) and grows at 2.11%. Sixty-five percent of Bolivia's population is rural and 65% are Quechua or Aymara speaking Indians; the correspondence is virtually exact. (Statistically, urban population is defined as towns larger than 2000.) These rural people, approximately 80% of whom are in the Altiplano, follow traditional ways of farming and animal raising, live largely in a subsistence economy, and do not speak Spanish. By the standards of development such as income, health, and nutrition they are the least developed sector of Bolivian society (Country Development Strategy Statement, USAID/Bolivia, 1979). Any action to solve such natural resource problems as deforestation, soil erosion, range degradation, and watershed management must perforce deal with this unique group of rural people.

Bolivia's large cities are reported to be growing rapidly, as people move from smaller urban places to the larger ones. Typical LDC urban environmental problems occur: inadequate water supplies; waste water and solid waste in open gutters and streams; generally unsanitary conditions in public markets; great congestion with vehicular traffic encroaching dangerously on pedestrian traffic; noise; dust; and low quality housing. Air pollution is not in evidence. Flooding problems in Cochabamba, La Paz, and other cities are serious.

Industrial pollution problems may be locally serious, but cannot be considered a threat to the national, or even regional environments. Thus, the rehabilitation of renewable natural resouces (forest, soils, range) or their protection and conservation, looms as the most important national task facing Bolivia, and one which must be accomplished with the cooperation of the poorest of the poor, and the segment of Bolivian society least benefited by development to date.

An equally important national commitment is needed to achieve a wise and resource-conservative development of the Oriente, much of which is inherently fragile due to climatic and edaphic conditions. Intact forests and the wildlife in them need to be viewed as national wealth that already supplies considerable regional income and if carefully managed can continue to do so indefinitely.

These challenges as well as the environmental and natural resources problems that Bolivia must confront are presented in greater detail in the following chapters.

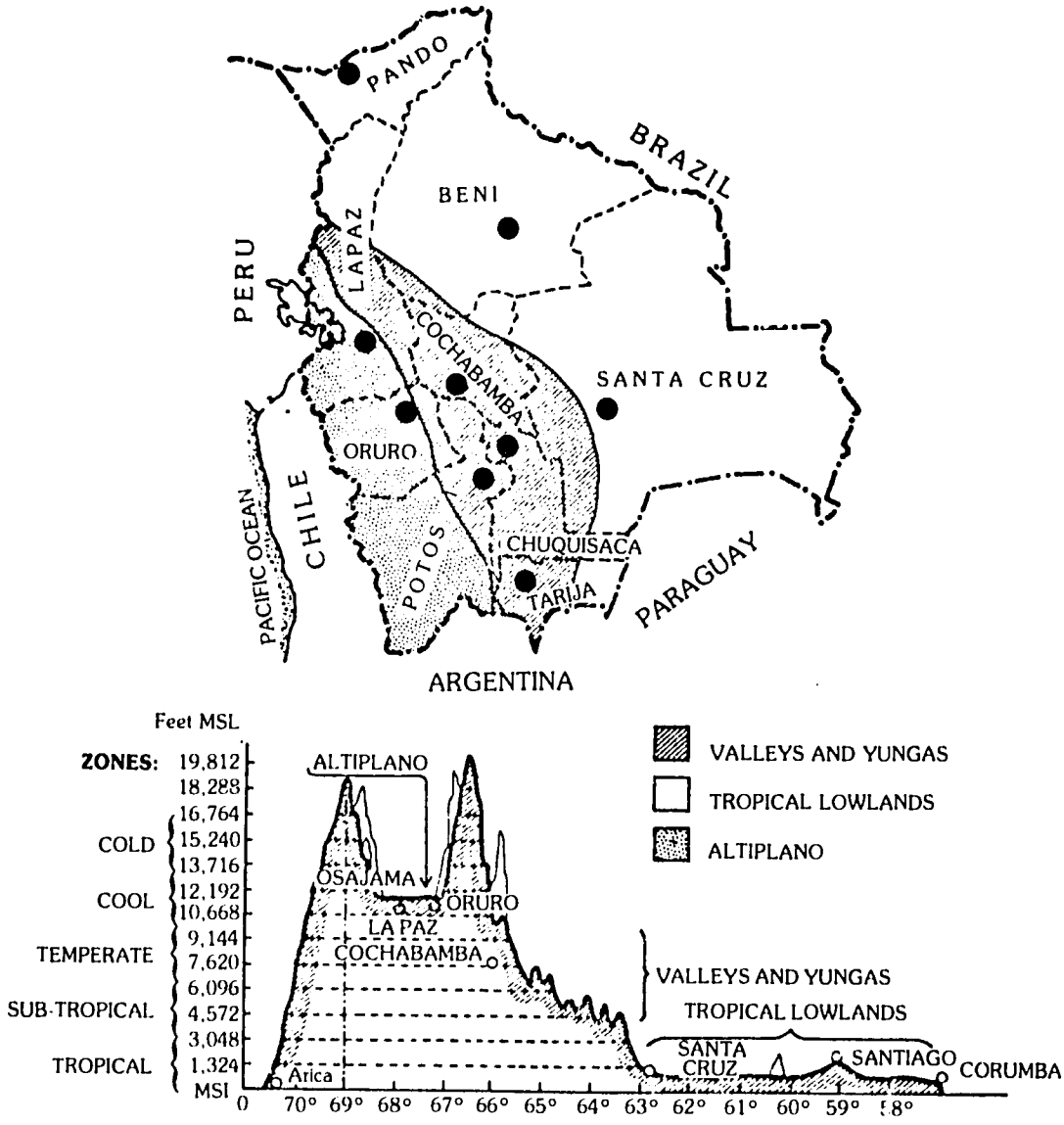


Figure 1-1. Geographic Profile of Bolivia

II. WILDLANDS AND WILDLIFE

Wildlands and Wildlife

Introduction

Bolivia is probably the wildest of the Andean zone countries. Its ½ million square kilometers of relatively undisturbed forests possess a rich and varied wildlife and are inhabited by diverse Indian tribes, who are largely hunters and gatherers. Although a number of parks and equivalent reserves have been decreed in Bolivia's forested Oriente, management of the areas is almost nonexistent. The construction of roads, land settlement in park areas, and uncontrolled hunting are threats to Bolivia's forested wildlands. Conflicting and overlapping claims by public agencies as well as private individuals characterize land tenure in the Oriente, and will complicate future management plans.

The term "wildlands" as used here refers to lands and waters which have been little affected by modern man, where natural processes such as evolution, native plant and animal reproduction, and natural nutrient cycling continue in a dynamic equilibrium. A very different set of circumstances affecting wildlife is found in the Altiplano, a completely altered environment. Special approaches to development will be required to harmonize the human uses of the Altiplano and the habitat needs for vicuna, guanaco, and the extraordinary bird life of the high elevation lakes.

For the most part Bolivia's wildlands are perceived as unsettled land, and planning documents set forth policies for "occupying space" in these wild areas, in order to relieve population pressures in the Altiplano.

Wildlands and wildlife in Bolivia are a very great asset which is presently undervalued and unmeasured. The forests of the Yungas buffer seasonal storms as well as the almost continuous orographic rains which feed the tributaries of the Amazon river system. They thus play a critical role in stabilizing steep slopes, in absorbing and releasing moisture, and thereby in preventing torrents, conserving stream channels, and maintaining stream ecology. Their removal would drastically alter the hydrographs and the ecology of the streams which feed the Beni and the Mamore Rivers.

The plant products of wild forests are diverse and valuable: rubber, Brazil nut, and quinine, to mention a few, worth at least $7.0 million in 1976 (Table 3-4), and probably much more, given that higher prices in Brazil encourage the illegal export of these products. The genetic values of the forest of Bolivia have not been realized, and presently they are not officially recognized. An outbreak of hemorrhagic fever in the Beni Department has been attributed to the proliferation of rats following the extermination of the wildcats as well as snakes and crocodiles.

Bolivia's thinly populated frontier, stricter control of skin trade in Brazil, the ease of smuggling skins into Paraguay and poor enforcement of the Convention on International Trade in Endangered Species (CITES) in Paraguay are factors which have favored the evolution of a highly organized, illegal skin trade, which passes both Brazilian and Bolivian animal skins through Paraguay on their way to international markets in Europe and the Orient. The smugglers do not hesitate to use strong-arm tactics as well as bribery to circumvent the law.* Only concerted international as well as national action will succeed in stemming the flow of skins and the slaughter of animals. The certain outcome of not enforcing the law will be species extinction.

In conclusion, one is hard pressed to imagine a more unfavorable situation for wildlife preservation in Bolivia's forested habitats.

Until effective control of hunting and trading can be attained, it may be necessary to preserve some species by breeding them. Primates, crocodiles, and some birds can be bred. (Reports that some traders are breeding wild animals could not be verified.)

Wildlife in Bolivia

Information on wildlife in Bolivia is scant. The director of the Departamento de Parques Nacionales, Caza y Pesca, had assumed the job one week before being interviewed by the team's wildlands expert, and no information was forthcoming from him. Interviews with several private persons and government officials yielded primarily general information. The best published information is contained in an IUCN-sponsored survey done in 1978 (Grimwood and Whitmore, 1978).**

The forests and savannas of the Oriente are habitats for monkeys (10 species), opossums (19 species), marmoset, anteaters (3 species), sloths (2 species), armadillos (12 species), tapiti, tapir, capybara, paca,

* The former director of the Parks, Wildlife and Fishing Directorate, Gaston Bejarano, had his life threatened several times while trying to halt illegal shipments of skins.

** A copy of this report is available at AID offices in La Paz, in the files of Michael Deal.

agoutis, several foxes, spectacled bear, jaguar, puma, ocelot, peccaries, several species of deer (including the marsh deer), and the maned wolf. Dolphins, manatees, several crocodiles, the South American river turtle, and the giant otter dwell in the streams and rivers

Bolivia's diverse bird life is notable for the colorful flamingos of the Altiplano lakes, the large rhea or nandu, tinamous (20 Bolivian species), many ducks and geese (including the Titicaca grebe), chachalacas, guans, curassows, toucans, macaws, and parrots.

Many species of fauna are endangered (Table 2-1).

Table 2-1. Endangered Species in Bolivia

Goeldi's monkey	*Gallimico goeldi*	Northern Pando Dept.
Giant anteater	*Myrmecophaga tridactyla*	Savannas
Giant armadillo	*Priodontes giganteus*	Savannas
Greater pichiciego	*Burmeisteria retusa*	Southern Chaco
Long-tailed chinchilla*	*Chinchilla lanigera*	Throughout Andean region
Short-tailed chinchilla*	*Chinchilla brevicaudata*	Throughout Andean region
Bush dog	*Speothus venaticus*	Northern Pando Dept.
Maned wolf	*Chrysocyon brachyurus*	Lowland savannas
Short-eared dog	*Atelocynus microtis*	Northern Pando Dept.
Spectacled bear	*Tremarctos ornatus*	Eastern cordillera, north of lat. 17°S
La Plata otter	*Lutra platensis*	Rio Paraguay drainage
Giant otter	*Pteroneura brasiliensis*	Amazon tributaries
Ocelot	*Felis paradalis*	Yungas & lowland forests
Jaguar	*Panthera onca*	Yungas & lowland forests
South American manatee	*Trichechus inunquis*	Rio Beni below rapids near Riberalta
Vicuna	*Vicugna vicugna*	Altiplano
Taruca (deer)	*Hippocamelus antisensis*	Eastern & western cordilleras
Marsh deer	*Blastocerus dichotomus*	Flooded savannas
Spectacled caiman	*Caiman crocodilus*	Amazon drainage
Black caiman	*Melanosuchus niger*	Amazon drainage
Dwarf caiman	*Paleosuchus palpebrosus*	Lagoons and swamps of savannas
Smooth-fronted caiman	*Paleosuchus trigonatus*	Amazon drainage

Table 2-1. (Continued)

Broaded-nosed caiman	*Caiman latirostris*	Rio Pilcomayo and other tributaries of Rio Paraguay
South American river turtle	*Podocnemis expansa*	Amazon tributaries
Garlepp's mountain finch	*Compsospiza garleppi*	Puna zone
Titicaca grebe	*Rollandia micropterum*	L. Titicaca (endemic)
Horned coot	*Fulicula cornuta*	Altiplano, fresh-water lakes

*Reported to be extinct now.

Source: Grimwood and Whitmore, 1978.

Much of Bolivia's wildlife is under heavy hunting pressure by skin, feather, and fur traders who sell to international markets. Forested habitats are increasingly being encroached by settlers and timber concessionaires, or minerals exploration crews.

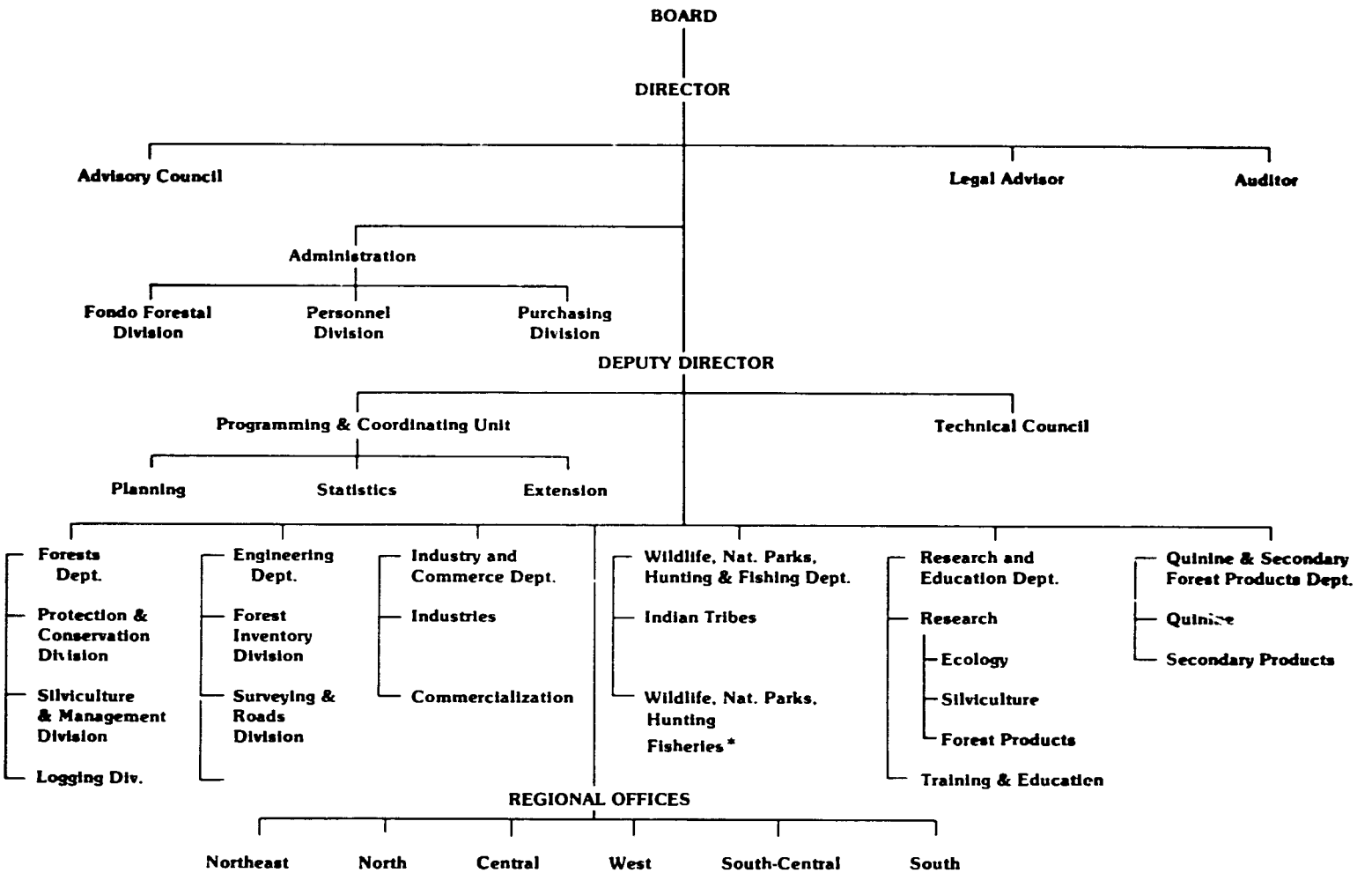
Bolivia's wildlife is administered by CDF. However, there is virtually no administration since there is only one man in the central office, and only five field staff, who attempt to control the legally permitted wildlife trade, mostly at airports where permits for export or transfer are controlled. Bolivia is a signatory to the 1973 Washington Convention on International Trade in Endangered Species (CITES) and maintains internal regulation in conformity with the convention. A 1975 Decree Law, Ley de Vida Sivestre, Parques Nacionales, Caza y Pesca sets the legal framework for wildlife management. Its regulations have not yet been enacted, however.

Bolivia has established nine parks, four wildlife reserves, one wildlife refuge, and one wildlife sanctuary (Figure 2-1). All are under the jurisdiction of the Departamento de Parques Nacionales, Caza y Pesca, of the Centro de Desarrollo Forestal. While these parks embrace the habitats of most endangered species, there is in fact little or no protection. Only two parks have wardens: Ulla Ulla and Isiboro-Secure.

Trade in Live Animals and Animal Products

Exports of live animals as well as skins are considerable. Trade statistics could not be obtained in Bolivia, however. Primates are principal species traded live. They are used in the United States and elsewhere for research. In 1978, the United States of America obtained 3,166 live monkeys from Bolivia, or 11% of the total imported in that year (Table 2-2).

The allowable number of animals that may be exported is set each year, and quotas are assigned to licensed exporters. However, with the exception of the



* In 1979, fisheries became a separate department.

Figure 2-1. Organization of CDF (from Stolz, 1978b)

primates (Pan American Health Organization, 1975) there have been no studies to determine the safe allowable export of any species. This is dangerous because of the unknown reproductive potential of most tropical species. The numbers appear mostly to be set by the demand the exporters have for the animals.

There are approximately five live animal exporters licensed in Bolivia. All but one are foreigners. The most notorious illegal exporter is the Austrian Theodore Bleichner, of Cochabamba. Theoretically, all exports of non-pest species must go either to zoos, universities for research or other research labs; only pests are to be exported in quantities for the pet trade such as blue-faced parrots (Gaston Bejarano, personal communication).

There is, in fact, little control of exports. In Santa Cruz where live animal exports are concentrated, Noel Kempf, the municipal zoo director, reviews all export papers. Although he ascertains that the zoo has two specimens of every species being exported, there is no control over the number of animals actually being shipped.

Table 2-2. Primates Shipped Live to the United States from Bolivia, 1978

Actus trivirgatus (Dourocouli)	231
Cebus apella (Black-capped capuchin)	82
Saimiri sciureus (Squirrel monkey)	1,845
Sanguinus rufiventer	1,008
Total	3,166

Source: World Wildlife Fund, USA.

The exporters interviewed found no difficulty in obtaining any species in demand except the chinchilla, which is now extinct in Bolivia.

The lucrative trade in live animals is enriching a few exporters, who are foreigners, and contributing little to development or improved welfare. Also, rare and endangered species are being illegally exported. Exporters rationalize this practice with the argument that it is preferable to export the animals than to leave them in Bolivia where they are not protected. Bribery and payoffs are commonplace in the business, and traders state that higher export taxes would mean larger bribes, which would increase smuggling to Paraguay in place of officially approved trade through Bolivian ports.

The great international demand for crocodile skins, cat pelts, and other animal products is also having an effect on Bolivia's wildlife. The major species hunted are spotted cats, foxes, crocodiles, otters, and peccaries.

The trade in animal skins such as cat pelts, crocodile or caiman skins is, like the live animal trade, very lucrative and virtually uncontrolled. The price of $500 received for a jaguar skin brings incredible wealth to a Bolivian hunter, easily exceeding a year's income from farming. There is no lack of professional hunters who supply traders. The great international demand for these products, especially cat pelts, does not augur well for the future of these species.

In accordance with the Convention on International Trade of Endangered Species (CITES), the export of skins of spotted cats and otters is illegal, so these are smuggled out of the country. The government does, however, permit limited export of two other endangered species — black caiman (*Melanosuchus niger*) and spectacled caiman (*Caiman latirostris*). They were reported in 1978 to have a quota of 1,000 and 7,000 skins per year, respectively (Grimwood and Whitmore, 1978).

The export of skins has been permitted by CDF, on a case by case basis, apparently. Modest taxes are levied for the skins. For example, in authorizations made in June 1979, a tax of 20 Bolivian pesos was levied for each fox skin, 80 pesos for each "Gato Brasil" skin and 2 pesos for each iguana skin. Earlier in the year CDF had authorized the export of crocodile skins. These export permits provoked citizen outcry in Santa Cruz because all Bolivian crocodiles are classed as endangered, and because of fears of ecological imbalances.

Fishes and Aquatic Habitats

Even less is known of fishes in Bolivia than of terrestrial animals. Despite Lake Titicaca's fame, it is not well-known. The last systematic study of the lake was undertaken in 1906. There have never been fish surveys or hydro-biological studies of Bolivia's rivers. Fish harvests in 1976 were only 2,300 metric tons (Boero Rojo, 1976), which may explain in part the lack of official attention to the fish resource.

Fish ecology in Lake Titicaca has been drastically altered by the introduction of the carnivorous lake trout many years ago, but the quantitative impact will never be known due to lack of information on the lake's fish stocks. However, the numbers of formerly dominant herbivorous *Orestias* spp. have declined due to trout predation. Being larger and more ferocious than native fish, the trout exceeded the strength of traditional fishing gear, and only recently have appropriately scaled nets been put in use. Recently trout populations have declined also. Although the reasons have not been scientifically established, some of the causative factors are unusually low water level for several years,

over-cutting of reeds (tortora), and the use of dynamite for fishing.

Lake Titicaca's hydrobiology and fishes are now being studied through two cooperative programs. Since 1974, OSTROM, the French overseas scientific research arm, has been providing technical support for studies of fishes, biology, sedimentology and geochemistry. Secondly, in 1979, Peru and Bolivia began a joint biological survey of the lake, with support from SELA, Sistema Economico Latinoamericano (funneled through the Corporacion Andina de Fomento). The Bolivian counterpart agency for these efforts is the Instituto de Geodinamica y Limnologia, of the Universidad Mayor de San Andres (La Paz). That institute has surveyed the bathymetry, bottom sediments and water chemistry of Titicaca and Poopo Lakes. In Titicaca's Lago Menor studies of fish stocks, stomach contents and primary and secondary production have been undertaken.

Bolivia's stream fishes and rivers are still to be studied. Important fishes encountered in both the Amazon and Plate River basins are raya (*Potamotrygon* spp.), surubi (*Pseudoplatystoma* spp.), dorado (*Salminus* spp.) and sabalo (*Prohiladus* spp.) (Terrazas, 1976). The Bolivian stretches of the tributaries of these two river systems are of great importance to species that migrate up-river to spawn, such as dorado, surubi, and pacu (*Myleus*). This function may be especially important for fishes of the Plate River Basin, since in other tributaries, especially the Parana River, migrations and spawning habitats have been totally disrupted by dams, and migrating species are disappearing.

Work with rainbow trout is going on, however. Near Coroico a well-equipped hatchery is producing trout. The imminent planting of trout in streams should be reviewed closely, however, to determine the potential impact on native stream species. Mature rainbow trout (over 15") eat only other fish. The hatchery may be an ill-advised and premature development. Enthusiasm for trout has been fueled by the good growth achieved, even in small lakes higher in elevation than Titicaca, and the attraction of this game fish for sports anglers.

Like terrestrial wildlife, Bolivia's fishes are virtually unmanaged. Fishing by dynamite is common. In the Pilcomayo River, fishing during spawning runs of dorado is a yearly event. Small streams are channeled to better trap the fish, which are literally caught by hand and flung to the bank as fast as people can work. If not monitored and managed accordingly, migrating fish in these rivers could decline over time.

A Department of Fisheries (Pesca) has recently been established in CDF. With the help of two foreign technicians, work has begun on a survey and identification of fishes of Bolivia. FAO may undertake a study of the fishery sector.

Parks and Equivalent Reserves

Government management of wildlands is achieved by two means: through the national forest system — discussed in the next chapter — and through the national system of parks and equivalent preserves, discussed here. Both systems are administered by the Centro de Desarollo Forestal. In the future, Departments may also become active in setting up and managing parks.

The first national park, Tuni Condoriri National Park, was established in 1942.

Bolivia now has nine national parks, four national wildlife reserves, one national wildlife refuge, and one national wildlife sanctuary. These are each described later. The legal basis for the system is the 1975 decree 12301, Ley de Vida Silvestre, Parques Nacionales, Caza y Pesca, promulgated in one year after the National Forest Law was decreed.

National parks and *wildlife reserves* are intended for the protection, preservation, management, and continuous production of wildlife (Table 2-3). Only native people can dwell in national parks, while some settlement of non-natives is possible in wildlife reserves.

Wildlife refuges are to protect, conserve, and propagate wildlife, principally those identified as endangered species. Neither habitation nor harvest of wildlife are permitted.

Wildlife sanctuaries are to protect rare or endemic species or special concentrations of wildlife that could be a tourist or recreational attraction.

Basically, national parks, refuges, and sanctuaries constitute natural areas without significant alteration or habitation by man. National reserves, on the other hand, will allow for human settlement but will protect wildlife and its habitat. In the reserves, new settlement will be discouraged as will other new non-compatible land uses.

Regulations for the 1975 law have been drafted but not approved. During 1979, they were being rewritten.

The most recent and complete study of Bolivia's parks was conducted in 1978 with support from the International Union for the Conservation of Nature (Grimwood and Whitmore, 1978). In 1970, UNESCO sponsored a study (Jungius and Pujos, 1970), and in 1969 Percy Baptista, now with CORDEPAZ, reviewed the parks. This study was not available for review, however.

Parks and equivalent reserves have been located and designated in a somewhat incoherent if not haphazard fashion. There has as yet been no national-level evaluation of wildlife and wildlands preservation requirements. Such a systematic review is needed to guide management policies and actions of the present system as well as to determine additional needs or modifications.

Table 2-3. National Parks and Wildlife Conservation Areas*

	Year Established	Department	Area (ha)	Distinction
National Parks				
1. Tuni-Condoriri	1942	La Paz	No boundaries	World's highest ski slopes.
2 Sajama	1945	Oraro	No boundaries ?	Once had the world's highest forest; now cut down.
3. Las Banancas	1966	Tarija	347	Control erosion.
4. Bella Vista	1946	La Paz	90,000	Scenic views of Yungas; orchids
5. Cerro de Comanche	1963	La Paz	50	Rare bromeliad *Puya raimondi*
6. Tunari	1962	Cochabamba	?	Watershed conservation
7. Mallasa	1936	La Paz	74	Urban recreation for La Paz
8. Isiboro-Secure	1965	Cochabamba	7.2 million	Pleistocene refuge; endangered caimans; Indians
9. Huanchaca	1979	Santa Cruz	541,200	Brazilian shield land forms; completely wild.
National Wildlife Reserves				
10. Cerro de Tapilla	1940	Potosi	?	Chinchilla protection originally; none remains
11. Lakes of Beni & Pando	1961	Beni/Pando	?	Control crocodile hunting
12. Manuripi-Pando	1975	Pando	1.54 million	Hylea forest; many endangered species
13. German Busch	1973	Santa Cruz	200,000	Endangered fauna
14. Ulla Ulla	1971	La Paz	240,000	1000+ vicuna
National Wildlife Santuaries				
15. Laguna Colorado (to become reserve)	1973	Potosi	300,000	Flamingos, vicuna
National Wildlife Refuge				
16. Huancaroma	1975	La Paz	?	Vicuna (180 in captivity)

*See Map National Forests, Parks, and Equivalent Reserves, Chapter 3, for locations.

National Parks

Tuni Condoriri

This high park is located in the Cordillera Real and ranges in elevation from 4,614 meters to 6,200 meters. Not far from La Paz, established in 1942, it is noted primarily for its ski slopes (the world's highest), a geophysics laboratory, and Lake Mullunc, reported to be stocked with trout.

The boundaries of the park have not been established. There is no management, but the popular Chacaltaya ski resort provides accommodations for tourists. Also, the Club Andino maintains a small refuge at 5,180 meters near Chacaltaya Glacier from which hikers on day excursions from La Paz begin their ascent to the summit, only 300 meters higher.

Sajama

Established in 1939, this park once contained a forest of quenua (*Polylepis tarapacana*) said to be the highest forest in the world (and giving credence to the probability that much of the Altiplano was forested before settlement by man). The park ranges from 3,850 meters at the base of Sajama volcano to its summit. It is the highest peak in Bolivia at 6,780 meters.

Outstanding wildlife includes the Andean condors, vicuna, Darwin's ostrich (nandu), and previously the chinchilla. On an overflight of Sajama made during the study period to verify the existence of the *Polylepis* forest, no trees were seen.

Dr. Erika Geiger reports having seen Polylepis on Mt. Sajama at 5,000 meters, however. It is known that by 1946 most of the forest had been cut to make

charcoal and only a few individuals remained. Simultaneously poachers exterminated the populations of tree, or long tailed, chinchilla *(Chinchilla laniger)*. The destruction of these unique trees illustrates the irretrievable loss of a genetic stock whose potential value is measured by the urgent need to reforest portions of the Altiplano, and the lack of success in growing pines and eucalyptus above 4,000 meters.

There is no management of the park and no information about its vicuna population. However, the entire Sajama District of Oruro Department is slated for assistance in cameloid production following a resources survey. This recently initiated CORDEOR project would start on a pilot project basis to improve llama and alpaca production and wool processing including weaving, and eventually work with the wild vicunas and guanacos (which resist domestication, but thrive in this environment).

INFOL, The Instituto Nacional de Fomento Lanero, is also interested in managing vicuna populations in cooperation with CORDEOR, and using the Sajama park for range. INFOL is presently guarding over 160 vicunas near Charana.

The introduction of chinchilla to the park should be considered. Past experience shows, however, that without protection, neither animals nor trees are likely to be conserved in this remote area.

Las Barrancas

This small park of 347 hectares was declared in 1966 and is located near Tarija. It was established for the purposes of controlling erosion as well as protecting wildlife, but Grimwood and Whitmore reported in 1978 that the park is very degraded.

The national significance of this park is not clear nor do its objectives and its extent appear to be compatible with the definition of a national park.

Bella Vista

This park was declared in 1946, and covers approximately 90,000 hectares of the Nor Yungas Province of La Paz Department, near Caranavi. Its boundaries have not yet been established, nor was the area reviewed in the UNESCO or IUCN studies.

The mapped boundaries show that it embraces portions of the Subtropical Lower Montane Wet Forest, the Subtropical Wet Forest, and the Subtropical Moist Forest. It appears that part of the park is being settled.

Cerro de Comanche

This rocky 50-hectare park was established 60 km southwest of La Paz in 1963 in order to preserve the *Puya raimondi*, a large, very rare bromeliad unique to this site, apparently. This spectacular plant was being cut down for firewood and threatened with extinction.

The park is not managed, however. Animals graze it and in 1966 a fire swept through the area. Adult plants were fortunately not killed.

Tunari

The Tunari National Park, decreed in 1962, is located on the mountains that overlook Cochabamba. These slopes comprise the upper catchment of tributaries that feed the Rocha River of the Cochabamba Valley, whose torrents cause increasing damage as the flood plain develops. The primary function of the park is watershed protection and management through reforestation with eucalypts and pines as well as conservation of native trees. The park does not possess the attributes of a national park, rather it is in reality a regional or urban periphery park that serves the important function of protecting critical watershed as well as providing recreational facilities (potentially) of easy access to urban dwellers.

The park is managed out of Cochabamba by a trained forester, Ing. Candido Pastor, in collaboration with the Municipality of Cochabamba.

Mallasa

Situated in the fantastically eroded Valley of the Moon area in the environs of La Paz, this 74-hectare national park serves as a recreational area for La Paz. It has 20-year old eucalyptus trees planted throughout. The trees nevertheless have not arrested headward gully erosion that is so extraordinary in this region of easily eroded clays (Arcilla La Paz formation). Attempts have been made to fill gully heads with solid waste from La Paz. Visitation to the park is increasing, according to Ing. Rene Prieto, and active management is needed to preserve the area's amenities.

Isiboro-Secure

The large size (1.1 million hectares), location, and characteristics of this park combine to make it one of the most important national parks and one with very difficult management problems. It was created in 1965. The park contains several endangered species, especially crocodilians, it is the home of several Indian tribes (Yuracares, Trinitarios and Chimanes), it is adjacent to a zone of active colonization in the Yungas, based largely on coca production and spurred by illegal trade for the cocaine market, and it spans the disputed boundary between the departments of Beni and Cochabamba.

Although the park has a resident manager, Sr. Hans Hofiman, the park's great extent is far beyound the capacity of a single person. Sr. Hoffman has had to convert his residence in Villa Tunari into park headquarters. He has no employees, no vehicle, and virtually no support or authority.

The park was created in 1965, following a recommendation by FAO expert, Ian Hutchinson, that a park was needed to protect the watersheds of the rivers which rise in the Sierra de Mosetenes. More importantly, however, it embraces a forested area which survived during the Pleistocene era when most of the Amazon became savanna. These islands of forests, termed Pleistocene refuges, subsequently became centers of diffusion for natural regeneration of the Amazonian forests. They are further remarkable for having evolved endemic species during the Pleistocene because of their isolation.*

The park is bounded by the Isiboro and Secure Rivers and the watershed divide of the Mosetenes and Sejeruma mountains and ranges in elevation from 4,000 meters to 300 meters. However, only a small area exceeds 2,500 meters.

Eight Life Zones are represented in the park, according to Unzueta (1975). (See Figure 3-1.)

- Subtropical Sub-alpine Rain Forest
- Subtropical Montane Rain Forest
- Subtropical Lower Montane Rain Forest
- Subtropical Rain Forest
- Subtropical Moist Forest
- Tropical Moist Forest Transition
- Tropical Wet Forest Transition.

Only small areas contain the higher elevation Subalpine and Montane life zones, however.

Wildlife in the park includes the endangered black caiman (*Melanosuchus niger*) occurring in the lakes of the northeast section, and the broad-nosed caiman or choco (*Caiman latirostris*). The black caiman is under heavy hunting pressure, as is the choco. In 1973, Federico Medem, world crocodile expert from Colombia, recommended a moratorium on crocodile hunting (Medem, 1973). However, hunting has continued, both legally and illegally. Ironically, protection and hunting control of the prized black caiman has been passed to the Bolivian Tannery Association (ASICUSA) in a 40,000-hectare area of the park, where they are reported to have posted 15 guards. This use of the park is contrary to the legal definition of park functions, but can be viewed as a pragmatic solution to poaching which enlists the recognition by skin traders that this precious resource could be exterminated but if managed is renewable.

In addition to illegal hunting, the integrity of the Isiboro-Secure National Park is threatened by illegal land settlement and the possible construction of a road from Puerto Patino on its south boundary, to the north. Seventy families recently entered the park and have begun farming. The Consejo de Coordinacion Interinstitucional del Chapare lodged a complaint in July, 1979 with the Minister of Agriculture and has suggested alternative remedies; however, as of October 1979, there had been no response. The director of the Programa de Desarrollo del Chapare, Dr. Winston Estremadoiro, is prepared to coordinate the relocation of the illegal settlers, as well as support a park guardian for several years until adequate protection is provided by CDF.

The road that threatens the park appears to be related to the idea of the Carretera Marginal de la Selva, that would border the Andean footslopes of the Amazon Basin. If built, the road would divide the park, and attract settlers, poachers, and timber cutters. Management and control would be virtually impossible, if the present difficulties are any indication. All of the park's objectives would be compromised by such a road. Forest destruction would be doubly disastrous, furthermore, due to the high rainfall and the erosivity of the soils (Cochrane, 1973) which will greatly limit agriculture and result in destructive torrents and flooding downstream.

Fortified management of the Isiboro-Secure park is urgent, since development is proceeding in the adjacent Chapare District to the south, where the OAS and AID are assisting to develop plans and projects for consolidating spontaneous land settlement and finding crops and crop systems adapted to this humid environment. The park could also serve to halt the northward march of land clearing by small growers of coca.

Huanchaca

The Huanchaca National Park was declared in 1979 with Decreto Supremo 16646. This is a potentially very interesting and valuable area because of its pre-Cambrian geologic history. It is part of the Brazilian shield and should have a high percentage of endemic species because of its age and isolation. The life zones include Subtropical Wet Forest and Subtropical Lower Montane Wet Forest. This 541,200 hectare park derives its name from the Serrania de Huanchaca

*Pleistocene refugia in the Amazon basin have been broadly delineated by Wetterberg (1976), and related to seven phytogeographic regions. The Isiboro-Secure National Park falls within the Yungas region and covers a portion of the Pleistocene refuge of this region. The refuge centers in the Serrania de Eva-Eva east of the San Miguel de Huachi, and embraces a portion of Chimanes Forest Reserve as well as the park.

located in Santa Cruz Department, on the border with Brazil. (Its mapped area only covers 380,000 hectares). According to Zefrain Fernandez, of GEOBOL, the area has no inhabitants and is especially scenic because of its high cliffs. Soils are generally poor in the area (Cochrane, 1973).

This new park has the resources to become one of Bolivia's outstanding natural areas. Planning surveys should seek collaboration with Brazilians. Brazil is reported to have established a continuous park on its side of the boundary. A Brazilian who has studied the park is Dr. Paulo Gunter Windisch, Universidade Estatal de Sao Paulo, Instituto de Biosciencias, Caixa Postal 178, 13500 Rio Claro, San Paulo, Brazil. Professor Miramy Macedo, Universidade Estatal de Mato Grosso, Cuiaba, could also be contacted. She is knowledgeable about the phytogeography of this general region.

National Wildlife Reserves

Four wildlife reserves have been established in order to protect outstanding or endangered wildlife.

Cerro de Tapilla

This reserve southwest of Potosi was declared in 1940 so as to protect the chinchilla. Although it appears in CDF's official list of National Parks and Equivalent Reserves, no information could be obtained on its status and characteristics. Neither IUCN or UNESCO study mentions it. Since the chinchilla is reported to be extinct in Bolivia, it appears to have failed in its mission.

The Lakes of Beni and Pando

Decreed in 1961, these lakes were declared reserves in order to legalize the hunting of crocodiles during August - November in these lakes. The reserve is not mentioned in the IUCN or UNESCO surveys.

Manuripi-Pando

Established by decree in 1975, this large reserve is the only one which protects wildlife in the true Amazonian forest (hylea) habitat. Its mapped area suggests a coverage of 1.54 million hectares (Fig. 3-3). The area contains some of Bolivia's most notable animals, especially primates: the endangered Goeldi's monkey, the pygmy marmoset, the red-bellied tamarin, and the emperor tamarin.

With assistance from the World Food Program, penetration roads are being constructed at several points into this wildlife reserve. Clearing and farming as well as game hunting will be encouraged as a result. The status and management needs of this reserve need to be determined soon. Critical habitats need definition.

German Busch

This small reserve located in the Serrania de Amboro near Santa Cruz was established by decree in 1973. Land settlement is taking place all around it (personal communication: Dr. Leslie Brownrigg). Grinwood and Whitmore (1978) report it to be partially degraded but still containing areas worthy of protection. Noel Kempf (personal communication) places the reserve area at about 200,000 hectares, and its elevation from 1,200 to 250 meters. According to Unzueta et al (1975), the region corresponds to Subtropical Wet Forest and Lower Montane Subtropical Wet Forest life zones. It is an area that will have to be investigated.

Ulla Ulla

The 240,000 hectare Ulla Ulla National Reserve for Andean Fauna was established in 1971 in order to ensure the return from near extinction of Bolivia's vicuna population. This wild relative of the native llama and alpacas resists domestication. The great demand for its exquisite wool, considered the finest in the world, had resulted in hunting pressures in Bolivia (as well as Peru, Argentina and Chile) that threatened extinction. Numbering only 97 in 1965, the herd has now increased to 1,139 representing over half the estimated 2,000 that now exist in Bolivia. Even larger herds have been attained in neighboring Peru.

The reserve is located 60 km north of Lake Titicaca between 3,800 and 6,000 meters above sea level. Life zones represented are sub-alpine wet forest (now grazing land), subtropical rain tundra, and perpetual snow (glacier). Nine glacial lakes set at the base of the magnificent Cordillera Apolobamba harbor a great variety of birdlife. Hot springs in the park area are frequented by local inhabitants for their health-giving properties.

Management of this reserve presents a number of complex issues, most important being the competition between the protected vicuna and herds of alpaca and llama. Three thousand families in the reserve graze approximately 150,000 llamas and alpacas on approximately 80,000 hectares of range also grazed by the vicuna. Overgrazing is a serious problem, and INFOL believes this has led to poor nutrition and a consequent

50 to 80% mortality in alpacas less than 1 year old. Under these same conditions the vicuna population has been growing 20% annually. The Ulla Ulla reserve is managed by the Instituto de Fomento Lanero, which has posted full time employees at the reserve site.

The area is now the target of an ambitious integrated rural development effort being funded by IBRD ($9.0 million loan) and IDA ($9.0 million concessionary loan), as well as the Inter-American Development Bank ($24 million in 1977). This project would integrate the production and marketing of wool from local cameloids, and improve rural welfare by means of road construction, educational and health facilities, and solar technology. Critical comments were voiced about this project, but could not be verified.

In October, 1979, the team observed several buildings and roads under construction, new corrals and research on cut forage for corral feeding. This project could possibly parallel a new rural development focus in Peru, based largely on vicuna wool, and now possible because of the successful build-up of vicuna herds. However, there were no plans for vicuna utilization in Bolivia at the time of the present study.

National Wildlife Sanctuaries

There is only one sanctuary, namely the Laguna Colorada National Wildlife Sanctuary, established in 1973, in the Potosi Department. It will shortly become a wildlife reserve, however. The sanctuary's objectives are to preserve rare Andean species such as the three species of flamingos (Jame's, Andean, and Chilean flamingos), guanaco, vicuna, nandu, and migratory species.

In September, 1979, an inter-institutional survey team visited the site to collect data and set limits. This team had representatives from INFOL, MACA, INC, CORDEPO, Ministerio de Planeamiento, Coordinacion Economica, Fuerzas Armadas and the Ministerio de Minas e Hidrocarburos (personal communication: Oscar Mendez, Jefe de Parques Nacionales for CDF). The sanctuary has been reclassified as a wildlife reserve under the name "Reserva Andina Eduardo Abaroa." It will probably occupy an area of about 300,000 hectares. It is presently inhabited by approximately 1,000 people involved in llama grazing or small-scale mining of sulfur, borax, or tungsten.

Most of Bolivia's vicuna population is near the Peruvian border in Ulla Ulla. The Laguna Colorada area is thought to be prime habitat for vicuna and is isolated from Peru's border where it is speculated Bolivia will lose many vicuna in the next year to either illegal hunting or vicunas voluntarily crossing into Peru at Ulla Ulla across the Rio Suches. The area was also prime habitat for chinchilla, which hopefully can be reintroduced once vigilance is acheived.

National Wildlife Refuges

There is only one wildlife refuge in the country, the Huancaroma Wildlife Refuge, declared in 1975. This is part of a private ranch of 11,000 hectares, where the principal business is dairy cattle and sheep. In 1970 there were about 70 vicunas; in 1979 there are 181 vicunas (Cardozo and Lopez, 1979).

This herd is contained in a large, perhaps 20 hectare, fenced area of irrigated alfalfa. It is basically a herd of "orphan" vicunas. The owner has been purchasing, for 15 pesos each, newly born vicunas captured in the wild by local people, who would otherwise kill them and sell their skins for about 7 pesos. A local woman nurses the young with cow's milk until they are old enough to graze. The herd is somewhat difficult to manage since it is an unnatural social group. Male vicunas from the wild animals in the environs, reported to number about 300, seek to entice the females to jump the fence, which is about 2.5 meters high, and they succeed at times. Thus, this sanctuary is in essence a temporary one for the young who have been separated from their mothers. It represents an emergency solution for preventing the demise of the local population.

Although this may be classed as a national refuge, it is financed completely by the owner.

Proposed Parks and Reserves

Presently three additional areas are being considered: Pilon Lajas National Park, Caquiahuaca Regional Park (La Paz Department) and the Laguna Rogaguado Marsh Deer Reserve.

Pilon Lajas National Park

This proposed park has been under study since 1976 (Schuerholz, 1977). It appears to cover the Rio Quiquibey valley and watershed. Its delineation on the map (Fig. 3-3) is approximate. It would cover approximately 280,000 hectares. Chimanes Indians live in the region.

The park is considered to be a contingency for the possible clearing and settlement of Isiboro-Secure Park. The Instituto Nacional de Colonizacion and CDF have agreed not to plan activities for the proposed park area until a decision has been made on its establishment.

Many people interviewed considered this to be a high priority park.

A dam which has been proposed on the Beni River, upstream from Rurrenabeque would inundate most of the Pilon Lajas park area. It was not learned whether or not this project is moving ahead.

Caquiahuaca Regional Park

CORDEPAZ is proposing this 250,000 hectare park in the Tuichi River basin northwest of Rurrenabeque. The park was studied by World Wildlife Fund scientist Schuerholz in 1977. Protection of the proposed area is needed to safeguard agricultural development in the San Buenaventura area, in the lower reaches of Tuichi River.

Laguna Rogaguado Marsh Deer Reserve

The proposed area in north central Beni Department was surveyed in 1977 to determine its suitability for protecting the endangered Marsh Deer (*Blastocerus dichotomus*) as well as other species in the area (Schuerholz, 1977a). It is thought to be the only remaining habitat in Bolivia for this deer, which is endangered throughout South America.

No action had been taken at the time of the team's survey. Hunters and ranchers are known to be pressuring the deer as well as its habitat.

Evaluation

Wildlife Protection and Conservation

The Altiplano wildlife, notable for the endangered vicuna, the extinct chinchilla, and remarkable bird life presents an entirely different management problem from the wildlife and wildlands in the forested Yungas and Oriente.

Altiplano wildlife must co-exist with man and domesticated stock, and in a greatly altered environment, heavily grazed and almost totally deforested. Only the adaptation of the vicuna to high altitude range conditions, not tolerated by sheep or cattle, has permitted its survival through the centuries. Protection and conservation measures must take into account, nevertheless, the needs of rural Indian inhabitants of the Altiplano. Since the carrying capacity of the Altiplano for people and stock has probably been reached (under present production and management systems), development must rely on better utilization of resources. The vicuna offers an alternative, not competition, and its conservation has an economic base.

The forested Yungas, and the jungles and savannas of the Oriente, on the other hand, are perceived as the frontier which will absorb population growth in the future. In this case, forests and wildlife must give way to agriculture and cattle raising. Thus the objective of conserving wildlife and wildlife habitat and the objective of populating and developing the Oriente appear to be in direct conflict. This view of development, however, does not hold wildlife as a renewable resource that could contribute to development. Present exploitation is lucrative but done by few people, many of whom are foreigners. Wildlife could play a great role in the economic life of the Oriente. If all trade and harvest were tabulated it might well be shown to be the case at present.

In 1978 Grimwood and Whitmore concluded that the worst abuses of the past in the export trade of wild animals and their products had been stopped, through Bolivia's observance of CITES and the illegality of exporting skins of spotted cats and other endangered species. Yet, inexplicably, the skin of the endangered black caiman is still authorized for export. Also illegal trade continues at a high volume. The threat and disturbances to animal habitats also have increased, not diminished, and the lack of management in wildlife reserves and parks is not reassuring.

There is at present a total lack of fisheries management, which should be remedied, particularly in regard to the migratory species that spawn in the smaller tributaries of the Amazon and Plate River systems.

Parks and Equivalent Reserves

The majority of these exist on paper only. This must be viewed as an accomplishment, in that it is the essential first step; however, in some cases as many as 25 years have elapsed and the subsequent steps, namely park planning, management and protection, have yet to be taken.

Overall institutional strengthening is needed. There is practically no planning capability, nor is there a professional cadre of park rangers or managers.

The park and reserve system contains areas that are individually justified and interesting, but taken together are a somewhat random collection of habitats, which do not represent the entire range encountered in Bolivia. For instance, the Chaco region and the Podocarp forests in Tariquia are not represented, nor are the savanna habitats of Beni embraced in the system.

A comparison of the existing network with the generalized World Biogeographic Provinces classification proposed by IUCN (Udvardy, 1975) or the more detailed Life Zone system, used in the Mapa Ecologico de Bolivia, reveals these discrepancies immediately, particularly the lack of representation of flora and fauna in southeastern Bolivia.

Park management is virtually non-existent, outside of Ulla Ulla, managed by Javier Lopez of INFOL, and Isiboro-Secure, managed by Hans Hoffman. At Tunari National Park, Ing. Candido Pastor has been assigned by CDF to manage the forest plantation activity.

Where parks clash with development aims, strong management is needed. In the Oriente and the Yungas, in particular, there is an urgent need to review the relationship of the parks to land clearing and road construction.

International assistance in the form of training, technical assistance, and perhaps funds could help make Bolivia's park and wildlife conservation system more viable. Such assistance must be matched, however, by clear policy decisions, that resolve inconsistencies or conflicts in development goals and provide political as well as budgetary backing to a strengthened park agency. Initially the role of parks and wildlife conservation within the framework of national as well as regional economic and social development must be examined. This could be accomplished by means of a survey terminating with a national level conference. Such an exercise would provide a point of departure or better definition for a series of activities.

Foreign Assistance and Cooperation

FAO is the principal international agency providing technical assistance in parks and wildlife management. No long term assistance has been provided to Bolivia, however, nor is any planned.

Surveys of Bolivia's parks and wildlife have been sponsored by IUCN (Grimwood and Whitmore, 1978), UNESCO (Jungius and Pujol, 1970), and the World Wildlife Fund (Schuerholz, 1977a). A UNDP sponsored survey of conservation priorities in the Amazon Basin, undertaken from Brasilia, included the Bolivian portion of the Amazon basin (Wetterberg, 1976). The IUCN and the World Wildlife Fund have informal collaborative relationships with the government developed by Gaston Bejarano during his tenure in the Departamento de Vida Silvestre, in MACA.

In Bolivia, the Man and the Biosphere Program is represented by Sr. Gaston Bejarano and Dr. Carlos Aguirre, both of the Ministerio de Planificacion y Coordinacion Economica. Work under the aegis of MAB has not yet been undertaken, however. Ecological transects are being contemplated.

Japanese technical assistance is being provided in fish culture. The second year of a 2-year effort is underway. SELA, the Sistema Economico Latinoamericano, is sponsoring a 2-year study of Lake Titicaca. The Japanese Monkey Center is undertaking the first year of research on primates. Geographical and geobotanic studies are being carried out by two researchers of the Universities of Bonn and Munich, in a 5-year project.

The University of Goettingen has recently begun a 4-year, $3.0 million project to develop the Instituto de Ecologia. The program will support three permanent professors, three temporary professors, 10 years of scholarships to German universities, vehicles and laboratory equipment. The Instituto will be affiliated with the 5-year-old Department of Biology at the Universidad Mayor de San Carlos, La Paz. The University is providing a $1.0 million new building for the Institute, salaries of Bolivian counterpart professors/researchers, and about $40,000 per year in materials.

Now in its first year, the Instituto de Ecologia has 15 students and has begun research in the Altiplano. Permanent research areas will be set up. An herbarium is being developed also. Dr. Cecilia Morales, a biologist, is the elected head of the Instituto; Dr. Erika Geiger, an ecologist, is her German counterpart from the University of Goettingen.

Recommendations

Institutional and Professional Development

Protection of endangered species

Better enforcement of the 1973 Convention on International Trade in Endangered Species is urgently needed throughout the region. Because the international frontier between Brazil, Bolivia, and Paraguay is so difficult to monitor, more strategic alternatives must be considered. The nations sharing the subtropical and tropical portions of the Plate River Basin must cooperate more effectively. A regional conference of the signatories of CITES, especially Bolivia, Brazil, and Paraguay, may be a productive and perhaps necessary step. AID, OAS, IUCN and UNEP could endorse and sponsor the conference.

Professional development

A trained cadre of park and wildlife administrators, planners, and managers must be created. Master's level and lower level educational opportunities should be developed. The forestry schools at Tarija and Cochabamba, as well as CORDEPAZ's proposed environmental education center at Tarila Regional Park could be employed for in-country courses and field experiences. Scholarships could be offered for advanced work in

wildlands and wildlife management. New graduates of the Tarija Forestry School would be obvious candidates. Graduates from the Universidad Mayor de San Carlos' degree program in Biology could also be candidates.

Policy and Program Development

National wildlands planning

A national strategy for the conservation and management of Bolivia's parks and equivalent preserves is needed. It must be based upon a national plan, which it is estimated would require 2 years to develop. Its preparation could serve, moreover, as an in-service training function for present staff. The planning effort would review the existing system of parks and reserves; evaluate it for representativeness, viability, and management needs; identify additional areas; and propose a long-term strategy for management, by national and/or regional authorities.

Two person-years of technical assistance is the estimated need.

Wildlife trade

One expert-month is suggested for the purposes of reviewing the present trade situation, illegal as well as legal, and making recommendations for improvements, modifications, better enforcement, etc.

Delineation of Indian homelands

Six person-months of expertise in ethnography or applied anthropology are recommended for the purpose of more accurately delineating the home territories of the various Indian groups. Criteria and recommendations for their tenure of park areas and national forests should be set forth in order to seek a humane and just treatment for these peoples.

Evaluation of development in relation to wildlands

Within and around parks, the needs of people must be reviewed in order to harmonize their requirements with those of wildlands management and conservation. Possibilities for ecologically and culturally adapted development projects which fortify rather than compete with conservation objectives should be sought, possibly through a combination of appropriate technologies and ecologically sound resource management, also known as eco-development (Miller, 1978).

Project Possibilities or Needs

Squatters in the Isiboro-Secure National Park

A relocation project is needed to remove these squatters, who number about 70 families.

New national parks or reserves

Two possibilities are suggested: (1) a MAB reserve which links the Ulla Ulla National Wildlife Reserve with the Caquiahuaca Park (La Paz Department), and which would thereby provide a continuous transect from glacier-capped peaks to lowland jungle, and (2) a national park in the Tariquia area of virgin Podocarp forests. Correspondence has already begun between IUCN, WWF, FAO, the U.S. Park Service and Bolivian authorities concerning this second possibility.

Environmental education

Support should be considered at two sites: (1) the zoo in Santa Cruz, where assistance to develop an interpretive program for the attending public is recommended, and (2) the new (or proposed) Tarila regional park being developed by CORDEPAZ, which is intended to include a center for environmental education.

III. NATURAL FORESTS

Natural Forests

Introduction

This is an overview of the natural forests of Bolivia from the perspective of conservation and rational use of the natural forest resource base. The distribution and extent of ecological forest types are synoptically treated. Governmental responsibilities and activities involving forest resources are outlined, as are foreign assistance programs involving natural forests. The demands upon forest lands and resources, some of which contribute to loss of the forest resource base, are reviewed.

Major forest management problems addressed involve conflicts with agricultural settlements, poor utilization of forest resources, lack of policy for timber concessions, disinterest in sustained yield of timber, absence of a land-use capability classification, and low institutional capabilty. Land-use capability classification, forest lands management, and dendrological survey are recommended to AID as projects essential to the conservation and rational use of Bolivia's natural forests.

Generalized Forest Descriptions

Dominated by the majestic Andes and the high intermountain basin known as the "Altiplano," Bolivia is seldom thought of as a forested country. Although the Altiplano, high Andean peaks, and dry intermountain valleys are essentially treeless, 62% of Bolivia's area (1,098,581 square kilometers) is less than 600 meters above sea level and is forested. The extensive lowlands, known as the "Oriente," form a broad arc from the Peruvian border in the northwest to the Paraguayan-Argentine border in the southeast. Approximately half of the country lies within the Amazon drainage system and roughly one-fourth is part of the upper Plate River drainage system. (The Altiplano is a closed drainage system feeding Lakes Titicaca and Poopo and the salt flats of Uyuni and Coipasa.)

Bolivia's geographic location between 09° 38′ and 22° 53′S latitude results in tropical, subtropical, and warm temperate climatic regimes (Figure 3-1). The "Cordillera Real," or eastern chain of the Andes, which attains a maximum width of 650 km in Bolivia, superimposes considerable heterogeneity upon the subtropical and warm temperate latitudinal regions. The ecological consequences of the physiographic and climatic heterogeneity are illustrated in the ecological map of Bolivia (Tosi et al., 1975).

Forests by Life Zone

The Life Zone system of ecological classification devised by Holdridge (Holdridge, 1947) has been used to prepare the 1:1,000,000 scale reconnaissance Mapa Ecologico de Bolivia. The descriptions given here are extracted from the map (Tosi et al, 1975) and the accompanying monograph (Unzueta, 1975), as well as from field observations and overflights made in September 1979. Figure 3-1 illustrates the Life Zone classification system and its terminology.*

A comparison of the number (48) of Life Zones found in Bolivia with the number (13) found in the United States east of the Mississippi River reveals the great range of ecological conditions in Bolivia and the corresponding variety in natural forests. Twenty-one of Bolivia's Life Zones sustain forests. These span the Tropical Life Zone forests of the Amazon, the slightly less torrid Subtropical forests between latitudes 12° and 16°S, and the cooler Warm Temperate forests of the Chaco region between 16°S latitude and the southern border of Bolivia (Figure 3-2).

Tropical Latitude Forests

The tropical region is restricted to the northernmost part of the country in Pando Department. The Tropical Moist and Tropical Premontane Life Zones contain very well-developed, floristically diverse forests with large volumes of potentially commercial timber. The Pando forests are in excellent condition, with the only significant human influence occurring along the Cobija-Porvenir road. The two Tropical Life Zones—moist and wet—occur as long, narrow transitional belts

* The Life Zone system terminology sometimes confuses at first glance. Each Life Zone is identified by the type of natural vegetation that would occur in zonal climatic conditions on zonal soils. Present vegetation does not always correspond to the potential natural vegetation under zonal conditions however. The vegetation may have been removed, or azonal conditions may prevail, resulting in vegetative associations dominated by atmospheric, edaphic, or hydric conditions. Thus, the Subtropical Moist Forest Life Zone presents natural forest, savanna (edaphic association, influenced by burning), and farmland.

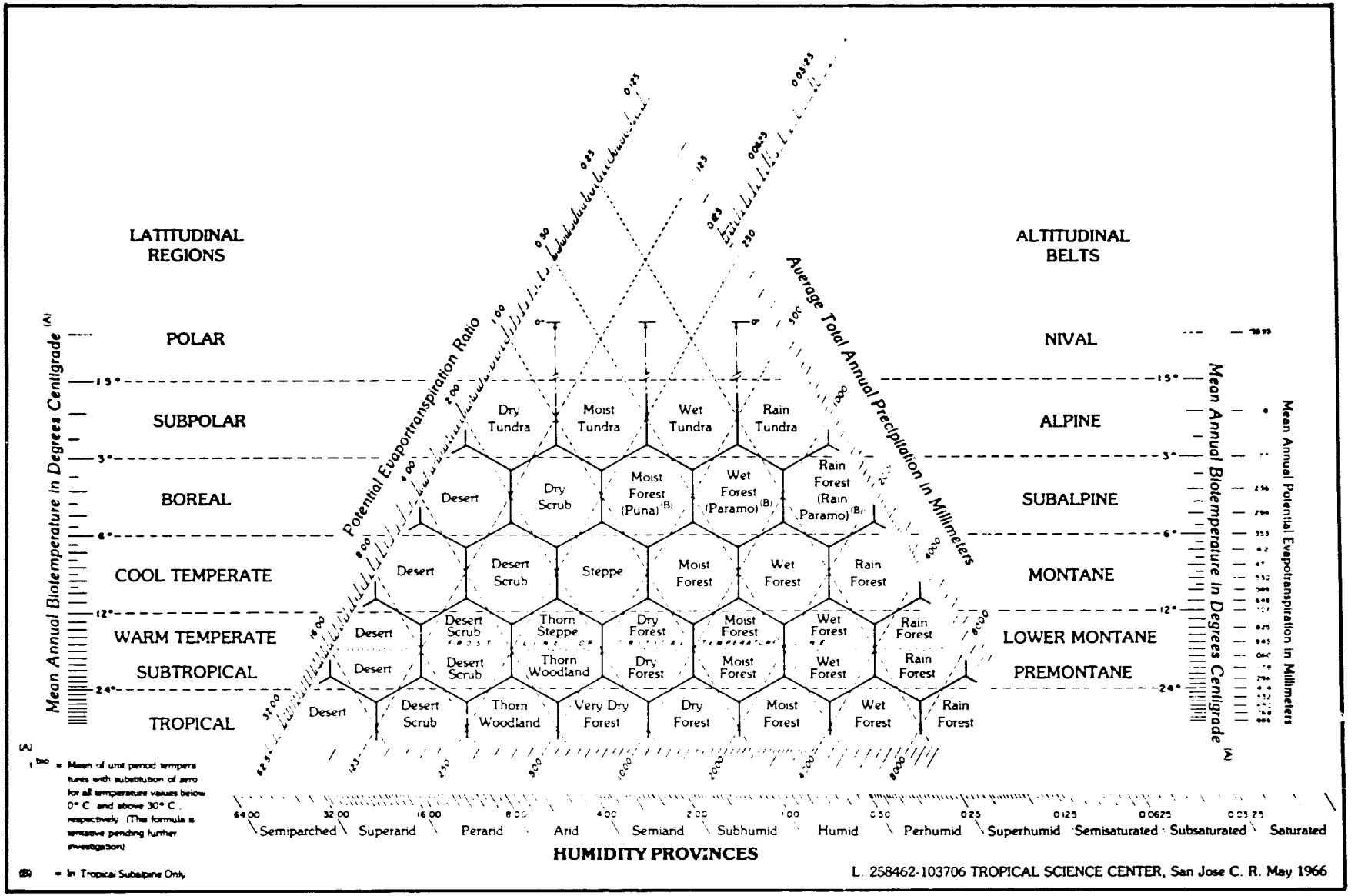


Figure 3-1. Diagram for the Classification of World Life Zones or Plant Formations by L. R. Holdridge

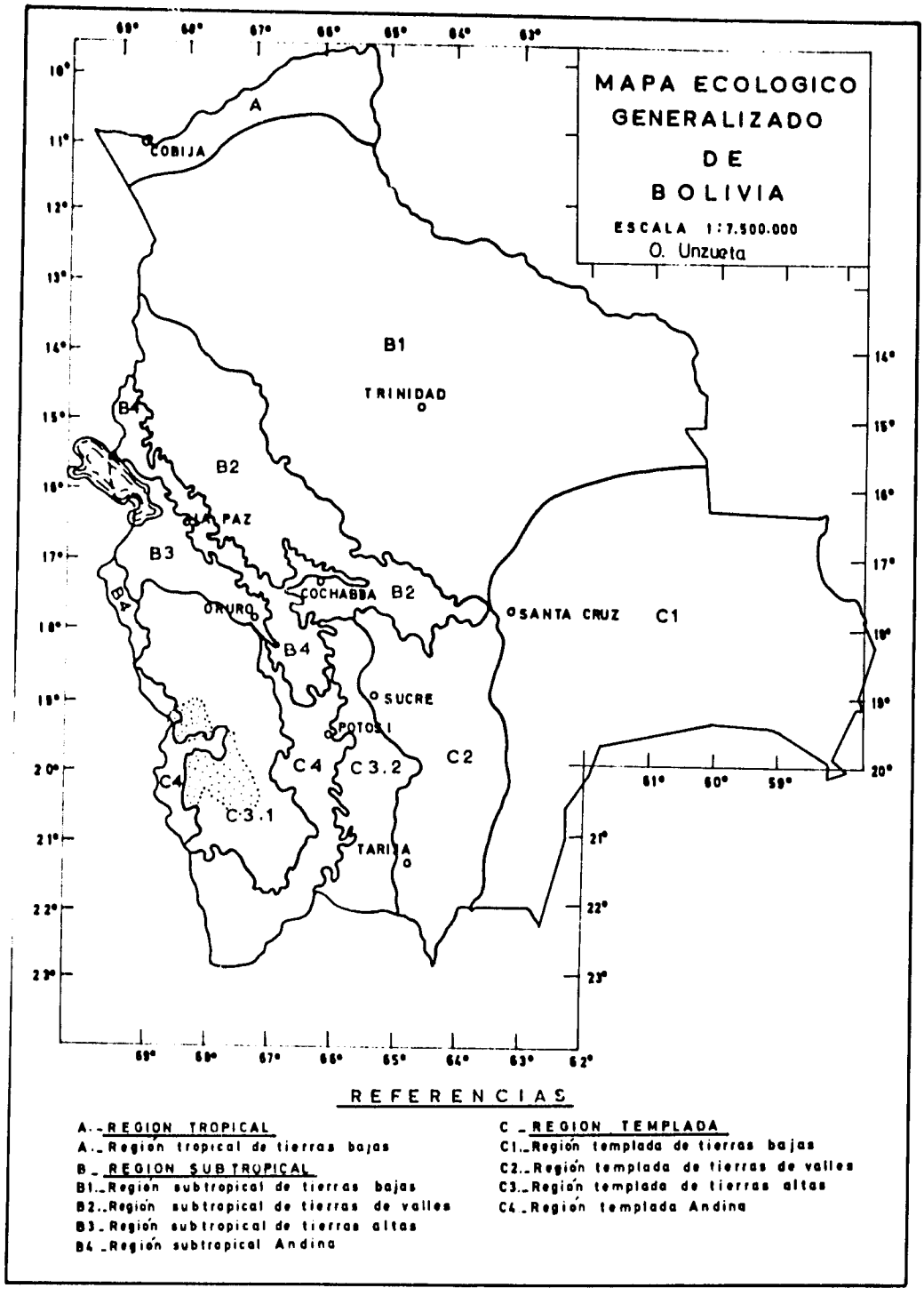


Figure 3-2. General Ecologic Map of Bolivia (Source: Unzueta, 1975)

extending to the Subtropical Life Zones along the low flank of the northern sub-Andean range.

Subtropical Latitude Forests

Practically the entire Beni Plain, stretching from Puerto Heath near the Peruvian border to the Serrania Huanchaca on the Brazilian border, is Subtropical Moist Life Zone. Even after deducting the 100,000 km² of savannas in central Beni Department and Iturralde Province of La Paz Department, this Life Zone still has the largest forested area (171,131 km², or 16% of the country). The Subtropical Moist Life Zone also is characteristic of valleys of the Beni River and its tributaries (e.g., the towns of Covendu, Guanay, Mapiri, Apolo, Chulumani, and Circuata). Compared with the tropical forests of Pando, the subtropical moist forests of La Paz, Beni, and Santa Cruz Departments are significantly lower in stature, less complex in structure, less diverse in species, and less voluminous in timber. The subtropical moist forests are characterized by an abundance of mahogany (*Swietenia macrophylla*), the exploitaton of which comprises the base of the timber industry in Santa Cruz.

The subtropical moist forests on the Beni Plain are under considerable pressure from savanna expansion due to cattle raising, conversion to agriculture, and timber operations. The Mapa Ecologico (Tosi et al, 1975) suggests most of this Life Zone to be altered by human activities. It is estimated that more than half of the tropical moist forests of the Beni Plain are ecologically disturbed.

In the valleys of the Beni River and its tributaries, the subtropical moist forests have been largely converted to agriculture, or are in the process of conversion.

Subtropical wet forests occur either as a narrow band along the northern front ranges or as a variable band above the moist valley floors. Except for the Caranavi Valley, the subtropical wet forests appear to have suffered little deforestation.

Subtropical Montane Wet and Rain Life Zones occur along the northern front ranges due to the combination of orographic lifting of warm air masses and decreasing temperature. These series of Perhumid and Superhumid Life Zones (Figure 3-1) occur in very dissected topography with minimal penetration of human activities; consequently, they are probably the least disturbed Life Zones in Bolivia.

Subtropical Lower Montane Dry and Moist Life Zones occur in deep, intermountain valleys of the eastern Cordillera, including the towns of Comarapa, Totora, Inquisiva, Tapacari, Arque, and Independencia. Because these Life Zones are among the most hospitable to humans, the valleys have cradled human settlement and agriculture and very little undisturbed vegetation remains.

Subtropical Montane Moist Life Zone is found in a few high valleys (e.g., the towns of Sacaca and Colquechaca). It is also the predominant Life Zone of the northern Altiplano, including the towns of Achacachi and Pucarani, and the Life Zone of the city of La Paz. The northern Altiplano is reputed to have once been forested (Manuel Posnansky, personal communication).

Warm Temperate Latitude Forests

Warm Temperate Dry Forest is the second most extensive Life Zone in Bolivia, stretching in a huge arc from Yacuiba to Puerto Suarez, and encompassing some of the valleys and plateaus of the southern Cordillera (e.g., Tarija, Sucre, San Pedro de Buena Vista, Valle Grande and Padilla). The forests are low in stature and generally open, but have an abundance of heavy, fine-quality timbers such as palo santo (*Bulnesia sarmienti*), cuchi (*Astronium fraxinifolium*), quebracho blanco (*Aspidosperma quebracho-blanco*), and quebracho colorado (*Schinopsis lorentzii*). Extensive pasturing of beef cattle is common and irrigation agriculture is expanding, but probably at least 75% of the Warm Temperate Dry Forest is still relatively undisturbed.

Warm Temperate Moist Forest, nearly as extensive as Warm Temperate Dry, is found along the southern sub-Andean range and in a vast unpopulated region east of the Dry Life Zone to the Brazilian border.

In comparison with Warm Temperate Dry Forests, the Warm Temperate Moist Forests are taller and more rich in species, but accommodate fewer of the fine-quality timbers. However, the sub-Andean forests do contain nogal (*Juglans boliviana*) of the walnut family. Except for areas around cities such as Santa Cruz, the Warm Temperate Moist Life Zone is relatively undisturbed.

Warm Temperate Wet Forests are found only in the hills of the sub-Andean range exposed to southern winds. These forests are well-developed, characteristically containing *Podocarpus* spp. and abundant epiphytes. Except for a large block of virgin forest at Tariquia south of Tarija, the *Podocarpus* forests of this Life Zone have been destroyed by man. The Podocarps of the virgin forest at Tariquia may be used for pulp, while other trees may be exploited for use in construction and furniture production. The Corporacion de Desarrollo de Tarija has been granted a concession for this area and is conducting feasibility studies for its exploitation with FAO assistance.

The Warm Temperate Montane Moist Life Zone extends over an extensive portion of the dissected southern Andes in Bolivia. Most of the ridges and upper slopes have for many years been used for annual crops; hence, little natural vegetation remains. Much less

extensive are the Warm Temperate Montane Wet and Rain Life Zones. However, due to excessive moisture and steep topography, only minor portions of these two Life Zones have been deforested.

In summary, four major groupings of natural forest remain in Bolivia:

- The Tropical Dry, Moist, and Premontane Moist Forests of Pando (37,680 km²), almost completely undisturbed by human encroachment.

- The vast Subtropical Moist Forests of the Beni Plain including the Tropical Moist-Cool Transition (187,031 km²). Although these forests are probably undergoing the most rapid rate of deforestation, it is impossible to estimate the total loss or the rate of loss.

- The Perhumid and Superhumid Life Zones of the subtropical region, covering flanks and valleys of the northern front ranges (Subtropical Wet, Tropical Wet-Cool Transition, Subtropical Rain, Subtropical Lower Montane Wet and Rain, Subtropical Montane Wet and Rain, totalling 88,460 km²). Although the Subtropical Wet and the Tropical Wet-Cool Transition Life Zones at the base of the front ranges are undergoing very active agricultural colonization, the remaining Life Zones within the front ranges are virtually undisturbed.

- The immense Warm Temperate Dry and Moist Life Zones, largely in the Santa Cruz Department (225,220 km²) which has a very high proportion of undisturbed forest.

Estimates of Total Area in Forest

The original forest cover, before human infiltration, is estimated to have been 598,321 km² (Table 3-1), or 54% of Bolivia. This estimate is based upon the surface covered by each Life Zone with forest potential (as measured by Unzueta (1975) from the Mapa Ecologico) less the area of natural (edaphic) savannas found in the Subtropical Moist Forest Life Zone in Beni, La Paz, and Santa Cruz departments, and mapped by GEOBOL with satellite imagery (Brockman, 1978, and Zerain et al., 1978).

An estimate of present forest cover can be derived from GEOBOL's Mapa de Cobertura y Uso Actual de la Tierra, prepared on the basis of satellite imagery. Total forest cover as mapped by satellite is 561,482 km² (Brockman, 1978), or 51% of Bolivia, 6% less than the originally forested area (Table 3-2).

However, the estimate of present forest cover taken from GEOBOL's satellite map of 561,482 km² is almost certainly on the high side. It shows 36,839 km² less cover than the estimate of original forests, which would mean that only about 12,000 km² of lowland primary forests have been cut down, once the 24,700 km² of original Altiplano forests are deducted.

Virtually all the low (10 to 15 meter) forests that once covered the Subtropical Montane Moist Life Zone of the northern Altiplano have been removed. This is presently one of the most densely populated life zones in Bolivia, although the satellite imagery shows much of the zone to be in natural pastures. (Small fields do

Table 3-1. Potential Forest Land of Bolivia. Base Data for Each Life Zone from Unzueta Modified with Data from Brockman (1978) to Exclude Natural Savannas

Life Zone	km²	Country Percentage
Tropical		
Dry	3,000	0.27
Moist	3,680	0.33
Moist, Cool Transition	15,900	1.45
Wet, Cool Transition	18,300	1.67
Premontane Moist	31,000	2.82
Tropical Total	71,880	6.54
Subtropical		
Dry	4,680	0.43
Moist	171,131	15.58
Wet	36,700	3.34
Rain	15,160	1.38
Lower Montane Dry	6,000	0.55
Lower Montane Moist	3,660	0.33
Lower Montane Wet	7,100	0.65
Montane Moist	24,700	2.25
Montane Wet	2,860	0.26
Montane Rain	4,270	0.39
Subtropical Total	280,331	25.25
Warm Temperature		
Dry	114,493	10.42
Moist	110,727	10.08
Wet	4,500	0.41
Montane Moist	12,700	1.16
Montane Wet and Rain	3,690	0.33
Warm Temperate Total	256,110	22.40
Total Forest	598,321	54.46
Total Non-forest	500,260	45.54
Total Bolivia	1,098,581	100.00%

not register in the satellite image.) Recently spontaneous settlements have encroached rapidly from Puerto Patino in the Yungas of Chapare Province, along a 10- to 30-km wide strip extending to the Yapacani River, in the Department of Santa Cruz. Satellite imagery fails to capture this development, or other small-scale settlements in the forested areas, so that the Mapa de Cobertura y Uso Actual de la Tierra underestimates the extent of deforestation in the humid lowlands. Moreover, the classification system employed in that map (see Table 3-2) is not compatible with that of the Mapa Ecologico.

A large area of lowland forests has also been disturbed as a consequence of selective logging. Satellite imagery interpretation does not allow the differentiation of selectively logged or degraded forest from virgin forest. The robustness of the Santa Cruz timber industry is evidence that a very large area of forest north and east of Santa Cruz must have been subjected to selective logging. Although no data exists to even give a rough idea of the areal extent of selective logging, it is likely that more than half of the subtropical moist forest on the Beni Plain has already undergone selective logging.

Finally, in the Altiplano, all forms of woody vegetation (including low bushes in the higher altitude Life Zones not tabulated in Table 3-1) have for many years been under cutting pressures for use in cooking and in smelting ore. In the Department of Oruro, the removal of low bushes may be decreed illegal due to substantial erosion.

Table 3-2. Areal Extent (km^2) of Forest Vegetation Types by Departments as Determined by Geobol's Interpretation of Recent Satellite Images (Brockman 1978). Due to Absence of Forests, the Departments of Oruro and Potosi Are Omitted from the Table.

	CODE	BENI	CBBA.	CHUQUIS.	LA PAZ	PANDO	STA. CRUZ	TARIJA	NATIONAL (%)
HIGHLAND (>3000m)									
Evergreen	211		1,280		1,340				2,620 (0.47)
INTERMEDIATE (3000-500 m)									
Evergreen	221	11,319	15,972		32,462		5,987		65,740 (11.71)
Evergreen and Semievergreen	221-222						511		511 (0.09)
Semievergreen	222			8,891			1,377	8,605	18,873 (3.36)
Semievergreen and Deciduous	222-223						486		486 (0.09)
Deciduous	223			5,378			12,713	6,980	25,071 (4.47)
Deciduous and Semievergreen	223-222			90			4,160		4,250 (0.76)
LOWLANDS (<500m)									
Evergreen	231	91,629	8,923		27,556	60,816	54,401	90	243,412 (43.35)
Semievergreen	232	2,138		77			96,833	1,226	100,274 (17.86)
Deciduous	233			3,362			84,192	9,563	97,117 (17.30)
Deciduous and Rangeland	233-133						3,128		3,128 (0.56)
TOTAL (km^2)		105,086	26,175	17,798	61,358	60,816	263,788	26,464	561,482
Percentage		18.72	4.66	3.17	10.93	10.83	46.98	4.71	100.00

Low forest of *Polylepis* or quenua, native tree of the Rose family.

Treeless and overgrazed slopes overlooking La Paz; eucalyptus plantation in middle foreground.

Demands Upon Forest Lands and Resources

The demand for timber and wood products places the greatest pressures on Bolivia's forests. In 1976, the latest year of available statistics, 366,000 m^3 of logs were harvested at a value of approximately $25 million (Table 3-3). Stolz (1978c) uses a value of 15 m^3/ha of industrial timber. Thus a minimum of 24,400 ha was selectively logged to supply the timber harvested in 1976. Unfortunately, no data exists to differentiate between harvesting in forest reserves or new areas of colonization.

Secondary forest products (firewood, charcoal, rubber, Brazil nuts, heart of palm, quinine, etc.) play an extremely important role, not only in the remote rural areas, but in the entire Bolivian economy (Table 3-4). These products were worth over $20 million in 1976. Rubber and Brazil nuts form the economic base for Pando Department and along the Itenez River in the Beni Department. The actual revenues produced by Brazil nuts and rubber are even greater than those shown in Table 3-4 due to the substantial flow of these products to Brazil, where the subsidized prices are two to three times higher than the Bolivian prices. (However, data for consumption of firewood appear high).

The demands on forest lands for conversion to agriculture and pasture, although substantial, have not been quantified. Stolz (1978c) estimated an annual loss of 45,850 ha, equivalent to 0.08% of the forest lands.

Bolivia's forest lands are also sources of commercial products such as cat, peccary, and crocodile hides, and live *Sanguinus* monkeys for health research. Although there appears to be an effort on the part of CDF to control hunting of endangered species, the volume of contraband skins is reputed to be very large.

At present there are no recreational demands on Bolivia's natural forests, and only two of the 17 national parks and equivalent reserves are prepared for recreational use (Tuni-Condoriri and Mallasa).

Treeless landscape of open rangeland at 4,200 meters, midway between Oruro and Cochabamba.

Tola brush used in the Oruro region for cooking.

Table 3-3. Timber Products in Quantities Harvested and Produced and Their Values for the Year 1976 (Data from Stolz, 1978c)

Product	Harvested Raw Material (m^3)	Production (m^3)		Value (US $1,000)	
		Internal	Export	Internal	Export
Saw timber	255,000	86,000	49,000	10,700	7,900
Railway ties	67,000	24,000	—	2,200	—
Posts	3,000	3,000	—	260	—
Rafts	14,000	14,000	—	530	—
Logs	19,000	17,000	2,000	810	432
Wood panels	8,000	2,000	1,000	900	1,670
Total	366,000	146,000	52,000	15,400	10,002

Table 3-4. Secondary Forest Products in Quantities Harvested and Produced and Their Values for the Year 1976 (Data from Stolz, 1978c)

Product	Harvested Raw Materials	Production	Value (US $1,000)
Firewood	3,400,000 m^3	3,400,000 m^3	12,500
Charcoal	80,000 m^3	16,000 m^3	704
Rubber	3,631 ton	2,962 ton	4,202
Brazil nuts	8,549 ton	4,845 ton	2,584
Heart of Palm	540 ton	360 ton	293
Quinine	88 ton	3.5 ton	228
Others	—	—	6
Total			20,517

Forest Management

This section reviews institutional aspects of forest management and the level of management being achieved.

Centro de Desarrollo Forestal

The Ministry of Rural Affairs and Agriculture (MACA) created a forestry department in 1954. Because of the inconsistent and vague legislation concerning the forest sector, the lack of forestry policy, and a vast amount of timber exploitation, the Center for Forestry Development (CDF) was created by means of Governmental Decree No. 22686, Ley General Forestal de la Nacion, August 13, 1974, or the National Forest Law.

According to Article 67 of the National Forest Law, CDF is a decentralized dependency of MACA with independent financing, legal personnel and administrative autonomy, with the objectives to promote, regulate, and financially manage the exploitation, commercialization, industrialization, restoration, protection, and conservation of the forest resources of Bolivia. The Law assigns the following functions and activities to CDF:

- Formulate forestry policy for the country and plans for its application
- Administer national forest resources
- Promote and carry out the inventory of forest resources
- Authorize, guide and financially manage forest exploitations according to the dispositions of the Forestry Law
- Authorize, promote and regulate the installation and functioning of forest industries
- Apply in national production forests a means to insure the restoration of the forest resources
- Present, reprimand and sanction the depredatory acts that damage the equilibrium of national forest resources
- Develop and promote experimental investigations and programs
- Coordinate international technical assistance to the forestry sector
- Classify and protect the forests in watersheds
- Comply with the dispositions and regulations of the Forestry Law and all other legal dispositions concerning the defense of forest resources
- Promote the training of the personnel necessary to the application of the dispositions
- Administer the National Parks and equivalent Reserves
- Promote the agreements and conventions with public and/or private institutions to favor development and the forest economy of the country
- Dictate the terms to regulate and classify forest products.

Chapter 15 of the Forestry Law created the National Forestry Fund (Fondo Forestal de la Nacion) to provide the financial base for CDF operations. The Fondo Forestal receives annual assignments from the national budget, 75% of the timber cutting permits (derechos de monte) granted by CDF, and 100% of the income from CDF sales, sanctions, fines, etc.

The regulations and by-laws of the Forestry Law were approved by the Government (D.S.) 14459) in February 1977 (Anonymous 1977). CDF had the assistance of the German Forestry Mission in the preparation of the Forestry Law regulations, forestry policy, and organizational development (Vollmer 1977a, 1977b).

Potential manpower for forestry in Bolivia is being trained at the School of Forestry in Tarija, which graduates Ingenieros Forestales after 5 years. These graduates have, for the most part, been absorbed by CDF (10 persons per year). In Cochabamba, a middle level forest ranger school will soon be offering a 2-year course. This program and the Tarija program have been assisted by West Germany. In October 1979, Dr. George Eisenhauer, head of W. Germany's federal forest research center, was sent by FAO to Bolivia to evaluate the progress and needs of these two centers for forestry education.

CDF is bureaucratically top-heavy and concerned mainly with timber harvesting. Approximately 75% of CDF personnel are involved in the financial management of timber (Table 3-5). Most of the foresters in CDF are involved in administration. Those few CDF foresters actually working in the field are involved in reforestation projects (e.g., Candido Pastor, Parque Tunari north of Cochabamba).

The scientific base of CDF's technical program appears to be very weak. Currently, CDF personnel are working with GEOBOL on the preparation of a forest map. The forest map is based on Beard's classification of Trinidad, which has a strong European

Table 3-5. Professional and Technical Forestry Personnel in Bolivia (From Stolz, 1978b)

	Forestry Engineer	Special Ag. Engn.	Forest Techn.	Special Agr. Tch.	Forest Guards	Other Professionals
CDF						
Main office-La Paz	6	5		2	1	4
West regional office				3	14	
Northwest regional office	2			3	4	
North regional office	3			1	4	
East regional office	9	5		13	22	
Central regional office	1	5		5	3	
South-central regional office				5	7	
South regional office	3	1		3	3	
Universities						
Tarija	9					
Santa Cruz	2					
Cochabamba		2				
Regional Development Corporations						
CORDBENI						
CORDEPANDO						
CORDEPAZ	1					
CORDECO	1					
CODETAR	5					
CODESA				2		
CORDECRUZ	1		1			
Consultants	4					
Private Industry						
Plantation Project	2					
Timber Companies				10		
Other Public Agencies						
IBTA	2					
SIDERSA		1				
CBF	3	2				
Banco Agricola	3					
Municipalities	2	1				
COFADENA						
Pilcomayo Watershed	4	2				
Professionals out-of-country	7					
Professionals not in forestry	3					
TOTAL	73	24	1	47	58	4

bias against tropical forests. GEOBOL's map depicts all the forests along the northern Andean front ranges as one forest type, covering at least seven Ecological Life Zones. In the southern lowlands and on the Beni Plain, the GEOBOL map differentiates numerous vegetation types. Thus, despite the 5 years of CDF work in preparing the forest map, it appears that the map will be of minimal utility for definition of commercial forest reserves.

The development of sustained yield management systems for the forest reserves, especially Chore and Guarayos, should be high CDF priorities. However, CDF professional personnel expressed little concern or interest in sustained yield or the protection of forest resources.

Even though CDF is only 5 years old, it has, politically speaking, grown quickly. There is considerable discussion in the country about graft associated with the granting of concessions. During some of the previous military governments, hundreds of thousands of hectares of concessions in Chiquitania were reputedly granted at the rate of $b1/ha ($b1 = US$0.05) for the Minister of Agriculture.

In summary, CDF is doing a poor job in carrying out the functions assigned by the Forestry Law and Regulations, particularly those related to conservation and use of the natural forest resources. It appears that CDF is little more than the government's fiscal agent for the sale of timber.

Forest Reserves

The 1974 decree, which created the CDF, empowered it to establish five categories of forests:

- Permanent production forests
- Permanent protection forests
- Temporary protection forests pending classification
- Special forests (merits management for other than production or protection)
- Multiple use forests.

The classification of forests involves 10 technical parameters:

- Physiography and soils
- Ecological characteristics
- Hydrologic regime and forest relationships
- Forest mass, species, volume, and forest type
- Variety and abundance of secondary products
- Variety and abundance of wildlife
- Scenic characteristics and importance
- Importance of the area for native Indian tribes
- Land tenancy
- Use of the forest.

An inter-institutional commission, the Forest Land Use Commission, was established within the same legislation to facilitate the classification and designation of different categories of forests, and to resolve possible conflicting claims or jurisdictions.

To date, nine forest reserves have been designated (Table 3-6). They are shown in the map National Parks, Forests, and Wildlife Reserves in Figure 3-3. However, not all have been classified.

Table 3-6. Forest Reserves in Bolivia

		Name	*Area in km²	Classification
a.	**	Tahuamanu	11,900	——
b.		Chimanes	10,300	Protection
c.		Chore	7,900	Production
d.		Guarayos	10,500	Production
e.		Chiquitania	61,700	——
f.		Quinera del Aten	600	——
g.		Manuripi	?	——
h.		Rio Boopi	2,260	Protection
i.		Rio Grande de Masicuri	No data	——
j.		Rio Pilcomayo	No data	——
		Total	105,160	

*Area of mapped surface. Differences exist in some cases between mapped surface and reported areas.

** See Map: National Parks, Forests, and Wildlife Reserves.

Source: Draft map, CDF, no title, 1979.

Forest Management Practices

The most serious problem confronting Bolivia's natural forests is the CDF's disinterest in forest management. As mentioned earlier, because all natural forests are owned by the state, the timber industries are completely dependent on CDF for the supply of timber. The sale of cutting rights in 1978 generated approximately $1 million, but efforts by CDF in silviculture or forest management have been negligible or non-existent.

The majority of the timber processed by the Santa Cruz industries comes from the Chore and Guarayos forest reserves north of Santa Cruz. According to Sachtler (1979), the Chore and Guarayos reserves are the only two certain future sources of timber for the Santa Cruz industries. According to Stolz (1978c), both reserves are in an advanced stage of exploitation. Until mid-1979, no attempt was made by CDF to protect the reserves, and as a consequence, spontaneous colonizers have deforested significant areas within the two forest reserves. CDF'S abdication of responsibility for the sustained production of timber from the Chore and

Guarayos forest reserves portends drastic consequences for the Santa Cruz timber industries.

CDF grants 5-, 10-, and 20-year timber concessions, which provide no incentive for the individual concessionaire to invest in forest management or silvicultural treatments to produce a second crop or a sustained yield of timber.

The need to achieve sustained yield forestry has not, however, completely escaped the timber concessionaires. In early 1979, the National Association of Timber Industries (Camara Nacional de Industrias Madereras) initiated a forest plantation program through an agreement with CDF. The Camara is voluntarily providing $300,000/year to support the program. Although CDF agreed to provide technical personnel, equipment and logistic support, no help ever materialized.

The Forest Plantation Program works with both exotics and native species, but it is distinguished by its work with native timber species. In the Chore Forest Reserve, a forestry station has been constructed, and is the site of species trials as well as regeneration studies.

Other work by the Program (described in the next section on Plantation Forests) includes reforestation of parts of the Pirai River watershed near Samaipata and species trials on sites in the Santa Cruz micro-region.

Foreign Assistance

The German Forestry Mission has been a major influence on the development of CDF and Bolivian forestry policies (Haggenmiller 1977; Stolz 1978a,b,c; Vollmer 1977a,b). The German Forest Mission assists

NATIONAL PARKS, WILDLIFE AND FORESTS RESERVES

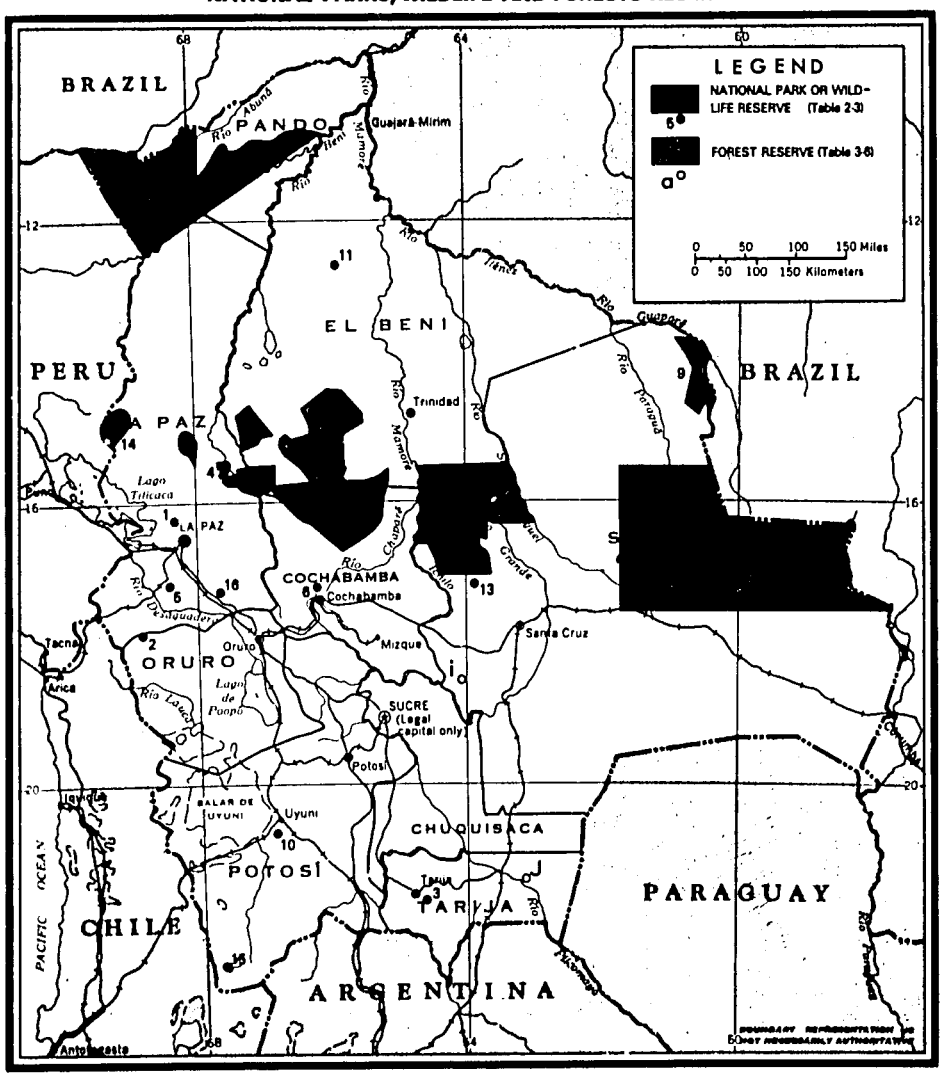


Figure 3-3. National Parks, Forests, and Wildlife Reserves

CDF in the construction and development of a national forestry school in Cochabamba for technicians and forest guards. When the school opens in 1981, five German professionals will instruct 25 technicians and 25 forest guards. A three-year program is planned for the technicians. Forest guards will complete studies in 1 year.

FAO is involved in a major cooperative project with CDF to inventory large forest areas in Beni and Pando Departments. Field work in Pando has been completed, but the analysis of data is not yet available. The inventory of the "Los Chimanes" forest in Gral. Jose Ballivian Province of Beni Department is part of a prefeasibility study (Sachtler 1979). The Chimanes inventory investigated 1,300,000 ha, of which 340,000 ha were determined to be commercially promising. Over 230 species of trees were encountered in the study area. Average standing timber volume is 75 m^3/ha, of which only 20 m^3/ha (involving 20 species) are presently commercial. Sachtler points out that the Chimanes forest and the Chore-Guarayos forest reserves are the only two areas that will be able to provide secondary woods to internal markets in the future.

The FAO inventory project is also performing exploitation, transport and marketing studies for timber from Chimanes and Pando, silvicultural work with native rubber and Brazil nut trees, and a strong program in dendrology that includes the development of a national forestry herbarium in Cochabamba.

In southern Bolivia, FAO foresters stationed in Santiago, Chile, are providing short-term technical assistance in the development of a timber harvesting and utilization plan for the last large block of virgin *Podocarpus* forest. The concession is held by the Corporacion de Desarrollo de Tarija. The CODETAR technician working on this project noted the lack of information on natural regeneration of *Podocarpus*. This must be viewed as a serious question, as all other *Podocarpus* forests that once covered the Andean foothills in Southern Bolivia have been removed.

There are several other foreign bilateral and international technical assistance projects involving the forestry sector. However, these are involved mostly with reforestation and plantation projects or erosion control and are described in later chapters.

Principal Forest Management Problems

In addition to the institutional weakness of CDF, principal problems affecting forest management in Bolivia are: (1) land clearing and land settlement, or colonizaciones, whether assisted by the government or spontaneous; (2) inadequate maps and information for classifying the forest resource; and (3) inefficient utilization.

Colonization

In both the forestry and conservation sectors of Bolivia, there is broad consensus that agricultural colonization is the most serious problem confronting natural forest resources. Opinions vary as to whether spontaneous colonization or directed colonization is more serious, but for our purposes they may be considered equal. Spontaneous colonization occurs along new public roads and occasionally along private timber extraction roads. The National Colonization Institute (INC) is primarily responsible for organized and directed colonization, although the Agrarian Reform Institute (IRA) is also involved in directed colonization. See Figure 3-4 for colonization areas.

Agricultural colonization receives the folowing criticisms:

- Virtually none of the timber is harvested
- Objective criteria in selecting areas for directed colonization are not used
- Areas for directed colonization are located in forest reserves.

Both timbermen and conservationists complain that colonists burn timber to make new agricultural clearings. According to the Forestry Law and Regulations, the timber on colonization areas belongs to the government and CDF is responsible for its exploitation. Yet the colonist claims the timber is his property, and he must be reimbursed for any timber taken from his property. However, because the logger or sawmill operator must pay a cutting fee to CDF, he refuses to pay the colonist. (The simple compromise of deducting the payment to a colonist from the cutting fee due CDF has not yet been established.) Spontaneous colonization often follows selective logging operations, so it is unlikely that any commercial timber remains for the colonist to sell. Colonists are also prone to cutting and burning much more forest than they can effectively cultivate.

Regional broad-scale environmental degradation does not appear to be a serious problem with directed colonization projects, primarily because they are located on the relatively flat lowlands. INC colonization projects are prohibited by Colonization Law from taking place in areas with slopes exceeding 15°. In contrast, spontaneous colonization is widespread along roads through the Yungas and to the foothills of the frontal range. These colonists literally burn their way upslope from the valley floors. Removal of the natural forest cover on steep slopes has led to serious erosion problems.

LAND SETTLEMENT AREAS AND PROTECTED AREAS

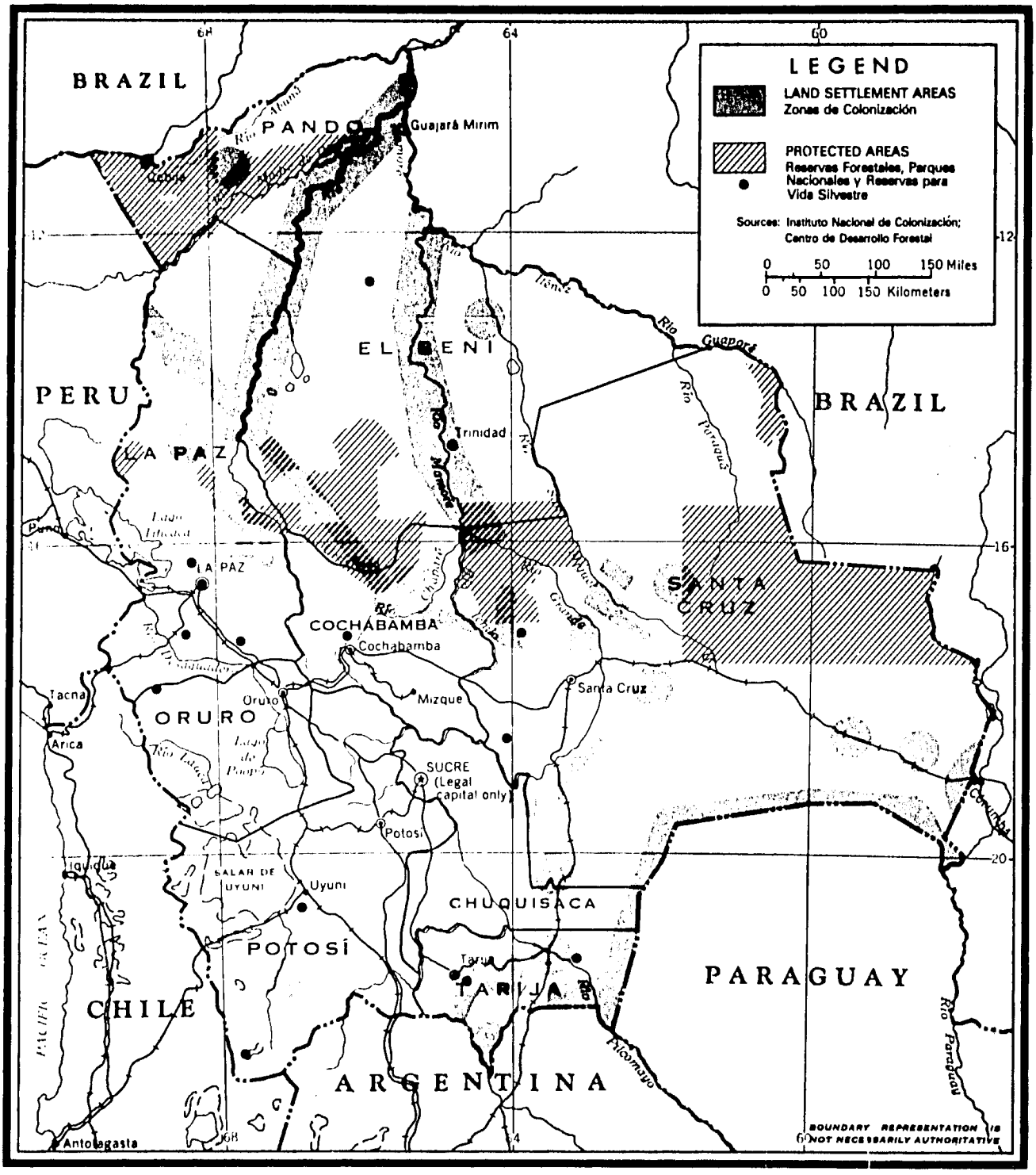


Figure 3-4. Land Settlement Areas and Protected Areas

Although INC and IRA personnel claim they performed soil studies before selecting areas for colonization projects, field evidence suggests that soil and land-use capability studies were not done, were ignored, or were based on inappropriate criteria. The extensive spontaneous and directed agricultural colonization of the Chapare is occurring largely on soils that are not likely to support sustainable agriculture, even with use of existing technology and crop preferences.

The maps of colonization (map 5 in Stolz 1978b) and forest reserves and National Parks (map 3 in Stolz 1978c) clearly illustrate the overlap of actual and projected colonization areas, especially in Beni and northern Santa Cruz Departments. Both the establishment of colonization areas in existing forest reserves and the designation of forest reserves in project colonization areas have been documented.

The Forestry Law and Regulations specify that all the forest and forest lands constitute a national patrimony, regardless of original ownership, and should be administered in the public interest by CDF. Because of the lack of adequate forest maps and the chaotic ownership status of lands in the Oriente, the Forestry Law created a Land Use Commission to minimize poor use of the country's forest resources and adjudicate inter-institutional disputes regarding land use. Athough created specifically to arbitrate conflicts between agricultural colonization projects and forest reserves, the Commission has failed to function. Discussions with government officials indicate an almost complete lack of communication between INC and CDF officials. Perhaps another important reason for the dysfunction of the Land Use Commission may relate to the lack of information on land-use capability.

Land-use Capability Classification

As mentioned in the preceding section, a land-use capability classification is fundamental to the effective utilization of the natural resource base of the country. In the absence of such information, resource development and utilization is chaotic, poorly organized, competitive, and extremely wasteful of the resource base.

GEOBOL has been working to provide INC with the information base necessary for the successful development of Bolivia's natural resources and is readying for publication a series of 1:250,000 maps of the Oriente showing physiographic units, soil and land-use capability. The land-use capability information will be an important planning tool for the vast unsettled areas of Bolivia's Oriente, where most of the natural forests are found. However, if not used carefully, this information could encourage clearing of forests in areas that should not be cleared.

The fundamental problem with GEOBOL's land-use capability classification is that it is based on the USDA-SCS (U.S. Department of Agriculture-Soil Conservation Service) land-use capability classification system. The SCS system does not work well for tropical and subtropical soils for several reasons. Developed in the temperate zone, the SCS system is not designed to account for the rapid and high rates of leaching that occur in tropical/ subtropical soils, and does not adequately provide for the low nutrient pools in the majority of tropical American soils and the very tight and efficient cycling of nutrients in tropical forest ecosystems. Thus, when tropical forests are converted to non-forest uses (breaking the closed nutrient cycle), substantial quantities of already scarce nutrients are lost from the system. Slash-and-burn agriculturists use the nutrients accumulated by the forest ecosystem. One of the reasons for abandonment after 1-3 years of cropping is exhaustion of the nutrient capital from the original forest.

The SCS system is inappropriate for tropical/ subtropical soils because it does not give sufficient emphasis to the very high susceptibility to erosion of many tropical/subtropical soils. Conversion of tropical forests to agricultural areas or pastures has often resulted in disastrous surface erosion and landslides.

In the SCS classification system, some of the classes usually include more than one major land-use. Despite various restrictions or qualifications included in the description of a specific class, planners may ignore the restrictions and select the preferred land-use option For instance, after crop production, pasture is often a preferred use. The SCS inclusion of pasture as an acceptable land-use on Classes III-V has been, perhaps, the primary cause for the conversion of forest to pasture in much of tropical America. However, pastures in the wet tropics do not tend to be economically productive operations due to their extremely low carrying capacity and exuberant woody invasion.

The inappropriateness of the SCS land-use capability system for tropical and subtropical soils is exemplified by comparing two areas on the GEOBOL maps. According to GEOBOL's classification, the soils of Pando (Tropical Moist and Premontane Moist Life Zones) are more suitable for agriculture than the soils between the town of Yapacani and the southern limit of the Chore forest reserve. The soils in the area north of Yapacani are some of the best agricultural soils in the Bolivian Oriente. Furthermore, most of the Ultisol soils of Pando Department will not sustain annual cropping, and are unsuitable for pasture. Beef-cattle pasturing along the Cobija-Porvenir road requires 5 ha per animal, and numerous signs of erosion are appearing on these rather gentle slopes.

GEOBOL's land-use capability map will not be of much use in resolving inter-institutional conflicts over

the most appropriate land-use because only three map units (of a total of 48 units) are designated a single land-use class. Thirty map units include two land-use classes and 15 units have three or more land-use classes. Many of the multiple combinations include classes III, IV, V, and VI, which offer for a single mapping unit alternative land-uses ranging from agriculture to production forestry.

Utilization of Forest Resources

As is typical of countries with vast forest resources, only the premium quality timbers are harvested. The Bolivian timber industry, based largely in Santa Cruz, has developed on virtually one species—mahogany (*Swietenia macrophylla*). Stolz (1978a) indicates that mahogany accounted for 70% of the timber harvested in the Santa Cruz region in 1974. He further states that six species—mahogany, laurel (various *Lauraceae* species), ochoo (*Hura crepitans*), cedro (*Cedrela* spp.), morado (*Machaerium* spp.) and jacaranda (*Dalbergia* spp.)—accounted for 70-97% of the harvested timber in 1974.

Even though the Santa Cruz timber industry now accepts 25 species (Jose Santistevan, personal communication), substantial numbers of good timber species are either being ignored, or cut and burned by colonists. To broaden the timber base, CDF is conducting wood quality and utilization tests on 25 unused timbers under the sponsorship of the Cartagena Agreement of the Andean Pact countries.

Postharvest utilization problems also occur because of the preference for mahogany. Often, solid mahogany wood is used for a variety of purposes where a veneer panel would suffice or where other woods could be substituted. The predilection for mahogany in national and foreign markets is rapidly depleting the stock of mahogany. Some researchers suggest that mahogany stock will last only 10 years (M. Sachtler, personal communication), others as few as 5 years (J. Santistevan, personal communication).

The key to improved utilization of the timber resources of Bolivia is familiarity with tree species present in the forests and their wood qualities and potential uses. Presently, information about Bolivian trees is practically non-existent. Most of the scientific names applied indiscriminately to Bolivian trees come from neighboring countries. Stolz (1978b) summarizes the results of 57 forest inventories conducted in Bolivia, but because of extreme vagaries in the usage of common names of trees and the lack of valid scientifc names, these forest inventory results must be used very cautiously (Hartshorn 1977, 1978). For these reasons, the FAO forest inventory project has placed strong emphasis on the collection of voucher specimens and the initiation of a national forestry herbarium.

Recommendations

Training and research in the Chore Forest Reserve

The facility for plantation forestry and natural regeneration developed by the Programa de Plantaciones Forestales (PPF) in the Chore Forest Reserve presents many opportunities for training and research. One to two months of design work would be needed to develop the possibilities. However, the review in October, 1979, by FAO-sponsored forester Dr. Georg Eisenhauer (head of West Germany's Federal Research Center for Forestry and Forestry Products) of the forestry schools in Tarija and Cochabamba should be consulted before determining technical assistance requirements. (His report should be available at CDF.)

The PPF has three projects: watershed reforestation near Samaipata, species trials on 12 sites in the Santa Cruz microregion, and species trials and natural regenerations studies in the Chore forest reserve. The forestry station constructed by PPF near Ayacucho in the Chore forest reserve is an ideal base for a major forestry project. The extensive areas of recently cleared forest and abandoned farmlands are perfect sites for species trials and for silvicultural treatment of young secondary forest. The selectively logged forest is appropriate for studies of natural regeneration, enrichment plantings, and other silvicultural treatments to facilitate a sustained yield of timber. Just outside the Chore forest reserve, between Ayacucho and Enconada, is an active area of spontaneous colonization that would be very suitable for agroforestry trials and research.

The PPF facilities in Chore could be expanded to allow practical training for forestry students and short courses for CDF personnel. Because the forestry schools in Tarija and Cochabamba either lack accessible forests or are near unrepresentative forests, the opportunity to receive practical training in the Chore forest reserve would be extremely beneficial. If possible, a second forestry station for training and research should be established in Pando.

Field evaluation of land capability in the Oriente

Approximately 8 person-months of technical assistance are estimated to be needed to accomplish this evaluation. Land-use capability classification is fundamental to the effective utilization of Bolivia's

natural resources. Near the end of 1979, GEOBOL will publish a series of 1:250,000 maps indicating land-use capability in the Oriente. GEOBOL's land-use capability maps are based on the USDA-SCS (Soil Conservation Service) land-use capability classification. The SCS system does not work well for tropical and subtropical soils. However, alternative systems have not yet been used in Bolivia, and the SCS-based classification may jeopardize forest resources by assigning preference to pasture.

It is absolutely essential that an independent evaluation of the land-use capability classification be conducted after the maps and accompanying explanatory documents become available. The field evaluation should be at least 2-3 months in duration and should include a tropical ecologist, tropical soils specialist, a natural resources specialist, and a soil conservation specialist in the evaluation team. It would be especially useful if the evaluation were part of a workshop involving a small group of experts (including Peruvians and Brazilians) assigned to review Bolivia's special needs.

The second stage of the project should involve a large-scale (1:50,000) field classification of land-use capability based on appropriate criteria. Large-scale mapping should be initiated in critical areas undergoing rapid changes in land use, such as along the northern front ranges.

Dendrological Survey and Construction of a National Forest Herbarium

An essential ingredient to improved utilization of the timber resources of Bolivia is new information about the tree species present in the forests and information about their wood qualities and potential uses.

The FAO forest inventory project has placed strong emphasis on the collection of voucher specimens and the initiation of a national forestry herbarium.

However, until a functioning herbarium is available, there will be negligible progress in improving knowledge about the Bolivian forestry. Without fundamental botanical information, there will be minimal improvement in the utilization of these natural resources.

The construction of a national forestry herbarium, coupled with major collection and testing efforts of Bolivian trees, is highly recommended. The dendrological survey could be included in a larger project to survey flora and fauna as part of the development of a natural history museum.

IV. PLANTATION FORESTS

Plantation Forests

The Status of Plantation Forestry

History and Extent of Plantations

Organized plantation forestry apparently began in Bolivia about 50 years ago with the planting of *Eucalyptus globulus* on the outskirts of La Paz, the nation's capital. Since then, however, progress has been extremely slow. Persons (1974) estimated the extent of forest plantations in Bolivia at from 5,000 to 24,000 hectares, primarily of eucalypts; Jacobs (1976), using FAO figures from 1965, reported 22,500 hectares of eucalypts alone. The most accurate figures are probably those by Stolz (1978), who reported 7,800 hectares established by 1975/76 and an annual increase in plantation area of about 12%. Using these figures, about 11,000 hectares would be planted by the end of the 1978/79 planting season. Table 4-1 gives an indication of the regional distribution of plantations as of 1975.

Table 4-1. Hectares of Forest Plantations Established From 1960 Through 1975 (Stolz, 1978)

Department	Conifers	Broadleaves	Total
Beni	—	167	167
Chuquisaca	—	821	821
Cochabamba	100	1,002	1,102
La Paz	153	1,203	1,356
Santa Cruz	—	57	57
Tarija	11	75	86
Total	264	3,325	3,589

Although there are a few large plantations, such as those around the cities of La Paz, Sucre, and Cochabamba, most of the plantations are in small plots less than one hectare in size and approximately one-third are in row plantings along roads and property boundaries. Most of the stands do not appear to have been established with any specific objective in mind; rather, they serve general, multi-purposes of beautification, fuelwood and mine timber production, and in some cases erosion control.

The major species is *Eucalyptus globulus*; probably 90% of the stands are composed of this species. The remaining stands consist largely of *Pinus radiata* and some *Cupressus lusitanica*, *C. macrocarpa* and *Acacia* spp. Other species have recently been planted on a trial basis, but have not yet reached a level of significance.

Organizations Involved in Plantation Forestry

The Centro de Desarrollo Forestal (CDF)

As set out by Articles 62, 64, and 78 of the forest law (*Ley General Forestal y Reglamento*) enacted since 1974, CDF is charged with overseeing and coordinating forest plantation programs on a national level and providing technical assistance to public institutions and private entities undertaking tree planting. Other articles in the law provide credits and fiscal incentives for importing tree seed and plantation machinery, require submission of management plans before privately owned plantations may be harvested, give legal authority to CDF to restrict harvesting of plantations on highly erosible sites, allow CDF to supervise fire prevention measures and pest and disease eradication in privately owned plantations, require registration of companies specializing in reforestation, and provide legal authority to obligate private landowners to rehabilitate degraded land under threat of expropriation (Vollmer, 1977a). Thus, CDF is not merely the caretaker of the national forest reserves; it is empowered to intercede in the management of forest plantations on private land. However, CDF lacks both the experience and resources to enforce the existing law. Also lacking is a program to encourage, rather than coerce, reforestation on non-public lands.

In 1978, the administrative framework to further reforestation was set up within CDF's *Departamento Nacional de Bosques* in the form of a special program called the *Programa Nacional de Plantaciones Forestales* (PRONAPLAF). PRONAPLAF has operational responsibility for all reforestation activities of

CDF. It has a national directorate in La Paz and representatives working out of regional offices. Since its establishment, PRONAPLAF has been fully occupied with consolidating its institutional base and making the technical preparations for reforestation programs.

With technical and material encouragement, PRONAPLAF could become a viable and significant force in promoting reforestation of Bolivia.

Regional organizations

La Paz. Plantations have been established by the city of La Paz since 1930 to reduce erosion on the steep, unstable slopes surrounding the city. West German bilateral assistance, through its *Mision Forestal Alemana*, has been cooperating with the project since 1968. *E. globulus* is the main species planted, with some *P. radiata*, *Cupressus* spp., and *Acacia* spp. Entrance by the general public and grazing animals has been restricted, and as a result, erosion has been slowed except on the steepest terrain and where gully erosion was extreme. The plantations have also greatly improved the aesthetics of the area. Some of these stands are now being selectively harvested for mine timbers. However, the threat of invasion by urban dwellers is becoming more acute each year.

A small urban park in the extraordinarily gullied Valley of the Moon sector of the city was planted in eucalyptus 20 years ago. The trees, which were planted at about 3-meter intervals, have failed to control gully erosion in the very erosible clays characteristic of the city.

Other significant plantings in the Department of La Paz were undertaken with *E. globulus* 15-20 years ago on communal and private land along the southeastern shore of Lake Titicaca. These small groups and line plantings near dwellings and along property boundaries are now yielding commercial mine timbers.

Cochabamba. With the help of West German bilateral aid, the city of Cochabamba 10 years ago initiated a series of small plantings and erosion control works on the hillslopes overlooking the city. The area has since been named a national park (Parque Nacional de Tunari) and has been passed to the jurisdiction of CDF. The park covers an area of about 6,000 hectares, of which 400 hectares have been planted. The major and most successful species are *P. radiata* and *E. globulus*, but a number of others, both native and exotic, are under trial. These species are evaluated in terms of their adaptability to different altitudinal levels, production of merchantable products, and effectiveness in soil stabilization. Regrettably, because the trials are not being statistically replicated, it will be difficult to utilize the results.

The most effective organization involved in plantation forestry throughout the Department of Cochabamba is CORDECO (the Corporacion de Desarrollo de Cochabamba). In the few years since its formation, CORDECO has established nurseries and begun reforestation projects in four areas of the department: Corani-Tiraki, the Rocha River watershed, the Biloma watershed, and Totora. CORDECO's present total nursery capacity is about 5,550,000 seedlings, or enough to plant 3,000-5,000 hectares annually in the department. However, only 500 hectares have yet been planted and only 600 hectares were to be planted during the 1979/1980 planting season.

CORDECO sells plants at cost and enters into agreements with landowners covering the establishment and management of plantations on private or communal land. It also is reforesting some of its own land.

Chuquisaca. Although it was not possible to visit the sites of forest plantation activities in Chuquisaca, it is known that this department, through the efforts of the Comite de Desarrollo de Chuquisaca (the Chuquisaca Development Committee), has been among the most active regions in the country in encouraging tree planting. In 1977, the Comite had four nurseries with a total capacity of 1,500,00 plants (Stolz, 1978); nursery capacity has undoubtedly expanded since then. The Comite promotes plantation development on private and communal land and signs contracts with landowners which specify the rights and responsibilities of each party.

Immediately south of Sucre, the capital of Chuquisaca, extensive areas of Eucalyptus plantations cover both sides of the road and two large hills. The trees appear to be about 15 years old; more recent plantings can be seen, as well.

Santa Cruz. The most effective forest plantation entity in the Department of Santa Cruz is the Programa de Plantaciones Forestales (PPF) (Forest Plantation Program), a semi-autonomous project set up in November of 1973 by special agreement between the Camara Nacional de Industrias Madereras and the Ministerio de Asuntos Campesinos y Agropecuarios. The project was to be financed by the timber concession rights paid to the government by the companies comprising the Camara.

The primary objective of the Forest Plantation Program is to develop and promote improved forest regeneration techniques in the Department of Santa Cruz. In early 1979, after several years of floundering due to poorly defined responsibilities of the two founding organizations, the Camara exerted itself—both politically and financially—to move the program ahead. This accounts for the current, tacit hands-off policy of CDF and the efficient and dedicated operation of the

Program ever since. The current major areas of work of the Program are:

- Pine plantings in the sub-Andean region around Valle Grande and the Pirai River watershed where floods and sedimentation are problems but where several good plantation sites are available
- Eucalypt plantings in the vicinity of the city of Santa Cruz, on portions of an estimated 68,000 hectares of land which have been abandoned after agricultural use
- Regeneration studies, primarily with native species, of the Chore Forest Reserve.

The Program has recently made excellent progress. Although adequately financed and efficiently operated, it could benefit from outside technical assistance.

Foreign Assistance in Plantation Forestry

West German bilateral aid

The West German Government, through its Mision Forestal Alemana, has been assisting reforestation activities around the cities of La Paz and Cochabamba since 1968. In the mid-1970's, the Mision engaged in a comprehensive study of the national forest service and national forest policy, culminating in the reports of Stolz (1978), Vollmer (1977a), and numerous recommendations such as that resulting in the formation of PRONAPLAF. Recently, the Mision has funded the building of a forest guard school in Cochabamba and there is a possibility that West German aid could become available for reforestation and erosion control projects in the Department of Tarija. A proposal has also recently been completed to establish a national tree seed center in Cochabamba. If funded, this would be a valuable aid to PRONAPLAF in promoting reforestation.

IDRC aid

The International Development Research Center (IDRC) provides $175,000 in financial support to CDF for pine and eucalypt trials with the goal of selecting fast growing species for fuel wood and charcoal needs. These studies are badly needed in Bolivia and will undoubtedly provide a great deal of valuable information for future reforestation activities. Nonetheless, this is only a research project and is not to be confused with operational-scale reforestation programs planned by CDF.

USAID

In October 1979, CDF submitted a draft project proposal to USAID requesting $2 million of PL 480 funds over a 5-year period to support reforestation on 6,000-9,320 hectares of communal lands in the Inter-Andean Valleys and Altiplano. The U.S. funds would go toward the purchase of machinery and tools needed to undertake the project and to cover salaries and other operational costs. If implemented, this would be the first USAID support for forestry in Bolivia. It is recommended that this request be approved as soon as possible, but that the project document first be amended as outlined in the October 14, 1979, memorandum from D. Harcharik to K. Johnson, USAID/Bolivia.

World Food Program (WFP)

At this time, WFP has no experience in reforestation projects in Bolivia. However, if the above-mentioned PL 480 project is approved, WFP would assist by providing $1.5 million in food aid to laborers in nurseries and to communities as an incentive to plant and tend trees, to utilize erosion control measures, and to engage in other beneficial community works.

FAO/UNDP

The Food and Agriculture Organization of the United Nations (FAO) and the United Nations Development Program (UNDP) are currently supporting an erosion control project, including reforestation, in Tarija. The project is being financed by international funds and is being operated by Bolivian nationals. FAO and UNDP have also been approached to support a reforestation program in the Department of La Paz beginning in January of 1980. This project, athough not yet finalized, would be similar to the proposed PL 480 project.

Technical Evaluation of Accomplishments

It was not possible to undertake a country-wide evaluation of the successes and failures of forest plantation efforts in Bolivia to date. However, such a survey is needed. The following general comments are based on information gathered from brief visits to nurseries

and plantation sites around La Paz, Santa Cruz, and Cochabamba and from available literature and conversations with individuals with longer experience in Bolivia.

Species

The preoccupation with planting *Eucalyptus globulus* has come under attack by individuals who note that this species is not well suited to controlling water-caused erosion. There is some basis to their argument. When young, eucalypts are very susceptible to grass competition, and clean weeding is necessary to ensure establishment and good growth. Athough eliminating the grass cover favors eucalypts, it is highly undesirable on steep or eroding terrain. In older, closed stands, *E. globulus* has a great demand for water and an exceptionally extensive and dense root system which enables it to compete for soil moisture with smaller, shallow-rooted plants. The elimination of cover is less important in humid areas, where undergrowth survives well under *E. globulus*, but in the drier Altiplano and valleys of Bolivia, the understory is sparse and litter accumulation does not prevent erosion.

On the eroded hillsides surrounding La Paz, better protection could have been achieved by constructing a series of gully control measures and planting shrubs, perennial grasses and creeping cover crops. Nonetheless, due to its good growth and favorable adaptation to the climate, *E. globulus* has helped to slow erosion on these slopes. Now many of these stands are too dense and should be thinned to allow more light to reach the forest floor and thus promote the growth of grass cover.

This does not imply that the planting of *E. globulus* should be ceased, or even slowed. On the contrary, planting should be expanded. The species is suited to the cool climate of high elevation tropical areas and can be planted up to an altitude of about 4,000 meters in Bolivia. In addition, it is easy to establish, grows fast, is generally of good stem form, coppices vigorously, is wind firm and is valuable as fuelwood, mine timbers, and rough construction. In addition, it is locally well known and is the only species with which there is sufficient experience in the country to be considered for large-scale planting (with the possible exception of *Pinus radiata* on certain sites). The only present limitations to growth are cold (above 4,000 meters), drought, and poor soils; thus, careful selection of sites is required. In view of the great demand for fuelwood, planting of *E. globulus* should be expanded in the form of small stands and windbreaks on suitable soils throughout the inter-Andean valleys and lower Altiplano. It can be planted on sites that are showing initial signs of erosion if grazing and pasture fires are controlled. Wide spacings (3 x 3 meters or greater) or early thinnings should be used to favor a grass understory. However, eucalyptus should not be used to check the more advanced stages of erosion. Experimentation with other tree species is underway, but needs to be expanded. In particular, there is need for more pine trials in the inter-Andean valley. Species such as *Pinus radiata*, *P. patula*, *P. merkusii* and *P. kessiya* merit further trial: they provide good construction timber, are tolerant of grass competition, grow well on degraded sites, and are valued for erosion control. At lower elevations (e.g., Santa Cruz) work with species such as *P. Caribaea*, *P. oocarpa*, and *P. elliotti* should be intensified in the heavily cut-over areas; in the high forest region, research needs to be initiated on natural regeneration and reforestation in the form of enrichment planting, agrisilviculture, and conversion planting with both native species and high-quality exotics.

At severely eroded sites, there is an obvious need for intensive soil conservation methods. Trees can be used as a component of complete control on such sites, but planting should be restricted to the gentle slopes and upland areas and should not be done in gullies or on the steepest side-slopes. The choice of species in erosion control should be based on the following criteria. These criteria are listed in order of importance where site rehabilitation is the primary objective and direct economic return is secondary (Harcharik and Kunkle, 1978):

- Good survival and fast growth on impoverished sites
- Ability to produce a large amount of litter
- Strong and wide-spreading root system with numerous fibrous roots. In landslide zones, deep roots are essential
- Ease of establishment and low maintenance requirements. The ability to readily establish from vegetative material is a definite advantage
- Capacity to form a dense crown and to retain foliage year-round, or at least through the rainy season
- Resistance to insects, disease and browsing by game, stock and smaller animals
- Soil improvement, such as through nitrification by legumes
- Provision of economic returns.

Species which have been successfully used in other countries for erosion control include *Acacia* spp., *Ailanthus altissima*, *Prosopis juliflora* and *Tamarix* spp. on sites receiving less than 700 mm of rainfall annually and *Alnus maritima*, *Casuarina equisetifolia*, *Gleditsia triacanthos*, *Gliricidia sepium*, *Pinus* spp., and *Robinia pseudoacacia* on wetter sites.

Work has been started with some of these species at Tarija and at the Parque Nacional de Tunari, but trials in other areas are also needed. Local species should not be overlooked for effectiveness in erosion control. For example, more research could be performed using *Polylepis incana* and *Buddleia coriacea* on the Altiplano.

Seed source

Little attention has been paid to seed source. For small-scale planting of *E. globulus*, seed has usually been collected from a few trees near nurseries. This practice could be improved by actively searching out, marking, preserving and mixing at least 10 trees of superior form and growth from which seed is collected for each nursery.

Provenance trials of *E. globulus* should be started on a number of sites. These could be conducted as an extension of the species trial program presently supported by IDRC. Seed sources should be selected from Australia, Spain, Portugal, Chile, and Peru, as well as from within Bolivia. But until such trials show that a particular source is superior, planting should be restricted to locally collected seed.

There are insufficient stands in the country from which to obtain *P. radiata* seed for expanded planting programs. Provenance trials with this species should also be initiated, using sources from California, New Zealand, Australia, Ecuador, and Chile; meanwhile, seed can be purchased from Chile.

Nurseries

Most Bolivian nurseries are small, poorly equipped, and labor intensive, but are able to meet the low demands for planting stock. Seed is generally sown in germination beds, then placed into polyethylene containers. The CORDECO nursery in Cochabamba also produces bare-root *P. radiata* stock. These techniques have been moderately successful, but hardier stock could be produced more efficiently through the judicious use of fertilizers and careful timing and scheduling of activities.

Outplanting and tending

Few planting sites were visited, and no operational planting was witnessed. Planting, however, is reportedly performed by only digging a hole about 30 cm deep and 30 cm square: no other on-site preparation is made. For eucalyptus, especially where heavy sod exists, it is advisable to hoe a 1/2 meter radius around each plant at the time of planting to reduce grass competition. Planting density varies, but generally 2,000 plants per hectare is recommended. This is adequate space but will still necessitate thinning, probably in approximately 5 years. On sites threatened with erosion, individual microsites should be selected based on their potential to promote tree growth, rather than sticking to a rigid plantation spacing. Little, if any, post-planting tending is practiced. This is justified on erosible sites, but elsewhere, weeding of eucalypts through the second year is advisable. Weeding is best performed by hoeing but, alternatively, by slashing and harvesting the grass for animal consumption. Insufficient attention is paid to encroachment by grazing animals and grass fires. Both are incompatible with plantation management and must be prevented. Pests and diseases have not yet posed serious problems.

Yields and rotations

There are no figures available on the productivity of existing plantations, but Stolz (1978c) estimated productivity of *E. globulus* to be from 2.6 m^3/ha/yr for the central Altiplano to 8.0 m^3/ha/yr for the northern and central inter-Andean valleys with a rotation age of 10 years. These figures appear reasonable given the present state of technology, but significant improvements could be made by paying more attention to seed source, planting site, fertilizers, and plantation tending.

The Need for Forest Plantations

Erosion Control

Tree planting plays an important role in reducing erosion. By selecting good species and applying appropriate management, trees may be the source of commercially valuable products. Therefore, pilot projects should aim toward complete control of erosion by integrating conservation and land use practices and should involve planting tree species capable of both soil stabilization and wood production.

The Demand for Forest Products

Fuelwood

Some erosion is attributed to the overcutting of trees and shrubs for fuel. Therefore, establishment of high-yielding forest plantations of good fuel species such as *E. globulus* may relieve the pressure placed on naturally existing woody plants to meet the country's fuelwood needs.

The demand for fuelwood is great. Stolz (1978c) conducted a comprehensive study that compared demand for forest products in Bolivia with existing wood resources. He estimated that, by 1992, a country-wide total of about 16,430 hectares of plantations would need to be harvested annually to meet the demand for wood products; of these, 12,550 hectares (76%) would be required for fuelwood alone. The projections (Table 4-2) take into account population growth rates, the different consumptive patterns of urban and rural populations, and realistic estimates of plantation productivity. Thus, the most urgent need for forest plantations is to provide fuelwood to inhabitants of the central and northern Altiplano and throughout the inter-Andean valleys.

Table 4-2. Hectares of Forest Plantations Required Annually to Meet the Demands for Wood Products (Stolz, 1978)*

	1982		1992	
Product	**Conifers**	**Broad-leaves**	**Conifers**	**Broad-leaves**
Fuelwood		12,250		12,250
Pulp (long-fiber)	360		670	
Mine Timbers	145	570	145	570
Charcoal		1,080		1,760
Matches		35		35
Others		1,000		1,000
Subtotal	505	14,935	815	15,615
TOTAL	15,440		16,430	

*Excluding demand presently being met by natural forests

Sawtimber

The demand projections made by Stolz (Table 4-2) are for plantations only. Stolz omitted sawtimber from his calculations, assuming that existing natural forests would satisfy the demand until at least 1992. Such reasoning may be correct for the short run, but there is already concern that merchantable sawtimber will be in short supply as early as 1989. Therefore, it is not too soon to begin studying means to regenerate these forest lands. Research into both natural and artificial regeneration methods must be considered an urgent priority.

It is worth noting that, in almost all cases, intensive plantation culture has proven to be the most productive forest regeneration system and must be considered as one of the regeneration alternatives for lowland tropical areas.

Constraints on Progress

Lack of Forestry Consciousness

Perhaps the greatest constraint on progress in plantation forestry in Bolivia is the public's lack of awareness of the value of tree planting.

Efforts to promote forestry and conservation have been minimal and hampered by, among other things, a complex land tenure system and cultural differences between the indigenous peoples, the mestizos, and the white governing classes. There is poor communication between the government and the rural peoples and distrust of government by indigenous communities. That these factors have hindered progress in plantation forestry is evident by the low figures reported for planted areas relative to the numbers of plants produced in nurseries. There are technical and financial difficulties as well, but the means to produce seedlings are available; what is lacking is simply the desire on the part of landowners to plant them. The government has not yet satisfactorily confronted this problem. Measures that could be taken to promote tree planting and conservation include incentives for tree planting, active extension programs, and conservation education through the school systems.

Weakness of CDF

CDF's National Forest Plantation Program, PRONAPLAF, is relatively new, and does not appear strong. Lack of funds, equipment, experience, and expertise have undoubtedly played a part in its weakness, but sufficient knowledge to expand planting does exist. It is simply not being utilized.

To fill the need not met by CDF, a number of regional organizations have begun to launch plantation programs (see section on regional organizations). There exists the prospect of both duplicating and dispersing efforts among organizations with similar goals. Much more could be accomplished by facilitating cooperation among CDF and regional organizations.

Unless greatly strengthened, CDF runs the risk of being reduced to a research organization charged with

developing appropriate plantation technology. Then implementation of that technology may be completely taken over by regional organizations. Plantation programs could be efficiently executed without such division of responsibilities by encouraging greater cooperation among CDF and regional organizations on specific planting projects. Amendment of the PL 480 proposal would do much to foster such collaboration.

Recommendations

Technical assistance to CDF

Three to four person-years of technical assistance are recommended to assist in the implementation of the proposed PL 480/WFP reforestation project. The forester given this assignment should be experienced in applied plantation research and operational planting and should be familiar with techniques for growing eucalypts and pines. He should work with the project manager for a minimum period of 3-4 years and should advise on all technical aspects of executing the project at the local level. In addition, he would identify research needed to improve the technical success of the project—such as expansion of species-site studies and initiation of fertilizer trials in both nurseries and plantations—and would assist CDF in planning and executing such research. This individual should be responsible for establishing coordination between CDF and other entities. He would also assist CDF in carrying out a country-wide assessment of the effectiveness of all existing plantations in wood production and erosion control.

Technical Assistance to Programa de Plantaciones Forestales

This assistance was requested during a visit by a team plantation forester to PPF. PPF's program requires an experienced tropical forester to develop research on tropical forest regeneration at the Chore Forest Reserve for a minimum of 3-4 years, with subsequent short-term follow-up assistance. He would plan and initiate research on all aspects of tropical forest regeneration, natural and artificial, and would also provide advice on the species trials research and nursery operations now underway in Santa Cruz. This assistance is an excellent opportunity to produce significant achievements with relatively little financial outlay.

National Educational Campaign in Forestry

Forestry awareness and an appreciation of the many values of trees should be an integral part of an education. Special funds need to be provided for this educational project, but approval of PL 480 with the amended budget would allow the immediate initiation of forestry promotional activities.

AID Support for the National Forest Plantation Project

This proposed project was reviewed separately by the team forest plantation expert, and a separate report submitted (Harcharik, 1979).

The request for $2 million over a 5-year period to support 6,000-9,320 hectares of communal tree plantations for fuelwood and erosion control in the Altiplano and inter-Andean valleys should be approved, with the incorporation of certain amendments (Harcharik, 1979). Successful implementation of this project would help relieve the pressure on natural wood resources for fuel, would help reduce erosion, and could provide the link between government and indigenous communities so badly needed before larger-scale activities can be contemplated. This is the key plantation priority in Bolivia today; it needs to be implemented as soon as possible.

V. SOIL EROSION AND WATERSHED CONDITIONS

Soil Erosion and Watershed Conditions

Introduction

Soil erosion on cropland and range is undoubtedly one of Bolivia's most serious resource managment problems. This observation, already recorded in published reports and books, was confirmed by field observations and all Bolivians interviewed by the team. All forms of water as well as wind erosion were seen, from the most fantastic gullied landscapes in Tarija and near the city of La Paz to the most subtle and insidious sheet and wind erosion on the flat Altiplano.

Notwithstanding the chronic and generalized nature of soil erosion, there is no national plan or program to counter this phenomenon.

In the plan for reorganizing MACA (being reviewed in October 1979), there is no institutional provision for a special office or program, and both erosion control and soil conservation are absent in the present organization of MACA. One explantation for the lack of concern for soil erosion is the attitude brought on by agrarian reform. There is a general perception that land is "free" now, that anyone can "get land from the Reforma Agraria (office)," according to the head of the Seccion de Suelos in MACA.

Only the pilot project in Tarija (for rehabilitating gullied lands) exists as an exception to this remarkable discrepancy in natural resources management in Bolivia.

Knowledge of the Soils Resource

General Surveys

The only map which depicts all the soils in Bolivia is the very generalized FAO-UNESCO Soil Map of South America, based on work by A.S.C. Wright in 1964 and other information. A more recent national map of land systems (Mapa de Sistemas de Tierras, 1:1,750,000 scale), by Thomas T. Cochrane, accompanies his monograph "El Uso Potencial de los Suelos de Bolivia; un Mapa de Sistemas de Tierras" (Cochrane, 1973), which also employs the land systems developed by A.C.S. Wright. More detailed 1:250,000 scale soils maps of land "complexes" have just been published by GEOBOL for each of the 38 satellite images that cover the Bolivian Oriente. Mapped at the association level, the soils are also classified according to their land use capability, following the U.S. Soil Conservation Service's eight-class land-use capability classification system. This work, not yet published at the time the team visited Bolivia, is intended to be used by the Instituto Nacional de Colonizacion in the selection and general planning of land settlement in the Oriente. GEOBOL recognizes that more detailed studies will be needed.

Detailed Surveys, Seccion de Suelos, MACA

Detailed mapping, using aerial photographic interpretation technique and field survey methods, has been performed by MACA's Direccion de Ingenieria, Riego y Suelos. Beginning in 1958, when soil mapping began in Bolivia, US SCS soils survey and land-use capability classification methods were followed. Since 1976, the 7th Approximation has been used to classify soils.

Present soil maps are prepared on request for regional development corporations, other government agencies, and different dependencies of MACA, such as INC and the Oficina de Reforma Agraria.

Existing soils studies and maps have been catalogued but are not compiled into one generalized map. Recently, some large areas of the Altiplano were mapped, but most of the surveys covered relatively small surfaces.

There are presently 26 soil mapping "technicians," 12 in La Paz, 6 in Cochabamba, 3 in Santa Cruz, 3 in Tarija, and 2 in Sucre. However, the Seccion de Suelos of MACA does not provide them with vehicles or laboratory facilities; instead, the surveyors must rely on vehicles provided by the agencies that request the work, and must use the laboratory facilities of IBTA (Instituto Boliviano de Tecnologia Agropecuaria) or CIAT (Centro de Investigacion Agronomica Tropical). None of the surveyors has had special training in soil erosion mapping or control. Nevertheless, the Chief of the Seccion de Suelos, Ing. Antonio Saenz, affirms that a map of soil erosion in Bolivia is of great importance.

Extent and Nature of Erosion

Actual surveys of erosion on a national or departmental basis do not exist, although several publications make reference to Bolivia's erosion problems (Grover 1974; Sainz, 1978; Lebaron, et al, 1979; Nelson, 1973). Wind and water erosion, and extreme degradation in dry areas leading to desertification, is known to occur.

Only in Tarija has the concern for soil erosion been matched by a program to combat it. The program called PERTT (Programa Ejecutivo para la Rehabilitacion de Tierras en Tarija) is described in more detail below.

Estimates of the amount of land in Bolivia affected by erosion range from 35% to 41%. Taking into account that 50% of the territory is forested, this would mean that as much as 80% of Bolivia's settled areas are affected by erosion. Field observations and overflights made by the team corroborate this general figure.

Bolivia's erosion problems are, to a great extent, worsened by the basic geomorphological instability of steeply sloping areas; areas with intense rainfall, such as the Yungas; areas with streams actively working downwards to a new gradient, such as the Tarija Valley; or areas subject to high winds. Disturbance, especially removal of vegetation, triggers the basic instability of such areas and may lead to rapid catastrophic erosion. Other erosion problems occur in essentially stable areas such as the Altiplano and also result in vegetative loss, but involve slower and less dramatic processes.

Over-grazing or clean-tilled cultivation are the most immediate causes of erosion and are often the last step in the progressive removal of vegetative cover—beginning with deforestation and ending with the bare soil exposed to the impact of rain and wind.

The most serious cases of erosion or land degradation in Bolivia are reported to occur in:

- Viacha, near La Paz
- Rio Arque, where erosion is threatening the railroad that links Oruro and Cochabamba
- Tarija Valley, where gullies have destroyed 70% of the agricultural soils
- Santa Cruz, where wind erosion causing longitudinal sand dunes affects some 200,000 hectares south of the city
- The Yungas, in all areas cleared of forest, from torrential rainfall.

Throughout the Altiplano, overgrazing and trampling by sheep and other livestock have led to serious wind and sheet erosion. The reduction of grazing pressures and use of fuel resources will be an essential part of erosion control in the Altiplano.

In the Inter-Andean Valley and Yungas, physical structures as well as vegetation management may be required to control erosion and runoff. A watershed management framework is needed in these valleys (and other steep basins).

In the Oriente, where the problems range from loss of soil fertility in the humid north to wind erosion in the drier south, control of erosion or degradation will require a variety of measures.

The map titled Erosion Susceptibility (Figure 5-1) is based upon the Mapa de los Sistemas de Tierras and accompanying monograph prepared by Cochrane (1973). Each of the over 200 land systems mapped by Cochrane was accorded a susceptibility rating on a scale of 1 to 4 for water and wind erosion, as shown in Table 5-1.

Table 5-1. Conversion of Land System Units to Levels of Erosion Susceptibility

Land System Symbol	Level of Susceptibility	Land System Symbol	Level of Susceptibility
Ia1	Wa3	Ie7	Wa2
Ia2	Wa4	Ie8	Wa
Ia3	Wa2	Ie9	Wa2, Gu
Ia4	Wa2	If1	Wa2, Gu
Ia5	Wa4	If2	Wa2
Ia6	Wa2	If3	Wa1
Ib1	Wa3, Gu	Ig1	Wa1
Ic1	Wa1	Ig2	Wa1
Ic2	Wa2	Ig3	Dep
Ic3	Wa2	Ig4	Wa1, Wi1
Id1	Wa2, Gu	Ih1	Wa2
Id2	Wa2	Ih2	Wa2, Wi3
Id3	Wa2	Ih3	Wa1
Id4	Wa2	Ih4	Wa4
Ie1	Wa3	Ih5	Wa3
Ie2	Wa2	Ih6	Wa2
Ie3	Wa2	Ih7	Wa1-2, Wi1-2
Ie4	Wa2	Ih8	Wa2
Ie5	Wa2	Ih9	Wa2
Ie6	Wa3	Ih10	Wa2
Ih11	Wa3	IIIc2	Wa1, Wi2-
Ih12	Wa1, Gu	IIIc3	Wa2, Wi3
Ih13	Wa3	IIIc4	Wa2, Wi2-
Ii1	Wa2	IIIc5	Wa2, Wi2-
Ii2	Wa2	IIIc6	Wa2, Wi2

Table 5-1. (Continued)

Land System Symbol	Level of Susceptibility	Land System Symbol	Level of Susceptibility
Ii3	Wa2, Gu	IIId1	Wa3
Ij1	Wa3	IIId2	Wa2, Wi3
Ij2	Wa3, Gu	IIId3	Wa3
Ij3	Wa3	IVa1	Wa2-3
Ik1	Wa3	IVa2	Wa2-3
Ik2	Wa1	IVa3	Wa2-3
Ik3	Wa2	IVa4	Wa1-2
Ik4	Wa2	IVa5	Wa2
Ik5	Wa2	IVb1	Wa1-2
Ik6	Wa2	IVb2	Wa2
Il1	Wa1	IVb3	Wa2-3
Il2	Wa1	IVb4	Wa1-2
Il3	Wa1	IVb5	Wa2,Wil-Gu
Il4	Wa1	IVc1	Wa2
Il5	Wa1	IVc2	Wa2
Il6	Wa1	IVc3	Gu
Il7	Wa3-4, C	IVc4	Wa3
Il8	Wa1	IVd1	Wa1
Im1	Wa3	IVd2	Wa1
Im2	Wa3	IVd3	Wa1, Dep
Im3	Wa3	IVe1	Wa1
Im4	Wa3	IVe2	Wa1
Im5	Wa1	Va1	Wa2
In1	Wa2	Va2	Wa1
Io1	Wa4	Va3	Wa2-3
IIa1	Wa3	Va4	Wa2-3
IIb1	Wa3, Wi3	Va5	Wa2
IIb2	Wa3, Wi2	Va6	Wa2
IIIa1	Wa2, Wi2	Vb1	Wa2
IIIa2	Wiw	Vb2	Wa2
IIIb1	Wa2,Wi2,Dep	Vb3	Wa1
IIIb2	Wa2, Wi1	Vc1	Wa2
IIIb3	Wa2, Wi1	Vd1	Wa1
IIIb4	Gu	Vd2	Wa2
IIIc1	Wa1, Wi2	Vd3	Wa1
Vd4	Wa1	VIIb3	Wa1
Vd5	Wa1	VIIb4	Wa1
Vd6	Wa1	VIIc1	Wa1
Vd7	Wa1	VIIc2	Wa1
Vd8	Wa1	VIIc3	Wa1
Vd9	Wi2	VIIc4	Wa1
Vd10	Wa1	VIIc5	Wa1
Vd11	Wi1	VIIc6	Wa1
Ve1	Wa1	VIIc7	Wa1
Ve2	Wa1-2	VIIc8	Wa1, Dep
Ve3	Wa1	VIIc9	Wa1
Ve4	Wa1-2	VIIc10	Wa1
Ve5	Wa1	VIIIa1	Wa1
Ve6	Wa1	VIIIa2	Wa1-2
Ve7	Wa1	VIIIb1	Wa1

Land System Symbol	Level of Susceptibility	Land System Symbol	Level of Susceptibility
Ve8	Wa1	VIIIb2	Wa1
Ve9	Wa1	VIIIb3	Wa1
Ve10	Wa1	VIIIb4	Wa1
Ve11	Wa1	VIIIc1	Wa1
Ve12	Wa1	VIIIc2	Wa1
Ve13	Wa1	VIIIc3	Wa1
Ve14	Wa1	VIIIc4	Wa1
Ve15	Wa1	IXa1	Wa1
Ve16	Wi1-2	IXa2	Wa2
Ve17	Wa1	IXa3	Wa1-2
Ve18	Wi1	IXb1	Wa1-2
Ve19	Wi2-3	IXc1	Wa1-2
Vf1	Wi2-3	Xa1	Wa1
Vf2	Wi3-4	Xa2	Wa1
Via1	Wa2	Xa3	Wa1
VIb1	Wa2	Xb1	Wi2-3
VIb2	Wa2	Xb2	Wi2-3
VIc1	Wi1, Dep	Xc1	Wa1
VIc2	Wi1	Xc2	Wa1, Dep
VIIa1	Wa1, Dep	Xc3	Wa1
VIIa2	Wa1, Dep	Xc4	Wa1
VIIa3	Wa1	Xc5	Wa1
VIIa4	Wa1, Dep	Xc6	Wa1
VIIb1	Wa1	Xc7	Wa1
VIIb2	Wa1	Xc8	Wa1
Xc9	Wa1	Xd3	Wa1-2,Wi1-2,Gu
Xc10	Wa1	Xe1	Wa1, Dep
Xc11	Wa1	Xe2	Wa1, Dep
Xd1	Wa1	Xe3	Wa1, Dep
Xd2	Wa1	Xe3	Wa1, Dep

Key: The levels of susceptibility are:

1 – None to slight susceptibility to water and wind erosion
1-2 – Slight to moderate susceptibility
2 – Moderate susceptibility
2-3 – Moderate to high susceptibility
3 – High susceptibility
3-4 – High to very high susceptibility
4 – Very high susceptibility
Gu – Active gullies associated with sheet and rill erosion
Dep – Deposition of material resulting from erosive processes
Wa – Water erosion
Si – Wind erosion

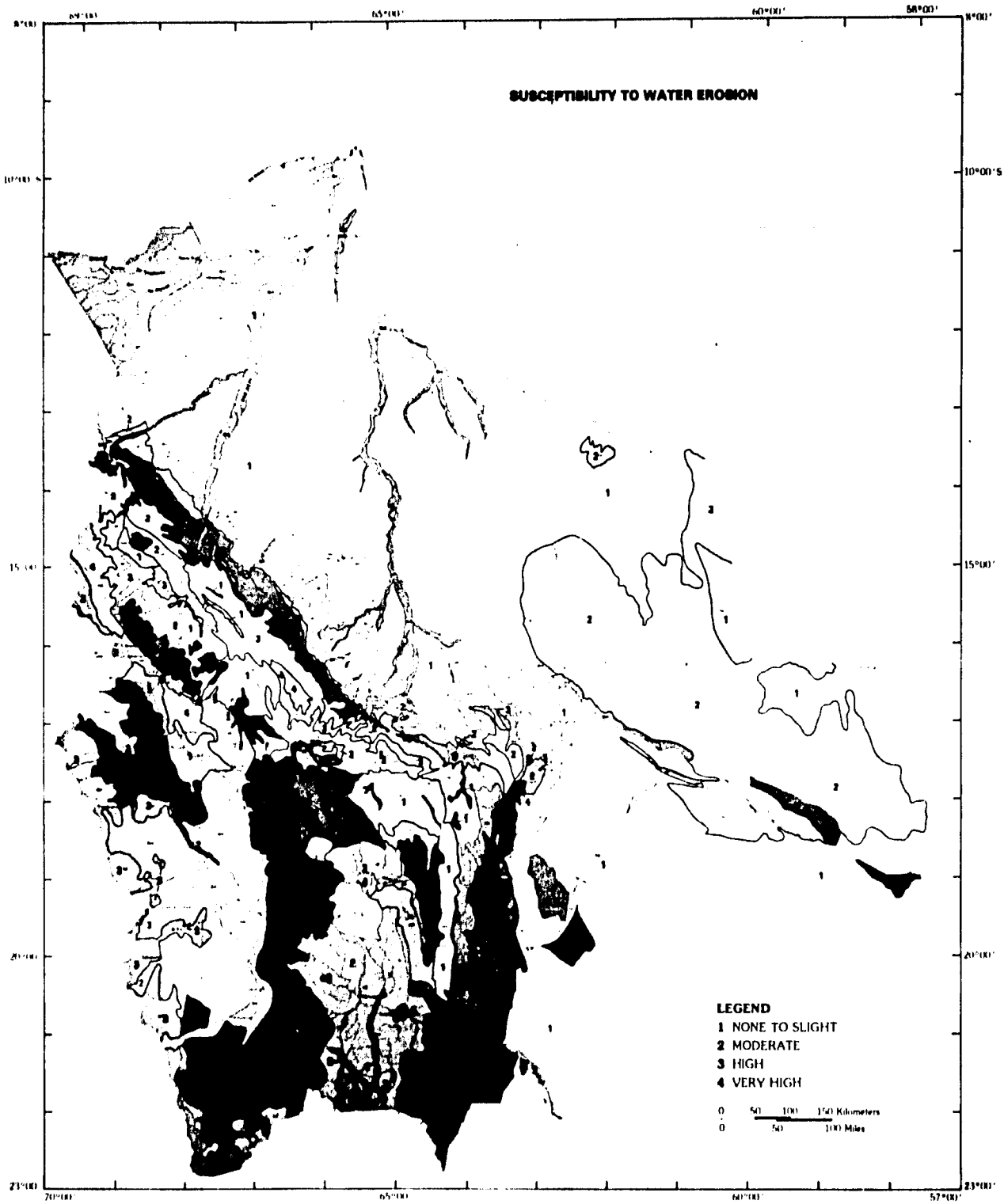


Figure 5-1. Susceptibility to Water Erosion

Base: *Mapa de los Sistemas de Tierras* (1974) by T. C. Cochrane

Gullied ridge top, resulting from animal traffic; near Cochabamba.

Land creep, slipping and, in foreground, gully erosion, on terminal moraine in Cochabamba valley.

There are 12 recognized forms of water erosion and all can be found in Bolivia. Seven of these forms can be placed in the "external" category, resulting from processes external to the soil. The remaining five forms are considered "internal," because the processes operate within the soil itself.

The external forms include:

- **Sheet erosion**—detachment of soil particles by raindrop impact and removal by overland flow
- **Rill erosion**—removal of surface and subsoil material in narrow, perpendicular channels, like a series of incisions across a field
- **Gully erosion**—removal of upland soil and material, and formation of channels by a concentrated flow of water
- **Streambank erosion**—removal of material by stream channel banks caused by the force of flowing water and caving of streambanks
- **Stream channel degradation**—removal of channel bed materials and downcutting of natural stream channels
- **Floodplain scour**—erosion of the floodplain surface by flood flows
- **Valley trenching**—formation and enlargement of a well-defined channel in a flood plain or other alluvial deposit.

The internal forms include:

- **Mud flows**—the simplest effect of water within a soil, producing saturation of an upper layer after very heavy rain, and transforming the mass into a viscous liquid that flows downhill
- **Soil creep**—the slow, jerking movement of a thin, superficial film of soil towards the bottom of a slope
- **Underground erosion**—an internal erosive action by water on certain categories of soils and rocks, acting by means of disintegration and underground circulation
- **Landslips**—a mass of material slipping along a super-saturated layer downslope causing a separation recess

- **Landslides**—loss of stability of a mass of earth or rock after undermining at the base.

There are various damages caused by these erosion forms, which include:

- Reduction in soil productivity
- Sediment production
- Land loss
- Land depreciation
- Structural and road damages
- Lowering of water tables.

In the dry Southern Altiplano, wind erosion is a serious problem. Also, south of Santa Cruz, approximately 200,000 hectares are affected by wind erosion, and it is believed that less rain now falls as a result (Derpsch, 1975).

All three wind erosion forms occur in Bolivia:

- **Dunes**—accumulations of sand or coarse material in the form of small hillocks which can shift from place to place

- **Accumulations**—advancing fronts of windblown materials of considerable width

- **Tongues**—elongated movements of sand and suspended material.

Dunes can be seen near the city of Oruro. Tongues of sand are extensively seen south of Santa Cruz.

The effects from wind erosion include:

- Health damages to humans and animals
- Structural damages to buildings, roads, fences, etc.
- Crop damages
- Soil damages.

Governmental Actions to Control Erosion

The national government has made no response to the problem of erosion, and none is planned. However, at the regional or departmental level, several steps have been taken. The most visible is the land rehabilitation program in Tarija.

Land Rehabilitation in Tarija

Tarija is the only place in Bolivia where a special effort is being made to control erosion and rehabilitate lands degraded by erosion. Efforts are focused on the 250,000 hectare Tarija Valley, 70% of which is affected by erosion. As a result, only 40,000 hectares in the valley are now under cultivation.

Erosion is spectacular in Tarija because the valley consists of lake sediments which are rapidly invaded by gullies. Tarija also contains the most fertile soils. Grapes, sugar cane and cotton are important cash crops of the valley.

In February 1978, an autonomous agency called the Programa Ejecutivo de Rehabilitacion de Tierras en el Departamento de Tarija (PERTT) was created through an interinstitutional accord for the purpose of recuperating eroded lands in Tarija Department through reforestation, agroforestry, and associated land treatment techniques. Details of PERTT's program, accomplishments, and the erosion problems in Tarija Valley are set forth in PERTT's planning document, *Plan Operativo, 1979.*

PERTT's first year budget (from MACA's CDF) was $3 million (Bolivian dollars). PERTT has an office and a technical staff of seven in Tarija, directed by Ing. Fernando del Carpio, a forester graduate of the Tarija Forestry School. Three nurseries with a total capacity of 2 million plants were developed by CODETAR and passed to PERTT. The program also has a D6 Caterpillar tractor, two jeeps, and a dump truck.

PERTT's short-term objectives are to develop an operational program, identify land rehabilitation methods, and promote land rehabilitation among land owners. In the long-term, PERTT aims to achieve an "ecological equilibrium" in the Tarija Valley, set criteria for land use and land management, bring degraded lands back into production, train technicians, and offer technical assistance to land owners. 1:5,000 aerial photographs have been used to plan work and diagnose the valley's erosional problems.

Three pilot areas have already been developed which demonstrate different techniques of land rehabilitation in gullied areas. The techniques involve fencing, small earthen check dams, bench terraces, contour terracing, land leveling and smoothing, reforestation and establishment of ground cover.

Small ponds have formed behind the earth check dams and some have been stocked with ducks. Wild mergansers were seen in one. No natural regeneration of annuals has been observed in the gullied areas. (The University of Tarija is monitoring natural regrowth in separate plots.) Tree species such as *Parkinsonia, Propsopis alpataco, Acacia cavens,* and *Eucalyptus cladocalix* (a forage species from Chile) have been planted. A severe frost in 1978 killed many of the trees that had been started, however. Sorghum, Atriplex (also stock from Chile), and *Chlorix guyana* were tried in the 1978/79 season for ground cover. The total cost of these various works averages $1,000 per hectare.

Results of the first year of work are very promising. The small ponds formed behind the earth dams

Gully, Tarija Valley.

San Jacinto Sub-watershed, Tarija Valley.

Typical rural home, Tarija.

Gullied area smoothed and with hand terraces; small earth dam with pond stocked with ducks.

are very attractive to the rural folk in this dry region. Small-scale drawdown farming seems feasible, but has not yet been tried. Ducks seem to thrive, and tree and ground cover growth is good in the eroded soils, indicating that rehabilitation is likely to be both economically attractive and technically feasible. Ing. del Carpio suggested that rehabilitation and gullied areas could be achieved by settling families on small farms of several hectares after treatment, with maintenance responsibility being passed to the settler. This method parallels trends in social forestry in India and Africa, in which families are given tenure or use rights in exchange for management. It is probably the best social solution for the problem of over-grazing by goats and sheep.

The experience gained during the first year of PERTT indicates needed changes and improvements. A soil scientist and soil conservation expert must be included on the staff. Sociologists or social anthropologists are also needed to shape outreach and extension work. Research on cropping systems and on different kinds of ground cover must be expanded. Plant cover for gully sides must also be tested, or some physical alternative for their stabilization must be developed. Finally, the emphasis of the technical intervention must be broadened from reforestation to agricultural land uses in the rehabilitated areas.

PERTT has begun to receive assistance from the World Food Program to support labor-intensive works, such as contour terracing. The UNDP has funded a 2-year technical assistance effort for 1978-1980 and assistance may be extended to 1981 or 1982. West Germany's help has also been requested. World Bank assistance in the preparation of studies for the San Jacinto dam and power plant can be added to the list. If this project is carried forward, the upper catchment (one of four catchments in PERTT's program area) will require priority attention. The World Bank has recommended raising the height of the dam to 1890 meters in order to ensure at least 50 years of dead storage (personal communication with Hugh Murphy, IBRD). In its present form the project does not include development or conservation in the upper catchment (part of which is susceptible to severe gully erosion and part of which is already gullied). However, work in the catchment to control erosion and runoff is considered by PERTT to be essential to the success of the dam.

Desertification

Two projects were being discussed or finalized in September 1979 concerning desertification. The first is a UNDP project for arresting and treating desert spread (BOL 78/013). Funding of $100,000 has been approved for a 1-year preparatory phase (1979-1980).

UNEP is taking steps to initiate an international desertification monitoring program which would involve Bolivia. The monitoring would be organized by regions, and Bolivia is a member of the South American region. A meeting of a special consultative group was to be held in late 1979 to discuss the program and its financing.

Watershed Conditions and Watershed Management

Except for the small San Jacinto hydropower project in Tarija Valley, no existing or planned hydropower project in Bolivia was found that explicitly includes consideration of watershed conditions and a concern for watershed management.

However, the concern for flooding in urban areas has apparently expanded to include awareness of watershed conditions. Torrential flooding accompanied by debris flows, land slips, and rock falls affects La Paz. In Cochabamba, much of CORDECO's annual budget is devoted to flood control and flood relief. The watershed protection role of the Tunari National Park above Cochabamba is widely recognized.

Concern for flooding and sedimentation of the Pirai River, on which Santa Cruz is located, has sparked a reforestation effort near Valley Grande in the upper watershed. In Oruro, yearly flooding of Lago Uru Uru is attributed to excessive runoff in the headwaters of streams feeding the Desaguadero River.

However, at the national level of government, a concern for watershed management was not found.

Because of the great elevation of the Andean Cordillera, the heaviest rainfall occurs in the middle and lower valleys of rivers that drain the eastern Andean front. It is in these sections, rather than the uppermost catchments, where vegetative cover is needed to buffer rain and prevent erosion. Still, extreme degradation of vegetation in the high catchments can lead to runoff problems, as experience in La Paz demonstrates.

The Zongo Watershed

This watershed illustrates some of the unique characteristics that may influence hydropower projects in the high Cordilleras of Bolivia and the attendant watershed management considerations. A system of small power plants located in the valley generates all of La Paz's electricity. Because the watershed is entirely controlled by the Bolivia Electric Power Company, land use is also controlled.

The Zongo River arises on the Eastern slopes of the Cordillera Real on snow-capped Mt. Condoriri,

north of La Paz. From this 5,680 meter peak, the river descends down a very steep valley and through the Yungas to empty into the Beni River. Its watershed vegetation ranges from alpine tundra to lowland tropical wet forest. However, the hydropower plants are all located above Coroico, between 3,000 and 4,600 meters.

Over-grazing is the principal threat to the upper watershed. The highest and steepest portions of the valley are above the tree line, which begins in this valley at approximately 3,800 meters. Attempts to grow Monterey pine (*Pinus radiata*) at 4,300 meters in 1979 failed due to frost kill in July. However, in the enclosure prepared for the pines (near the first generating station), grasses reached 40 cm and presented a thick carpet of dry matter, unlike the surrounding overgrazed range.

At 4,000 meters, potato and oca cultivation is apparent, but relatively little of this valley land is devoted to farming. Glaciated erosion forms terminate at approximately 3,800 meters. Below the terminal moraine, the first signs of woody vegetation are seen, and there are a few tall eucalypts at 3,700 meters near a small community. At this point, the valley assumes a V-shape and appears to have a steeper gradient. The lushness and diversity of the vegetation in the valley rapidly increase below 3,300 meters. Large specimens of *Cupressus* and eucalypts were seen. Valley sides close to form a gorge at this elevation; below the elevation, rainfall surpasses 2 meters per year and reaches more than 4 meters at elevations between 1,000 and 2,000 meters. Thus, in the Zongo (as well as in other valleys on the eastern slopes of the Cordillera Real) land use is extremely limited (down to 3,000 meters) by cold, steepness, and humidity. Although land use is limited, sheet erosion is occurring due to over-grazing.

Erosion and consequential reservoir sedimentation are not a concern to the power company. Almost all the water used for power generation is obtained from snow melt, impounded in the Zongo Lake immediately below the glaciers at about 4,700 meters. The water is passed from plant to plant through a system of tunnels, canals, and small regulating dams in what is essentially a run-of-the-river system of generation, made possible by the very steep gradient of the Zongo River. (Nevertheless, a small check dam at 4,180 meters just above the terminal moraine was observed to be completely full of sediment. Over-grazing of surrounding slopes was very evident.)

The engineers in charge of the project consider that this system could be repeated in other valleys. This unique and fortuitous combination of factors explains, in part, the lack of perception of watershed management as essential to hydropower projects.

Assessments of Critical Watersheds

Other hydropower projects may not share the same characteristics as the Zongo development; consequently, watershed management may be more crucial to their success. The general locations of these projects were provided by the Direccion Nacional de Electricidad (Min. de Energia y Hidrocarburos) but the characteristics of their reservoirs or other engineering works were not described.

A comparison of the locations of these works with the erosion susceptibility analysis is shown in Table 5-2. The comparison was made subjectively, in terms of the criticality of their watersheds.

Table 5-2. Evaluation of Watersheds with Hydropower Plants

Watersheds with Power Plants	Rating of Watershed (on basis of erosion susceptibility)
Present	
Rio de La Paz	Most critical
Zongo	Critical
Kami	Critical
Miguilla	Less critical
Corani	Less critical
Rea Rea	Less critical
Tullma	Less critical
Ruffo	Less critical
Yura	Less critical
Totora	Less critical
Panata	Not critical
Proposed	
Pilaya	Most critical
San Jacinto	Critical
Pilcoayo	Critical
Rio de La Paz	Critical
Misicunni	Less critical
Miguilla	Not critical
Corani	Not critical
Rio Grande	Not critical

Recommendations

National Erosion and Sedimentation Survey

Only subjective information exists on erosion in Bolivia, with the exception of the Tarija Valley. Quantitative data on the erosion problem — its forms, extent,

soil losses and loss tolerance levels, and physical and economic losses resulting from erosion — do not exist. Without quantitative data at some appropriate level of approximation, a national response to erosion cannot be articulated and designed.

While some data on sediments has been collected, an over-all understanding of sedimentation is lacking. A national sedimentation survey would bring together existing information, obtain new measurements, and determine sediment yields, gross erosion and delivery ratios, siltation rates in reservoirs, flood plain and structural damages, and other data necessary to assess and respond to serious sedimentation problems.

It is estimated that 30 person-months of technical assistance and transportation, instrumentation and laboratory access would be necessary for both erosion and sedimentation surveys. The Altiplano Valleys and cleared Yungas would be priority areas for erosion surveys; critical catchments should get first priority for sedimentation surveys.

Erosion Control Demonstrations

Demonstration of erosion control is being supported by AID in Lesotho, and more recently in Jamaica. In Bolivia, activities could be developed at centers located near or in communities. These centers would carry out research, demonstrations, education, and training.

Model Management Plan for Two Important Watersheds

Important watersheds would be those supplying water to major public works or other developments downstream, which are susceptible to erosion. A preliminary identification of critical watersheds is made in Table 5-2. (The definitions must be further refined through field verification.)

The overriding social and economic importance of the hydrological role of critical watersheds justifies a special effort at coordinating and guiding land use. Land use zoning, restrictions on use, special conservation structures and techniques, and reforestation or establishment of permanent ground cover in certain areas are some of the measures that may be needed. An overall plan must be developed to determine needs, select measures, and finance, organize and implement management efforts.

It is recommended that two model plans be developed — one for a critical watershed in the Valleys area of Bolivia, and one in the Yungas. The Tarija Valley experience already underway could be viewed as a model for the Valleys, but current plans have focused only on rehabilitation of gullied areas and arresting headward erosion of gullies. This plan could be expanded to include entire watersheds, or sub-watersheds. A strategic opportunity for such a model would be the San Jacinto subwatershed in the Tarija Valley.

Two initiatives for the Yungas could provide opportunities for planning: Caquiahuaca, where CORDEPAZ is proposing a regional park, and Valle Grande, on the Pirai River watershed where the Santa Cruz-based Programa de Plantaciones Forestales has already begun reforestation efforts in order to control flooding.

The establishment of an institutional framework for the planning may require special effort in the initial phases. In the evolution of a foreign assisted project, this might be accomplished in the early planning phases. For instance, in the Project Identification phases in AID's project cycle, this could be accomplished by means of a workshop which reviews the results of this report and field verification of critical watersheds and explores the institutional implications for subsequent planning and action. Currently, the only institutional model which exists is that of PERTT in Tarija. Special conditions at Tarija suggest that other solutions may have to be considered for watersheds with different environments and management needs.

Approximately 5 person-months of technical assistance in preliminary project design will be needed. A five-step procedure is suggested to prepare model work plans. The first step could be accomplished in the design phase for a technical assistance project in support of this activity.

The five steps in the development of a model watershed work plan are those used in the highly successful FAO/UNSF watershed management project in Korea (FAO, 1969). These include the following:

- Review of available data, selection of watersheds
  - Study of existing watershed maps, aerial photos and pertinent data
  - Field inspection trips and discussions with national and local technicians
  - Selection of watersheds based on consideration of certain factors
- Collection and inventorying of physical and economic data in watersheds
  - Soil surveys and geological investigations
  - Hydrological and meteorological investigations
  - Flood studies
  - Agricultural economic studies
  - Agronomic studies
  - Ground-surveys for map control purposes
  - Engineering surveys

- Analysis and interpretations of data
  - Physical data
  - Economic data
  - Photogrammetric data
- Preparation of interim report and work plans for pilot demonstration areas
- Preparation of watershed work plans.

Training for Erosion Control and Watershed Management

Presently in Bolivia there are no opportunities for technical education in soil conservation and watershed management, except the Forestry School in Tarija, where Ing. Fernando del Carpio of PERTT gives several classes on soil conservation and land rehabilitation.

More course work needs to be offered at existing institutions, particularly the Forestry School in Tarija and the University in Cochabamba. At the same time, the immediate deficit in trained technicians must be remedied through special courses and on-the-job training. On-the-job training could be provided at the erosion control demonstration centers proposed earlier.

Presently, there are no periodic short courses in erosion control or watershed management in Latin America. Special courses would have to be established. A traveling seminar is suggested. Subject matter should include Bolivia's problem areas and present examples in neighboring countries of erosion control techniques. Long-term training in Spanish could be pursued in Venezuela (CIDIAT), Turrialba (CATIE), or Spain. In the U.S., the University of Arizona and Utah A+M University offer course work in watershed management.

National Program for Conservation Education

Conservation of soils and other natural resources is not a part of educational programs in Bolivia. However, there is wide agreement on the need for this type of education. As an illustration of program content, two documents were presented to the Direccion de Ciencia y Tecnologia (Ministerio de Planification y Coordinacion Economica): (1) Conservation Education in Developing Countries (manuscript by Robert D. Flannery, May 1979), and (2) A Proposal for a Southern Africa Center for Education, Research, and Demonstration in Natural Resources Conservation and Management (document prepared by Robert D. Flannery for the Lesotho Agricultural College).

VI. ALTIPLANO RANGE

Altiplano Range

Introduction

Very little work has been performed on range in the Bolivian Altiplano. That work which has been done—principally measurements of productivity in caged enclosures—indicates that the Altiplano is potentially one of the richest, most productive grasslands in the world, rivaling or exceeding the best natural range in the western United States. However, this research has been overlooked due to lack, until recently, of trained range scientists in MACA, and due to lack of applicability of research observations to the land use patterns and community life of the Aymara and Quechua peoples in the Altiplano. Most planning documents view the Altiplano as cold and infertile

This chapter reviews the significance of range as a natural resource, the characteristics of Altiplano grasses and their agricultural potentials, and the present condition of rangeland.

Definitions

The complete meaning of range is not conveyed by the terms *pastos naturales*

Range is defined as the vegetation occupying water-limited areas that are not cultivated Rangeland differs from forestland in that water limits the number of trees. Areas that were once forested can become rangelands through erosion; rangelands can become true deserts by the same process

In the Bolivian Altiplano rangelands are found extensively at elevations above 4000 meters, and at lower elevations where conditions are dry, steep, or rocky. However, in the more humid, cultivated northern Altiplano where farmlands and rangelands merge, fallowed fields also function as a range resource The native species which spontaneously regenerate on farmlands offer an important contribution to the total range resource. An overview of range resources and range management must therefore include these fallowed areas.

Range Science is the study of water-limited vegetation (grasses, forbs, shrubs) in an ecological framework.

Range Management is vegetative management in water-limited areas to protect the soil resource while maintaining or improving the livelihood of people. Therefore, range management is the ecological pivot point between the soil resources and the goods resulting from these resources. In Bolivia's unique Altiplano environment, range management fulfills a key role in erosion control and the maintenance of soil productivity for agricultural uses.

Range Characteristics and Potential in the Altiplano

Range potential for the highlands cannot be quantified exactly due to lack of necessary data However, the relative potential of the highlands can be assessed from a review of the physical and climatic data, history of use, botanical composition, exclosures from use, and range studies

Characteristics

The highlands are an oval-shaped area extending from Lake Titicaca to Argentina and Chile covering abut 210,000 km² The Altiplano is the western north-south segment which lies between two cordilleras and occurs over about 172,000 km² The passes through the eastern north south range lead to a series of high valleys that fall rapidly in elevation from the average Altiplano elevation of 4,000 meters (Lebaron et al, 1979)

All the highland areas have a pronounced dry season that lasts over 6 months However, conditions in the northern Altiplano are much more humid than the southwestern portion (Figure 6 1), with rains concentrated December to February Hail is common and a threat to crops

In the mountains and the high elevation areas of the Altiplano, frost is a common occurrence. Both in the Altiplano and the highest parts of the valleys, it is possible to have frost every month of the year (Lebaron et al, 1979) However, the greatest proportion of the Altiplano experiences frost 112-192 days a year, with the northern region experiencing the least and the southern region the most (Cardozo, 1970).

The climate and physical characteristics make the highlands well suited to range production. Parker (1979) states that the proximity of Bolivia to the

equator (15°S), plus the extreme variations in elevation and precipitation, endows the highlands with a wealth of botanical resources. More than 100 valuable livestock forage species have been identified. Further, Parker (1974) states it is relatively easy to find native rangeland pasture and watershed species that are superior, in terms of palatability and productivity, to the ecological equivalents in the United States. An example of this is 'Big Bluegrass' (*Poa ampla*), one of the best native grasses in the 11 western U.S. states for yield and soil stabilization, growing to a height of 0.55 meters. An equivalent grass of the Altiplano, *Poa aff. pardoana*, grows to nearly twice that height and is equally palatable to livestock.

The Inca Empire was extremely wealthy because of its rangelands and the rangelands were protected as if they were gold. Condarco (1970) states that during the Incan Empire, about 80% of the population of the Bolivian Altiplano raised llama and alpaca in an extensive, seasonal grazing system. Grazing was the principal production system because edaphic and climatic constraints limited agricultural production and the presence of extensive grassland area was well suited for animals.

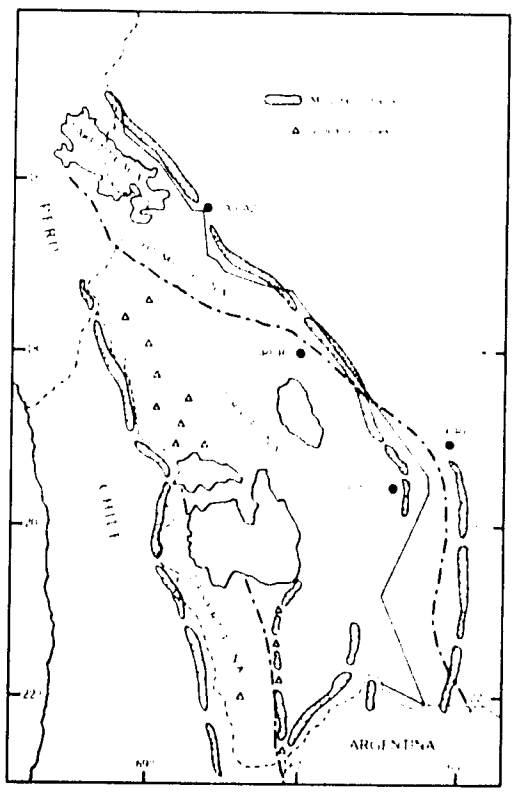


Figure 6-1. General Climatic Zones of The Bolivian Altiplano (Puna) (Cabrera, 1968)

The Indians of the Altiplano seemed to the Europeans to be extraordinarily wealthy. The "secret" to this wealth was thought by the Europeans to be the hundreds of thousands of alpacas and llamas grazing on the Altiplano. This mistake of thinking animals, not grass, are the "secret" to wealth, was not made by the Incas. Moore (1958) points out that, during the Inca's reign, the penalty for cutting grass without permission was death.

After centuries of abuse and overuse, the potential of the Altiplano's range is not apparent. Over-grazing has dramatically changed range quality and drastically reduced production.

Research on Range Potential

During 1974-1976, Dr. Karl Parker of Utah State University studied productivity of the Altiplano range under AID sponsorship. In addition to setting up caged enclosures, Dr. Parker investigated range pitting and furrowing, organized a range plant herbarium with 1,500 plants, and facilitated scholarships for range science studies at USU. (Seven reports contain the results of Parker's work; they are available in La Paz in the office of Dick Peters, an AID Agricultural Development Officer.) Other work by USU technicans focused on enhancing the quality of native sheep, improving their management for commercial production, and developing markets for wool and meat products.

Forage production has also been measured at Belen and Patacamaya Research stations in the Altiplano. One of the graduates from USU, Humberto Alzerreca, based his recent thesis on the range resource potential of Bolivia.

However, in general, range research is almost non-existent. Clipping and botanical work are conducted by IBTA at stations in Belen and Ulla Ulla, near Lake Titicaca, and at Patacamaya between La Paz and Oruro. (Dr. Mario Tapia of IBTA has a Ph.D. in range science from Colorado State University, but is not working directly in the field.) Four technical persons work on range research, including Sr. Humberto Alzerreca (recent USU graduate in range science), Sr. Raul Lara, botanist, and two "tecnicos." Sr. Alzerreca has neither a vehicle for field work nor a budget for travel expenses. Nevertheless, Alzerreca and Lara have prepared a first inventory of Altiplano range species (Table 6-1).

Range Potential

Parker (1974) concluded that the ambient condition of the Altiplano favors quadrupled production of

Table 6-1. Caracteristicas de Algunas Forrajeras-Nativas Del Altiplano (Lara and Alzerrela, 1976)

Nombre Científico	Nombre Comun	CARACTERES IMPORTANTES			ECOLOGIA				Respuesta ecológica al pastoreo	Valor forrajero.	Protección contra erosion	Influencia en Cuencas
		Forma	Tamaño cm.	Duración	Altura sn/m.	Suelo	Topografía	Drenaje				
Fam: Caryophyllaceae Picnophyllum molle Remy	Coca de vicuna Huari Coca	Pulvinado	1-5	Perenne	3 800-3 500	Variable	Variable	Medio	Incrementa	Regular	Medio	Negativo
Fam: Compositae: (Asteraceae) Parasthrephya quadrangulare (Meyen) Cab	Thola	Subfrutice	40-80	Perenne	3 800	Arcilloso	Plano	Bueno	Incrementa	Regular	Medio	Positivo
Baccharismi chrophylla H B K	Kerhua thola	Subfrutice	50-150	Perenne	3 000 4 000	Variable	Variable	Bueno	Incrementa	Regular	Medio	Positivo
Fam Cyperaceae Carex nebularun Phil	Ajsa	Pulvinado	10-15	Perenne	3 800	Variable	Variable	Pobre	Incrementa	Regular	Medio	Positivo
Carex sp	Serci pasto	Erecto	10-30	Perenne	3 800	Variable	Variable	Pobre	Incrementa	Regular	Medio	Positivo
Scirpus rigidus (Steud) Boeck		Erecto	5-10	Perenne	3 900	Areno Pedregoso	Variable	Medio	Incrementa	Regular	Medio	Positivo
Fam: Chenopodiaceae: Atriplex cristata H.& B.	Ullpuyuyo	Decumbente	10-30	Perenne	3 700	Alcalino Arcilloso	Plano	Pobre	Decreciente	Bueno	Alto	Positivo
Suaeda fruticosa (L) Forsk	Cauchi	Erecto ramificado	10-30	Perenne	3 900	Alcalino Arcilloso	Plano	Regular	Decreciente	Bueno	Alto	Positivo

Table 6-1. Caracteristicas de Algunas Forrajeras-Nativas Del Altiplano (Lara and Alzerrela, 1976)
Table 6-1. (Continued)

Nombre Cientifico	Nombre Comun	Caracteres Importantes			Ecologia				Respuesta ecológica al pastoreo	Valor forrajero.	Protección contra erosion	Influencia en Cuencas
		Forma	Tamaño cm.	Duración	Altura sn/m.	Suelo	Topografia	Drenaje				
Fam: Geraniaceae: Erodium cicutarium (L.) L' Herit ex Ait.	Alfilerilo reloj-reloj	Procumbente	3-6	Anual	3.000 3.900	Variable	Variable	Bueno	Invasor	Regular	Medio	Positivo
Fam: Genetaceae: Ephedra americana H.B.K.	Sanu-Sanu	Erecto	2.5	Perenne	3.700 4.400	Variable	Variable	Bueno	Decreciente	Bueno	Alto	Positivo
Fam: Gramineae: (Poaceae) Aciachne pulvinata Benth	Paco-Paco	Pulvinado	5-10	Perenne	3.800 4.000	Variable Arcillo	Variable	Bueno	Incrementador	Bueno	Alto	Positivo
Agropyron attenuatum (H.B.K.) Roem & Schult	Toja	Erecto Procumbente	30-70	Perenne	3.800 4.000	Areno-Arcilloso	Quebrada	Bueno	Decreciente	Bueno	Alto	Positivo
Aristida adscancionis L.	Caballo huchinca	Erecto	30-60	Perenne	2.900 3.900	Arcilloso superficial	Quebrada	Bueno	Incrementador	Regular	Medio	Positivo
Aristida asplundii Henr	Yawarilla	Decumbente	2-5	Perenne	3.500 4.000	Degradado	Plana	Regular	Incrementador	Pobre	Alto	Positivo
Fam: Gramineae: (Poaceae) Bouteloua simplex Lag.	Llapa	Decumbente	1.5-5	Anual	2.500	Degradado	Plana	Bueno	Invasor	Pobre	Bajo	Negativo
Bromus lanatus H.B.K.	Cebadilla	Semi erecta	15-80	Perenne	2.500 4.300	Organico	Serrania	Regular	Decreciente	Bueno	Medio	Positivo

Table 6-1. Caracteristicas de Algunas Forrajeras-Nativas Del Altiplano (Lara and Alzerreia, 1976)
Table 6-1. (Continued)

Nombre Científico	Nombre Común	Caracteres Importantes			Ecologia				Respuesta ecológica al pastoreo	Valor forrajero.	Protección contra erosion	Influencia en Cuencas
		Forma	Tamaño cm.	Duracion	Altura sn/m.	Suelo	Topografia	Drenaje				
Bromus unioloides H.B.K.	Cebadilla	Variable	10-90	Anual o Perenne	2.500 4.300	Variable	Variable	Regular	Decreciente	Bueno	Alto	Positivo
Calamagrostis heterophylla (Wedd.) Pilg	Konkor-Kara	Erecta	10-60	Perenne	3.000 4.500	Variable	Variable	Regular	Decreciente	Bueno	Medio	Positivo
Calamagrostis vicunarum (Wedd) Pilg.	Crespillo	Erecta	10-30	Perenne	3.000 4.500	Variable	Variable	Bueno	Decreciente	Regular	Medio	Positivo
Distichlis humilis R.A. Phil	Orkochiji	Decumbente	2-6	Perenne	3.800	Alcalino	Plano	Regular Pobre	Incrementador	Regular	Alto	Positivo
Eragrostis sp.	Tonkotonko	Erecto	15-30	Anual	3.800	Variable	Serrania	Bueno	Decreciente	Bueno	Medio	Positivo
Festuca dolichophylla Pilg	Chillihua	Macollo denso	30-110	Perenne	3.500 4.500	Variable	Variable	Medio	Decreciente	Bueno	Alto	Positivo
Festuca orta phylla Pilg	Paja brava	Macollo denso	30-70	Perenne	3.800	Arenoso degradado	Variable	Medio	Incrementador	Pobre	Medio	Negativo
Festuca riges cens (Presl.) Kunth.	Paja-brava	Macollo denso	30-70	Perenne	3.800	Degradado	Variable	Medio	Incrementador	Pobre	Medio	Negativo
Hordeum muticum. Presl.	Cola de raton	Erecto	30-45	Perenne	2.900 4.000	Alcalino	Plano	Pobre	Decreciente	Bueno	Alto	Positivo
Muhlembergia fastigiata (Presl) Henr.	Cachu Chiji	Decumbente	3-8	Perenne	3.000 4.000	Variable	Variable	Pobre	Incrementador	Regular	Alto	Positivo

Table 6-1. Caracteristicas de Algunas Forrajeras-Nativas Del Altiplano (Lara and Alzerreia, 1976)
Table 6-1. (Continued)

Nombre Cientifico	Nombre Comun	Caracteres Importantes			Ecologia				Respuesta ecologica al pastoreo	Valor forrajero.	Proteccion contra erosion	Influencia en Cuencas
		Forma	Tamano cm.	Duracion	Altura sn/m.	Suelo	Topografia	Drenaje				
Muhlembergia peruviana (Beauv.) Steud	Napa	Erecto	3-8	Anual	3.000 4.000	Variable	Ondulado	Bueno	Incrementador	Pobre	Bajo	Negativo
Nassella meyeniana (T & R.) Parodi	Pasto-Pluma Yawara	Erecto	30-100	Perenne	3.500 4.000	Aluviales	Ondulado	Pobre	Decreciente	Regular	Medio	Positivo
Paspalum pygmaeum Hack	Cachu Chiji	Variable	3-6	Anual	3.500 4.000	Aluviales	Ondulado	Pobre	Decreciente	Regular	Medio	Positivo
Pennisetum chilense (Desv.) Jacks ex R.E. fries		Erecto	15-100	Perenne	3.000 4.000	Arenoso	Serranias	Medio	Decreciente	Variable	Alto	Positivo
Poa buchtienii Hack		Macollo denso	40-100	Perenne	3.600 4.400	Variable	Serrania	Medio	Decreciente	Bueno	Alto	Positivo
Poa candamoana Pilg	Chachua	Semi-erecto	20-60	Perenne	3.800	Variable	Serrania	Bueno	Decreciente	Bueno	Alto	Positivo
Poa gymantha Pilg	Grama	Erecto	15-25	Perenne	3.500 4.000	Suelto organico	Serrania	Medio	Decreciente	Bueno	Alto	Positivo
Poa horridula Pilg		Macollo denso	30-80	Perenne	3.500 4.000	Variable	Serrania	Medio	Decreciente	Bueno	Alto	Positivo
Poa pardoana Pilg		Macollo denso	30-50	Perenne	3.500 4.000	Variable	Variable	Medio	Decreciente	Bueno	Alto	Positivo
Stipa ichu (R.&P.) Kunth	Ichu	Macollo denso	30-100	Perenne	3.000 4.000	Variable	Variable	Bueno	Incrementador	Pobre	Medio	Negativo
Stipa sp.	Yawara	Erecto	20-70	Perenne	3.800	Variable	Variable	Bueno	Decreciente	Regular	Alto	Positivo

Table 6-1. Caracteristicas de Algunas Forrajeras-Nativas Del Altiplano (Lara and Alzerreia, 1976)
Table 6-1. (Continued)

Nombre Científico	Nombre Común	Caracteres Importantes			Ecologia				Respuesta ecológica al pastoreo	Valor forrajero.	Protección contra erosion	Influencia en Cuencas
		Forma	Tamaño cm.	Duración	Altura sn/m.	Suelo	Topografia	Drenaje				
Fam: Juncaceae: Juncus bruneus Buch.		Graminiforme	20-40	Perenne	3.900	Húmedo	Variable	Pobre	Decreciente	Regular	Medio	Positivo
Juncus balticus Wild.		Graminiforme	20-30	Perenne	3.900	Húmedo	Plano	Pobre	Incrementador	Regular	Medio	Positivo
Fam: Leguminosae (Fabaceae) Trifolium amabile H. B. K.	Layu	Decumbente	5-15	Perenne	3.900	Profundo	Plano	Bueno	Decreciente	Bueno	Alto	Positivo
Medicago denticulata Willd	Carretilla	Decumbente	5-15	Perenne	3.900	Variable	Plano	Bueno	Decreciente	Bueno	Alto	Positivo
Astragalus Garbancillo Cav.	Garbancillo	Erecto	20-40	Anual	3.700	Variable	Variable	Bueno	Invasor	Tóxico	Bajo	Negativo
Fam: Plantaginaceae Plantago Sericea R.&P.		Rosulada	3-5	Perenne	3.900	Variable	Variable	Bueno	Incrementador	Regular	Bajo	Negativo
Fam: Rosaceae: Lachemilla Pinnata (R. & P.) Rothm	cillo cillo	Decumbente	2-4	Perenne	3.900	Aluvial	Variable	Medio	Decreciente	Bueno	Medio	Positivo

range vegetation. This figure was based on 55 caged enclosures in seven different extensive range sites. In some cages, 2 years of protection resulted in ten times the production of uncaged areas. Production over 8 metric tons (air dry) per hectare were recorded. In addition, species composition within the cages changed from less palatable and less nutritious species to more palatable, more nutritious species. In Tiwanaku, where a pre-Incan monument has been fenced for the last 15 years, the unpalatable *Stipa ichu* has virtually been eliminated while a more desirable species (for animal production, watershed protection, erosion control, and soil development) has increased dramatically (Table 6-2). The production at this site is 6,660 kg/ha, exceeding any range in the United States.

Resiliency and adaptability of the native species have been shown in the other range studies also. At Belen Research Station, native grasses yield heavily: *Hardium andriolu*, 2,320 kg/ha; *Nasella pubifloru*, 4,820 kg/ha; *Bromus catharticus*, 2,680 kg/ha; and *Calamagrostis* spp., 3,100 kg/ha (Cardozo, 1970). At the drier Patacamaya Research Station, Alzerreca (1979) found that after 4 years rest, the production on severely sheet and wind-eroded land had increased

slightly to 994 kg/ha, but the composition dramatically changed to a more favorable mix.

Considering the long history of overgrazing by sheep and cameloids, the resiliency and productivity of the Altiplano range is remarkable. Both climate and the high elevations are probably contributing factors. For example, plant growth at high altitudes is more efficient due to the large amounts of intense sunlight and the conservative evapotranspiration of plants. This has the direct effect of producing plants with broader leaves which in turn increases forage production (Parker, 1974). Generally, non-native species do not reproduce on the Altiplano, and the problem of exotics achieving a dominant "weed" status does not occur in overgrazed areas. With protection and rest, the original species mix will return. Therefore, weed eradication is not a need in the overgrazed areas of the Altiplano. As elsewhere in the world's ranges, it tends to be an expensive, time-consuming, and frequently unsuccessful battle.

Table 6-2. Composition and Production of Three Grasses at Tiwanaku (15-Year Enclosure)

Species	Herbage (kg/ha)	Composition (%)	Forage (kg/ha)
Festuca dolichophylla	6,630	94.6	6,300
Bromus uniloides	270	4.0	270
Stipa ichu	90	1.4	0
Total	6,660	100.0%	6,570

Source: Alzerreca, 1979.

Finally, the nutrient quality of the grasses of the highlands is good. Temperate grasses are higher in TDN (Total Digestible Nutrients) than tropical grasses because the cooler temperatures require the grasses to maintain a higher percentage of their nutrients in the form of simple sugars. In contrast, tropical grasses convert more of their nutrients into hard-to-digest fibers. The nutrient quality of the Altiplano grasses is high even in late winter (Table 6-1). One native highland grass, *Bromus uniloides*, has 19% crude protein, as high as well-handled alfalfa. Also, this range feed is available year-round.

These factors add up to represent a very high range resource potential in the highlands.*

* This potential is not exclusive to the highlands. Some areas of the lowlands are suitable for grazing and are a productive range resource.

Present Situation of the Altiplano Range

The Altiplano range is seriously overgrazed, and in some places degraded. The phenomenon of overgrazing must be understood in terms of the social and economic organization of the Altiplano Indian communities, since communal lands and individual properties are the basis for organizing land uses. Lebaron and his former AID colleagues analyzed their experiences in Bolivia during 1971 to 1977 and concluded that overgrazing is not the result of uncontrolled and competitive grazing on commons; rather, it is controlled and occurs collectively with community sanction (Lebaron et al, 1979). Thus, overgrazing is a tragedy resulting from a collective—rather than individual —decision, and from lack of alternatives.

Grazing System

Although the highlands range resource is heavily grazed, animal control is evident. Range utilization is uniform over the different land capability classes (from meadows to dry lands). This grazing uniformity of land with different potentials is a testimony of controlled grazing.

Communities control grazing in several ways (Dorsy, 1979):

- By placing limits on absolute numbers;
- By pre-season inspection to set number of weeks or or months of allowable grazing. Even daily grazing is never allowed to exceed 8 hours/day. The remainder of the day the animals are penned, which facilitates the manure gathering process;
- By setting numbers to the ability of the base property to carry animals during the non-grazing period.

Adherence to community dictates on grazing is undoubtedly made feasible by the sharing of wealth or surpluses. During the time of the Incas, the system of controlled grazing was based on a tradition of mutual aid and this system of mutual aid still exists. Families within the community will exchange labor, work for hire to obtain desired seed and/or special products, make arrangements to combine excess seed with excess land, practice sharecropping, give animals or fowls to those that suffer unusual losses, or give gifts to those that are unable to provide for themselves. However, in spite of mutual aid and grazing controls, the pressures to have large flocks which exceed the carrying capacity of the range remain great. These pressures arise from the following factors.

- The reproductive rate of the animals is only 50%. This means that twice the animals are needed to get a desired return. If a family needs 8 sheep to feed themselves, then 16 must be carried.
- Excess animals are traded or sold for goods and services. The more that goods are desired, the more animals must be grazed.
- A number of animals must be grazed to provide food for celebrations.
- Animals are subject to natural disasters and diseases and larger numbers are insurance against such risks. For instance, it is less risky for a family to lose 40% of 35 animals than to lose 20% of 15 animals.
- Animals serve as emergency food or cash during poor crop years. Frost can severely damage crops but produce little effect on the range resource; therefore, livestock production would be unaffected.
- There is social status in owning large flocks.
- Additional animals require little additional labor.
- The animals are a source of not only meat but milk, wool, and home fuel. The value of animal manure for fuel has probably been underestimated.

External economic incentive is not a factor. There is a demand for mutton in the urban or the semi-rural areas, but beef is the preferred meat. Mutton has a restricted, but steady, sale in the rural Indian markets (Draper, 1973). Although there is a good demand for llama and alpaca wool, the sale of cameloid meat in urban areas of Bolivia traditionally has been outlawed. Its consumption is shunned by non-Indians, and there are arguments that the meat is nutritionally inferior and carries diseases such as syphilis and trichinosis (Fernandez, 1978). However, in rural Indian communities, it commands a slightly higher price than mutton.

Sheep and Range Degradation

Compared to the native llamas, alpacas, and vicunas, sheep are very destructive of rangeland. Their hooves compact the soil more than the pads of the cameloids, and this added compaction reduces the soil's water intake (Cardozo, 1979). Sheep graze the range more selectively than the cameloids, which causes the preferred plants to be eliminated from the plant community and replaced by undesirable plants or bare ground (Alzerreca, 1978). Sheep convert the native range to meat less efficiently than the cameloids, and mutton is lower in protein and higher in fat than the meat of the cameloids (Fernandez, 1978). In addition, sheep eat the roots of plants; cameloids do not.

The poorly adaptive sheep may also have a higher mortality than the cameloid during years of drought. If this is true, Indians would need to retain greater numbers of sheep than cameloids to ensure the family's wellbeing during drought years.

Grazing Use of Fallowed Cropland

In addition to livestock production, the Indians of the highlands cultivate small plots of land for various crops. This crop production interacts with animal production. Potatoes, a principal crop, is subject to nematodes if grown in the same field successively for too many years. Therefore, Indian communities always have some fields lying fallow. When a cultivated field is fallow, animals are allowed to graze any growth without concern for maintenance of a vegetative cover on the soil. This type of system, although good for maintaining animals, increases erosion. This erosion must depress yields, but no study of this trend has been undertaken. Reduced water holding capacity due to loss of organic matter may be of equal or greater importance than actual physical soil loss. The effects of overgrazing and erosion on crop production need to be studied.

Recommendations

Communal, Subsistence Framework

The communal, largely subsistence nature of the rural population in the Altiplano, and the apparent overstocking of the range (and perhaps excessive crop production) can limit range conditions and potentials. Development and change—leading to more productive range and soil resource management in the Altiplano—must work with the communities and the surrounding environment in order to overcome the inherent limitations of management. Projects will have to be introduced at the community level and designed in terms of the total land and range resources of the ayllu. Research and trials now under way have not been designed so as to test the feasibility of application at the ayllu level.*

Improving agricultural production on ayllu lands is likely to be the key to improving range resources.

* Efforts at introducing innovations and results of experiments appear to focus largely on agricultural cooperatives, comprised of only a portion of an ayllu's farmers.

Forage production could insure against unseasonal drought or cold, and both limit mortality and increase reproductive rates by supplying better nutrition. This, in turn, could reduce the need to possess large numbers of animals.

It seems inevitable that practical trials must be designed for a number of "demonstration" communities. The total resource and food production system must be understood, both in terms of the social and economic organization and the physical environment.

Preliminary Research and Survey Agenda

- Survey of motives and incentives for maintaining large numbers of animals. We hypothesized that flocks can be reduced by greater crop production, more productive integration of range and cropland uses, preference for llamas and alpacas over sheep, and improvements in the fuel situation. Other values and factors must be reviewed, e.g., ceremonial uses or obstacles to markets for cameloid meat.

- Survey of carrying capacity of livestock rangeland and cropland for human nutritional needs in several ayllus.

- Investigation of the reasons for the herding of sheep, rather than cameloids, and the potential for their substitution by llamas and alpacas.

- Research and development of native range species and management systems, which are adapted to the combined agricultural and range use of the land resources. Examples of R&D are:
  - Use of mulch in fields to conserve water
  - Establishment of especially useful species on terrace walls and steeper field boundaries (e.g., forage and firewood species)
  - Trials with crop associations, planting dates, spacing, depth, and direction of rows
  - Production and management potential of bofedales (spring seeps)
  - Studies of native legumes and their properties/values
  - Preparation of range potential map(s) which includes ayllu boundaries
  - Trials with range improvement methods (resting, rest-rotation, pitting, furrowing, and combinations of these) and measurement of effects through paired watersheds (one treated and one not treated)
  - Trials with re-seeding
  - Studies of range utilization by different herbivores (composition of diet, forage intake, nutritive value, etc.)
  - Study of the effects of "flushing" of animals during critical reproductive periods on green native species
  - Use of range in drought periods by different herbivores, and the effect on the range.

VII. POLLUTION AND HEALTH IMPACTS

Pollution and Health Impacts

Introduction

This chapter reviews environmental problems and the human health consequences of pollution in cities and mining areas. Water supplies, air quality, solid wastes, sewers and sewage treatment, industrial pollution, disease vectors, pesticides, accidents, and other problems are reviewed and the impact of each is examined. Also, the response of the government to the various problems is evaluated.

The four major urban centers of Bolivia are La Paz, Oruro, Cochabamba, and Santa Cruz. Urban centers in Bolivia have not grown as rapidly as many other Latin American nations. Between 1950 and 1975 the total urban population (cities of 2,000 or more) grew from 1.0 million to 1.9 million, at a rate of 2.9%. The proportion of urban dwellers in the country was 33% in 1950 and 35% in 1975. One reason for the relatively slow urban growth was the agrarian reform initiated in 1952. Between 1975-2000, a 3.4% growth rate is expected for cities; during the same period, rural areas are projected to grow 2.1% (Bolivia, 1976).

Institutional Framework

Pollution Control

There are two institutional focal points for urban and industrial pollution control or management at the national level: the Division de Ingeniería Sanitaria (DIS) of the Ministerio de Prevision Social y Salud Publica (MPSSP), and the Instituto de Salud Ocupacional (INSO), also of MPSSP. Both are located within MPSSP's Departamento de Ecología. The DIS has the authority but very limited capability; in contrast, the INSO has capability, but no authority.

The Division de Ingeniería Sanitaria is charged with controlling air pollution; however, no staff or budget have been assigned to the task. DIS is also the national level body responsible for general sanitation, water supply, and sewage treatment works. DIS has a staff of 318. 150 people work on the enforcement of regulations on food sanitation and 168 people work on rural and basic sanitation. Rural and basic sanitation is concerned with small community water supplies, construction of latrines, and improvement of public markets and laundries.

An industrial pollution control program does not exist at the central governmental level. Although the plant manager at ENAF's Vinto refinery stated that international standards and practices are followed in air and water pollution control, the team's observations were to the contrary.

The Instituto de Salud Ocupacional (INSO) has a staff of 66 workers, equipment for sampling and analyzing air and water pollution, and the potential to monitor environmental pollution and community health. By law, it is obliged to charge for its services. There has been no "demand" for monitoring; however, 'one-time' surveys are done. For example, surveys of pesticides intoxication in Santa Cruz were contracted by private cotton growers. INSO is undoubtedly the best prepared organization in Bolivia to monitor pollution and its health impacts.

Comprehensive and coordinated planning for environmental health factors is not presently being conducted within the government. However, the present program emphasis on the water supply and sewage sector appears adequate.

The departmental and municipal levels of activity were not reviewed. However, the Department Development Corporations are developing industrial parks. Given the absence of a national level industrial pollution control agency, the DDC's are the key institutions concerned with non government industrial activity and its environmental effect.

Water Supply and Sewerage

Nineteen agencies are involved in developing water supplies in Bolivia. Five are national level; nine, local level, and five, international. The sector was recently reviewed by the Pan American Health Organization (PAHO, 1979) and the World Bank (IBRD, 1976). Despite a doubling of expenditures on water supplies between 1975 and 1978, large increases in urban populations have resulted in a static relationship between those with and without access to safe water.

Two central government departments are responsible for water supplies and sewerage systems: the Ministry of Housing and Urban Affairs (Div. de Infraestructura Urbana) (DIU) and the Ministerio de Prevision Social y Salud Publica (Division de Ingeniería Sanitaria). The latter is concerned only with rural sanitation

services, including small community water supplies.

A national plan for water supplies and sewers being prepared by the DIU was 75% complete in late 1979.

In 1976, the World Bank lent Bolivia $11.5 million to improve and extend water supply in approximately 70 rural communities and two cities, and extend sewerage in Sucre. AID recently lent $4.0 million to the Ministerio de Prevision Social y Salud Publica to build 200 small water supplies and 7,600 latrines.

Principal Problems and Their Health Consequences

Notwithstanding Bolivia's relatively slow rate of urban population growth, the serious problems of pollution and other environmental health factors are evidenced in human health statistics.

Water Supplies and Water Related Diseases

The provision of clean, safe water supplies in Bolivia has not kept pace with population growth, especially in urban areas. Two diseases related to water show high incidences: gastroenteritis (18,236 cases per 100,000 inhabitants) and typhoid fever (55 cases per 100,000). (See Table 7-1.) Between 1970 and 1977, the rate of both these diseases increased. This is due, in part, to the fact that the proportion of the population with access to safe water declined from 46% in 1950 to 39% in 1976 (PAHO, 1979), despite an increase of approximately 780,000 individuals offered clean water. Bolivia therefore ranks 25th in the 27 Latin American nations concerning adequacy of water supplies.

In a 1976 appraisal of the urban and rural water supplies and sewage project, the World Bank noted that diseases related to unsafe water or unsanitary conditions caused about 12% of the total number of reported deaths for all ages (World Bank, 1976).

Sewage and Sewers

In 1973, only 23% of the Bolivian urban population was served with sewerage or sanitation facilities (World Bank, 1976). Only one city, Santa Cruz, has a sewage treatment plant and sewerage connections to most urban residences. A design has just been completed for a system in Cochabamba (to be financed by the IDB). In rural areas, only 8% of the homes have latrines and only 1% have septic tanks. (See Table 7-2.)

Table 7-1. Incidence of Eleven Transmissible Diseases, 1978.

Diseases	Rate per 100,000
Gastroenteritis	18,236
Influenza	1,706
Malaria	387
Tuberculosis	322
Measles	635
Whooping cough	90
Gonorrhea	100
Syphilis	58
Chicken pox	56
Mumps	51
Typhoid Fever	55*

*From the Department of Statistics

Source: Ministerio de Prevision Social y Salud Publica

Table 7-2. Levels of Sewer and Sanitation Services in 1976

	Urban Areas	Rural Areas	Total
Sewers	30%	0%	12%
Septic tanks	4%	1%	2%
Latrines	14%	3%	8%
Without any service	52%	96%	78%

Source: PAHO, 1979.

This situation exacerbates the human health problems caused by the lack of safe water supplies.

Open sewers—which also serve as storm water drains—by inviting contact with sewage by people, rats, flies, domestic animals and insects, increase the potential for incidence of disease. The use of untreated sewage for irrigating food crops can close the disease transmission cycle, also increasing the incidence of water related disease. The water of the La Paz River has become so polluted that horticultural production downstream from the city has had to be curtailed. In La Paz, many trucks were noted being loaded with sand from the sewage-carrying river bed below the city. This sand, distributed throughout the city for construction and many other purposes, distributes both the

sewage and the disease organisms among human life in the city. In Oruro, children were seen playing in the sewage flowing openly in streets in front of their houses.

Additionally, a large amount of garbage and trash is thrown in open sewers. This practice adds to the numbers of flies, rodents and odors, while increasing the cost of maintenance.

Sewage in Open Gutters, Oruro.

Solid Wastes

Ing. Rene Prieto, formerly with the Municipality of La Paz and in charge of planting vegetation in the city's garbage dumps, considers the solid wastes to be one of the city's principal urban problems. According to Ing. Luis Araoz, of the Ministry of Health's Division de Ingenieria Sanitaria, only 30% of the urban population of Bolivia has garbage and trash collection services.

In La Paz, collected garbage is buried in a number of landfills, formerly open dumps. In the past, as many as 5,000 hogs were raised on the garbage, but the transmittal of trichinosis led to institution of the landfill technique and cessation of hog raising, although the team observed a few still rooting in the uncovered garbage. Pickers also sort through the dumped trash for salvageable items.

Various trees have been planted on the fills, especially *Acacia melanoxylum*. Eucalypts were also seen (the elevation is approximately 300 meters lower than the city's center and warmer than the Altiplano). However, erosion and slumping still occur.

In cities other than Santa Cruz, garbage and trash collection services are supported by municipal governments and are reported to be very deficient.

There are several health hazards created by deficient waste disposal. Garbage dumps and discarded trash become habitats for vectors of human disease such as flies, mosquitos, and rats. Trichinosis in hog flesh was in the past a problem related to the unsanitary conditions in the La Paz garbage dump. Another potential hog disease, similar to Foot and Mouth Disease in cattle, is Vesicular Exanthema. It, too, could be caused by conditions at garbage dumps and garbage eating by hogs.

Air Pollution

Except for a few measurements made in La Paz of suspended particulates, settleable particulates, and sulfur (PAHO, 1973), there is no data on Bolivian air pollution. Results of the measurements in La Paz show levels of pollution that were low, compared to similar size cities in the U.S. However, air pollution near industrial installations becomes serious at times.

There is no governmental control on air pollution. The Instituto de Salud Ocupacional rates air pollution from refineries and foundries as the most serious problem, with vehicle exhaust emissions the next most serious problem. The high elevation and intense solar radiation of La Paz are thought to intensify the creation of secondary pollutants (Delgado, 1979). At the ENAF refinery in Vinto, arsenic, antimony and sulphur contaminate gaseous emissions, noticeably affecting the plant when there are temperature inversions (personnal communication, Dr. Edmundo Duran).

Wind-borne dust must also be considered a pollutant with potentially adverse effects on human health, and has widespread occurrence in both rural and urban areas, particularly in the Altiplano.

Respiratory infections are a principal source of morbidity as well as mortality in Bolivia, but the major diseases — influenza and tuberculosis — are transmissible. Air Pollution, especially dust, could be a contributing factor; however, overcrowded housing, lack of

heat, and malnutrition are probably more important factors. The only respiratory disease clearly linked to air pollution is silicosis, an occupational disease of Bolivian miners (USAID, 1978).

Industrial Pollution

The principal sources of industrial pollution in Bolivia are the large foundry and refinery complexes owned and operated by the Empresa Nacional de Fundiciones (ENAF). Water pollution from plants and foundries represents the principal environmental threat. The major plants are located in the interior drainage basin of the Altiplano on the shores of Lakes Titicaca and Uru Uru (north of L. Poopo). A sulphur plant near Eucalipto owned by the military empties effluent directly into the Desaguadero River, but is reported to idle most of the time due to lack of ore. Air pollution from foundries is also serious, but is more localized in its impacts and is hazardous principally to plant workers.

On Lake Titicaca, water from a stream emptying into the lake, and contaminated by operations at Mina Matilde, was analyzed during both the dry and rainy seasons by chemists from the Universidad Mayor de San Andres (Arze & Salm, 1979). Samples were taken along the stream and at its mouth. The absence of lake vegetation near its mouth had suggested significant pollution, and the extremely slow turnover time of the lake's water (64 years) effectively reduces its capacity to absorb and cycle pollution. High levels of zinc, lead, and manganese were measured; turbidity and coating of aquatic vegetation with fine sediment were also noted. Cultivation of the lake shore and irrigation with lake waters were mentioned as potential avenues for lake contaminants to the food chain. Uptake by plants was not measured, however.

At ENAF's tin and antimony foundry in Vinto, near Oruru, the team was shown a series of small decantation lagoons into which the plant's liquid effluent is channeled to eventually empty into a dry wash that drains into Lake Uru Uru. The plant's safety engineer and doctor reported that 50 ppm of arsenic has been found in water discharged from the last lagoon. Furthermore, people living in the area draw water from the small canal that connects the lagoons for use in stock watering, making abodes, and even bathing and cooking. (See photo). The effluent is undoubtedly entering the groundwater. Ironically, plant

Canal Linking Settling Ponds of Arsenic-Contaminated Wastewater from the Refinery. Residents Were Reported Using This Water for All Domestic Purposes.

ENAP Tin Refinery at Vinto, Near Oruro (Settling Pond in Foreground)

employees are potentially exposed to the arsenic because one family sells flavored drinks at the plant gate made with contaminated water from the canal. The plant doctor was "not authorized" to warn them of the health hazard, although he had reported the situation to his superiors. At the Vinto plant, stack gases contain 0.5% SO_2 and some antimony. In an interview, the plant manager asserted that there was no pollution.

Lake Mulluni was reported to be polluted by effluents from a concentrating plant. This lake supplies La Paz' drinking water.

Other reports of industrial pollution, not seen or documented, were: sugar mills in Santa Cruz and Tarija; refinery waste pollution of irrigation sources in Sucre (World Bank, 1978); Mina Chollja (northeast of La Paz); cotton mills (Santa Cruz); and Villa Montas oil seed plant (Tarija). Locally, streams in the Yungas are reported to be seriously damaged by gold placer mining that uses hydraulic methods for working valley sediments.

Much concern has been generated by plans to construct a pesticides manufacturing plant near La Paz. Although its construction has been delayed, it is feared that the plant design would generate pollution.

Future industrial growth in Bolivia is likely to be concentrated around a number of "industrial parks" that are being built or have been built in Cochabamba, Santa Cruz, and Oruro. These parks have separate sewers and treatment plants. However, the current lack of standards on industrial pollutants inhibits the design of treatment systems. A 1976 IDB loan of $6.5 million to the Santa Cruz Public Works Committee for its industrial park included the financing of consultants to prepare studies on environmental procedures of the park.

Pesticides

Poisoning and death from pesticides are two most serious problems, according to statistics from studies recently conducted by the Instituto de Salud Ocupacional (INSO, 1979, reviewed below). A recent assessment for AID on the use of pesticides by small farmers describes a situation that is completely beyond the control of the authorities to correct, being characterized by inadvertent poisoning, deaths from intoxication, excessive application of pesticides, and general ignorance or neglect of precautions in handling and use, especially among field laborers (Caltagirone, 1979). Also, pesticide residues in food are not monitored.

There are numerous pesticides available in Bolivia, including very toxic formulations such as methyl parathion, ethyl parathion, and Furadan (Caltagirone, 1979). Systemic, contact, and ingestion pesticides are handled and mixed indiscriminately without precautions such as gloves and protective clothing.

About 95% of the pesticides are applied to cotton, especially in the Santa Cruz and Tarija areas. Tomatoes and sugar cane also receive applications. A number of deaths in Tarija, originally believed to have been caused by yellow fever, was the result of pesticide poisoning. Furthermore, the mortality rate of children in the tomatoe-growing area of Comarapa is exceptionally high. Over 300 persons were treated for pesticides posioning in Santa Cruz during 1976 and 1977 (INSO, 1979). Caltagirone found a total disregard for safety of field laborers in Santa Cruz. INSO surveyed 16 cotton growing areas in Santa Cruz and found that over half of the workers examined had symptoms of pesticides intoxication. None of the working areas had first aid kits for treating pesticide poisoning.

Additionally, regulations and laws controlling pesticides are virtually ignored.

In the health sector, DDT has been used to control mosquito vectors of malaria (USAID, 1978). In 1977, approximately 42,000 homes were sprayed by the Servicio Nacional de Eradicacion de la Malaria.

Traffic Accidents

Traffic accidents are the leading cause of accidental deaths in Bolivia (USAID, 1978).

The death rate from traffic accidents in Bolivia (Direccion General de Transito, 1978) is almost equivalent to that in the U.S. (National Safety Council, 1978) 18 per 100,000, compared to 22 per 100,000, respectively (both figures for 1978). However, injury rates are much lower: 67 per 100,000 in Bolivia, compared to 840 per 100,000 in the U.S. Congestion in Bolivia's rapidly urbanizing areas undoubtedly favors traffic accidents. Approximately half of all traffic accidents take place in the La Paz Department; there, accidents increased from 2760 in 1977 to 3355 in 1978.

Urban Flooding and Debris Flows

Flooding, associated erosion, and landslides are perennial threats to many Bolivian cities, including La Paz (flooding, landslides, rockfalls), Cochabamba (flooding), Oruro (flooding), and Trinidad (flooding). The largest budge item in the Corporacion de Desarrollo de Cochabamba is protection, clean up, and compensation for annual flooding. In La Paz, torrential rains can trigger rock falls onto the main road connecting the lower and upper sections of the city.

Environment and Health in Lowland Settlements

In cities and smaller settlements in the Oriente and Yungas, the altered environment poses both real and potential threats of a number of diseases. Of greatest concern are those diseases transmitted by vectors, such as malaria, Chagas disease, yellow fever, and schistosomiasis.

Anopheles darlingi is an increasingly common vector of malaria in the Bolivian lowlands. Deforestation improves its breeding habitat of sunlit pools with water lettuce *(Pistia)* and water hyacinth *(Eichornia)*. Also, the mosquito commonly rests in the shade and thus seeks homes when trees have been removed. The reduviid bug, which carries Chagas disease, dwells in the thatch roofs of rural houses. Jungle yellow fever could become an urban problem if *Aedes aegypti* is inadvertently introduced. Schistosomiasis is not yet a problem, but its potential should be determined using surveillance instituted in the irrigated project at Ibapo-Izozog.

Recommendations

Reduce Pesticides Hazards

Interventions are required at all steps of the system whereby pesticides are mixed, distributed, and applied. Professional and institutional development is sorely needed. Public education must also be undertaken. Diagnosis and treatment of poisoning must be improved through education and provision of facilities and medicine.

Integrated pest management should be developed as soon as possible. Experiences with IPM in cotton production elsewhere in the world (Peru, Texas, Louisiana, and Mexico, for instance) prove that the method is cheaper, safer, and more effective than sole reliance on chemicals.

Institute Industrial Pollution Control Program

Control of industrial pollution in Bolivia is sorely needed. An institutional capacity with mandates backed by laws and regulations must be created. A preparatory phase could be undertaken with technical assistance from AID, UNEP, UNIDO, and CIFCA. An ad hoc intergovernmental planning group is likely to be needed. Representation from the DDC's, central government, and universities would be desirable. The governmental ownership/participation in various industries, especially mining and energy, should facilitate the organization of industrial pollution control. International technical assistance could be especially useful in studies of the economic impact of pollution control, both for the industry itself and the entire economy.

Set Air and Water Quality Goals

A planning and consultative process is needed to develop technical criteria and offer political support for air and water quality goals.

Technological Alternatives to Sewage Treatment and Safe Water

Institutions presently charged with developing these services appear unable to undertake additional work or absorb more foreign assistance. Small scale, appropriate technologies should be explored to shift the organizing and executing initiative to communities.

Regulations for the 1978 Codigo de Salud

Until these regulations are drafted, the health hazards of air, water, and land pollution cannot be effectively managed by the Ministerio de Prevision Social y Salud Publica. If necessary, international technical assistance should be offered through UNEP's Latin American and Caribbean Office, PAHO, AID, or other interested development assistance entities.

Strengthen INSO

The laboratory and staff capabilities of the Instituto de Salud Ocupacional cannot be fully realized without a larger budget and stronger political mandate. If strengthened, INSO could undertake many of the key tasks required to control industrial pollution by developing pollution standards, monitoring, researching criteria, and conducting impact studies. Also, INSO could be the focal point for the international technical assistance recommended above.

VIII. INSTITUTIONAL PERSPECTIVE

Institutional Perspective

Introduction

This chapter presents observations on the institutional dimension of Bolivia's environmental and natural resource problems. Descriptions of institutions appearing in earlier chapters are recapitulated and additional institutions are examined, including the Ministry of Planning and Coordination and the Instituto Nacional de Preinversiones. A cursory analysis of the principal institutional and related problems follows.

The legal basis for the management of natural resources, pollution, and sanitation are summarized in the "Draft Environmental Report on Bolivia" (Library of Congress, 1979), and the various laws are, of course, readily available in Bolivia. The principal laws or decrees are:

- Ley General Forestal de la Nacion (Decree 22686), 1974
- Ley de Vida Silvestre, Parques Nacionales, Caza y Pesca (Decree Law 12301), 1975
- Codigo de Salud (Decree Law 16629), 1978

The first two laws authorize the Centro de Desarrollo Forestal, MACA, to manage forests and wildlife. The third, which is the health code, vests sole authorization in the Ministerio de Prevision Social y Salud Publica for controlling all forms of air, water and land pollution. The Departmental Development Corporations are also legally empowered to protect the environment.

Institutions Concerned with Pollution

There are two ministries concerned with pollution. However, the principal industrial polluter—the mining and metals refining industry—appears to be unaffected by their work.

Ministerio de Urbanismo y Vivienda

Its Division de Ingenieria Urbana is charged with questions of water supply and sewage. (Solid wastes are handled at the municipal level.) Presently, the DIU is receiving technical assistance and financial support from a $11.5 million World Bank loan to upgrade water supplies and Sucre's sewerage. (Details are presented in Chapter VII.)

Ministerio de Prevision Social y Salud Publica

There are three Divisions within the Departamento de Ecologia:

1. **Division de Ingenieria Sanitaria** — charged with controlling air and water pollution, approving licenses for plants developing rural water supplies, and solving problems of general sanitation in cities and rural areas. The delay in beginning work under an AID loan for rural water supplies and latrines is attributed to the structural weakness of this division.

2. **Instituto de Salud Ocupacional** — charged with providing services to requesting agencies. With a staff of 66, laboratory equipment for sampling and analyzing, and a good grasp of pollution monitoring and surveillance work, this is an underutilized institution with considerable potential for enforcing regulations, establishing criteria and setting standards.

INSO sends multidisciplinary teams to review occupational health questions arising in different industries and develop programs for controlling health risks. The Institute has also sponsored short courses. Disciplines represented by INSO's staff include medicine, chemistry, biochemistry, nursing, engineering, laboratory technicians, statistics, and teaching.

Insufficient budget allocation is the principal obstacle to INSO's functioning. INSO should (but does not) receive funds from the state Social Security account (according to Art. 43, Ley de Racionalizacion de la Seguridad Social) (INSO, 1979).

3. **Division de Epidemiologia.** No specific data was obtained on its charge or program. This division publishes periodic bulletins on the status of communicable diseases in Bolivia.

Institutions Concerned with Natural Resources

MACA is the institutional home for land, forests, and wildlife resources. Management of water resources is divided among a great number of agencies. Non-governmental agencies also play important roles in research and surveys.

Centro de Desarrollo Forestal

The organization of CDF is depicted in Figure 2-1. The Departamento de Vida Silvestre y Parques Nacionales has jurisdiction over wildlife exploitation and various parks and wildlife reserves. The Departamento is understaffed — with only a director and five field staff — and unable to control the very active and lucrative illegal export of live animals and animal products to international markets. Indian tribes in forested areas are also under this department's jurisdiction. Although the work was not reviewed, no evidence of special programs was discovered in the fields.

The Departamento de Bosques is charged with managing the nation's forests and conducting reforestation. Field observations and interviews in the Oriente by team members produced the conclusion that this department is very weak and has done little except tax logging concessionaires and establish nurseries in departmental capitals.

It is commonly known that, in the past, CDF personnel have accepted bribes for permitting illegal cutting and illegal export of timber and wildlife. When bribery has failed, physical threats have been made. The ideas of preservation and conservation have not yet tempered this exploitive approach to the Oriente's forests and wildlife. Much more political power must be invested in CDF if the organization is to fulfill its legally mandated functions.

CDF's reforestation program was found to be equally weak and was not coordinated with local reforestation efforts. Thus, nurseries developed by both CDF and local authorities exist in many places. There was little evidence of extension and outreach for reforestation.

Many of CDF's staff are recent graduates from the Forestry School in Tarija and are relatively inexperienced.

Additional details on CDF are presented in Chapters II and III.

Seccion de Suelos

MACA's Division de Ingenieria, Riego y Suelos, is the official soil mapping entity in Bolivia. However, it is poorly equipped and ill-prepared to survey or take action on Bolivia's serious erosion problems.

The section has a staff of 22 soil survey technicians, who for the most part have no field vehicles. Also, the section no longer has laboratory facilities; these facilities were transferred to IBTA, which charges a fee for analyses.

U.S. Soil Conservation Service methods of soil mapping and classification are followed, although the head of the section recognizes that the methods are not suited to many of Bolivia's soils.

Additional information can be found in Chapter IV.

IBTA

The Instituto Boliviano de Tecnologia Agropecuaria is the site of research on natural grasslands and pastures in Bolivia. Present work is carried out by a recent graduate of USU, Ing. Humberto Alzerreca, and a botanist, Raul Lara. However, efforts are hampered by the lack of a vehicle. Clipping and range regeneration work is being pursued at experimental stations in Patacamaya, Belen and Ulla Ulla. In general, research has not been developed for diffusion among Indian communities; rather, it is more applicable to livestock raising units of the kind found in the U.S. The attention presently accorded range research is miniscule in relation to the very great potential of the Altiplano grasses.

There is no international technical or financing assistance being provided.

Servicio Nacional de Meteorologia y Hidrologia

This service operates a network of meteorological stations (347) and stream gauging stations (63). Details on the consistency and quality of observations were not obtained. Stations originally established by ENDE, the national electricity company, have been turned over to the Servicio. The Servicio is a dependency of the Ministerio de Transporte y Comunicaciones.

Pollution of waters is not monitored by this or any other agency.

GEOBOL

The Servicio Geologico de Bolivia has developed one of the most competent teams of natural resources surveyors in Bolivia in its Programa de Satelite Tecnologico de Recursos Naturales (also referred to as Proyecto ERTS-Bolivia). Since 1973, the program has

received technical assistance from NASA and funding from NASA, UNDP, USAID, Canada, and GEOBOL. Accomplishments include a geological map of Bolivia, a Mapa de Cobertura y Uso Actual de la Tierra (Vegetation and Landuse), and most recently, a set of 1:250,000 maps of land complexes in the Oriente region.

Since GEOBOL salaries are almost double those earned in government ministries, some of the best professionals have been attracted to the program.

The aim of the ERTS-Bolivia effort to inventory and map the natural resources of Bolivia will be eventually limited by the cartographic detail possible with satellite imagery. Presently, 1:250,000 scale is the most detailed possible; even the smaller scale Cobertura y Uso Actual Map failed to capture significant changes in vegetation and land use. However, other forms of remote sensing, such as aerial photogoraphs and side looking radar, could be employed to overcome these limitations.

PERTT

This is the only institution in Bolivia devoted to combating soil erosion. The Programa Ejecutivo de Rehabilitacion de Tierras en Tarija is a separate and special institution established through an inter-institutional agreement between CODETAR, the Prefecture of Tarija Department, the Universidad Boliviana Juan Misael Saracho (Tarija), the Asociacion San Jacinto, and MACA and created by decree (D S 15401) in April, 1978. PERTT was formed in an attempt to coordinate the urgent task of halting erosion and restoring the productivity of eroded lands in Tarija Valley

PERTT has seven staff persons, two nurseries, a D6 caterpillar tractor, dump truck and several jeeps It has begun to test land restoration methods in three pilot areas. The UNDP and the World Food Program have supported the planning formative stages and the present program of PERTT. West German assistance has also been requested.

MACA's CDF and Oficina de Reforma Agraria have not been able to assist PERTT; as a result, the program has built nurseries and undertaken land surveying and titling work.

Additional details on PERTT are found in Chapter V.

Non-governmental Institutions

Instituto de Ecologia

This special training and research institute in La Paz is affiliated with the Universidad Mayor de San Andres. It is supported by a 4-year $3.0 million grant from the University of Goettingen, which will provide three full-time professors, three temporary professors, 10 years of scholarships to German universities, and laboratory equipment. Although largely a teaching institution, the Instituto has begun to perform surveys and studies at several sites in the Altiplano and develop an herbarium.

The Instituto's president is a biologist, Dr. Cecilia Morales. Co-director is Dr. Erika Geiger, an ecologist from the University of Goettingen.

A $1.0 million facility is presently under construction to house the Instituto, which is temporarily located at Calle Jose Perez 275 in La Paz.

Instituto de Geodinamica y Limnologia

This small institute, established in 1975, is also affiliated with the Universidad Mayor de San Andres. It has undertaken limnological studies in Lakes Titicaca and Poopo and has laboratory capability for physical and chemical analyses of water and sediments. OSTROM, the French overseas research organization, has supported the Instituto since 1974 The Instituto is the Bolivian representative and secretariat for joint Peruvian Bolivian studies of Lake Titicaca

Instituto de Ingenieria Sanitaria

This teaching institute is attached to the Universidad Mayor de San Andres However, it has a staff of four laboratory technicians and can analyze "biological oxygen demand" and "chemical oxygen demand" in water - two key indicators of pollution levels PAHO supports this institute, which was established in 1972.

Sociedad Boliviana de Ecologia

This newly formed group of private citizens met on several occasions with the team. Its estimated 30 members include some of the most informed and concerned individuals in La Paz. In November, 1979, the Sociedad planned to hold a national conference on the environment in Bolivia, sponsored by the Academia Boliviana de Ciencias. The Sociedad meets weekly at Calle Mexico No. 1638.

The Sociedad's objectives are to protect and conserve nature, make contacts with national and international institutions with similar aims, undertake educational work, and perform studies.

Environmental Policy and Planning Institutions

The Ministerio de Planificacion y Coordinacion is officially charged with developing environmental policy. The Instituto Nacional de Preinversiones would be the most appropriate agency to undertake environmental impact assessments. The Regional Development Corporations can also undertake environmental planning at the local or regional level.

Ministerio de Planificacion y Coordinacion

The Direccion de Ciencia y Tecnologia was charged in July, 1979, with undertaking a 1-year study on environmental policies and programs for presentation to the government. A Comision Interinstitucional del Medio Ambiente was to have been established to gather and compile existing studies, identify principal problems, and elicit project ideas. UNDP support of this effort is described below. A Congressional commission was to be set up to draft legislation. As of late September, 1979, no visible progress was evident on these works and only one person in the Division had been assigned to work on these tasks. The change of government in October, 1979, has undoubtedly delayed this work.

With the assistance of the Centro Internacional de Formacion en Ciencias Ambientales (CIFCA, based in Spain), the Direccion recently held a short course in La Paz on environmental management in mining and metallurgy.

UNDP support to the Ministry for the development of scientific and technical information on the environment for the purposes of long-term planning and for pre-investment studies was scheduled to begin in September, 1979 (Project No. BOL/79/008). It was to be a 1-year program, receiving $168,000 support from UNDP and approximately $100,000 from the Bolivian government, and fielding 10 short-term consultants to work with the Direccion and with INALPRE (see below) on guidelines for: pre-investment studies, evaluation methods for proposed alternatives, technological packages for the chemical industry, a dossier of science and technology project proposals in transport, non-conventional and energy alternatives, a general diagnosis of Bolivia's environmental situation, outlines for environmental policy, a dossier of project proposals for solving environmental problems, and a data bank on technical assistance projects. This project appears overly ambitious in its objectives. These objectives are to be accomplished with only 6 months of consulting by experts in ecology, environmental legislation, environmental engineering, and social aspects of environment.

The Direccion is also the focal point for "Man and the Biosphere" work, but no research has yet been undertaken or MAB reserve established.

The coordinating role of the Division is of considerable importance and utility. The former director, Dr. Carlos Aguirre, expressed the need for more links between universities and government agencies, and the role of his division in promoting this cooperation. He also stated the need for small highly-focused projects which would develop the basis and criteria for deciding how to develop environmental and natural resources institutions.

The Comite Nacional de Proyectos, in the Ministerio de Planificacion y Coordinacion, which approves all projects proposed by government agencies and regional development corporations, could also guarantee that projects feature protection of the environment.

Instituto Nacional de Preinversiones (INALPRE)

Environmental assessment of development projects could be the responsibility of this agency, and its director anticipates technical assistance in environmental impact analysis from the UNDP project. INALPRE reviews and approves all bids from the private sector for pre-investment studies of government-financed projects, and finances some studies. It has prepared guidelines for the preparation and negotiation of proposals, but as yet, no environmental criteria have been set forth.

INALPRE has received $5.0 million from IDB, $1.0 million from Venezuela, and will be assisted by $2.5 million from the Federal Rep. of Germany. UNIDO is providing the technical assistance of two persons.

Departmental Development Corporations

The laws that have established these corporations authorize them to protect the environment. The corporations also are administrative focal points for each of the departments, where integration of local and national services and programs takes place. Consequently, the DDCs are well situated to reveal — and thus avoid — unwanted environmental impacts caused by the action of one sector of the economy on another Until recently, the DDCs have principally worked on urban infrastructure and industrial development.

However, several DDCs have now turned to rural development questions, as well. Thus, they could become institutional focal points for remedial or preventive actions aimed at natural resources use and urban and industrial pollution. However, because DDC's aim to foster economic activity, a basic addition to their philosophy or doctrine would be needed.

A complete review of the programs and projects of each DDC was not possible. Projects and activities of three are listed below. They illustrate the diversity of directions and interests among regions in Bolivia.

An evaluation of all the DDCs was recently conducted for AID (McKee and Popper, 1979). Their evaluation concluded that their strengths and weaknesses vary considerably, but in general, DDCs are vigorous and viable institutions.

CORDEPAZ

Ing. Percy Baptista in CORDEPAZ is the only professional in Bolivia with special training in wildlands management (University of Michigan). He has proposed and planned regional parks and environmental education, and has furthered research on trout culture in high elevation lakes and streams. (Due to a general strike by CORDEPAZ employees, Ing. Baptista could not be interviewed.)

CORDEOR

This corporation in Oruro is making several attempts to improve range management in the Sajama district (which includes the Sajama National Park), and increase productivity of llama and alpaca wool and, eventually, vicuna wool. Related projects include an inventory of native flora and fauna and the formation of a *jardin botanico*. CORDEOR also proposes to undertake major reforestation with local species such as quena *(Polylepis* spp.) and quishar *(Buddleia* spp.). To arrest moving dunes near Oruro, CORDEOR's planning director has proposed a law that would prohibit cutting woody bushes *(tolares)*, a local source of fuel. CORDEOR has also proposed a dam in La Paz Department to control floodwaters of the Desaguadero River.

CODETAR

This corporation sits on the board of the Programa Ejecutivo de Rehabilitacion de Tierras en Tarija. Recently, CODETAR has obtained a forest exploitation concession for a 1.3 million hectare area that includes the last surviving block of virgin *Podocarp* forest in Bolivia. CODETAR desires to achieve a sustainable yield harvesting cycle of the forest, and has expressed interest in establishing a reserve in a portion of the forest. FAO foresters based in Santiago, Chile, are assisting CODETAR in the technical preparations for this project.

Evaluation

The institutional framework for addressing the various problems of pollution and related human impacts is quite distinct from that protecting land, water, forests and wildlife resources. There is no agency that controls or monitors pollution, nor is there any process that formally reviews the pollution dangers of new industry. Regulations for the 1978 Health Code, which charges the Ministerio de Prevision Social y Salud Publica with reviewing the environmental health hazards of new industries and controlling land, water and air pollution, have not yet been established. More significantly, the Instituto de Salud Ocupacional has not been allocated sufficient budget to carry out its work. It is the only institution with the capacity to monitor and assess the health impacts of pollution and recommend remedial measures.

Local entities are in the best position to detect water and air pollution, but the Departmental Development Corporations and state enterprises such as YPFB and ENAF (the petroleum and mining industries, respectively, who are both polluting water and the atmosphere) appear unconcerned about air and water pollution, and assign it very low priority. The only exception is new industrial parks developed by the DDCs, which feature built-in sewage collection and treatment.

In the case of land, forests, range and wildlife resources, all within the jurisdiction of MACA, the seriousness of conservation and associated management problems is matched in degree by the weakness of the various offices in MACA responsible for these resources. In fact, there is no office charged with combatting erosion, and no office responsible for promoting better range use and management. CDF's handling of forests, parks and wildlife is extemely inadequate.

At the departmental level, the DDCs are beginning to take action on problems with clear economic consequences, such as flooding, erosion of farmland, and range management. DDCs are launching longer term efforts as well, such as reforestation, conservation education, parks, and range management.

There are a number of reasons for the relative weakness of Bolivia's institutional response to environmental problems:

- Lack of continuity of effort, due to instability of central government
- Insufficient political resolve to implement existing legislation, through adequately funded and staffed programs and the promulgation of appropriate regulations
- A general perception that conservation measures and pollution control do not contribute to economic growth and production
- Lack of experienced and trained technical staff, especially in soils, range, parks, wildlife, and natural forest management
- Lack of an overall, objective determination of environmental problems, undertaken with the intent of shaping policies, programs or actions.

ACRONYMS

Acronyms

BID	Banco Interamericano de Desarrollo
CDF	Centro de Desarrollo Forestal
CIDA	Canadian International Development Agency
CIFCA	Centro Internacional de Formacion en Ciencias Ambientales
CODETAR	Corporacion de Desarrollo de Tarija
CORDECO	Corporacion de Desarrollo de Cochabamba
CORDEOR	Corporacion de Desarrollo de Oruro
ENAF	Empresa Nacional de Funciones
ENDE	Empresa Nacional de Electricidad
GEOBOL	Service Geologico de Bolivia
IBTA	Instituto Boliviano de Tecnologia Agropecuaria
IDRC	International Development Research Center
INALPRE	Instituto Nacional de Preinversiones
INC	Instituto Nacional de Colonizacion
INFOL	Instituto de Formento Lanero
MACA	Ministerio de Asuntos Campesinos y Agropecuarios
NASA	National Aeronautics and Space Administration
OMS	Organizacion Mundial de Salud (World Health Organization)
OPS	Oficina Panamericana de Salud (Pan American Health Organization)
PERTT	Programa Ejecutivo de Rehabilitacion de Tierras en Tarija
PPF	Programa de Plantaciones Forestales
PRONAPLAF	Programa Nacional de Plantaciones Forestales
SELA	Sistema Economico Latinoamericano
US SCS	United States Soil Conservation Service
USU	Utah State University
YPBF	Yacimientos Petroliferos Fiscales Bolivianos

LIST OF PERSONS INTERVIEWED

List of Persons Interviewed

La Paz

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Cochabamba

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Miguel Petit-Ayala	Chief OAS - Chapare Development Study
Ing. Constantine Soto	Tecnico Forestal CODECO

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Pol Poppin	Associate Expert FAO Project Inventariacion y Manejo de Recursos Forestales

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Manfred Sachtler	Director FAO Inventariacion y Manejo de Recursos Forestales (BOL/74/031)
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