CGIAR Challenge Program on
WATER & FOOD

Andean System of Basins: Watershed Profiles

Enhancing Agricultural Water Productivity Through Strategic Research

Ma. Catalina Ramírez and Héctor Cisneros

Contribution for the
Sustainable Development
of the **Andes**
Issue 7, November 2007

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CONDESAN

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Foreword

The nine basin profiles of the CGIAR Challenge Program on Water and Food (CPWF) provide a broad overview of the basin areas, their development, their potential, and how the water used for agriculture can be made to produce more food. Careful use of the basin water in producing more hydropower, better transport, enhanced stocks of fish and aquatic plants, and cleaner water for humans and animals will contribute to the reduction in poverty levels.

The Challenge Program now has an approved Research Strategy, this series of baseline publications, and a number of research projects operating, all of which should contribute to the achievement of its vision and goals.

The Challenge Program on Water and Food wishes to acknowledge the significant input by members of its management team into the writing, review, and revision of the nine Basin reports.

Dr. Francis Gichuki led the conceptualization of the basin profiles and worked to support the CPWF Basin Coordinators in compiling, revising, updating and finalizing them.

L. Reginald MacIntyre and Ida M. MacIntyre did the final detailed editing to bring the documents to publishable form.

This work would not have been possible without the ongoing help and support of the CPWF Steering Committee, especially Dr. Frank Rijsberman, its chair, the 19 CPWF Consortium institutes and of those who provided the wide range of data acknowledged in the Introduction that follows.

Jonathan Woolley*, Program Coordinator*
CGIAR Challenge Program on Water and Food (CPWF)

Introduction

One of the greatest challenges of our time is to provide food and environmental security. A vital step in reaching this goal is to increase the productivity of water used for agriculture, leaving more water for other users and the environment—getting more "crop per drop." The Consultative Group on International Agricultural Research (CGIAR) approaches this problem from a research perspective.

The Challenge Program on Water and Food (CPWF) generates research-based knowledge and methods for growing more food with less water, and develops a framework for setting targets and monitoring progress. Five interrelated research themes have been defined to ensure that the key research topics are being addressed in all locations. The themes are: Crop Water Productivity Improvement, Water and People in Catchments, Aquatic Ecosystems and Fisheries, Integrated Basin Water Management Systems, and Global and National Food and Water Systems.

The themes will serve as the focal point for synthesizing results from the various countries and regions, and bring out generic conclusions from the overall research program. The Benchmark Basins provide a geographic focus, and the river basin is where the water problems and issues converge, especially in developing countries, and this is where CPWF will carry out its research (www.waterforfood.org). The basins are: Andean System, Indo-Gangetic, Karkheh, Limpopo River, Mekong River, Nile River, São Francisco, Volta, and Yellow River.

CPWF is based at the International Water Management Institute (IWMI–www.iwmi.cgiar.org) in Sri Lanka. IWMI is one of the fifteen CGIAR-supported Future Harvest Centers (www.cgiar.org).

This report on the Andes System of Basins presents a comprehensive synthesis of the agricultural water use and productivity in the Basins. The characteristics of seven watersheds in the system are included. We thank the colleagues who helped gather the information on which this report is based. The original draft profile was shared with all Basin team members who supplied data and reports on specific problems and issues in their region. In preparing the final profile, we made extensive use of IWMI's data sets, and published sources: World Development Report (2000, 2003, 2004), World Development Indicators (2001, 2003), Human Development Report (2000, 2003, 2004), Global Poverty Monitoring Database, World Income Inequality Database, World Resources Institute, and various Internet sources. We also acknowledge the use of CIAT and CONDESAN data sets and thank CIP Research Informatics Unit for generate all of the maps included in this publication.

For consistency across basins/sub-basins, indicators were identified and included in each theme covered by the profile. Research problems, socioeconomic conditions, and issues and opportunities were categorized for each basin. The goal was to identify factors affecting agricultural productivity, food security, health, environmental sustainability, and poverty.

The collection of these data across a wide range of topics and geographic areas proved to be a time-consuming task. Some of the data are not as current as we would like, but the report should serve as a useful baseline document on which CPWF can build its project activities.

CPWF welcomes comments and feedback on this document other numbers in the Baseline Report series.

Andean system of basins: an overview

The Andean System of Basins consists of seven watersheds (Table 1) located in the Andes Mountains in Colombia, Ecuador, Peru, and Bolivia (Figure 1). The selected watersheds represent a wide range of ecosystems, and biophysical and socioeconomic conditions, illustrating the heterogeneity presented in the whole Andean region.

Table 1: Andean System of Basins

Watershed	Country
Fuquene	Colombia
La Miel	Colombia
El Angel	Ecuador
Ambato	Ecuador
Alto Mayo	Peru
Jequetepeque	Peru
Tunari	Bolivia

Figure 1: Andean System of Basins for the Challenge Program on Water and Food

In the tropical Andes, the steep slopes and high altitudes result in diverse ecological, cultural, and resource use. Different types of ecosystems are found at different altitudes.

Tropical wet and moist forests occur between 500 and 1,500 m. Various types of cloud forests extend from 800 to 3,500 m, including the montane and premontane cloud forests (*yungas, ceja de selva,* or *ceja de la montaña*) that cover more than 500,000 km² in Peru and Bolivia. These are among the richest and most diverse forests on Earth. At higher altitudes (3,000-4,800 m), grassland and scrubland reach up to the snow line. These ecosystems include the *paramo*, a dense alpine vegetation growing on a thick mat of sponge-like, highly absorbent mosses and grasses in the cold, humid reaches of the northern Andes, and the drier *puna*, characterized by alpine bunchgrass species surrounded by herbs, grasses, sedges, lichens, mosses, and ferns in the cold but dry southern tropical Andes. In addition to these main ecosystems, there are also patches of dry forests, woodlands, cactus stands, thornscrub, and matorral (www.biodiversityhotspots.org/xp/hotspots/andes).

Spatial water distribution varies widely throughout the Andean region, which has the driest place on Earth, the Atacama Desert in Chile, and one of the wettest places on Earth in western Colombia in the Choco region, with over 11,500 mm of rain annually (http://lwf.ncdc.noaa.gov/oa/climate/globalextremes.html).

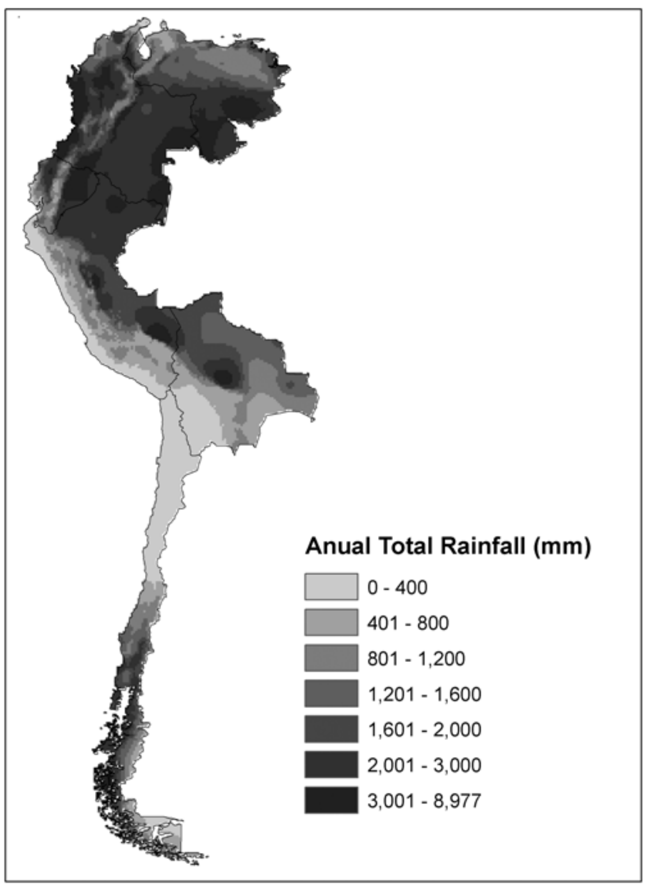


Figure 2: Spatial distribution of annual rainfall

There are about 90 million people living in the four countries that contain the seven watersheds of the Andean System of Basins. Most of the people live in the Andean region and on the coasts (Figure 3) , causing great pressure on the natural resources and on the fragile ecosystems. Some of the population hotspots are represented by the large cities in the high Andes Cordillera, including: Bogota, Colombia, at 2,650 m; Quito, Ecuador, at 2,800 m; Arequipa, Peru, at 2,360 m; and La Paz, Bolivia, at 3,600 m. Some of the demographic characteristics of the ASB countries are given in Table 2.

Table 2: Demographic characteristics of the ASB countries

	Total population (millions)	Estimated population 2005 (millions)	Population growth rate (annual %)	Population density (people/km)	Population density, rural (people/km^2 2000)	Population (% rural)	Rural population growth rate (annual %)
Bolivia	8.52	9.21	2.11	7.85	161.30	37.11	0.77
Colombia	43.04	45.70	1.64	41.43	375.70	24.53	-0.28
Ecuador	12.88	13.81	1.79	46.52	297.26	36.58	0.67
Perú	26.35	28.01	1.51	20.58	190.91	26.87	0.24

Source: World Bank (2001)

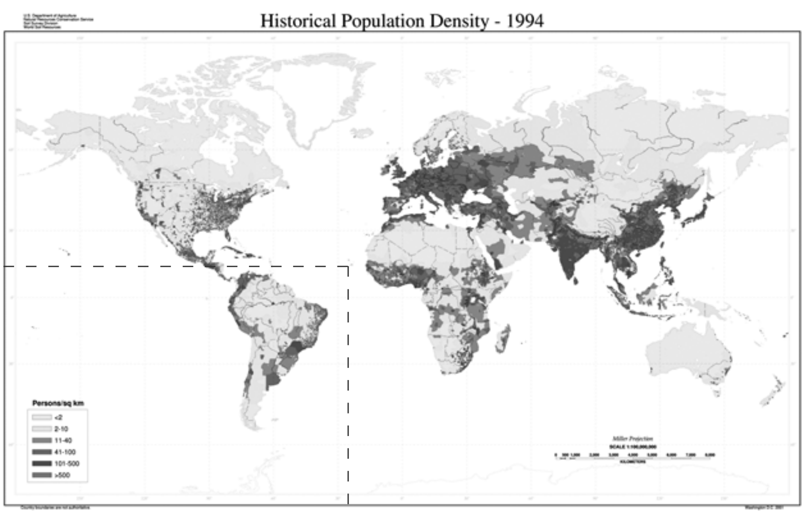


Figure 3: South America Population Density Map 1994
Source: antwrp.gsfc.nasa.gov/apod/ap030305.html

Colombia has the largest labor force (about 19 million), followed by Peru (10 million), Ecuador (5 million), and Bolivia (3.5 million). Agriculture employs only a small proportion of the total labor force, a marked contrast with Southern African and Southeast Asian countries, though there are some disparities among the ASB countries.

Some social indicators for the ASB countries are given in Table 3. Most of the indicators are higher for Colombia, with Peru and Bolivia ranking at the bottom. A broad discussion of these human welfare indicators is omitted here, because their impact is weighted up, largely, in composite indices such as the Human Development Index (HDI) and the Human Poverty Index (HPI), presented in Table 4.

Table 3: Selected social indicators for the ASB countries

	Adult literacy rate (%) 2003	Net primary enrolmen rate (%) 2002-03	Access to improved water source (%) 2000		Life expectancy at birth (years) 2003		Mortality rate (per 1000 live births) 2003		Births attended by skilled health staff (% of total)	Public expenditure on health (% of GDP) 2002
		All	Urban	Rural	Female	Male	Infant	Under 5		
Bolivia	86.5	95.0	95.0	64.0	66.2	62.0	53	66	65	4.2
Colombia	94.2	87.0	99.0	70.0	75.4	69.3	18	21	86	6.7
Ecuador	91.0	100	90.0	75.0	77.3	71.4	24	27	69	1.7
Perú	87.7	100	87.0	62.0	72.6	67.5	26	34	59	2.2

Source: United Nations Development Programme (2005)

Following United Nations typology, HDI and HPI can be used to construct relative poverty profiles for the ASB countries. HDI is a combination of *longevity* (life expectancy), *knowledge* (literacy and education), and *standard of living* (purchasing power and cost of living), where the lower the figure, the worse is the state of human development in a country. HPI converts HDI into a poverty index, which becomes a measure of economic development and human welfare. HPI is a measure of *human deprivation* defined in terms of *survival* (percent dying under 40 years), *knowledge* (illiterate adult percent), and *economic provisioning* (health, sanitation, infant mortality).

Therefore, both HDI and HPI are composite indices and the underlying concept of poverty is that of multiple human deprivations. Poverty profiles for selected countries using these indices are presented in Table 4. All ASB countries fall into the "medium human development" category (the other two categories being high and low human development) in terms of their HDI: Colombia is highest, and Peru, Ecuador, and Bolivia are lowest. Country rankings are similar when HPI is used as a measure of human development: Colombia is at the top, and the other three countries rank close to each other. Even with HPI, all ASB countries fall into the "medium human development" category.

Table 4: Human development indicators for the ASB countries

	Human Development Index (HDI)		Human Poverty Index (HPI)	
	Value	Rank (over 117)	Value (%)	Rank (over 103 developing countries)
Bolivia	0.687	113	30	30
Colombia	0.785	69	7.4	8
Ecuador	0.759	82	10.6	22
Peru	0.762	79	12.0	26

Source: United Nations Development Programme (2005)

Baseline conditions, future outlook, and vision (ASB)

Vision and Targets

CPWF would like to mobilize watershed stakeholders to work toward addressing the watershed problems. To achieve this we need to develop a shared common vision. From the CPWF perspective this vision is:

"Agricultural water productivity in the watershed is increased in ways that effectively contribute to poverty alleviation and to the attainment of food, health, and environmental security."

CPWF goals include:

- Food security for all at the household level.
- Poverty alleviation, through increased sustainable livelihoods in rural and peri-urban areas.
- Improved health, through better nutrition, lower agriculture-related pollution, and reduced water-related diseases.
- Environmental security through improved water quality as well as the maintenance of water-related ecosystem services, including biodiversity.

The vision for the Andean System of Basins is to:
"Enhance water productivity by taking advantage of the diverse and dynamic assembly of partners from the public and private sectors, and using a common approach and effort, abilities and resources, to make and facilitate coordinated operations in investigation, qualification, development, and initiation of policies that contribute to sustainable socio-economic advancement."

The goal of the Andean System of Basins research for development program under the Challenge Program on Water and Food is to:
"Improve the food security, quality of life, health, and environment in the ABS countries, and increase water use efficiency in agriculture, linking it to the research agenda of CPWF."

We hope to achieve these goals by addressing the following research priorities:

- Assessing the potential of environmental externalities as a mechanism for generating new development dynamics (rural investment with the poorest sectors) in Andean watersheds.
- Developing and validating an information system and a planning process in the watersheds to prioritize public and private investment, the management of Andean System of Basins relations between high and low catchments, and reach an effective integration between research and development.
- Generating and consolidating sound discussion/negotiating platforms in the watersheds to promote new rural investment through strategic alliances between the public and private sectors.

- Designing and validating mechanisms to guarantee that changes in land use produced by environmental and social externalities have a positive impact on the income and well-being of the poorest people.
- Designing and validating community organization models to guarantee that externalities are effective forces in regional development.
- Producing ecoregional information to facilitate the process of extrapolating production alternatives from the pilot watersheds to other Andean areas.
- Demonstrating that CONDESAN's (Consorcio para el Desarrollo Sostenible de la Ecoregion Andina—Corsortium for Sustainable Development of the Andean Ecoregion) experiences in the Andes accelerate development in mountain regions with lower income levels.

Research Agenda

Data, information, and knowledge gaps

The generally poor knowledge of high Andean hydrology is surprising, given the importance of water supply to often densely populated regions. Along with a lack of data, there is wide variation in the landscape (complex and steep topography, small fields with different land uses), drainage pathways are often modified, and the physical properties of the soils (high porosity but low conductivity and strong hysteresis) differ greatly from those of the common soil types in temperate and tropical regions (Veneklaas *et al.*, 2002).

There is little or no information on irrigated areas and crops to allow a meaningful analysis of crop intensity. In addition, data on irrigated lands are not sufficiently precise and, in some cases, refer to physical irrigated lands, making it difficult to estimate the actual crop intensity.

The main knowledge gaps for the Andean System of Basins are in the following areas:

- *Water legislation*. This is required to recognize feasible alternatives in land and water uses, and to generate acceptable policies for the area.
- *Compensation mechanisms between lower and upper watershed producers*. These would promote alternative land/water uses.
- *Water concessions and assigning mechanisms*. How water is being allocated through the watersheds has to be clarified to improve or extend workable mechanisms to other locations.
- *Diagnosis and analysis*. Problems, causes, and relationships between watershed components have to be identified to help develop improved strategies.
- *Strategic alliances for investment*. These will identify public or private organizations willing to make investments in the rural area, and design strategic alliances between partners.
- *Policy and advocacy*. New policies are needed to improve general conditions and to promote changes in land and water management practices.
- *Integrated land management*. What are the possible alternatives in land use and management that

will help improve agricultural yields, reduce poverty, improve health, increase water productivity, and preserve the environment?

- *Quantification of environmental goods and services*. Services or goods offered by the local system that can benefit any stakeholder in the area have to be better known and quantified, so that alternatives and management practices can be assessed.
- *Capacity building*. The type of needs in the area will help define the types of capacity building (funds, grants, training, coaching), and who should be involved in these processes.
- *Education and networking*. Changes in land/water use practices have to go hand-in-hand with a better knowledge of the processes, causes, and consequences of current and improved land/water management practices.

Section 1- Fuquene Watershed

Resources and Agricultural Production

BIOPHYSICAL SETTING

Location and Area

Fuquene Lake is located in the Andean Mountains of Colombia in the Ubate-Chiquinquira Valley at 2,543 m (Figure 4). Fuquene Watershed covers1,750 km^2 extending between 5°35' N, 73°54'W and 5°19'' N, 73°35'W (Montenegro-Paredes, 2004). The lake is located 80 km northeast of Bogota.

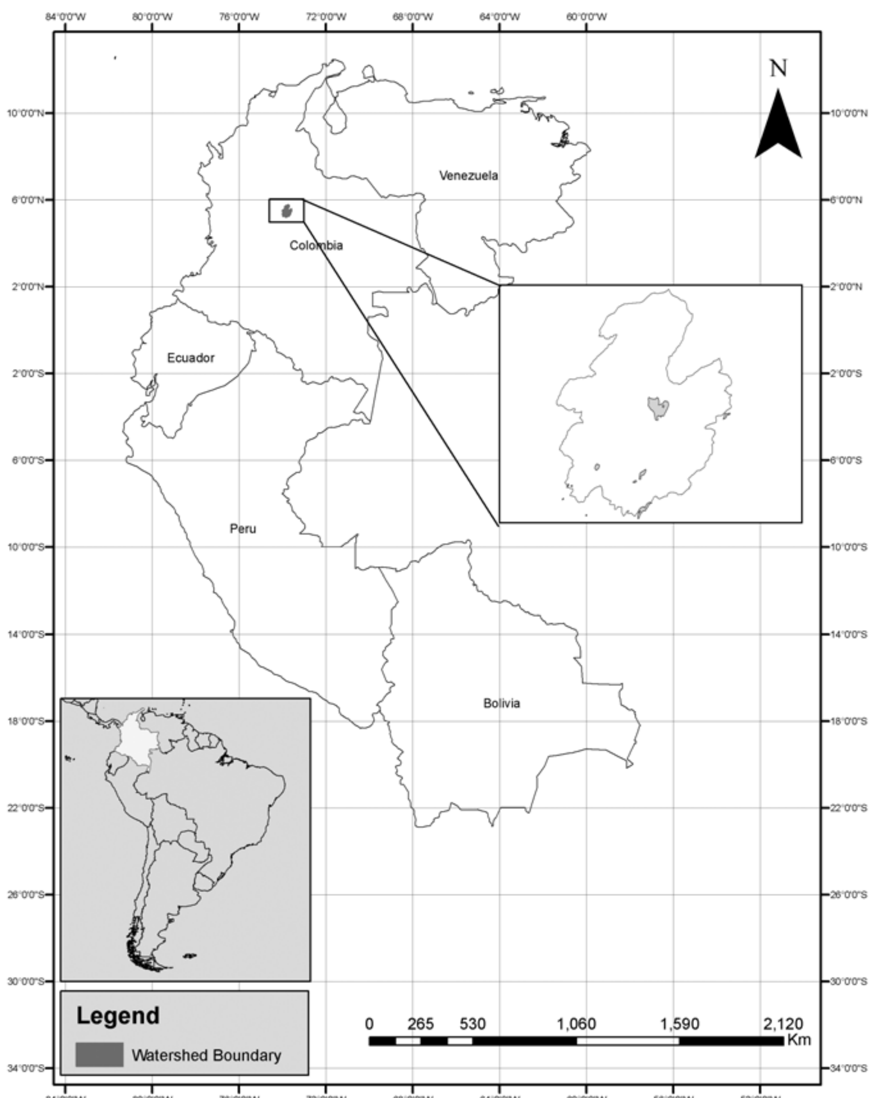


Figure 4: Location of the Fuquene Watershed

Topography

Fuquene Watershed covers an inter-Andean valley with plains near Fuquene Lake, and steep slopes surrounding the lake. The altitude varies from approximately 3,600 m at the highest point to 2,543 m, at the lake surface.

Drainage Network

The Fuquene Watershed drainage network is a system of three interconnected lakes, Cucunuba, Palacios, and Fuquene; one reservoir, El Hato; and two main rivers, Ubate and Suarez, and many small rivers and creeks. The main water bodies in the watershed are shown in Figure 5. The lake gathers water mainly from the Ubate River that starts at 3,600 m on the Peña Vidriado Mountain in the Carmen de Carupa municipality. The Ubate River flows from south to north through the Ubate – Chiquinquira Valley.

Fuquene Lake also receives water drained by the Upper Ubate, Suta, Cucunuba, and Lenguazaque river watersheds. Fuquene Lake drains only into the Suarez River, which is also fed by other rivers having a larger watershed than Fuquene Watershed, ending at Magdalena River, which is one of the main rivers in Colombia.

Rivers in the Fuquene Watershed usually reach their maximum discharge in May andNovember, dropping to their lowest values in February and August. The calculated annual average discharge for the Ubate River is 3.9 m^3/s in the upper part of the river, and 10.2 m^3/s close to Fuquene Lake. The water level of Fuquene Lake, however, tends to remain constant due to the hydromorphology of the first portion of the Suarez River (Montenegro-Paredes, 2004).

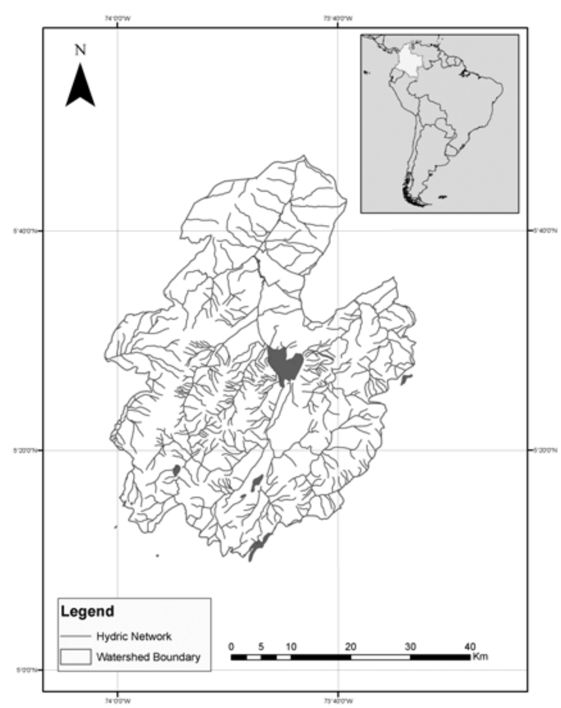


Figure 5: Drainage network of the Fuquene Watershed

Climatic Conditions

The temperature is stable with little seasonal fluctuation. The mean monthly temperature is 12-13.2°C at Ubate and 12.4-13.5°C at Chiquinquira. The mean monthly humidity varies between 70 and 80%. The watershed has two dry and two wet seasons yearly as follows: dry season months from December to February and from June to August, and wet season months from March to May and from September to November, with 700-1,500 mm of rain (JICA-CAR, 2000).

Geology, Mineral Resources, and Soils

The area has sedimentary rocks from the Cretaceous Age with syncline and anticline formations oriented northeast to southwest. The geological formations described for this area are (Montenegro-Paredes, 2004):

- *Simiti formation (Kis).* Shale and black siltstones, with sandstone alternating with thin shale layers. This formation is associated with the generation of acid soils on mountainous landscapes and surrounds the lake.
- *Chiquinquira formation (Kichi).* Sandstone layers of fine-grained and black shales. This formation is associated with acid soils characterized by low fertility, and texture that ranges from fine to medium, located to the west side of the lake.

  Surface soils are well drained and have low permeability, and are generally prone to erosion.
- *Alluvium and Colluvium (Qal).*Lacustrine and riverside siltstone clay, conformed by glacial deposits and terraces of nonconsolidated material surrounding the lake. Surrounding areas correspond to well-drained acid soils of high salinity on the east plains. There are soils from old lakebeds that are characteristic of swamp areas.

Ecosystems and their Plant and Animal Resources

Fuquene Watershed contains 249 species of fauna and flora that have been identified to date. Several endemic species inhabit the area, including 25 species of migratory birds. Sixteen plant areas have been identified for Fuquene Lake. Although the lake contains 40% of known plants of the Bogota Savannah and Ubate River plains, only seven plant areas are considered as frequent or abundant. Fuquene Lake is a lacustrine system characterized by a limnetic subsystem with nonconsolidated soils, aquatic beds, or areas of submerged vegetation (Global Nature Fund, 2006).

Among the most significant species, two endemic fish are found in the lake: a kind of catfish locally known as "the captain" (*Eremophilus mutissi*), a "lesser captain" (*Pygidium bogotense*), and a scaly fish *Grundulus bogotensis*. Fish are important as food resources for indigenous and local peasants. Birds represent the most outstanding natural asset of the site, however. The Andean grebe (*Podiceps andinus*), currently a globally extinct bird, and the local extirpated population of the ducks *Anas georgica niceforoi* and *Anas cyanoptera borreroi* were found in the lake until the 1960s. Alien aquatic weeds such as the lowland water hyacinth (*Eichornia crassipes*) and the Brazilian elodea (*Egeria densa*) now infest the lake.

Fishes such as the widespread carp (*Cyprinus carpio*), and the common goldfish, although exotic, currently represent a modest resource for local fisheries (Montenegro-Paredes, 2004; Global Nature Fund, 2006).

The surrounding landscape is sloped high Andean sub-xerophytic enclave, with important plant species such as the remarkable endemic *Agave cundinamarcensis*. Wetter slopes on the east side were formerly covered by extensive neotropical oak forests (*Quercus humboldtii*), now reduced to precious tiny relicts (Global Nature Fund, 2006).

Figure 6: View of Fuquene lake and surrounding area
Photo: Marcela Quintero

Economic interests and land degradation have reduced the lake area (see Figure 6), converting it into grassland suitable for cattle breeding. This rich ecosystem is now seriously threatened by these developments.

SOCIOECONOMIC SETTING

Demographic Attributes

The Fuquene Watershed includes the following towns (see Figures 4 and 7): Carmen de Carupa, Ubate, Tausa, Sutatausa, Cucunuba, Suesca, Villapinzon, Lenguazaque, Gacheta, Fuquene, Susa, Simijaca, San

Miguel de Sema, Raquira, Caldas, Chiquinquira, and Saboya (Pulido, 1997; Santos, 2000; and Van der Hammen, 1998). According to the 1993 DANE (National Department of Statistics) census, the population of the watershed area is about 181,000.

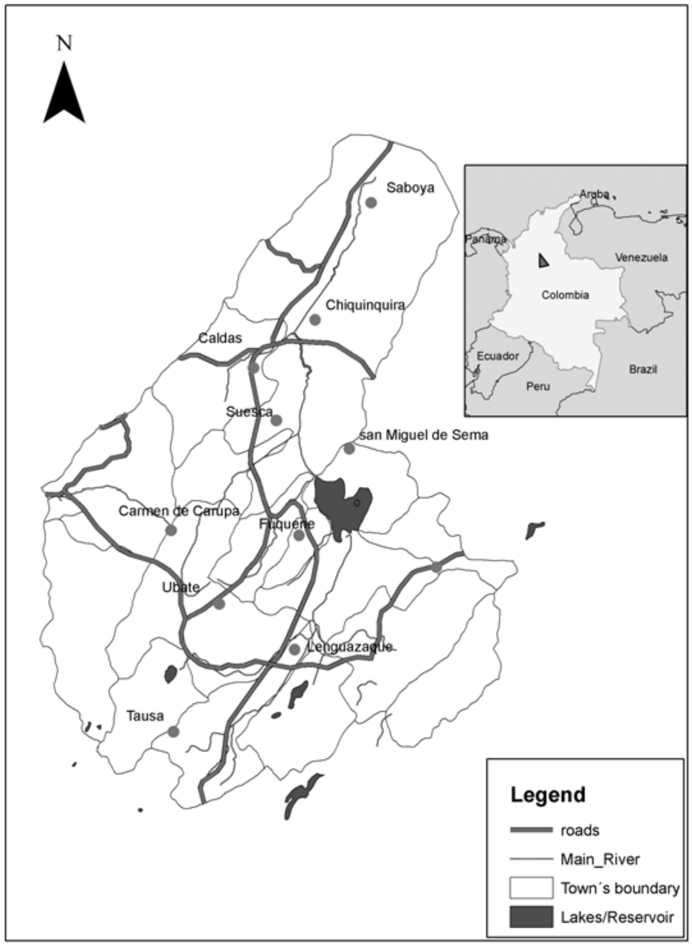


Figure 7: Towns and main water bodies in Fuquene Watershed
Source: Santos (2000)

According to the DNP (National Planning Department) the ICV[1] (life condition index) varies between very low to high. For the towns in the Fuquene Watershed the ICV values are medium high, medium, medium low. The neonatal mortality rates (from very low to no deaths) have values of high, medium, and low, showing considerable variation in living conditions.

1 The ICV combines in a single number measures of infrastructure, access to public services, education, illiteracy, family income, and other factors. The value increases when the living conditions improve. The ICV can be high (more than mean ± 2 SD), medium high (between high and mean ± 1 SD), medium (between medium and high).

Figure 8: House near Fuquene lake
Photo: Marcela Quintero

Agricultural Labor Force

The main source of employment in the region is agriculture and livestock. Other economic activities include dairy products, factories, and mining. There is a shortage of labor because of out-migration to large urban centers.

Education and Literacy

Most of the rural people have completed only low levels of primary education, and the illiteracy rate is quite high. In some municipalities school attendance is low because of long distances to schools, lack of transport, low income, low teaching standards, and the need to have young people work on the farms or in other economic activities.

Economic Activities

The predominant activities in Fuquene Watershed are agriculture, livestock, and mineral extraction. In economic terms, agriculture is less important than livestock breeding.
The most important crops are potato, wheat, pea, and corn (JICA-CAR, 2000).

Livestock, particularly dairy cattle, is the main activity in the area, and it is having a major environmental impact on soils and is degrading the ecosystem. There is a close relationship in Latin America between livestock breeding and the destruction of forests, soil compaction, and high runoff rates.

Breeding cows for milk production is the main economic activity, supplying a large proportion of the country's milk needs. There is also dual-purpose cattle breeding for meat and milk on the slope areas, especially at Carmen de Carupa, Villapinzon, Tausa, and Caldas municipalities.

There are 280 coal mines within the watershed borders, and stone and sand are extracted for building purposes. The average area of the mines is between 10 and 12 ha (JICA-CAR, 2000). Mining is having important negative environmental impacts, such as gas production and groundwater pollution.

Some people are involved in handicraft production as a main source of income. These artisans usually live close to the lake and use aquatic plants as source material for their handicrafts.

INSTITUTIONAL SETTING

Governance and Organization

The role of the Colombian government regarding the natural resources is to plan and use the natural resources guaranteeing its sustainability, conservation, restoration, or substitution. This work is the responsibility of the Environment Ministry and the National Environment System (SINA). They are responsible for national policy and development plans related to environment and renewable natural resources (Gomez Torres, 2003).

The "corporaciones autonomas regionales" (CAR) are the most important environmental groups in the area of jurisdiction. They are in charge of managing and executing policies, plans, and programs related to the environmental and renewable natural resources. The goal is sustainable development and adherence to the country's legal framework.

In 1961 the Colombian Government created CAR (Corporacion Autonoma Regional) with the main objective to protect the environment in the Ubate and Suarez river valleys.

The area covers 18,706.4 $km^2$and includes nine river watersheds (CAR, 2006): Bogota, Negro, Sumapaz, Magdalena, Minero, Macheta, Blanco, Gacheta, and Ubate-Suarez where the Fuquene Watershed is located. The purpose of this regional organization is to preserve the natural resources of the area that contribute to quality of life, social welfare, and a healthy environment for future generations.

Policy Framework

CAR is responsible for the implementation of legislation regarding natural resources, water quality, and water management. CAR is also responsible for developing land-use guidlines at the watershed level.

Local and regional stakeholders in the Fuquene Watershed include (Maya and Castillo, 2004):

- Small-scale and large-scale cattle breeders and farmers, slaughterhouse and dairy factory owners, mine owners (they do not own the mine but the right to exploit it), owners of recreational farms, fishers, handicraft workers, and tourism-related people (hostel owners, boat owners). The people throughout the watershed are organized in local associations (water supply systems users association, irrigation systems users association, farmers associations, and so on).

- Local governments in each town (*alcaldias*), and the Corporacion Autonoma Regional (CAR) guide land use in the watershed. At the national level some ministries are involved in environment, energy, agriculture, and other areas.
- International agencies and nongovernmental organizations are concerned with the conservation, sustainable development, and local improvements.

LAND RESOURCES MANAGEMENT

The land use in the watershed is shown in Table 5. Grass for cattle breeding is found in the lower part of the watershed in flat areas. Agriculture is divided into three main crops: potato, corn, and wheat. Wheat production is located in the northwest part of the watershed, potato to the southeast, and corn around Fuquene Lake. Crops are part of a rotational system with pastures (Figure 9).

Table 5: Land use in the Fuquene Watershed

Land use	Area (km^2)	(%)
Forest	97	5.6
Thicket	72	4.1
Grass on flat land	301	17.2
Grass on slopes	314	17.9
Agriculture	929	53.0
Lake	30	1.7
Urban area	9	0.5
Total	1,752	100.0

Source: JICA-CAR, 2000

Agricultural Production

Although agriculture is not the main economic activity in the Fuquene Watershed area, it is an extremely important one that consumes most of the water. Potato, wheat, pea, and corn are the most common crops. Potato is the most important product in both production and income. The potato-growing areas are on the slopes of the watershed, and livestock activities are mainly carried out in the flat parts of the valley.

Figure 9: Some agricultural practices on hillsides
Photo: Marcela Quintero

WATER RESOURCES MANAGEMENT

Water Availability

The runoff coefficient (the ratio between the volume of water that runs off a surface and the volume of rainfall that falls on the surface) of the Ubate subwatershed is 0.4, which is higher than the runoff coefficient of the Suta and Lenguazaque sub watersheds (0.2).

During wet seasons, the average discharge is 6.21 m^3/s at Colorado station and 16.12 m^3/s to the north of Tolon station. In dry seasons the calculated values were 2.27 m^3/s and 4.90 m^3/s, respectively. Fuquene Lake has maintained an average water level of 2,539 m elevation from 1968 to 1998. During this time the highest reported value was 2,540.5 m and the lowest was 2,538 m. The water stage fluctuation is between 15 and 40 cm (Montenegro-Paredes, 2004).

Groundwater levels have been recorded for 30 years in four stations. The data show a small seasonal fluctuation. The yearly mean level variations are: 33, 33, 15, and 50 cm for each one of the four stations (JICA-CAR, 2000).

Water Demand, Allocation, and Use

In the watershed lowlands there are three irrigation systems covering 203.4 km^2. These irrigation systems act by infiltration, using water from a river diverted by the irrigation channel infiltrated into the soil and taken up by the grass. This area also obtains water from periodic floods caused by the lake and from groundwater capillary action. There is no irrigation system on the hilly side, which is mainly used for crops, especially potato rotated with grass.

The water used by the irrigation systems comes from surface water. The water used by these systems is estimated at 97.8 million m^3/year = 3.10 m^3/s (JICA-CAR, 2000).

The water needed for stock breeding comes from irrigation channels and the grass fields drainage channels, and is estimated at 0.06 m^3/s (JICA-CAR, 2000).

Towns in the watershed have a water supply system covering more than 94% of the domestic urban demand, and some of the rural, institutional, and industrial needs. The people not covered by these systems have small rural water supply systems, and some of the industries use groundwater wells. The water demand by activity in the Fuquene Watershed is presented in Table 6. The main use of water is for agriculture, which consumes more than 85% of the total.

Table 6: Water demand estimated by activity

Uses	Water demand (m^3/s)	%
Agriculture	3.10	87.8
Stock breeding	0.06	1.8
Domestic	0.31	8.8
Institutional	0.03	0.8
Industrial	0.03	0.8
Total	3.53	100.0

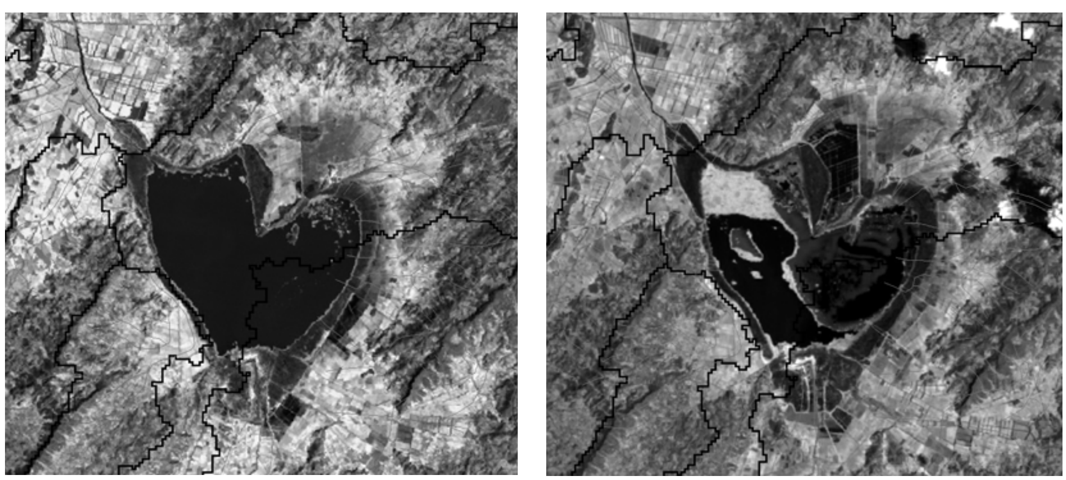
Source: JICA-CAR (2000)

Challenges related to food, water, and environment

There are many challenges in the Fuquene Watershed related to the problems identified in the area. These problems arose because of the disorganized development of the main activities contributing to the rapid degradation of the ecosystem. Some of the problems in the Fuquene Watershed are:

- ***Destruction of forests and the upper watershed.*** This decreases the soil's ability to retain water.
- ***Erosion.*** There are 13,000 ha seriously eroded and another 40,000 threatened due to improper agricultural techniques, monoculture, and mechanization of steep slope areas. This process has forced people to migrate to towns, thereby increasing the size of poor urban areas.
- ***Sedimentation.*** Slopes of more than 50% without vegetative cover, combined with intense rainfall, produce soil loss of 16 t/ha in a single rain event.

- ***Pollution.*** Intensive stock breeding and agriculture generate contaminants such as nitrogen, phosphorus, and organic matter that ends up in the water bodies, causing eutrophication in Fuquene Lake. Only two towns have a wastewater treatment plant, and the other 15 towns pour their wastewater directly into the lakes and rivers. About 50 dairy companies dump their wastewater into the sewage systems. As a result, only about 159 ha of Fuquene Lake (2,959 ha) have a clear water surface (Figure 10).
- ***Health concerns.*** Fuquene Lake is suffering from eutrophication because of the invasion of aquatic plants. The plant decomposition generates toxic substances affecting water quality, and jeopardizes human health downstream. Many rural dwellers still live in poverty, with no access to sanitation facilities. Some of the water supply systems have sedimentation problems and/or no water treatment plants. The high pollution rates and the lack of wastewater treatment may endanger the health of the downstream communities, whose water supply systems depend on the water quality of surface bodies.
- ***High drying rates*** **of Fuquene Lake (39.9 ha/year) are diminishing the water storage volume of the lake, as well as its free water surface area.** This creates problems for the fauna and flora, and also alters the natural water cycle.
- ***Loss of biodiversity.*** It is important to preserve Fuquene Lake to maintain its flora and fauna. There are 91 vertebrate species, some considered endemic, and 62 plant species, with one endemic. There are now 40% fewer animal species than 40 years ago in the watershed, due to environmental problems, and some species are facing extinction (Montenegro-Paredes, 2004).



1987 **2000**

Figure 10. Coverage change in the lake by aquatic plants between 1987 and 2000
Source: http://www.condesan.org/andean

Baseline conditions, future outlook, and vision

The Fuquene Watershed is a highly degraded ecosystem due to excessive stock breeding and unsustainable agricultural practices. Despite its high economic productivity (dairy production), many of the residents remain poor, especially in the high parts of the watershed. Pollution in the surface water bodies is endangering the communities downstream. The lake surface and water quality are being negatively affected by sedimentation processes and agricultural practices that are also causing erosion in the highlands. Loss of biodiversity is becoming a serious issue.

Solutions must be found to protect people, plants, and animals from pollution dangers, while offering economic alternatives to improve the livelihoods of the rural poor through better land practices and improved water management.

PARTNERSHIPS FOR TRANSLATING VISION INTO ACTION

Some of the identified partners in the Fuquene Watershed are already developing activities, including:

- **CONDESAN-GTZ through the Cuencas Andinas Initiative, are working under a research-action program.** The research aims to prioritize different land-use alternatives that encourage stakeholders and policymakers to make investments and partnerships.
- **CAR has been developing projects aimed at improving the environmental conditions in the area, ranging from reforestation programs and protection areas to foster better land use practices.** The Checua Project, for example, aims to reduce erosion problems and sedimentation rates in the lake by building structures and stimulating farmers and stock breeders to adopt better resource use and working practices.

RESEARCH AGENDA

Research Priorities

The complete list of research priorities for the Andean System of Basins for CPWF was summarized earlier. The main research topics for the Fuquene Watershed are to:

- ***Quantify the hydrologic budget of the watershed.*** This would help us to recognize water patterns, storage capacity, and other hydrological issues that may contribute to understanding physical processes in the watershed.
- ***Quantify the sediment budget.*** Together with the hydrological budget, and with the help of mathematical models and sufficient data, we can define the causes and possible solutions to alleviate sedimentation problems.
- ***Determine current land-use patterns*** *and the impact of potential land-use changes on watershed hydrology*. Models, together with meteorological data, soil, and water samples, maps, and other data

can help in the assessment of the consequences of different land-use practices.

- *Formulate optimal restoration strategies*. An integral evaluation of the alternatives on land use, water use may help to formulate an optimal strategy to restore the ecosystem. Biophysical and economic models plus expert analysis are tools that can address this issue.
- *Water quality control*. Research in this area will contribute to the prevention of health problems in the region, and will record trends related to the land-use practices. Water quality monitoring is urgently needed in the Fuquene Watershed.
- *Understand the extreme hydrologic responses*. To avoid serious production risks, we need to know and understand the hydrology of the Fuquene Watershed. Effects of natural events such as climate variations, seasonal fluctuations, and other major hazards might be diminished if the hydrological response of the watershed is known.
- *Promote social networks knowledge*. Conflicts exist between extremely diverse groups, often separated by terrain, but connected as net suppliers or competing users of water. This increases the vulnerability of individual groups and obstructs the path to improvement. Mountain and hill communities are isolated and often marginalized. Lack of efficient, equitable, and sustainable water allocation mechanisms that are acceptable to all watershed stakeholders constrain overall capacity of water to support rural livelihoods.

Section 2 - Alto Mayo Watershed

Resources and Agricultural Production

BIOPHYSICAL SETTING

Location and Area

The Alto Mayo Watershed is located in Peru (Figure 11). It has an approximate area of 7,700 km^2 (770,000 ha) extending between 5°20’ and 6°20’ S and 76°40’ and 77°50’ W.

The watershed is located 680 km north of Lima (PEAM and PROFONANPE, 2003).

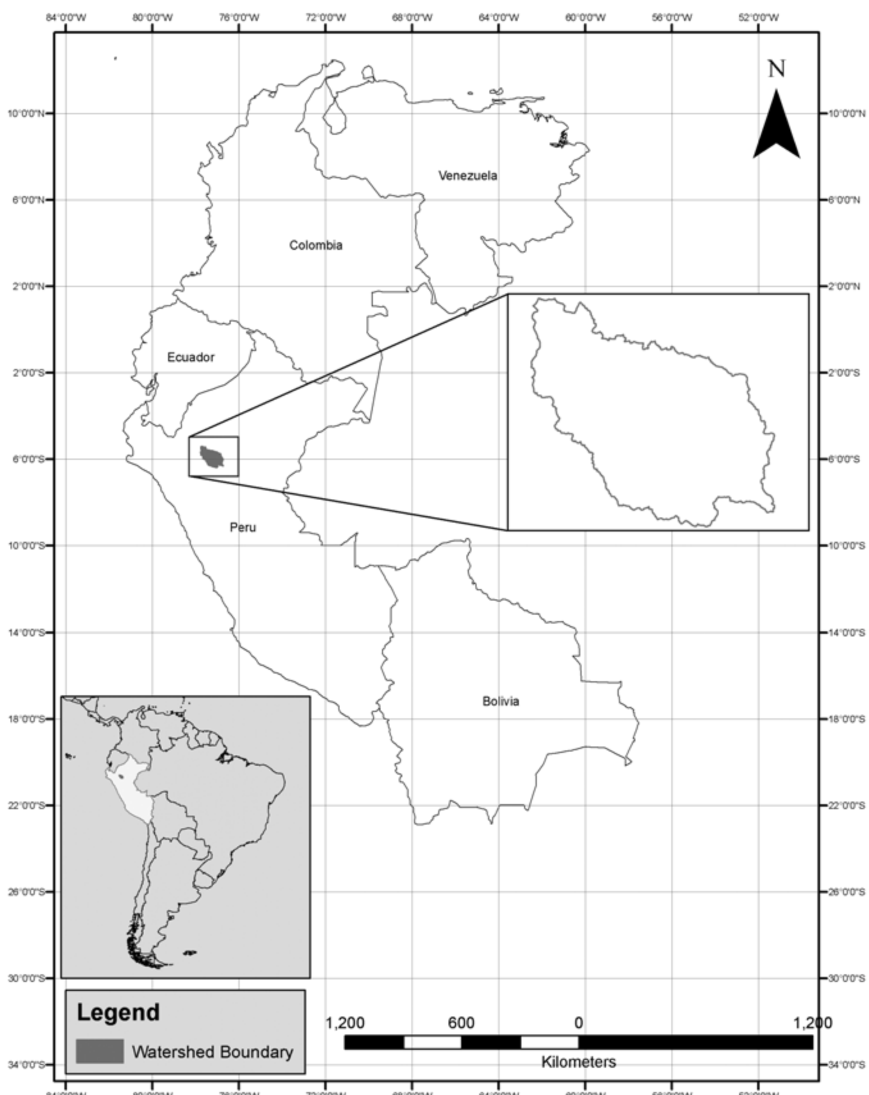


Figure 11: Location of the Alto Mayo Watershed

The watershed comprises the Rioja and Moyobamba provinces in the San Martin Department, and the Rodriguez de Mendoza Province in the Amazon Department. Its valley is densely populated, including the important cities of Rioja and Moyobamba.

Topography

The study area is located in the Sub-Andean or premontane forest zone. The Alto Mayo Watershed comprises elevations between 800 and 3,800 m. The topographic features define two areas: the lower part between 800 and 900 m with flat areas and smooth relief, and the upper part from 900 to 3,800 m completely surrounding the lower part, with rugged terrain formed by the Cahuapanas Cordillera at the northeast side and the Eastern Cordillera higher than the Cahuapanas to the southwest (Figure 12).

In the Alto Mayo Watershed there are three geomorphologic units defined by their origin (Proyecto Cuencas Andinas *et al.*, 2004,2006):

1. Structural origin units

- ***Anticlinorium Cordillera.*** There are two structural cordilleras running parallel to each other, separated by a tectonic depression at the southeast side, converging at the western side. Steep slopes and canyons define its young stage of evolution.

  The Cahuapanas Cordillera differs from the Eastern Cordillera based on lithological characteristics.
- ***Structural depression.*** Located at the northwestern side of the Cahuapanas Cordillera, this unit represents a tectonic depression with smooth slopes.
- ***Plateau.*** This is located over the Cahuapanas Cordillera in the central part of the watershed. The plateau has smooth shapes and soft rock (limestone) that allows the river flow to create a canyon.
- ***Saline domes.*** Two saline bodies in the form of dome structures appear in the landscape, and result in salinization of soil due to salt uptake by water.

2. Depositional origin units

- ***Lacustrine plain.*** This is the result of deposition of clay and gravel from the lacustrine medium that existed in the Quaternary - Pleistocene. Most of the agricultural and urban activities are located here.
- ***Low and high hills.*** Between the lacustrine plain and the Cahuapanas Cordillera there is a transitional area with sand and gravel deposition forming smooth sloping hills.

3. Fluvial origin units

- ***Alluvial flooding plains.*** These are located on both sides of Mayo River. The large seasonal flows and meandering shapes generate considerable erosion.
- ***Alluvial bottom U-shaped valleys.*** The Huascayacu, Avisado, and Naranjos rivers have U-shaped bottoms.
- ***Alluvial bottom V-shape valleys.*** Shallow valleys are usually V-shaped.

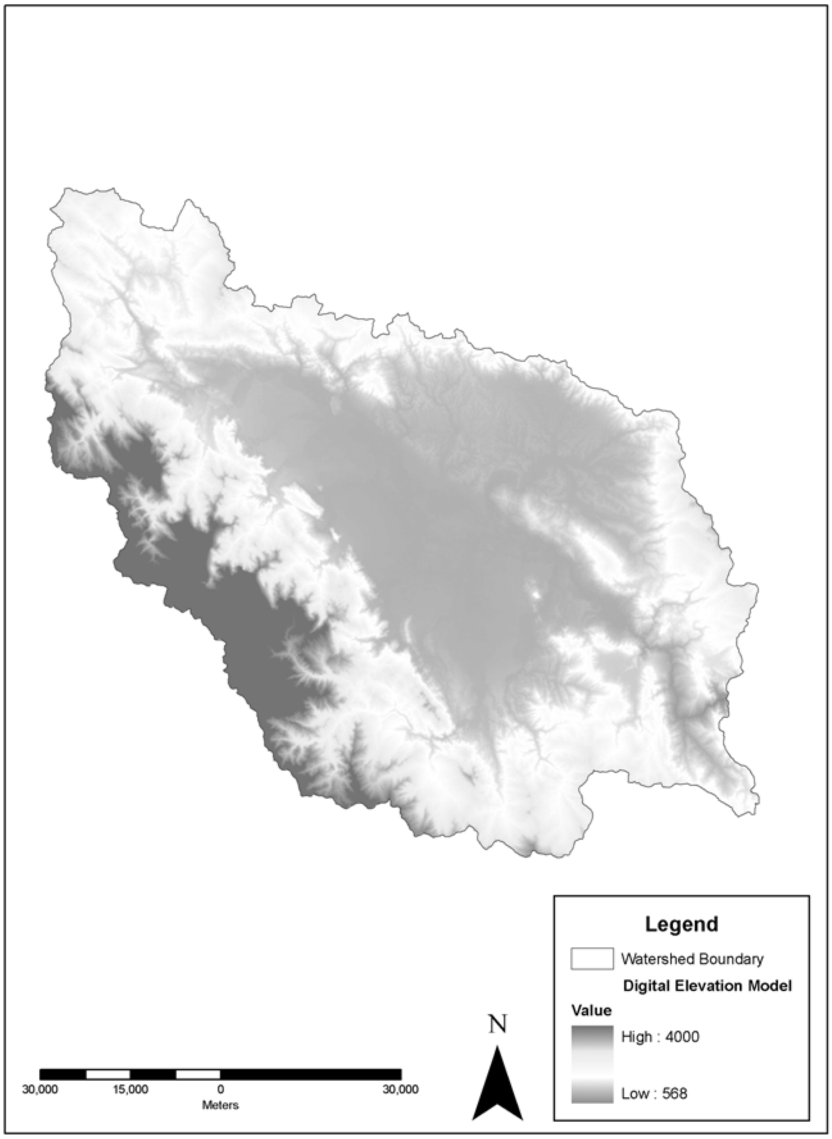


Figure 12: Alto Mayo Watershed digital elevation model

Drainage Network

The watershed has an elongated shape, fed mainly by the Mayo River. The Mayo River originates in the mountainous area of Sierra Cahuapanas and the Eastern Cordillera, and is fed mainly by seasonal precipitation. Within the Alto Mayo wathershed there are 30 subwatersheds. The main tributaries of the Mayo River are (Figure 13): Serrañoyacu, Amangay, Aguas Claras, Mirador, Naranjos, Túmbaro, Naranjillo, Soritor, Yuracyacu and Río Negro on the right bank, and Huasta, Cachiyacu, Tioyacu, Avisado and Huascayacu rivers on the left (Proyecto Cuencas Andinas *et al.*, 2004).

To help define the watershed hydrology, the Proyecto Cuencas Andinas *et al.*, (2004) divided it into three areas: lower, middle, and upper. The river is widest in the lower area (about 150 m),with large

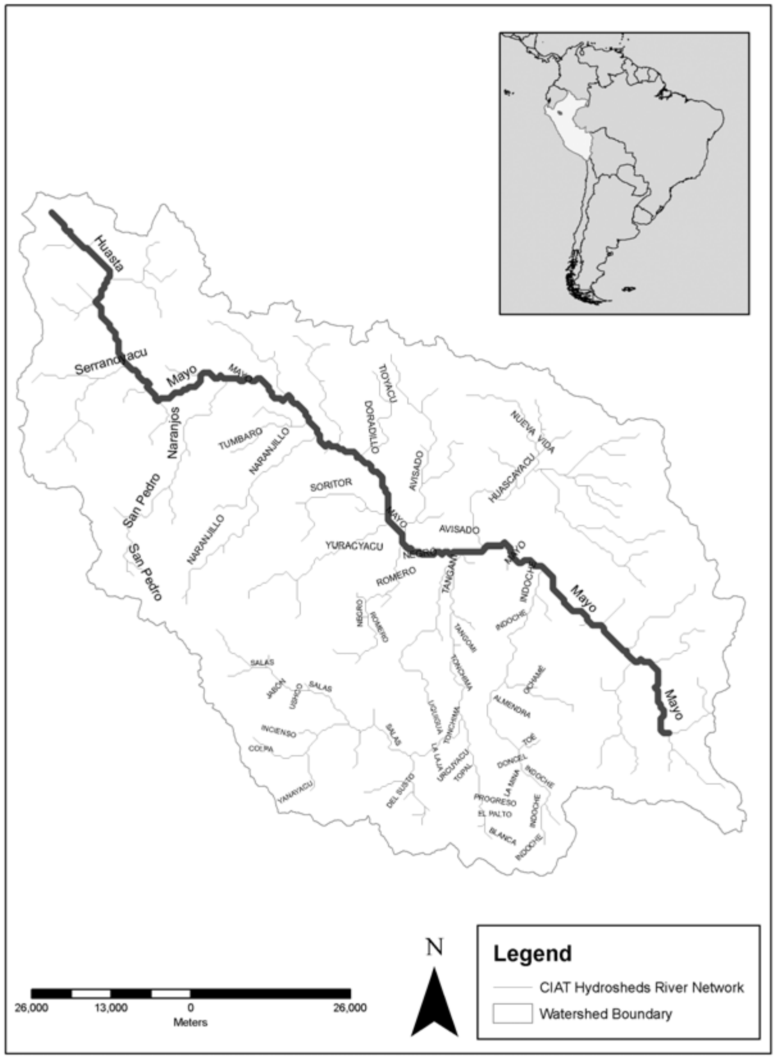


Figure 13: Alto Mayo Watershed drainage network

meanders and long straight trenches. In the middle area the meanders are less pronounced and separated by small straight trenches (dendritic flow).

In the upper part, the long straight trenches create rapids.

Climatic Conditions

The weather in the Alto Mayo Watershed is influenced by its altitude and meteorological events from the premontane and low forest area. The wind comes from the northeast, containing moisture that becomes rain when it arrives at the Andes Cordillera, causing high precipitation levels on the eastern side.

The following climate information is taken from Proyecto Cuencas Andinas *et al.,* (2004):

Precipitation levels are highest from December to May, and the mean yearly precipitation ranges from 1,000 to 2,000 mm.

Temperature is quite constant throughout the year, with little variation in mean monthly values, ranging from 23.3 °C in April to 22.7 °C in July in the Moyobamba station, 23.3 °C in April to 22.3 °C in July in the Rioja station, and from 25.6 °C in November to 23.8 °C in August at the Conquista station. The yearly mean temperature is 23.2 °C for Moyobamba station, 22.9 °C for Rioja station, and 24.6 °C in the Conquista station.

Evaporation is measured daily in the Moyobamba and Rioja weather stations. The mean yearly value is 415.2 mm in Moyobamba and 562.2 mm in Rioja. The mean monthly values vary from 39.1 mm in December to 30.5 mm in February at Moyobamba station and from 58.6 mm in August to 43.9 mm in February at Rioja.

Relative humidity information collected from the Moyobamba station showed a range from 84.2% in March to 80% in August.

Geology, Mineral Resources, and Soils

The geology of the area includes sedimentary rocks, mainly from maritime origin, but also continental origin, forming a mountain range subject to strong water erosion, and covered by dense tropical vegetation.

PEAM and PROFONANPE (2003) classified three zones, based on rock composition as follows:

- ***Eastern Cordillera***, in the middle and southwest part of the study area, consisting of a sequence of limestone with large structural deformations.
- ***Alto Mayo Depression***, in the central part of the study area, and covered by a thick layer of alluvial deposits.
- ***Cahuapanas Cordillera***, in the middle and northeast part of the study area, formed by a sequence of sandstone and limestone.

Ecosystems and their Plant and Animal Resources

Velez Rosas (2003) reports that there is an incomplete inventory of species in the area, although there is a wealth of birds and plants. The main gaps are in the inventories for mammals, reptiles, fish, and amphibians. There is almost no information on the latter two.

Limited studies indicate there are 573 plant species in the area, 25 being endemic and 177 native to Peru. There are 417 species of birds, with 96 under serious threat.

The area is characterized by scenic landscapes, spectacular geological formations, and unique flora and fauna. The forest zones in the protected area correspond to forest protection classes I and II (designated by forest legislation). Classes I and II are not suitable for intensive agriculture because of the significant slopes. They are managed to preserve the river watersheds, wildlife, scenic and scientific values, and social interest (Figure 14).

Figure 14: Landscape and scenery of the watershed
Photo: Marcela Quintero

SOCIOECONOMIC SETTING

Demographic Attributes

The population of the Alto Mayo region in 1993 was 137,961, according to the INEI (National Institute of Statistics and Informatics) census. The projections for 1999, 2001, and 2003 suggest considerable population growth (Table 7).

Table 7: Moyobamba and Rioja population

Province	Population 1981	Population 1993 (INEI)	Projection for 1999 (INEI)	Projection for 2001 (INEI)	Projection for 2003 (INEI)
Moyobamba	36,285	68,730	95,034	106,033	108,152
Rioja	37,935	69,231	92,211	104,237	105,798
Total	74,220	137,961	190,245	210,270	213,950

Source: INEI (1993)

The population growth rate was 12.5% for Moyobamba between 1972 and 1981 decreasing between 1993 and 2002. In Rioja Province this value decreased from 24.6% for 1972–81 to 4.9% in 1993–02.

Table 8: Urban and rural population growth rate (%)

Province	Urban			Rural		
	1961-72	1972-81	1981-93	1961-72	1972-81	1981-93
Rioja	2.9	11.0	8.8	11.7	24.6	4.9
Moyobamba	2.0	4.2	6.0	4.7	12.5	10.7

Source: Proyecto Cuencas Andinas *et al.* (2004)

The population density for Moyobamba Province in 1993 was 19.2 persons/km^2 increasing to 28.1 persons/km^2 in 2002. In Rioja Province the population density for 1993 was 28.4 persons/km^2 and increased to 36.4 persons/km^2 by 2002.

Moyobamba was the first city founded in the Peruvian forest by the Spaniards in 1540, becoming an important center from where soldiers, dealers, and missionaries embarked on their journeys. After 1975 there was a large migration to the city with the opening of the road "Presidente Fernando Belaunde Terry." This high migration trend was more intense on the right riverbank, although migration on the left bank increased later (Proyecto Cuencas Andinas *et al*., 2004).

The population included Creoles (European descendants born in a Spanish American colony) who founded Moyobamba, indigenous groups, and migrant populations.

In the Alto Mayo Watershed there are 14 indigenous communities. In the INEI (1993) census the total indigenous population was 1,783, and according to PEAM and PROFONANPE (2003) the total indigenous population for 2002 was 4,559. This represents only 2% of the actual residents. About 137,810 ha belong to indigenous communities, which is 18% of the watershed area.

Public Services Coverage

Access to public services is a good indicator of living conditions. In particular, access to drinking water and sewage systems is important for health reasons.

The coverage of drinking water and sanitation services in the area is inadequate. Cuadros and Mauricio Tixe (2004) indicate that 51% of households do not have access to wells or piped water.

There are only two cities in Moyobamba Province and one city in Rioja Province that have proper drinking water treatment plants, and the rest of the cities have no treatment facilities. Only one city in the watershed has a wastewater treatment plant. In other cities wastewater is thrown into the rivers (Table 9).

Table 9: Basic services coverage

District	Province	Population 2002	Pop. without potable water	Pop. without sewage system	Pop. without electricity	Poverty classification[a]
Nueva Cajamarca	Rioja	37,814	73.6	94.5	74.8	Very Poor
Elias Soplin Vargas	Rioja	5,637	18.2	99.9	99.0	Very Poor
Awajun	Rioja	3,525	71.4	99.4	75.0	Very Poor
Yuracyacu	Rioja	5,799	94.6	58.7	52.8	Very Poor
Pardo Miguel	Rioja	11,141	13.2	59.6	98.9	Poor
San Fernando	Rioja	4,929	90.9	96.7	98.7	Poor
Posic	Rioja	1,145	97.0	100.0	0.0	Poor
Yorongos	Rioja	2,994	11.0	100.0	81.8	Poor
Rioja	Rioja	25,378	53.6	79.4	39.2	Poor
Habana	Moyobamba	1,493	0.0	99.7	51.4	Very Poor
Soritor	Moyobamba	14,612	82.5	99.5	54.8	Very Poor
Jepelacio	Moyobamba	24,664	47.3	90.5	71.9	Poor
Yantalo	Moyobamba	2,463	70.5	99.8	11.3	Poor
Calzada	Moyobamba	4,461	45.3	89.1	51.4	Poor
Moyobamba	Moyobamba	54,068	30,4	64,4	51,1	Poor
Alonso de Alvarado	Lamas	10,479	38.6	98.0	60.9	Very Poor
Pinto Recodo	Lamas	13,128	80.1	100.0	97.3	Very Poor
Tabalosos	Lamas	12,184	38.3	93.4	70.2	Poor
San Martin	El Dorado	5,685	67.3	100.0	97.9	Very Poor
Vista Alegre	Rodríguez de Mendoza	326	0.0	100.0	97.9	Extreme Poverty
		241,925	51.6	84.5	65.4	

Source: Cuadros and Mauricio Tixe (2004)
[a]The poverty classification was determined using the "relative poverty" approach.

Health

The Health Ministry covers the needs of 85% of the population, and the other 15% is covered by a private organization. The most common diseases in the area are respiratory infections, diarrhea, parasitosis, and anemia.

Poverty

The Moyobamba population has a life expectancy of 70.2 years, and for Rioja it is 71.6. According to the PRONNA classification (normal, middle, poor, very poor, and extreme poverty) (National Food Support Programme), five of the six Moyobamba municipalities are very poor, except for the capital, which is categorized as poor. For Rioja Province most of the municipalities are classified as poor, including the capital, and one municipality is classified in the extreme poverty category.

The Human Development Index[2] for Moyobamba Province increased from 0.524 in 1993 to 0.542 in 2000 (from medium-low to medium), and in Rioja Province from 0.512 in 1993 to 0.543 in 2000 (from medium-low to medium).

According to the relative poverty approach to measure poverty (PEAM and PROFONANPE, 2003), the Alto Mayo region presents the lower three of the five[3] levels of poverty. The poverty levels found in the Alto Mayo watershed are:

- Extreme poverty. Areas where the total expenditure is less than the basic shopping basket.
- Very poor. Households where the total expenditure is less than the basic food basket.
- Poor. Households that can cover the basic food basket, but not other basic needs such as health and housing.

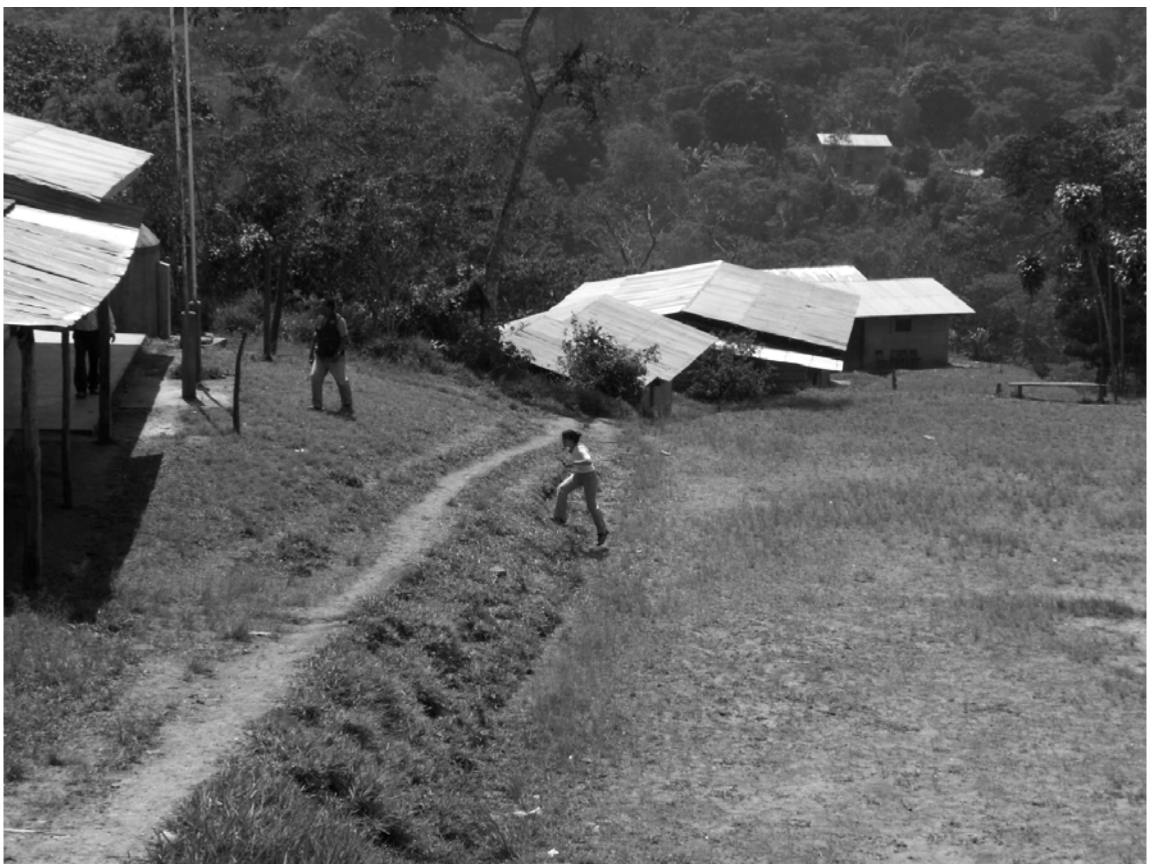


Figure 15: Settlement close to Moyobamba
Photo: Marcela Quintero

[2] HDI is obtained by taking into account income, school attainment, and quality and life expectation. Peru is classified as high (0.643-0.745), medium-high (0.569-0.642), medium (0.531-0.568), medium-low (0.473-0.530), and low (0.367-0.472).

[3] Relative poverty classification: Medium, Acceptable, Poor, Very Poor, and Extremely Poor.

Agricultural Labor Force

The main economic activity in the Alto Mayo watershed is agriculture. The population involved by activity is shown in Table 10. The primary sector involves agriculture as well as mining, stockbreeding, and fisheries.

Table 10: Labor force and sector involvement

Province	Population			Economic sector			
	Total	Men	Women	Extraction	Transformation	Services	Other
Moyobamba	23,291	18,352	4,939	13,252	1,577	5,602	2,468
Rioja	22,906	19,024	3,882	1,680	1,680	4,877	1,789

Source: INEI (1993)

Education and Literacy

The school enrolment rate in Moyobamba Province is 71.6% and in Rioja Province it is 71.5% (Proyecto Cuencas Andinas *et al.,* 2004). The Human Development Index according to the United Nations Development Programme (2005) estimated that the secondary education enrolment rate was 53.4% for Moyobamba and 58.2% for Rioja.

The illiteracy rate of the people older than 5 years for 1993 was 19.1% (17.5% Moyobamba, 20.8% Rioja) according to INEI. In both provinces the illiteracy rates are higher for women than for men (Table 11).

Table 11: Literacy levels

Province	Total	Literacy levels			
		Read and write		Cannot read and write	
		Men	Women	Men	Women
Moyobamba	59,281	27,090	21,717	4,052	6,324
Rioja	58,792	26,848	19,605	5,012	7,204

Source: INEI (1993)

Economic Activities

The economic activities in the Alto Mayo Watershed include (Proyecto Cuencas Andinas *et al.*, 2004):

- Coffee rice, bean, plantain, cassava, fruit, and vegetable production.
- Stockbreeding.
- Mining (salt, limestone, clay and coal).
- Handicrafts.
- Tourism.
- Industry.
- Palm oil production.

The main economic activity within the watershed is agriculture, although tourism is becoming more important. Tourism generates 300 direct jobs and 9,000 indirect jobs.

The industrial sector is weak, except for the cement industry, which is responsible for most of the actual mines in the area. The others are small, and most are operated by individual households. Industrial activities include brick production, liquor production (from sugarcane), and straw hat production.

INSTITUTIONAL SETTING

Governance and Organization

The management of natural resources in Peru involves several decentralized public organizations, including an environmental management office. These offices are present at different levels within public organizations, and their activities are restricted to those of the governmental entity to which they are attached. As an example, the following ministries have environmental offices with different levels and functions: Energy and Mines Ministry, Fisheries Ministry, and Industry Ministry (Charpentier and Hidalgo, 1999).

An attempt to solve this difficult organizational arrangement was tried in 1994. The central government created CONAM (National Environment Council) for intersectoral coordination, with up to five levels from national to regional offices.

Every regional government has to be concerned about natural resources management. In Alto Mayo, PEAM was created by the Regional Government of San Martin, to provide support to sustainable rural development. This project is supported by the German agency GTZ (Deutsche Gesellschaft für Technische Zusammenarbeit).

Policy Framework

CONAM is in charge of promoting national environmental policies. It plans, promotes, coordinates, controls, and monitors environment and natural resources. According to CONAM "The environmental policy in Peru is oriented to guarantee the sustainability of the country in its three dimensions: social, economic and ecologic."

In 1987 a protected area of 182,000 ha was created under the name "Bosque de Proteccion de Alto Mayo," to protect the high part of the watershed, control water flows, and prevent erosion.

Municipally protected areas were designated by Moyobamba Province to complement the protected area, adding 18,350 ha of protected land in the region (Cuadros and Mauricio Tixe, 2004).

LAND RESOURCES MANAGEMENT

Within the Alto Mayo Watershed there are 182,000 ha of protected natural areas. These are natural zones recognized and protected by law to preserve biodiversity, water, and other cultural, scientific, and landscape values.

Land use in the watershed is given by Table 12.

Table 12: Land use in Alto Mayo Watershed

Land use	Area (ha)	(%)
Undisturbed forest	354,137	44.6
Secondary vegetation (includes coffee plantations and montane forests)	309,672	39.0
Grass	76,227	9.6
Scrubland	29,379	3.7
Water bodies (includes rice plantations)	22,233	2.8
Urban areas	2,382	0.3
Total	794,030	100.0

Source: Cuadros and Mauricio Tixe (2004)

Agricultural areas are included in the classification of secondary vegetation, water bodies, and grass in the land-use table, and comprise about 10.4% of the total watershed area.

Forestry activities are no longer significant to the deforestation process in the Alto Mayo Watershed. Shifting agriculture is now the main destructive force on the natural resources in Alto Mayo. Between 1999 and 2002, the undisturbed forest loss was 14.7% of its area, as a result of increased coffee and rice production. The annual deforestation rate for the same period was 1.2 and 7.1%, an alarming increase (Cuadros and Mauricio Tixe, 2004).

Agricultural Production

Traditionally agriculture has been the main economic activity in the Alto Mayo Watershed. The main crops are corn, rice (lowlands), and coffee (highlands). Crops such as cassava, plantain, and fruit are for local consumption (Table 13).

Table 13: Crop areas (2001-02)

Crop	Area (ha)	% of the total crop area
Rice	26,944	32.6
Grass	22,698	27.5
Coffee	20,000	24.2
Plantain	4,654	5.6
Cacao	4,490	5.4
Corn	980	1.2
Cassava	898	1.1
Bean	490	0.6
Sugarcane	490	0.6
Other	980	1.2
Total	82,624	100

Source: Cuadros and Mauricio Tixe (2004)

WATER RESOURCES MANAGEMENT

Water Availability

The Mayo River has an annual average discharge of 277.1 m^3/s (PEAM and PROFONANPE, 2003). The highest values occur from November to March with a monthly average of 404.3 m^3/s and the lowest values from July to September at 142.6 m^3/s.

INRENA calculated annual water availability for the Alto Mayo River Watershed of 4,777 million m^3 (see http://www.inrena.gob.pe/irh/irh_infointeres_atdr_altmayo.htm).

Water Demand, Allocation, and Use

There is an irrigation system within the watershed, used mainly for rice cropping. The area covered by the irrigation system is shown in Table 14.

Table 14: Irrigation system coverage

Area	Sub-area	Area under irrigation (ha)
Mayo River right bank	Naranjos	301.6
	Naranjillo	2,295.1
	Yuracyacu	8,785.6
	Tóchima	4,677.5
	Indoche	924.2
Mayo River left bank	Huasta	255.8
	Tioyacu	1,853.1
	Avisado	1,893.6
	Huascayacu	580.4
Protected Forest		—-
Total		21,566.8

Source: http://www.inrena.gob.pe/irh/irh_infointeres_atdr_altmayo.htm

The total annual water demand calculated by INRENA for 2003, based on the irrigation system, is 280 million m^3. Adding in the human consumption estimated at 11.7 million m^3, the water availability (4,777 million m^3) is still much greater than demand.

Challenges related to food, water, and environment

There are many challenges in the Alto Mayo Watershed related to the problems presented in the area. These problems arose because of disorganized development activities, which contributed to the rapid degradation of the environment, as follows.

- ***High poverty levels.*** All people living within the watershed are classified as poor, in the three lower ranks of the five in the poverty classification.
- ***Low productivity levels.*** Inappropriate techniques and resource exploitation have led to low productivity levels in agricultural production. The result has been low incomes and degraded land.
- ***Poor infrastructure.*** Basic services do not reach the entire population, with limited access to water, sanitation, and electricity. Transport has two sections, the right river bank where the towns are

connected by roads, and the left bank where only a few kilometers connect some towns and become impassible during heavy rains.

- ***Deforestation*** is the main environmental concern in the area. It destroys the ecosystem, breaking the flow of services provided by forests: water storage capacity for dry periods, decrease of peak discharges, biodiversity benefits, and landscape beauty.
- ***Loss of biodiversity.*** The watershed shelters many plants and animals, some of them native and little known. Their loss would be tragic.
- ***Erosion*** is caused by improper agricultural techniques that lead to degraded land.
  This forces people to move to virgin forest areas, which contributes further to forest destruction (Figure 16).

Figure 16: Erosion and deforestation
Photo: Marcela Quintero

Baseline conditions, future outlook, and vision

The Alto Mayo Watershed is an important ecosystem from the point of view of its rich biodiversity and human cultures. These characteristics are threatened by the massive migration process and uncontrolled exploitation of natural resources. The problems include rapid deforestation, ecosystem destruction, land degradation, and poverty.

PARTNERSHIPS FOR TRANSLATING VISION INTO ACTION

Some of the groups in the Alto Mayo Watershed are already developing activities, including:

- CONDESAN-GTZ, through their initiative Cuencas Andinas, are working under a research-action plan. The research prioritizes different land-use alternatives that encourage stakeholders and policymakers to form partnerships and encourage investment.
- PEAM has been developing projects targetted at sustainable rural development of the region. PEAM is a governmental agency that conducts economic, social, and environmental projects.

RESEARCH AGENDA

Research Priorities

The complete list of research priorities for the Andean System of Basins was summarized earlier. The main research topics to be addressed for the Alto Mayo Watershed are to:

- ***Quantify the hydrologic budget of the watershed.*** This would help us to recognize water patterns, storage capacity, and other hydrological issues that may contribute to understanding physical processes in the watershed.
- ***Quantify the sediment budget.*** Together with the hydrological budget, and with the help of mathematical models and sufficient data, we can define the causes and possible solutions to alleviate sedimentation problems.
- ***Determine current land-use patterns and the impact of potential land-use changes on watershed hydrology.*** Models, together with meteorological data, soil, and water samples, maps, and other data can help in the assessment of the consequences of different land-use practices.
- ***Formulate optimal restoration strategies.*** An integral evaluation of the alternatives on land use and water use may help to formulate an optimal strategy to restore the ecosystem. Biophysical and economic models, plus expert analysis, are tools that can address this issue.
- ***Determine poverty profiles and identify stakeholders.*** Knowledge of the social network and human situation in the watershed is a fundamental factor to start developing effective poverty alleviation and ecosystem restoration strategies.

Figure 17: Deforestation patches in the hillsides
Photo: Marcela Quintero

Section 3 - El Angel Watershed

Resources and Agricultural Production

BIOPHYSICAL SETTING

Location and Area

El Angel Watershed is located in northern Ecuador (Figure 18). It belongs to the larger San Juan Watershed that drains into the Pacific in Colombia. It is located in Carchi Province, with a total area of 292 km^2 (300 km^2 taking into account the influence area) between 0°30′ and 0°45′ N and 78°05′and 77° W (Arellano *et al.*, 2000). The watershed comprises three municipalities: El Angel, Mira, and Bolivar.

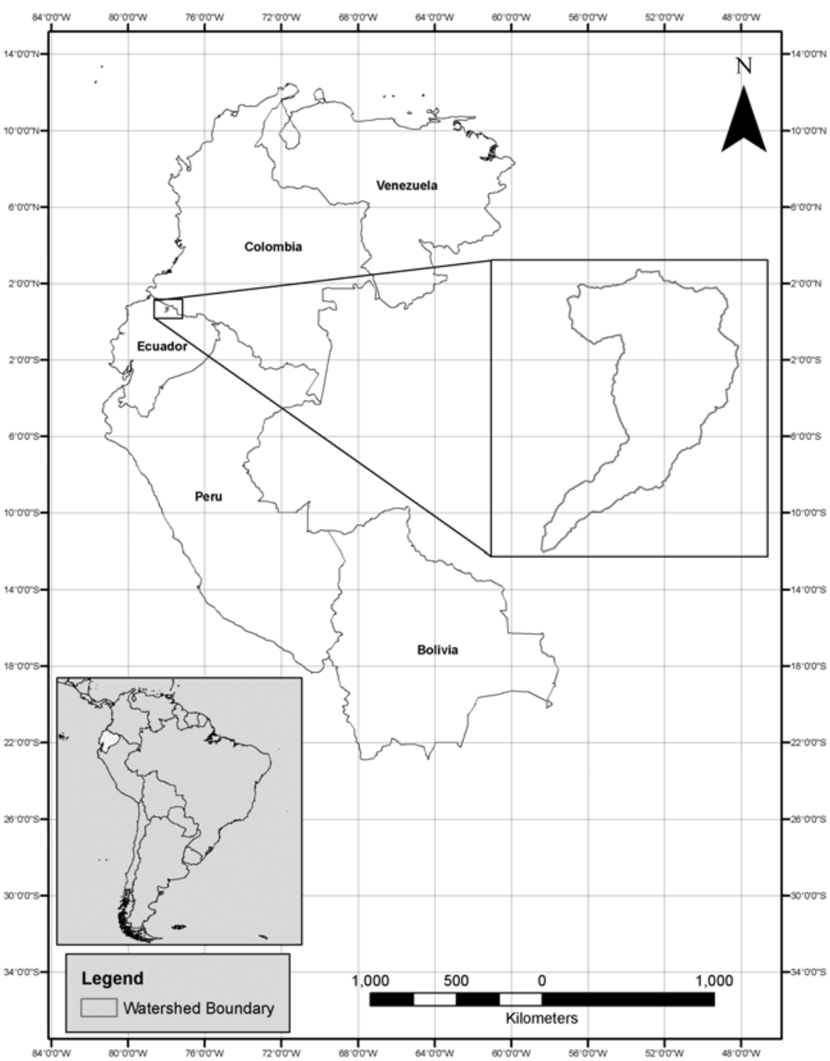


Figure 18: Location of the El Angel Watershed

Topography

The watershed is located in the Andes, with altitudes varying between 1,500 and 4,100 m (Figure 19), in a small area with rugged terrain.

The topography has been shaped by volcanic activity in the area. The watershed is elongated in the same direction of the river flow that runs through a narrow valley ending in the Chota River. The watershed borders two volcanoes in the west, Iguan (3,879 m) and Chiltazon (3,967 m), and with a massif whose highest peaks are more than 4,000 m.

The slopes are steep, varying from 15 to 40%. The areas higher than 3,500 m have a smoother topography than the low areas. The lakes and swamps are located in the upper part as a result of this shape (Schott, 1998).

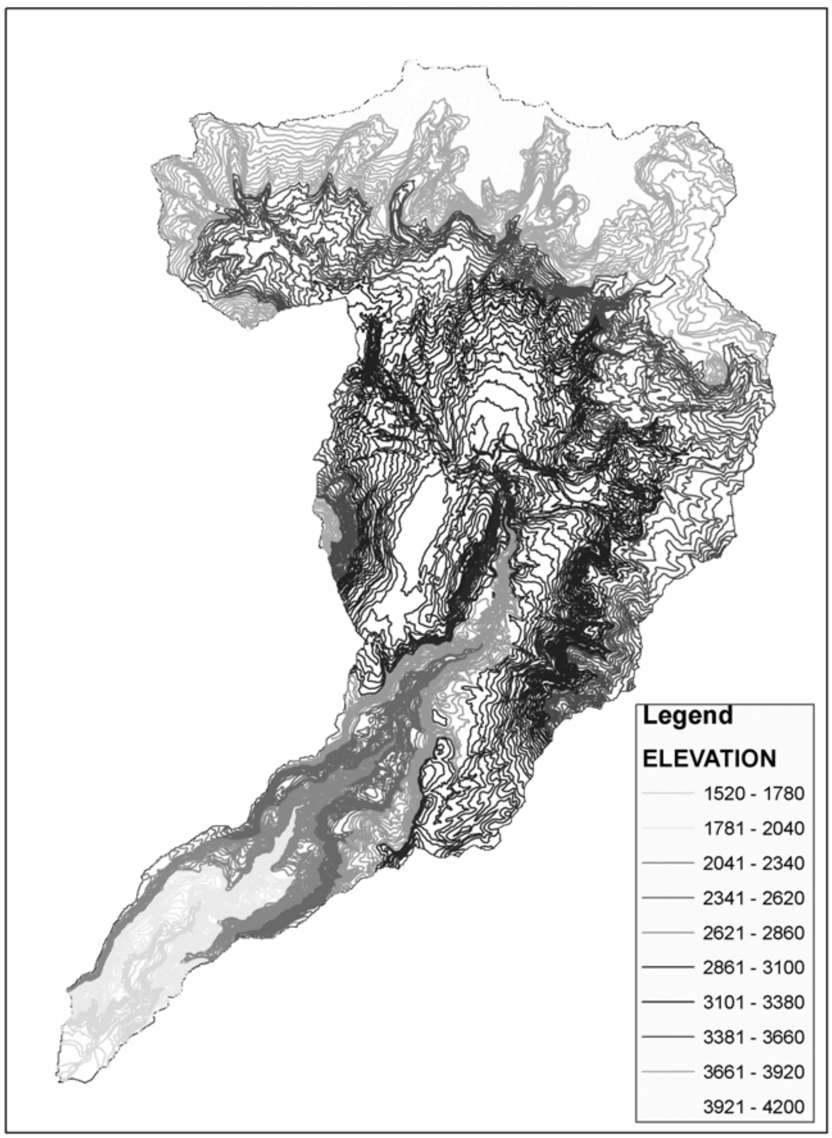


Figure 19: El Angel Watershed contour lines

Drainage Network

El Angel is the main river in the watershed, and has its origins in the *paramos,* flowing eventually into the Chota River. The El Angel Watershed is part of a larger watershed that drains into the Pacific through the San Juan River. The San Juan is a binational watershed between Colombia and Ecuador.

The natural drainage system (Figure 20) has been altered by activities in the area, and irrigation channels have been constructed diverting water from the natural courses. This irrigation scheme has been inefficient and has caused several problems.

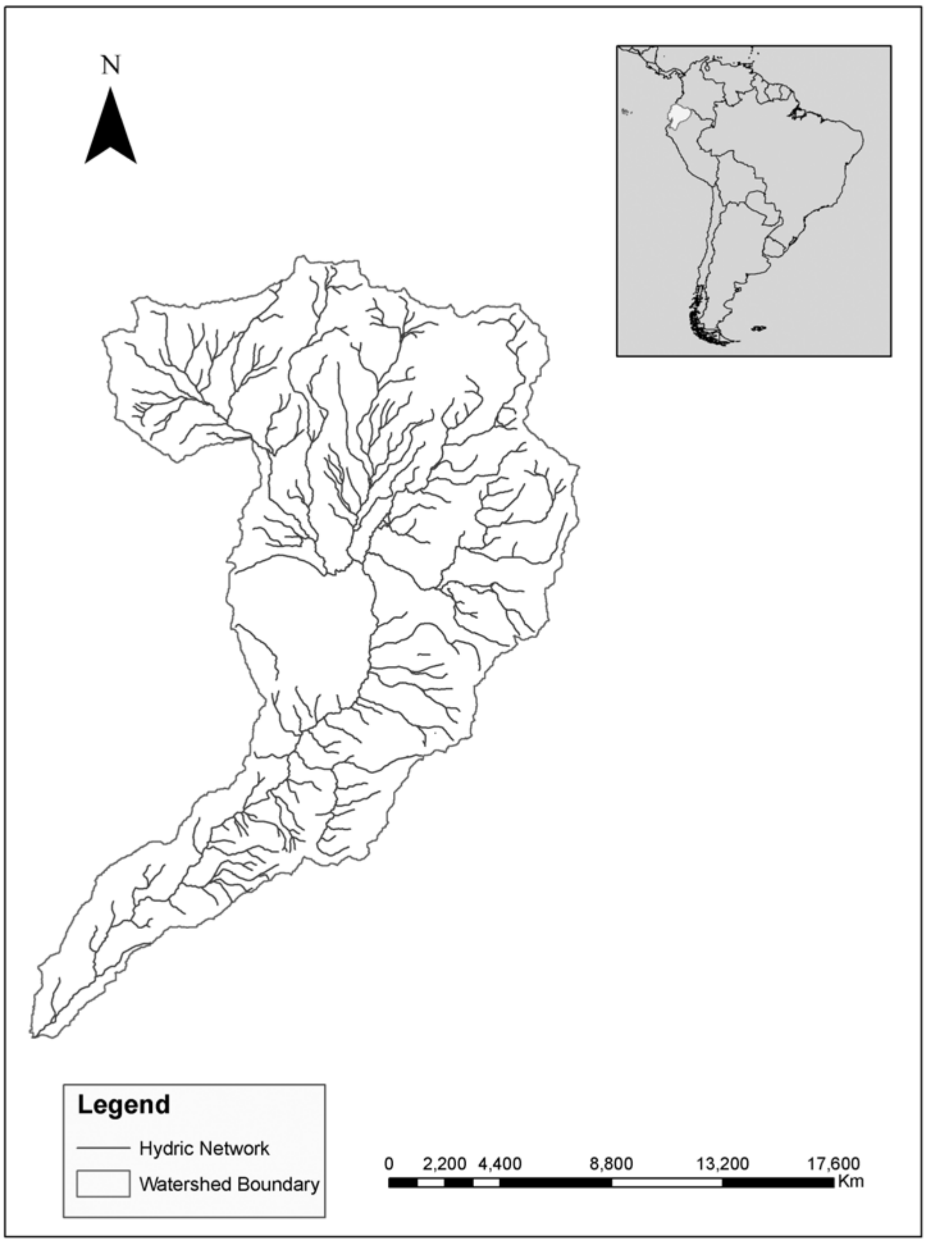


Figure 20: Drainage network of the El Angel Watershed

Climatic Conditions

The watershed is divided into three climatic zones, based on altitude: Upper, Middle, and Lower, with different climatic conditions.
(http://www.ires.ubc.ca/projects/Carchi/htmlenglish/introen.htm)

***Upper zone* (3,100-4,100 m):** Altitude and exposure are the major factors that affect climate. Maximum temperatures rarely exceed 20°C, and minimum temperatures are often below 0°C. Average temperatures fluctuate between 4 and 8° C. Total annual rainfall ranges from 800 to 2,000 mm, mostly delivered in long but low-intensity showers. Relative humidity is always higher than 80%.

***Middle zone* (2,400-3,100 m):** Minimum temperatures rarely drop below 0°C, and maximums do not exceed 30°C. Average temperatures range from 12 to 20°C. There are approximately 1,000 to 2,000 hours of sunlight annually. Annual rainfall fluctuates between 500 and 2,000 mm, and relative humidity ranges from 65 to 80%.

***Lower zone* (1,500–2,400 m):** Average temperatures vary between 12 and 20° C, with little difference between winter and summer. There are approximately 1,500 hours of sunlight annually. Relative humidity usually ranges between 50 and 80%.

The watershed has one rainy season from October to December, one dry season from June to September, and one season with normal precipitation from January to June. The uneven distribution of precipitation is one of the main problems in the area, creating water scarcity problems in the dry season (Consorcio Carchi, 1998).

Geology, Mineral Resources, and Soils

Most of the materials found in the area correspond to volcanic formations from El Boliche, Tres Quebradas, and Yanacocha. The watershed has three geomorphological zones: volcanic relief, glacial relief, and fluvial relief.

The predominant soils in the upper zone of the watershed are black Andean derived from volcanic ash (Andepts or Andisoles), whose physical and chemical properties are suitable for cultivation. Soils rich in organic matter with good field capacity are suitable for the production of potatoes and milk cattle. In the middle zone, Andisole soils are also abundant but have less clay, organic matter, and hard ash than those at higher altitudes. In the lower zone, the soils are sandy, originating from metamorphic material sensitive to erosion (http://www.ires.ubc.ca/projects/Carchi/htmlenglish/biofisen.htm).

Ecosystems and their Plant and Animal Resources

The rich biodiversity of the watershed is mainly a result of its range of altitudes.

In the upper areas, above 3,100 m, lie the high plateaus or *paramos* (Figure 21), with tropical ecosystems at high altitudes containing plants and animals adapted to extreme climatic conditions. In this zone there are remains of highly diverse Andean forest ecosystems. The vegetation protects the soil and allows the slow accumulation of organic matter. These circumstances give to the *paramos* a large water-storage capacity and the ability to regulate water flow. The vegetation of the area also has the ability to capture water from the moist air, creating an important source of water.

In the middle zone, agricultural lands grow corn and bean crops in abundance, although natural vegetation is scarce. Nevertheless, natural vegetation cover is sometimes present, especially in wet areas such as valleys and depressions. The thicket is the dominant vegetation in the area, and is the transition between the herbaceous vegetation in the high areas to the tree-shaped vegetation cover from the hillsides (Schott, 1998).

In the lower area, there is a dry valley with little precipitation, limiting biodiversity and resulting in an arid ecosystem suitable for acacias and cacti.

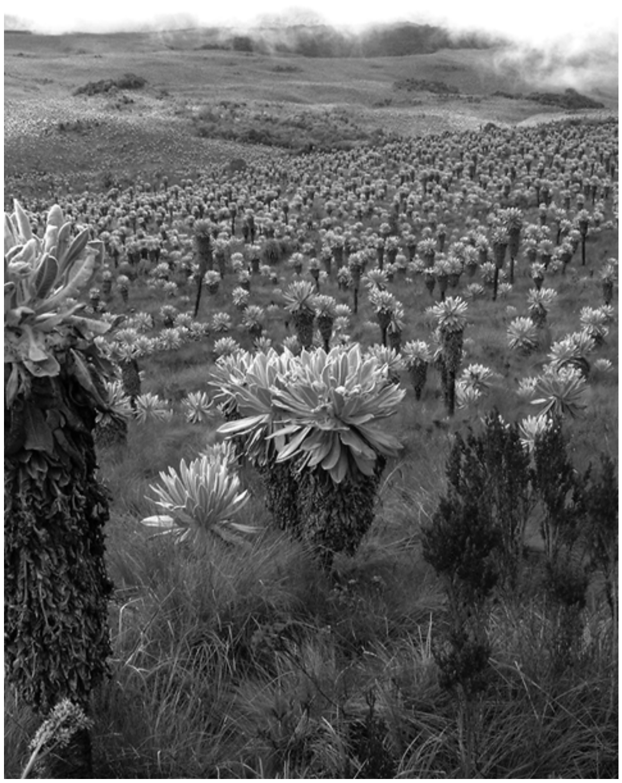


Figure 21: View of the *paramo* ecosystem
Photo: Robert Hofstede

In the upper part of the watershed, an ecological reserve protects this strategic area for water collection. The zone has characteristics of the wet *paramo,* with plants such as *frailejon* (*Espeletia* sp.), and shelter for Andean animal species, some of which are at risk of disappearing (for example, *venado de paramo* (*Odocoileus lasiotis*)). The area of this reserve is 15,715 ha, located between 3,600 and 4,218 m.

Figure 22: View of the El Angel natural reserve
Photo: Elías Mujica

SOCIOECONOMIC SETTING

Demographic Attributes

The El Angel Watershed is located within the limits of three municipalities: Espejo, Mira, and Bolivar (Figure 23). The urban area of Espejo municipality is El Angel, so the name is used in some of the literature to refer to the municipality.

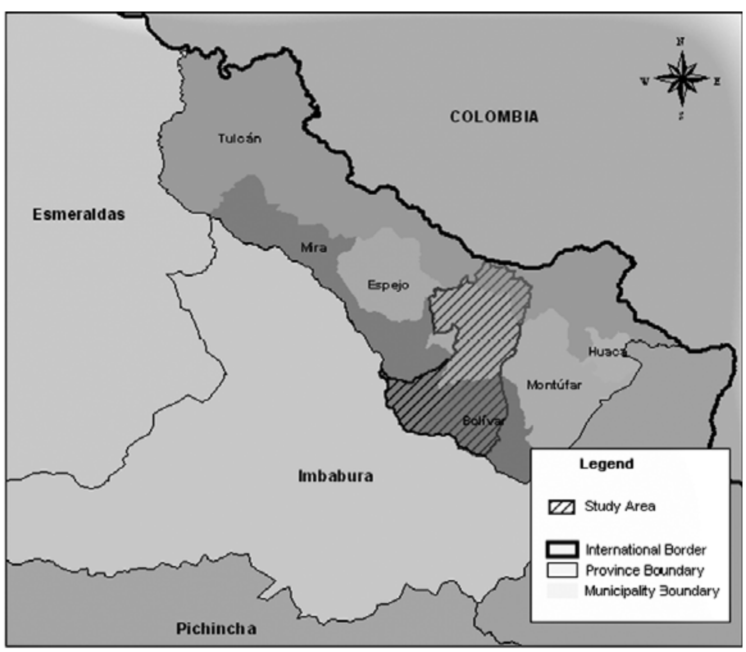


Figure 23: El Angel Watershed and municipalities

According to INEC (2001), the total population of these three municipalities was 40,332.

The census gave data on gender diversity and the rural and urban population, and showed that there were more rural dwellers in the watershed (Table 15).

Table 15: Total population in the El Angel Watershed

Municipality	Population	Men	Women	Rural	Urban
Bolivar	13,898	7,114	6,784	11,322	2,576
Espejo	13,515	6,576	6,939	9,132	4,383
Mira	12,919	6,517	6,402	10,023	2,896
Total	40,332	20,207	20,125	30,477	9,855

Source: INEC (2001)

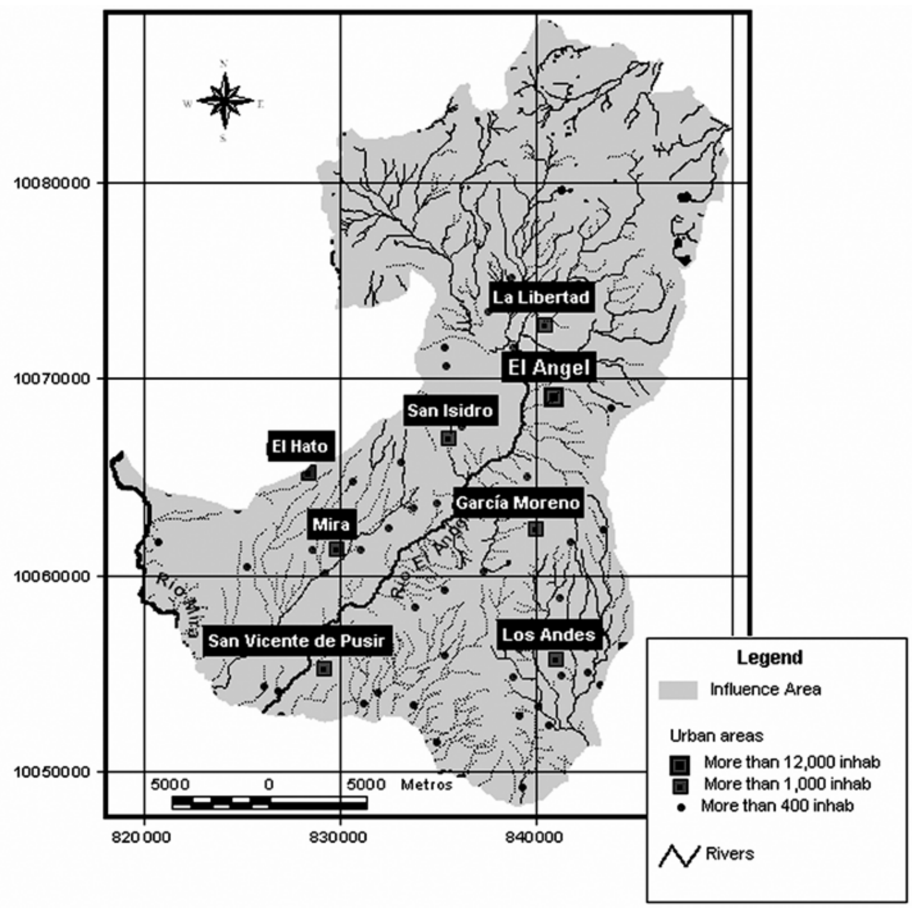


Figure 24: Urban areas within the El Angel Watershed

Agricultural Labor Force

The main source of employment in the region is agriculture and livestock, with most of the economically active people involved in these two activities (Figure 25). The service sector provides some employment, and there is no important industry or extraction work within the watershed.

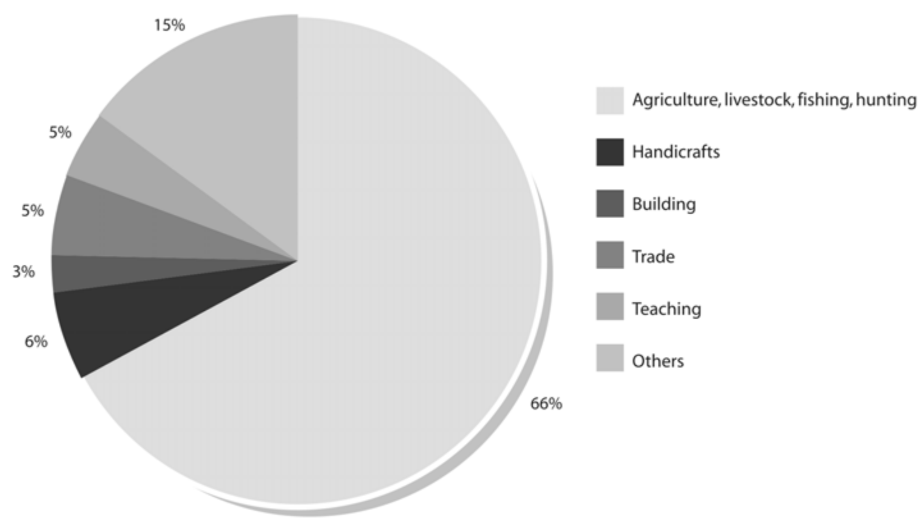


Figure 25: Percentage of people involved in economic activities
Source: INEC (2001)

Education and Literacy

Illiteracy rates are presented in Table 16. According to INEC (2001), the illiteracy rate for Ecuador is 8.4%, and the municipalities involved show values below and above. The average illiteracy rate for rural areas is 13.7%, which is higher than the values of the municipalities.

Table 16: Illiteracy rates

Municipality	Total (%)	Men (%)	Women (%)
Bolivar	7.7	6.3	9.1
Espejo	7.5	5.2	9.5
Mira	10.7	9.0	12.3

Source: INEC (2001)

The average number of years in school were measured in the 2001 census. For Bolivar the number was 5.1 years; for Espejo 6.0 years; and for Mira 5.4 years, all lower values than the national average of 7.1 years.

Economic Activities

Agriculture provides most of the income for rural residents of El Angel Watershed.

Agriculture also plays an important part in urban income, in addition to jobs derived from state and municipal functions. The percentage of people in each economic sector shows a majority in the primary sector, which includes agriculture (Table 17). The secondary sector refers to industry, and tertiary to services (http://www.ires.ubc.ca/projects/Carchi/htmlenglish/use.htm) .

Table 17: Labor force and sector involvement

Municipality	Primary sector	Secondary sector	Tertiary sector	Total
Bolivar	3,975	330	857	5,162
Espejo	2,755	578	1,276	4,609
Mira	3,519	398	855	4,772
Total	10,249	1,306	2,988	14,543

Source: INEC (2001)

INSTITUTIONAL SETTING

Governance and Organization

The Ecuadorian Environment Ministry is in charge of the environmental policy design and coordinating strategies for sustainable use of natural resources at the national level.

Nevertheless, the Ecuadorian Government has a decentralized model in which every regional government has the ability to regulate the use of natural resources within the policy boundaries of the Ministry.

Policy Framework

In Ecuador, there are two kinds of governmental entity: autonomous ones, and those dependent on the central government.

Stakeholders involved in El Angel Watershed include: *National*: Environment Ministry and Parliament, where laws and policies are designed; *Regional*: Provincial governments are in charge of applying policies; *Watershed*: The municipalities and residents.

LAND RESOURCES MANAGEMENT

Land use in the watershed is given in Table 18. Agriculture is the main economic activity, with almost half of the total area used for agricultural purposes. There is a natural protected area in the upper part of the watershed that protects the *paramos* ecosystem, and ensures that this ecosystem continues capturing and storing water for use within the watershed.

Table 18: Land use in the El Angel Watershed

Land use	Area (km^2)	(%)
Paramos	111.7	37.4
Thicket	4.2	1.4
Agriculture	145.2	48.7
Grass	15.3	5.1
Erosion	22.0	7.4
Total	298.4	100

Agricultural Production

Plot distribution between the three zones is relatively uniform, although there are more large plots in the upper zone that has higher rainfall. The main difference in land use between the three zones is in the relation between agricultural use and pasture for livestock. Agriculture increases as altitude decreases, while the opposite is true for natural and cultivated pastures. These trends are consistent with larger plot size, higher rainfall, and lower temperatures of the upper zone (http://www.ires.ubc.ca/projects/Carchi/htmlenglish/use.htm).

Upper Zone

Crop rotation revolves around the potato. The normal practice for establishing pastures or renewing fields is to plant potatoes first, especially on the high plateau and in the middle zone. Rotations are based on the low diversity of crops that are adapted to the upper zone, such as: potato, pea, barley, wheat, and grass. Other crops, such as bean, are not sown as often due to phytosanitation problems, and pea crops commonly take their place in the rotations.

Middle Zone

The main crop is corn, rotated regularly with bean or potato. About 21% of plots are filled with corn for 4 consecutive years, which causes problems with phytosanitation as well as low yields.

Lower Zone

The main crop of the lower region is bean, which is sown for 4 years continuously and represents 35.1% of the plots and 25% of the surface area. There is another form of rotation that involves sowing bean for 2 years, followed by 2 years of tomato (another important crop in this zone). Crop rotation is not carried out in most of the plots. In some cases, for example with pepper and bean, rotations may actually create phytosanitary problems. In the lower region, corn and bean are rotated year after year. Aniseed, a new crop, is often sown after bean, depending on a farmer's requirements.

WATER RESOURCES MANAGEMENT

Water Availability

According to most of the literature consulted for this report, it is not clear whether there is a shortage or a surplus of water within the watershed. In official estimates, the water flow has a surplus of 1.6 l/s which, in agricultural terms, permits an expansion of 1,610 ha of irrigated land. On the other hand, the Planes de Desarrollo Cantonales, studies by Cornell University, and the International Water Management Institute, indicate that a deficit and/or considerable fluctuations exist, which cause difficulties in planning water volume and flow. Moreover, hydrometeorological stations do not provide extensive or solid histories of flow, and the many readings are blank or contain obvious errors.

Due to the variability of water availability throughout the year, there is a severe shortage of water during the 3-month dry season when the total discharge is about 10 m^3/s. During the rainy season, discharge is about six times greater. These extremes are caused by the lack of storage/retention capacity of the watershed (http://www.ires.ubc.ca/projects/Carchi/htmlenglish/water.htm).

Water Demand, Allocation, and Use

Following the State's Water Law, El Angel Watershed was licensed for various uses of water: domestic, irrigation, industrial, and other uses such as fisheries. In reality, water use differs from what the law allows. For example, water for domestic use is also used for irrigation and crop watering, while water for irrigation is used for human consumption and washing of fertilizer equipment. This situation causes problems with human health and the degradation of water resources.

In addition, the approved exploitation flow exceeds water availability, thus generating conflicts between users. In the upper zone, despite being near the water source, most people feel that the amount of water available for agriculture is insufficient. This perspective is also held by those in the middle zone, whereas those in the lower region (with a water deficit for much of the year) feel the water supply is adequate (http://www.ires.ubc.ca/projects/Carchi/htmlenglish/water.htm).

The water uses in the watershed are given in Table 19, showing that most of the water is used for agricultural purposes.

Table 19: Approved licences for water use

Use	Number of licenses	Flow (l/s)	%
Domestic	23	34.3	0.7
Industrial	7	436.5	8.3
Potable	12	70.4	1.3
Irrigation	186	4,428.5	84.5
Fisheries	4	257.0	4.90
Other	4	17.4	0.3

Source: Corporación Grupo Randi Randi (2005)

Challenges relate to food, water and environment

There are many challenges in the El Angel Watershed. The problems arose because of uncordinated development of main activities, which contributed to the rapid degradation of the ecosystem. Some of the problems are:

- ***Destruction* of the upper watershed ecosystems, *paramos,*** which decreases the land's ability to retain water. This is caused by agricultural expansion.
- ***Erosion.*** Human settlement on the slopes of Carchi is both rapid and uncontrolled.
  Agricultural practices on this land, along with inappropriate methods of cultivation, result in soil degradation. In addition, the lack of suitable agricultural land causes many people to cultivate areas that are susceptible to erosion and landslides.

- ***Deforestation.*** The deforestation rate in the upper part of El Angel Watershed between 1965 and 1993 was 1.9%, especially on the left bank of the river, due to population growth and the lack of land. In the middle zone the natural vegetation has almost disappeared.
- ***Pollution.*** Intensive use of pesticides in agriculture, especially in potato crops, has caused a negative impact on water quality. Accumulation of pesticides in groundwater threatens the environment and human health.
- ***Loss of biodiversity.*** The rich biodiversity of the area has been greatly impacted by development. Agricultural expansion has extended into sensitive areas such as the high planes and the dry valleys of the Andes. This has resulted in the displacement or extinction of some local plant and animal species.
- ***Water use and management.*** The middle and lower altitude zones are either partially or totally dependent on water for production. The reality is that the water supply is currently insufficient, and conflicts about availability will surely increase. Most irrigation systems are quite old and technologically primitive, and the channels are often poorly organized and inferior. The investment that needs to be made to resolve problems of water transport, distribution, and use is muchlarger than either communities or local authorities can provide. Nevertheless, the development of the watershed depends upon finding and implementing solutions to these problems.

Baseline conditions, future outlook, and vision

El Angel Watershed is a small area in the highest part of the Andean mountains.

Although the characteristics of the *paramos* ecosystems serve as a buffer zone to avoid water-related problems, there is not enough water to satisfy all the needs of people, especially in dry months. Approved licenses for water exploitation exceed the water availability, and inequities result in problems between users. Pesticide pollution, deforestation, and erosion caused by agricultural practices are among the main problems of the watershed.

PARTNERSHIPS FOR TRANSLATING VISION INTO ACTION

In the El Angel Watershed area there is an organization of stakeholders in a consortium that organizes initiatives: the Carchi Consortium. In an effort to focus more local attention on the problems in the watershed, specifically on sustainable development and natural resource management, an informal consortium was created in 1994 that included a number of national and international institutions working in the watershed. The Carchi Consortium now plays an important role in the development of communities and the exchange of information among institutions involved in the management of the watershed. The Carchi Consortium is comprised of a group of public and private organizations that work together for a common interest: improving the living conditions of El Angel Watershed residents within a sustainable development framework. The consortium works under a horizontal model where every group can participate and express its opinion.

RESEARCH AGENDA

Research Priorities

The complete list of research priorities for the Andean System of Basins for CPWF was summarized earlier. The main research topics to be addressed for the El Angel Watershed are to:

- ***Quantify the hydrologic budget of the watershed.*** This would help us to recognize water patterns, storage capacity, and other hydrological issues that may contribute to understanding physical processes in the watershed.
- ***Determine current land-use patterns and the impact of potential land-use changes on watershed hydrology.*** Models, together with meteorological data, soil, and water samples, maps, and other data can help in the assessment of the consequences of different land-use practices.
- ***Evaluate the effects of water control works.*** This would ensure water flows in dry periods.
- ***Water quality control.*** Research in this area will contribute to the prevention of health problems in the region, and will record trends related to land-use practices.
- ***Understand the extreme hydrologic responses.*** To avoid serious production risks, we need to know and understand the hydrology of the El Angel Watershed.

  Effects of natural events such as climate variations, seasonal fluctuations, and other major hazards might be diminished if the hydrological response of the watershed is known.
- ***Develop social networks knowledge.*** Conflicts exist between extremely diverse groups, often separated by terrain, but connected as net suppliers or competing users of water. This increases the vulnerability of individual groups and obstructs the path to improvement. Mountain and hill communities are isolated and often marginalized. Lack of efficient, equitable, and sustainable water allocation mechanisms that are acceptable to all watershed stakeholders constrains overall capacity of water to support rural livelihoods.

Section 4 - La Miel Watershed

Resources and Agricultural Production

BIOPHYSICAL SETTING

Location and Area

La Miel Watershed is located in Colombia at the eastern slopes of the Central Cordillera.
It is located between 5°15' and 5°46' N and 75°13' and 74°39' W. It comprises six municipalities in the Caldas Department: Samana, Pensilvania, Norcasia, Victoria, Marquetalia, and Manzanares. The watershed has an area of 1,105 km^2 (CORPOCALDAS, 1999). It hosts one of the tallest dams in the world, which is used for energy generation (Miel Hydropower Plant). The total watershed area to the dam is 770 km^2.

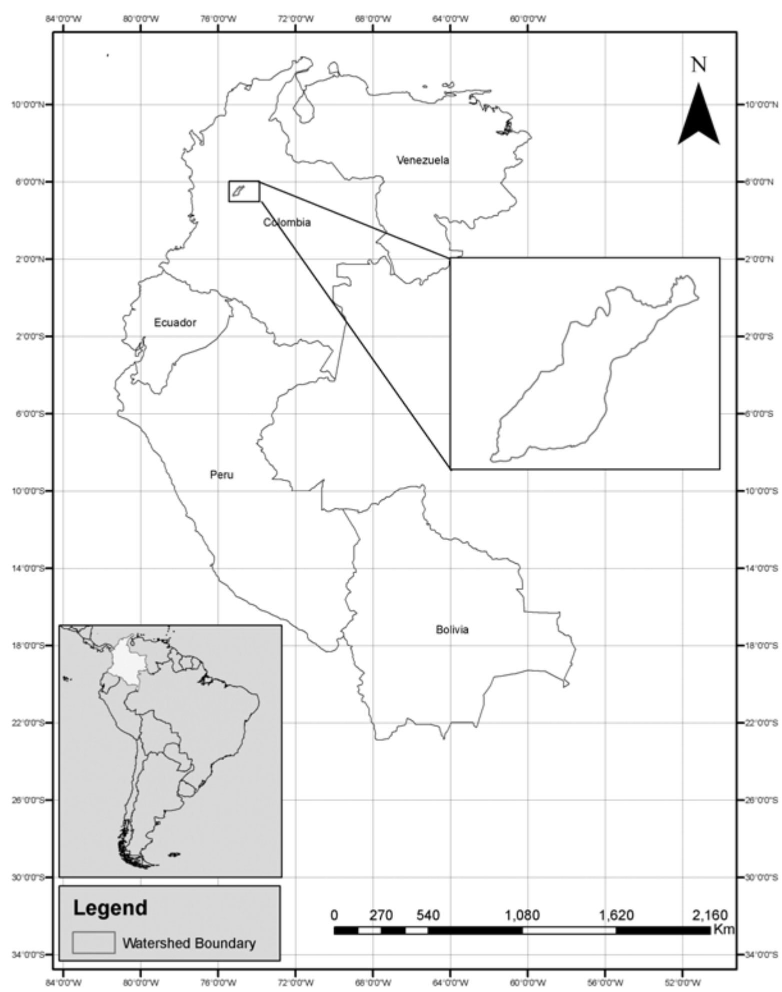


Figure 26: Location of the La Miel Watershed

Topography

The Watershed has a very rough topography, with altitudes from 160 to 3,500 m (CORPOCALDAS, 1999) This characteristic is one of the main contributors to the conservation of one of the last relicts of untouched Andean montane forests. As well, it provides many opportunities to build hydropower generation plants making use of the steep slopes and the great range of altitude.

There are two topographic zones. The first comprises the flat sectors ending in rounded hills, with slopes varying from 15 to 25%, corresponding to the low parts of the watershed and the influence area. The second is composed of narrow fluvial valleys limited by steep slopes, varying from 25 to 70%, corresponding to the middle and upper part of the watershed (CORPOCALDAS, 1999).

Drainage Network

The Miel River starts in the Andean forests of the watershed, and is fed by numerous creeks and generous rainfall. It flows northeast and drains into the Magdalena River, which empties into the Caribbean Sea. The Miel River is 68 km long from its source to the dam.

Some of the main water bodies within the watershed are: Tenerife River, Moro River, Manso River, San Diego Lake, Pensilvania River, Salado River, Samana River, Dulce River, and Negra Creek. (CORPOCALDAS, 1999, 2000).

Climatic Conditions

Precipitation in the watershed is constant during the year, with over 7,000 mm annually.
The precipitation exceeds evapotranspiration by 5,500 mm/year.

The yearly precipitation in La Miel Watershed ranges from 2,000 mm in the Magdalena River Valley up to 7,500 mm at 1,000 m. In the upper part of the watershed the precipitation varies between 2,000 and 4,000 mm.

In the reservoir area the annual precipitation is 4,200 mm. There are two wet seasons and two dry seasons in the area. The higher precipitation occurs in September, October, and November, and from April to May. The dry seasons are from June to August and from December to March.

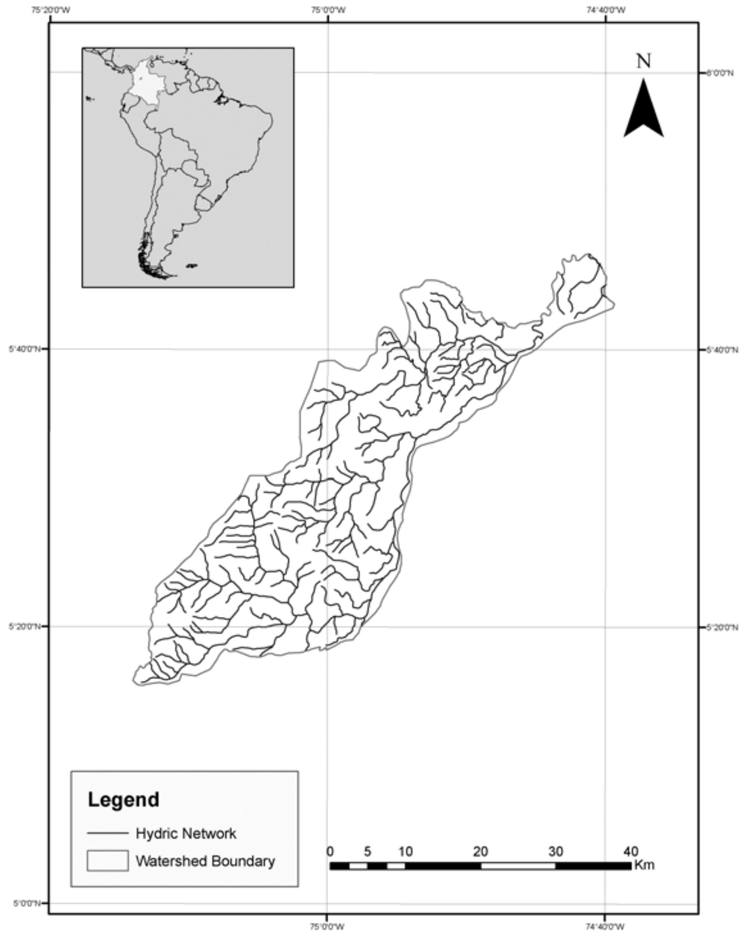


Figure 27: La Miel Watershed drainage network

The two meteorological stations studied had rain on 170 days at Norcacia and 201 days at El Vergel. Relative humidity varies daily from 90 to 100% in the coldest days to 40 to 60% during the hottest part of the day.

The temperature near the reservoir ranges from 22 to 30°C. The values registered by the El Vergel weather station (520 m) are: maximum temperature 35°C; average temperature 26°C (Hidromiel S.A., 1993)

Geology, Mineral Resources, and Soils

The geology of the area varies with age and composition. The age of the rocks varies from Palaeozoic to Cretaceous and Tertiary.

From the Palaeozoic age, there are metamorphic rocks such as quartzite, schist, granite, and marble. From the Cretaceous and Tertiary agesthere are different igneous and sedimentary rocks.

In the Central Cordillera where the watershed is located, orogenic activity has been intense, generating large folding and geologic faults.

Ecosystems and their Plant and Animal Resources

There are different ecosystems in the watershed, depending on altitude. Extremely steep slopes in the higher areas have discouraged human settlement, thereby preserving natural forests. In the upper part of the watershed (1,600–2,100 m) in the Samana and Pensilvania municipalities, there is an Andean forest called *La Selva de Florencia* (Florencia Forest). It is one of the last Andean forests in Colombia. This is a strategic ecosystem because it is considered as a water source for two watersheds: La Miel and Saman. The importance of this protected area (6,000 ha) is not only due to its important water-regulation function, but also to its wealth of fauna and flora. For example, the tistis monkey (*Sanguinus leucopus*), a little-known species threatened by extinction, was identified in the Florencia forest. The area also contains 231 known birds, some of which are endemic or threatened by extinction.

Figure 28: View of the Florencia Forest

SOCIOECONOMIC SETTING

Demographic Attributes

Betancourt (1999a, b) estimated there were 50,000 people living within the watershedborders.

Despite the large area and wealth of natural resources, the municipalities within the watershed are among the poorest of the Caldas Department. The NBI[4] index for the municipalities is presented in Table 20. The higher the index number the lower the quality of life. All municipalities in the watershed have higher NBI index numbers than the mean NBI for the Department, indicating an overall lower quality of life.

[4] NBI index: The unsatisfied basic needs index identifies the proportion of people who cannot cover one or more basic needs. The index combines infrastructure conditions, economic dependency, and schooling.

Table 20: The NBI index for municipalities in the Caldas Department

Municipality	NBI (%)
Manzanares	37.89
Marquetalia	37.33
Norcacia	60.84
Pensilvania	36.56
Samana	56.30
Victoria	46.29
Caldas Departament	28.90

Source: DANE (1993)

Figure 29: Municipalities in the La Miel Watershed

Agricultural Labor Force

The economy of the region is based on coffee production. Most of the people working in coffee production are between 30 and 60 years old. Most have only primary education, a key factor affecting technological change and modernization of the agricultural sector (CORPOCALDAS, 1999).

Education and Literacy

According to DNP *et al.* (2005), the illiteracy rates vary form very high to very low, under six levels: Very Low, Low, Middle low, Middle, High, and Very High. The illiteracy rates in the Caldas Department range from Middle to Low. Pensilvania, Manzanares, Marquetalia and La Victoria have a Middle low rate and Samana has a Middle illiteracy rate.

Using the DNP classification for school attendance in Caldas Department, the level varies from Middle High to Low. Pensilvania, Manzanares, Marquetalia and La Victoria have a Middle level, and Samana has a Low level.

Economic Activities

The main economic activities in the Caldas Department within the watershed are agriculture and livestock production. The main crop of the region is coffee, with plantations located in the middle part of the watershed between 2,000 and 1,000 m. This commodity provides the main income of the people in the area.

Livestock is the second important economic activity, mainly located in the lower part of the watershed due to its proximity to the *Magdalena Medio* region that supplies meat for most of the eastern part of the country. There is also pig and poultry production in the area.

Extractive activities such as timber and mining have been important to the economy of the region.

INSTITUTIONAL SETTING

Governance and Organization

The role of the Colombian state in natural resources is to ensure sustainability, conservation, restoration, or substitution. The Environment Ministry and the National Environment System (SINA) were created to oversee these responsibilities. They develop national policy and plans to protect the environment and renewable natural resources.

The "corporaciones autonomas regionales" (CARs) are the most important environmental entities in the area of jurisdiction. They manage and execute policies, plans, and programs to ensure sustainable development within the country's legal framework

In 1971 CRAMSA (Corporacion Regional Autonoma para la Defensa de Manizales, Salamina y Aranzazu) was created to solve a specific problem of erosion in the three municipalities (Manizales, Salamina, and Aranzazu). The entity evolved into CORPOCALDAS, the regional corporation for the Caldas Department in Colombia (25 municipalities). It manages the environment and renewable natural resources and its sustainable development.

Policy Framework

CORPOCALDAS is the regional entity in charge of managing the environment and renewable natural resources in the Caldas Department.

In 2005 the Colombian government established the Florencia Forest as a natural protected area. It comprises 10,018 ha from which 6,300 ha are primary forest. This area belongs to the Natural Parks System.

LAND RESOURCES MANAGEMENT

The land-use classification in La Miel Watershed is presented in Table 21.

Table 21: Land use in the La Miel Watershed

Land use	Area (km^2)	Area (%)
Agriculture	235	22
Erosion	1	0
Primary Forest	139	13
Secondary Forest	339	32
Grass	325	31
Reforestation	20	2
Water	1	0
Urban	1	0
Total	1061	100

About 47% of the watershed area is occupied by forest (primary, secondary, and reforestation), followed by grass (31%) and agriculture (22%).

Land use in the watershed defines three distinct zones:Upper: Where most of the primary forest is located; Middle: Coffee-growing zone; and Lower: Livestock zone.

Agricultural Production

From the total land used for agriculture, 96% is used for coffee plantations. Some contain "shadow" crops mixed in, and these are mostly banana. Other crops present in the watershed are sugarcane, fruit, and cacao.

WATER RESOURCES MANAGEMENT

Water Availability

La Miel River has an average flow at the dam site of 84.3 m^3/s. The flow regime is bimodal, having high flows during the rainy seasons: October to December and April to May. The lowest flow values are present during January-March and June-September (Hidromiel S.A., 1993).

The area is characterized by its abundant rains in the upper part of the watershed, and the many surface water bodies feeding La Miel River.

Water Demand, Allocation, and Use

The water uses in the area include human consumption, animal consumption, agriculture, and hydropower generation.

The allocation for the hydropower plant is 74 m^3/s corresponding to 88% of the average flow of La Miel River. La Miel I dam is located at the northeastern side of the Caldas Department within the Norcacia municipality boundaries. It stores the water coming from La Miel River downstream at its confluence with the Moro River. The installed capacity is 396 MW in three units. The total capacity of the reservoir is about 571 million m^3 (ISAGEN, 2006).

Challenges related to food, water, and environment

CHALLENGES IN LA MIELWATERSHED

There are many challenges in the La Miel Watershed related to its specific characteristics, such as its extensive biodiversity, hydropower potential, and social conditions. Some of the problems in the La Miel Watershed are:

- ***Erosion.*** Due to the steep slopes and the type of soils, some areas are highly susceptible to erosion, particularly in the upper part of the watershed.
- ***Sedimentation.*** The slopes and the intense rainfall produce important soil losses in areas with low vegetative cover. This poses a threat to reservoir capacity, endangering energy generation.
- ***Loss of biodiversity.*** It is important to preserve the "selva de florencia" because of its role in biodiversity conservation, as well as providing a hydrological buffer zone. Hydropower infrastructure has impacted the ecosystems, altering important habitats for unique species.

Baseline conditions, future outlook, and vision

La Miel Watershed is a region with huge potential for biodiversity and surface water, and potential for hydropower generation plants. Despite this potential and its abundant natural resources, municipalities in the watershed are among the poorest in the Caldas Department in Colombia. This has resulted in unsustainable development and use of natural resources, through the extension of agriculture into fragile areas.

Solutions must be found to improve living conditions while protecting the environment, offering economic alternatives to the rural poor through better land practices, and improved water management.

PARTNERSHIPS FOR TRANSLATING VISION INTO ACTION

- **CONDESAN-GTZ** through the Cuencas Andinas Initiative, are working under a research-action outline. The research aims to prioritize different alternatives that encourage stakeholders and policymakers to improve land use.
- **CONDESAN-Universidad de Caldas,** through the inter-institutional cooperation agreement, are aiming to improve the quality of education and to promote capacity building.
- **CORPOCALDAS.** is required by law to develop a land use plan for the area under its jurisdiction. CORPOCALDAS is now working on such a plan for La Miel River.
- **ISAGEN** is the mixed private/public company in charge of operating La Miel Hydropower Generation Plant.

RESEARCH AGENDA

Research Priorities

The complete list of research priorities for the Andean System of Basins for CPWF are summarized earlier. The main research topics to be addressed for La Miel Watershed are:

- ***Quantification of the hydrologic budget of the watershed.*** This would help us to recognize water patterns, storage capacity, and other hydrological issues that may contribute to understanding physical processes in the watershed.
- ***Quantification of the sediment budget of the watershed.*** This would help us to estimate the amount of sediment produced by the watershed, and that are affecting the infrastructure downstream.
- ***Determine current land-use patterns and the impact of potential land-use changes on watershed hydrology.*** Models, together with meteorological data, soil, and water samples, maps, and other data can help in the assessment of the consequences of different land-use practices.
- ***Evaluation of the effects of water control works*** to ensure water flows in dry periods.
- ***Social networks knowledge.*** Conflicts exist between extremely diverse groups, often separated by terrain, but connected as net suppliers or competing users of water. This increases the vulnerability of individual groups and obstructs the path to improvement. Mountain and hill communities are isolated and often marginalized. Lack of efficient, equitable, and sustainable water allocation mechanisms that are acceptable to all watershed stakeholders constrains overall capacity of water to support rural households.

Section 5 - Jequetepeque Watershed

Resources and Agricultural Production

BIOPHYSICAL SETTING

Location and Area

The Jequetepeque Watershed is located on the north coast of Peru between 7° 6´ and 7°30´ S and 78°30´ and 79° 40´ E. The location corresponds to the western part of the Andean Cordillera. The watershed area is 4,372.5 km^2 distributed in the regions of La Libertad (Pacasmayo and Chepen provinces) and Cajamarca (Cajamarca, Contumaza, San Pablo, and San Miguel). It covers a total of six provinces and 30 districts (Figure 30).

Both the Pacific and Atlantic influence the Jequetepeque Watershed weather.

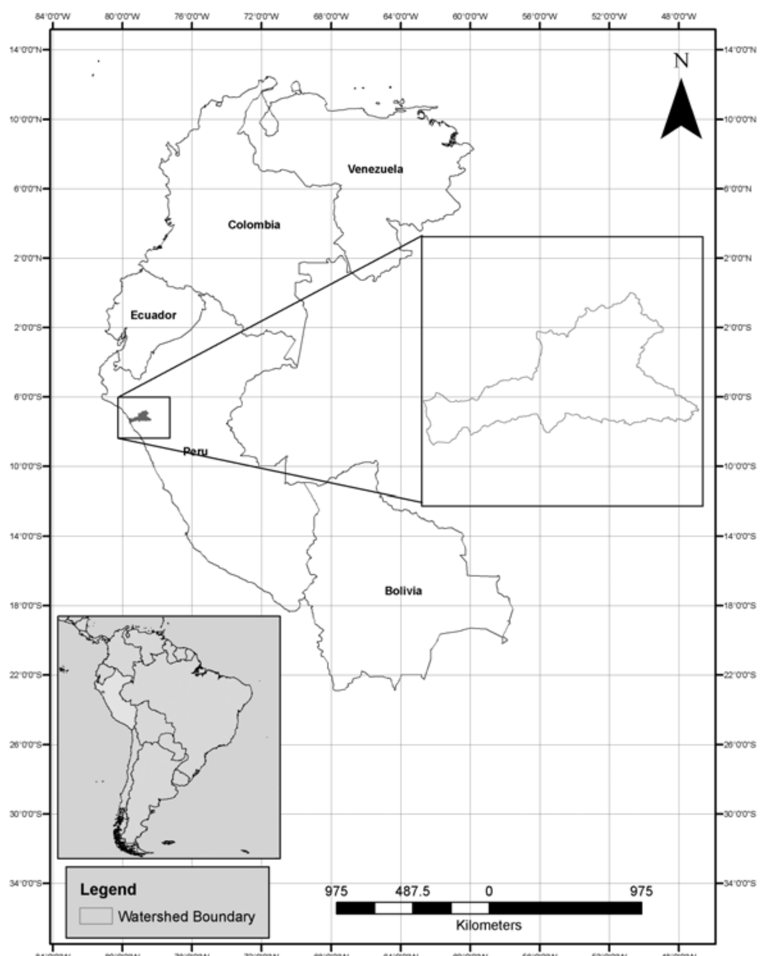


Figure 30: Location of the Jequetepeque Watershed

Topography

Altitudes in the Jequetepeque Watershed range from sea level to 4,188 m. The topographic configuration determines ecological regions with diverse microclimates.

There are three distinct sectors:

- Lower Jequetepeque, ranging from 0 to 225 m, formed by desert slopes and plains. In this area the Jequetepeque River is the only alluvial river plain.
- Middle Jequetepeque, from 225 to 600 m, formed by the arid and semi-arid Andes, with some seasonal tributary rivers.
- Upper Jequetepeque, from 600 m to the divide, formed by the Western Cordillera, with climates from semi-arid to pluvial peri-glacial, with numerous lakes.

Drainage Network

The main river in the watershed is the Jequetepeque (Figure 31). It has its source in a lake at the Agopiti hill in the Cajamarca Department at 3,800 m. The river runs from east to west flowing into the Pacific. The average slope of the Jequetepeque River is 2.4% and the total length is 158 km (SENAMHI, 2006)

The main tributaries include the Pallac River (12 km), the San Miguel or Puclush River (32 km), and the Magdalena River (70 km) (CONDESAN, 2000).

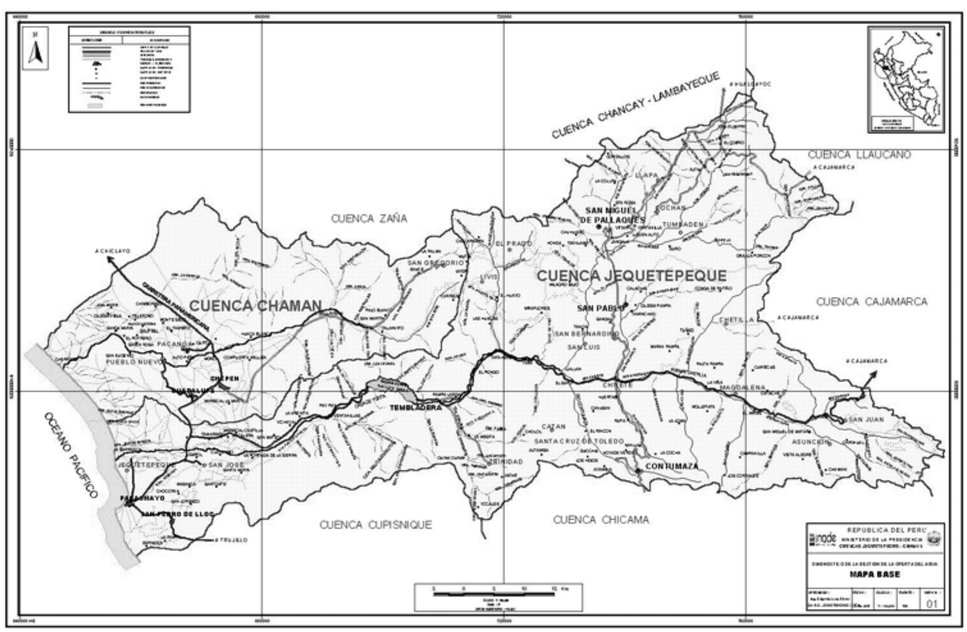


Figure 31: Jequetepeque-Chaman watersheds
Source: INADE

Climatic Conditions

The average annual rainfall in the upper part of the watershed is 500-1,000 mm. The lower part receives less than 200 mm. There is also a clear contrast in the precipitation distribution over time. In the upper part of the watershed there is rain throughout the year, with higher precipitation from January to March, and lower values from July to September. In the lower part of the watershed most of the precipitation falls during the hottest months. The rainfalls are intense, sometimes with catastrophic results. The Niño phenomena have important effects on the lower part of the watershed.

Rain is scarce close to the coast due to the temperature of the water on the Peruvian coast. Precipitation in the upper part of the watershed is due to the Amazon influence.

The temperature varies from 23°C in the coastal desert (400-800 m) to 3°C in the Andean *paramos* (4,000 m). Evaporation varies from 200 mm in the valley up to 1,500 mm in the Andean zone. The relative humidity ranges from 80 to 90% in the valley to 60% in the upper part.

Geology, Mineral Resources, and Soils

The Jequetepeque River Basin is located over sedimentary and volcanic-sedimentary formations, as follows:

- ***Recent deposits (Qr-al/e)*** These deposits are located in the lower part of the valley, at the mouth of the river. They are eolic, allowing for agriculture to be practised.
- *Calipuy Group (Ti-vca)* Formed by volcanic sediments from post-tectonic activity, and characterized by easily erodible materials in the high parts.
- ***Chicama Formation (Js-chic)*** The rocks in this formation are soft due to the composition of clay and lime, appearing in the upper parts of the Jequetepeque Watershed.
- ***Goyllarisquizga Group (Ki-g)*** This group consists of white massive quartzite and brown and grey sandstones.
- ***Chimu Formation (Ji-chic)*** This covers large areas of the Jequetepeque River, forming rocky outcrops at the river banks. It is formed by sandstones and quatzites.
- ***Yumagual Formation (Ks-yu)*** This formation covers small extensions, presenting rocks such as limestones and marl.
- ***Cajabamba Formation* (Ks-ca)** This is composed of calcareous rocks near the creek banks in the form of steep slopes, and is located in the upper part of the watershed.

The soils in the lower part of the watershed are of alluvial or eolian origin, containing mainly fine sand.

Ecosystems and their Plant and Animal Resources

Because the soil is overexploited by agriculture and livestock, there are almost no natural vegetative areas in the watershed. Land-use maps show there is less than 1% of the total watershed area as natural forest.

Four regions in the watershed are defined by altitude (INADE, 2001:

- ***Jalca*:** This is the highest region in the watershed at over 3,500 m. The vegetation in this area is natural forest.
- ***Quechua*:** This area is between 2,300 and 3,500 m, with a temperate climate and rough landscape. The main crops are cereal and potato in the higher parts and corn and fruit in the valleys. Other crops are pea, bean, and wheat.
- ***Yunga*:** This region is at 500-2,300 m, the largest area in the watershed. It has a rough landscape with steep slopes and valleys. The weather ranges from temperate to warm, and the main crops are sugarcane, fruit, rice, and vegetables.
- ***Chala*:** Below 500 m, this region is where most of the agricultural lands are located.

SOCIOECONOMIC SETTING

Demographic Attributes

The Jequetepeque Watershed includes six provinces in two departments: Chepen and Pacasmayo provinces in La Libertad Department, and Contumaza, San Miguel, Cajamarca, and San Pablo provinces in Cajamarca Department.

According to the 1993 INEI census, the population in the Jequetepeque Watershed was 261,499, and the projection for 2000 was 306,139, with 145,247 rural and 160,892 urban.

About 25% of the population in the area is below the poverty line. Education levels are low, particularly in the rural areas and the upper part of the watershed (CONDESAN, 2000).

Agricultural Labor Force

According to INEI (1993), 47% of the watershed inhabitants are involved in agricultural and livestock breeding activities (Figure 32).

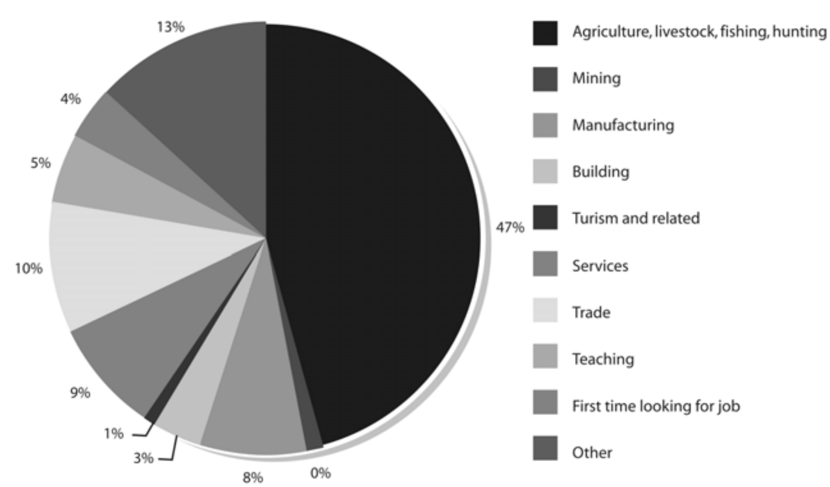


Figure 32: People involved in economic activities in the six provinces of the Jequetepeque Watershed

Economic Activities

Agriculture is the main economic activity within the watershed. In the upper part of the watershed the main crops are wheat, corn, rice, barley, pea, and potato. In the lower part, the main crops are rice and corn.

Livestock is also an important economic activity. In the upper part of the watershed cows are kept for milk production. This area is an important supplier of milk, and producers are involved with dairy product industries such as INCALAC-Nestlé.

In the lower part on the watershed there is also livestock, but of less importance. Animals are bought for fattening and selling. In the lower Jequetepeque, poultry breeding is an important source of income.

Other economic activities in Jequetepeque Watershed include handicraft production, mining, and forestry.

INSTITUTIONAL SETTING

Governance and Organization

The organizational model in Peru for natural resources management involves several decentralized public organizations with environmental management offices. These include: Energy and Mines Ministry, Fisheries Ministry, and Industry Ministry. The functions of these offices vary depending on their designated rank.

In an attempt to solve organizational difficulties, in 1994 the Peruvian government created CONAM (National Environment Council) for intersectorial coordination.

CONAM has up to five levels from national to regional offices.

Policy Framework

CONAM is in charge of promoting national environmental policies. Its role is to plan, promote, coordinate, control, and monitor the environment and natural resources.

According to CONAM "The environmental policy in Peru is oriented to guarantee the sustainability of the country in its three dimensions: social, economic, and ecologic."

The original development project for a dam and irrigation system was part of the Ministry of the Presidency, and managed by INADE (Instituto Nacional de Desarrollo) by the Autoridad Autonoma de la Cuenca y el Proyecto Especial Jequetepeque-Zaña (DEJEZA).

Since the completion of the dam (1987), two-water user groups have come into being:

The Lower Jequetepeque Group and the Upper Jequetepeque Group. In 1998 DEJEZA turned over dam management to a private company (OPEMA) that works for 13 irrigation commissions of Lower Jequetepeque. The situation remains confusing, with overlapping authorities among state agencies, OPEMA, and the water user groups.

LAND RESOURCES MANAGEMENT

Taken from the land-coverage map, Table 22 contains data on land-use distribution in the Jequetepeque watershed.

Table 22: Land use in the Jequetepeque Watershed

Land use	Area (km²)	%
Forest	461.51	10.6
Agriculture	757.49	17.3
Water Bodies	15.37	0.4
Scrubland	751.68	17.2
Thicket	2079.45	47.6
No vegetation	294.39	6.7
Reforestation	12.29	0.3
Total	4372.18	100

Source: INADE (2001)

Agricultural Production

The range of altitudes and weather conditions have resulted in a wide variety of crops grown in the area.

In the Upper Jequetepeque, the main crops are potato, corn, wheat, barley, pea, sugarcane, fruit, and rice. Wheat is the most important crop in terms of cultivated area, and is consumed by families mainly as flour. The second most important crop is corn, and is also cultivated for local consumption. Following corn, rice is the third crop in terms of cultivated area, and 80% of production is for the local market. This crop is cultivated by more specialized farmers. The yields are low because of high production costs.

In Lower Jequetepeque, the cultivated area is double the area of the Upper Jequetepeque. The main crop is rice, both in terms of cultivated area and also yield. The rice produced goes to the national market.

WATER RESOURCES MANAGEMENT

Water Availability

The discharges in the Jequetepeque River are strongly seasonal, with 65% produced from February to April, with the balance discharged over the remaining 9 months. The annual average discharge volume is 816 million m^3 (INADE, 2001). The *El Niño* phenomenon influences the discharges, creating important differences between years in the total volume discharged.

The Upper Jequetepeque experiences water scarcity during the second half of every year, affecting water availability both to the upper and lower watershed areas. There are occasional restrictions in the second annual crop-growing season. In some years the rainy season produces mudslides and crop losses as well as floods.

Water Demand, Allocation, and Use

Within the Chaman-Jequetepeque (Figure 31) watersheds there are five hydropower plants, with the Gallito Ciego plant providing the most power. To control discharge variability over time, the Gallito Ciego Dam was built and later used for hydropower generation. The net capacity of the Gallito Ciego reservoir is 392 million m^3

(CONDESAN, 2000), and it has the potential to irrigate 42,000 ha and to produce hydroelectric power (Table 23).

Table 23: Data (in millions m^3) from 56 consecutive years of discharge of the Jequetepeque River at Gallito Ciego Dam

Description	Total annual	Dry season	Wet season
Complete series (56 years)			
Maximum	2,701.1	36.2	2,346.5
Average	816.5	142.7	673.8
Minimum	87.9	13.1	74.8
Wet years (25 years)			
Maximum	2,707.1	361.2	2.346.5
Average	1,177.1	185.8	991.3
Minimum	837.0	69.4	637.8
Dry years (31 years)			
Maximum	815.2	205.3	738.0
Average	525.7	107.9	417.7
Minimum	87.9	13.1	74.8
Irrigation demand			
Actual	720.1	275.0	445.1
Future	790.0	310.2	479.8

Source: INADE (2001)

In dry years water availability is insufficient to satisfy irrigation needs; the same is true for dry periods.

Above the dam, there are over 620 small irrigation systems serving 15,000 ha and 3,000 families. In Lower Jequetepeque, inadequate water management practices (rice farming) have resulted in serious salinization problems. In general there is not enough water to meet demands (CONDESAN, 2000)

The water uses in Jequetepeque Watershed are agricultural, domestic, livestock, and industrial. Agriculture makes the highest demands, followed by domestic, industrial, mining, and hydropower. The total annual water demand is estimated at 720.1 million m^3 (UNESCO, 2004).

Challenges related to food, water, and environment

CHALLENGES IN JEQUETEPEQUE WATERSHED

There are many challenges in the Jequetepeque Watershed. Many of the problems arose because of poorly planned development initiatives that contributed to the rapid degradation of the environment. Some of the problems in the watershed are:

- ***Devastation* of the coastal zones during *El Niño,*** resulting in millions of dollars of damage to property and infrastructure below the dam, and over 1,000 ha of cropland lost above the dam.
- *Lack of potable water and water for irrigation* in the Quechua and Yungas zones.
- ***Rapid sedimentation of Gallito Ciego Reservoir.*** It is estimated that between October 1987 and June 1998, 100 million m³ of solids have come into the reservoir, and 60% of that load came with the recent *El Niño* (1997-98).
- ***Decrease in the forested areas of the watershed.*** An initial push in the 1970s for reforestation in the watershed has not only come to a close, but the eucalyptus and pine are now being harvested more rapidly than they are being replaced.
- ***Changes in the hydrological cycle,* due** to the expansion of agriculture in the high Jalca zones, that have disrupted the properties of the upper watershed.
- ***Salinization*** of coastal soils due to poor irrigation and drainage practices, has increased the affected area to 15,000 ha.
- ***Increase of environmental problems (pollution)*** due to mining activities and poor management of municipal wastewater.

Baseline conditions, future outlook, and vision

The Jequetepeque Watershed is a highly degraded ecosystem as a result of inefficient use of water, and unsustainable agricultural practices, that cause erosion and sedimentation.
The sediment ends up in water bodies, negatively affecting their quality. The *El Niño* phenomenon affects greatly the runoff, and sediment loads are higher in *El Niño* years,
diminishing the capacity of the Gallito Ciego Dam.

Solutions must be found to protect people, plants, and animals from pollution dangers, while offering economic alternatives to improve the livelihoods of the rural poor. The alternatives should include better land practices and improved water management.

PARTNERSHIPS FOR TRANSLATING VISION INTO ACTION

The following partners in the Jequetepeque Watershed are already developing activities, including:

- CONDESAN-GTZ, through the Cuencas Andinas Initiative, are working under a research-action outline. The research aims to prioritize different land-use alternatives that encourage stakeholders and policymakers to form partnerships and encourage investment.
- CIPADECJ (Comite Interinstitucional para el Desarrollo de la Cuenca del Jequetepeque) is the unifying body in the watershed. This commission was founded in 1993, and now includes seven of the leading NGOs in the region, six municipalities, as well as the coordinating irrigation committees from both above and below the dam.

RESEARCH AGENDA

Research Priorities

The complete list of research priorities for the Andean System of Basins for CPWF was summarized earlier. The main research topics to be addressed for the Jequetepeque Watershed are to:

- ***Quantify the hydrologic budget of the watershed.*** This would help us to recognize water patterns, storage capacity, and other hydrological issues that may contribute to understanding physical processes in the watershed.
- ***Quantify the sediment budget.*** Together with the hydrological budget, and with the help of mathematical models and sufficient data, we can define the causes and possible solutions to alleviate sedimentation problems.
- ***Determine current land-use patterns and the impact of potential land-use changes on watershed hydrology.*** Models, together with meteorological data, soil and water samples, maps, and other data can help in the assessment of the consequences of different land-use practices.
- ***Update water user profiles in the watershed.*** Complicated laws and people ignoring rules have resulted in a chaotic patchwork of water concessions that often exceed by several times the entire flow rates in the channels. It will be important for the team to show that efficient water use can result in a win-win situation.
- ***Improve water quality control.*** Stream monitoring and data collection will be necessary prior to developing improved urban wastewater management plans.
- ***Understand the extreme hydrologic responses.*** To avoid serious production risks, we need to know and understand the hydrology of the Jequetepeque Watershed.

  Effects of natural events such as climate variations, especially the effects of *El Niño,* might be diminished if the hydrological response of the watershed is known.

Section 6 - Ambato Watershed

Resources and Agricultural Production

BIOPHYSICAL SETTING

Location and Area

The Ambato Watershed is located in the Ecuadorian Andes in Tungurahua Province, which is located in central Ecuador between 0°56' and 1°34' S and 78°4' and 78°58 W (CNRH *et al.*, 2004). The watershed has an approximate area of 1,310 km^2 constituting 40% of the area of Tungurahua Province (Galárraga Sánchez and Guamán Rios, 2005).

The watershed covers the Ambato, Mocha, Tisaleo and Quero municipalities.

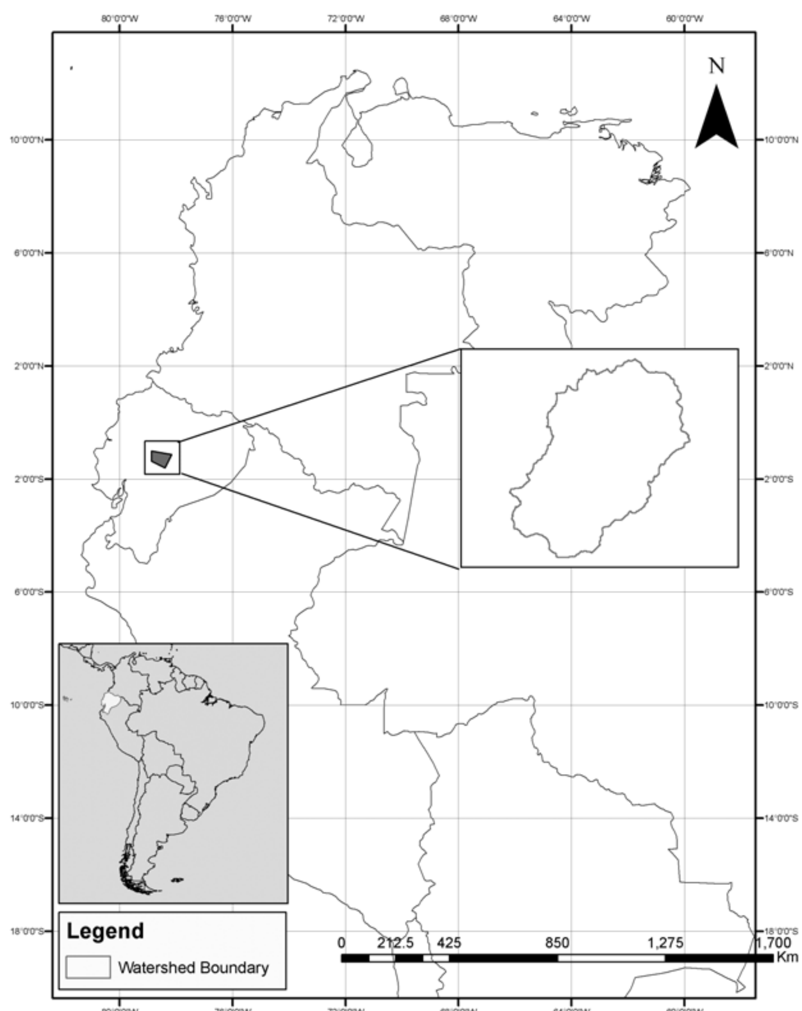


Figure 33: Location of the Ambato Watershed

Topography

The Ambato Watershed elevations vary from 2,200 to 6,310 m. The western watershed limit is a mountain chain whose highest point is the Chimborazo Volcano (6,310 m). The watershed ends in the valley at 2,200 m.

Drainage Network

The Ambato River flows from west to east draining into the Patate River. The main tributaries are the Calamarca, Alajaua, Colorado, and Pachalinca rivers (Figure 34).

There is a series of constructed drainage channels that take the water from the *paramos* to the lower areas.

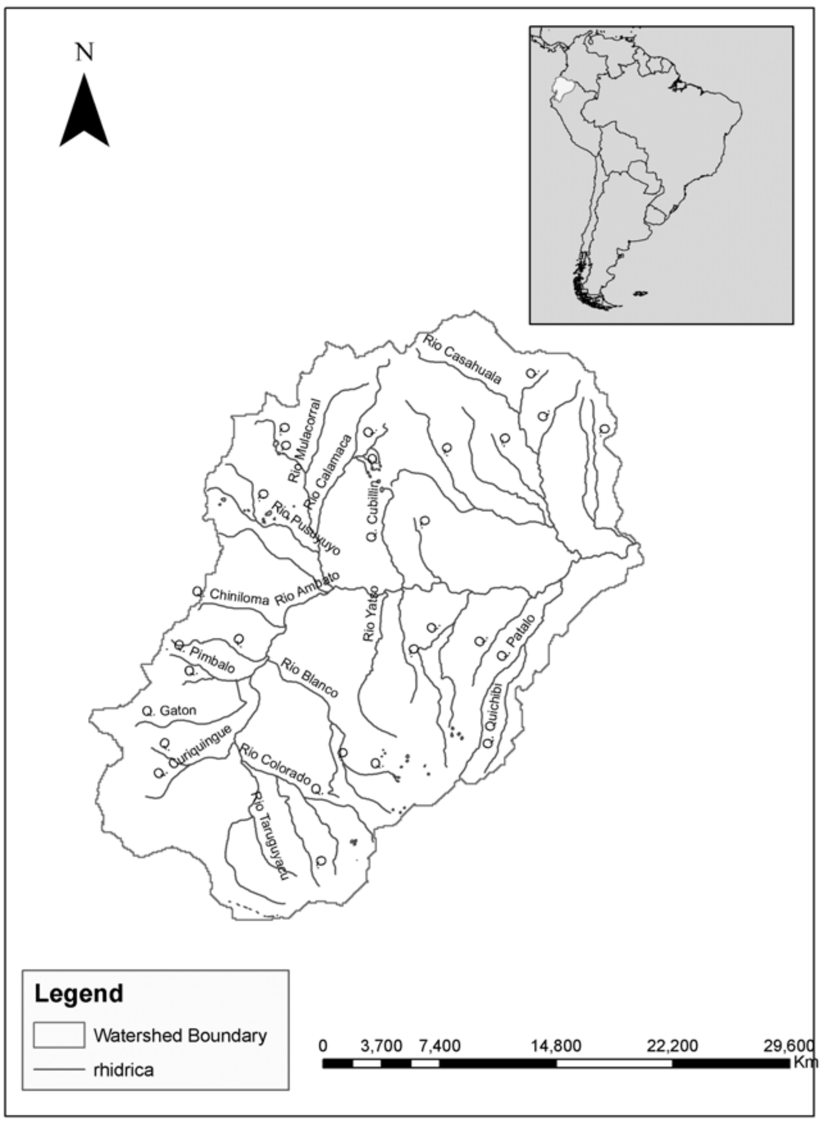


Figure 34: Ambato Watershed drainage network

Climatic Conditions

Three climatic zones are defined by altitude: Lower Zone (<3,200 m) with temperate weather; Middle Zone (3,200 –3,500 m), cold; Upper Zone (>3,500 m), very cold, known as *paramo*.

The *paramo* has mean yearly temperatures of 4-8°C, mean yearly precipitation from 800 to 2,000 mm, and relative humidity exceeding 80% (Arias *et al*., 2005).

The Middle Zone has a mean yearly temperature between 12 and 20°C, and a mean yearly precipitation of 500 to 2,000 mm. This zone has two rainy seasons: one from February to May and the second from October to November. The relative humidity ranges from 65 to 85% (Arias *et al*., 2005).

The Lower Zone has a temperate climate with less than 500 mm of annual rainfall.

Geology, Mineral Resources, and Soils

The geomorphology of the area has been influenced by volcanic activity. The volcanoes in the area (Chimborazo, Carihuyrazo) were covered by snow and ice in the quaternary, eroding the soil and creating water courses.

In the upper part of the watershed, basaltic rocks are predominant. In the middle part with gentle slopes, ash was deposited thereby increasing the mineral composition of the soils.

In the valley of the Ambato River the climate is drier and its soils are less developed than soils in the *paramo.*

Ecosystems and their Plant and Animal Resources

Some of the ecosystems present in the area are the *paramos* and the premontane forest.

The *paramo* ecosystem starts at 3,600 m. The main characteristics are its adaptation to extreme weather conditions such as strong winds, extreme temperature variations from 0 to 25°C, sun exposure and less atmospheric pressure, and lower oxygen levels. These characteristics result in the development of many endemic species.

There are patches of premontane-montane forests located between 3,300 and 3,700 m. These forests form the transition between the forest and the *paramo*.

The lower part of the watershed is used for agriculture and livestock production.

SOCIOECONOMIC SETTING

Demographic Attributes

The watershed has a population of 320,000 (Proyecto Cuencas Andinas, 2004). The average population density is 240 people/km^2. Population data for municipalities in the watershed in 2001 are given in Table 24.

Table 24: Population data for Ambato Watershed municipalities

Province	Municipality	Population		
		Total	Urban	Rural
Tungurahua	Ambato	287,282	154,095	133,187
	Mocha	6,371	1,122	5,249
	Tisaleo	10,525	1,038	9,487
	Quero	18,187	2,238	15,949
		322,365		

Source: INEC (2001)

Agricultural Labor Force

Data on people older than 5 years involved in economic activities are presented in Table 25.

Table 25: Numbers of people over 5 years of age engaged in economic activities

Economic activities	Ambato	Mocha	Tisaleo	Quero	Total
Agriculture, livestock, hunting, fisheries, forestry	29,054	1,736	2,953	6,340	40,083
Manufacturing	25,672	339	919	335	27,265
Construction	6,275	61	112	134	6,582
Trades	27,455	193	338	355	28,341
Teaching	5,974	28	37	68	6,107
Other	33,459	403	591	888	35,341

Source: INEC (2001)

Most of the people in the watershed are involved in activities related to agriculture and livestock.

Education and Literacy

According to Galárraga Sánchez and Guamán Rios (2005), one of the main problems in the watershed is the lack of skilled workers; 70% of the productive people have only primary school education. As a result, the labor force is inefficient, and earn low salaries that do not cover their basic needs.

Economic Activities

The main source of income of residents of Tungurahua Province is agriculture and livestock. About 62% of income in the province in 2001 came from agriculture and livestock. Data for the municipalities in the watershed are given in Table 26.

Table 26: Income sources for municipalities in Tungurahua Province

Activity	Income origin (%)				
	Tungurahua Province	Ambato	Mocha	Quero	Tisaleo
Agriculture and livestock	62.1	52.4	64.4	87.0	80.5
Other	37.9	47.6	35.6	13	19.5

Source: INEC (2001)

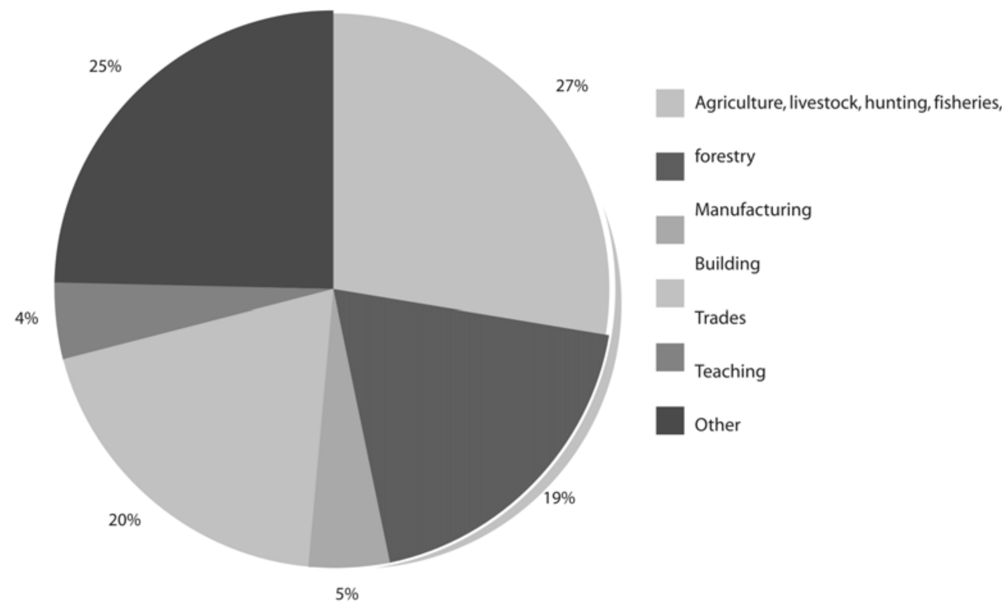


Figure 35: People involved in economic activities

INSTITUTIONAL SETTING

Governance and Organization

The Ecuadorian Environment Ministry is in charge of environmental policy design and strategies coordination for the sustainable use of natural resources at the national level.

Nevertheless the Ecuadorian Government has a decentralized model in which every regional government has the ability to regulate the use of natural resources within the policy boundaries of the Ministry.

Policy Framework

In Ecuador there are two kinds of governmental entities: autonomous ones, and those that depend on the central government. The Consejo Provincial de Tungurahua coordinates both sectors and all the nongovernmental entities in the Ambato Watershed. The Consejo is also in charge of improving, protecting, and preserving natural resources (Galárraga Sánchez and Guamán Rios, 2005).

The Agencia de Aguas de Ambato is in charge of water management in the watershed area, its main function being the allocation of water (Galárraga Sánchez and Guamán Rios, 2005). PROMACH is in charge of the management of the Ambato River Watershed, and it depends on the Environment Ministry for support.

The Environment Ministry has functions related to policymaking in the area of control and management of protected areas and wildlife.

LAND RESOURCES MANAGEMENT

Land use in Tungurahua Province is shown in Figure 36 (INEC, 2001). Almost half of the land is *paramo* and forests.

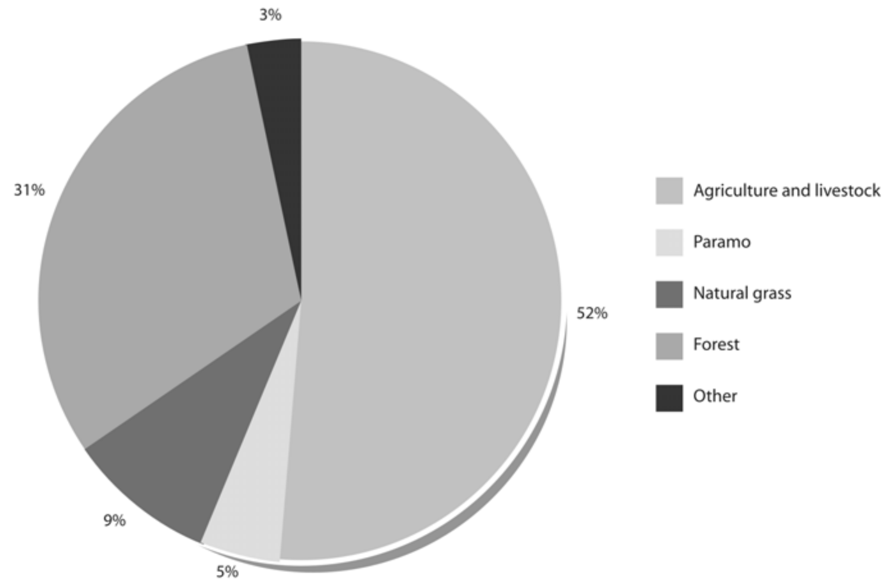


Figure 36: Land use in Tungurahua Province

Agricultural Production

Agriculture is the main economic activity in the watershed, occupying most of the area of the province. Altitude determines the kind of crops grown and the land tenure changes:

- In the area between 3,500 and 4,200 m, the main activity is extensive livestock breeding for meat production. This is the fragile *paramo* ecosystem area.
- The main activities in the area between 2,800 and 3,500 m are livestock for milk production and agriculture. The main crops are cereals and Andean tubers.
- In the lower part (from 2,100 to 2,800 m), the main economic activities are growing fruits, breeding small animals, mainly chicken, handicraft production, and light industry.

WATER RESOURCES MANAGEMENT

Water Availability

According to Galárraga Sánchez and Guamán Rios (2005), there is a lack of suitable and sustainable management of water resources in the Ambato Watershed. This results in a yearly water shortage of 903.35 million m^3. This shortage is especially felt in the 7-9 dry months. The highest precipitation within the watershed is between 200 and 400 mm.

Water Demand, Allocation, and Use

The main sources of water are the moisture captured by the *paramos* vegetation, the melting of the snow peaks, and rainfall. The watershed is classified as an area prone to desertification because of its low levels of precipitation.

The water that comes from the *paramos* is directed to irrigation purposes. From the 10.8 m^3/s of water captured by the channels, 94 % is used for irrigation purposes, and 6% for human consumption, including the urban areas in the valley (Girard, 2005).

Challenges related to food, water, and environment

CHALLENGES IN AMBATO WATERSHED

There are many challenges in the Ambato Watershed. The problems arise because of unstructured development, leading to rapid deterioration of the ecosystem. Some of the problems in the Ambato watershed are:

- ***Water scarcity.*** Low precipitation, population pressure, poor infrastructure, and vegetation cover losses are causes and consequences of water scarcity.
- ***Destruction of cloud forests and the paramos.*** Shifting agriculture into these fragile areas decreases the ability of the watershed to compensate for extreme events.
- ***Erosion.*** Annual erosion in the upper part of the watershed is 1,250 t/km^2, higher than in other parts of the region (Galárraga Sánchez and Guamán Rios, 2005) .
- ***Poor infrastructure and inappropriate water use techniques.*** These problems are exacerbated by an uneven distribution of water rights concentrated in the lower parts of the watershed.
- ***Low education levels, low income, lack of credit, lack of technical assistance, and lack of knowledge of appropriate technologies.*** These shortcomings prevent communities from improving natural resources management, thereby improving their quality of life.
- ***Institutional framework.*** There is a weak institutional organization and a lack of clear water and land management policies throughout the Ambato Watershed.

Baseline conditions, future outlook, and vision

The Ambato Watershed has problems in both the quality and quantity of water. This is due to the degradation of the *paramo* ecosystem, inadequate exploitation of surface water, and low precipitation levels. The main reason for the *paramo* degradation is the expansion of agriculture by farmers seeking to improve their living standards.

Environmental, socioeconomic, and institutional problems have been identified.

Solutions must be found to protect people, plants, and animals from pollution dangers, while offering economic alternatives to improve the livelihoods of the rural poor through better land-use practices and improved water management.

PARTNERSHIPS FOR TRANSLATING VISION INTO ACTION

Partners in the Ambato Watershed are already developing activities, including:

- **CONDESAN-GTZ, through the Cuencas Andinas initiative.** The research is aimed at identifying and prioritizing land-use alternatives, and to encourage stakeholders and policymakers to develop partnerships and increase investment.
- **PROMACH (Proyecto Manejo de la Cuenca Hidrografica del Rio Ambato).** In 1993, through the Environment Ministry, GTZ started a project to improve management of the Ambato Watershed. The project has produced results in some sub-watershed areas, and has helped PROMACH collect valuable biophysical and socioeconomic data.

RESEARCH AGENDA

Research Priorities

The complete list of research priorities for the Andean System of Basins for CPWF are summarized earlier. The main research topics for the Ambato Watershed are to:

- ***Quantify the hydrologic budget of the watershed.*** This would help us recognize water patterns, storage capacity, and other hydrological issues that may contribute to understanding physical processes in the watershed.
- ***Quantify the sediment budget.*** Together with the hydrological budget, and with the help of mathematical models and sufficient data, we can define the causes and possible solutions to alleviate the sedimentation problem.
- ***Determine current land-use patterns and the impact of potential land-use changes on watershed hydrology.*** Models, together with meteorological data, soil and water samples, maps, and other data can help in the assessment of the consequences of different land-use practices.
- ***Formulate optimal restoration strategies.*** An integral evaluation of the alternatives on land and water use may help formulate an optimal strategy to restore the ecosystem. Biophysical and economic models plus expert analysis are tools that can help address this issue.
- ***Understand the extreme hydrologic responses.*** To avoid serious production risks, we need to know and understand the hydrology of the Ambato Watershed. Effects of natural events such as climate variations (*El Niño*), seasonal fluctuations, and other major hazards might be diminished if the hydrological response of the watershed is known.
- ***Improve social networks knowledge.*** Conflicts exist between extremely diverse groups, often separated by terrain, but connected as net suppliers or competing users of water. This increases the

vulnerability of individual groups and obstructs the path to improvement. Mountain and hill communities are isolated and often marginalized. Lack of efficient, equitable, and sustainable water allocation mechanisms that are acceptable to all watershed stakeholders constrains overall capacity of water to support rural livelihoods.

Section 7 - Tunari Watershed

Resources and Agricultural Production

BIOPHYSICAL SETTING

Location and Area

Tunari is not a physical watershed but a mountain range north to the Cochabamba Valley in central Bolivia. The southern slopes of the Tunari mountain range in the Cochabamba Department cover an area of approximately 412 km^2 . The influence area covers Quillacollo and Cercado provinces. This area can be divided in 39 watersheds with very steep slopes. The 39 watersheds supply water to Cochabamba Valley from the Tunari Mountains. The valley has an area of 450 km^2.

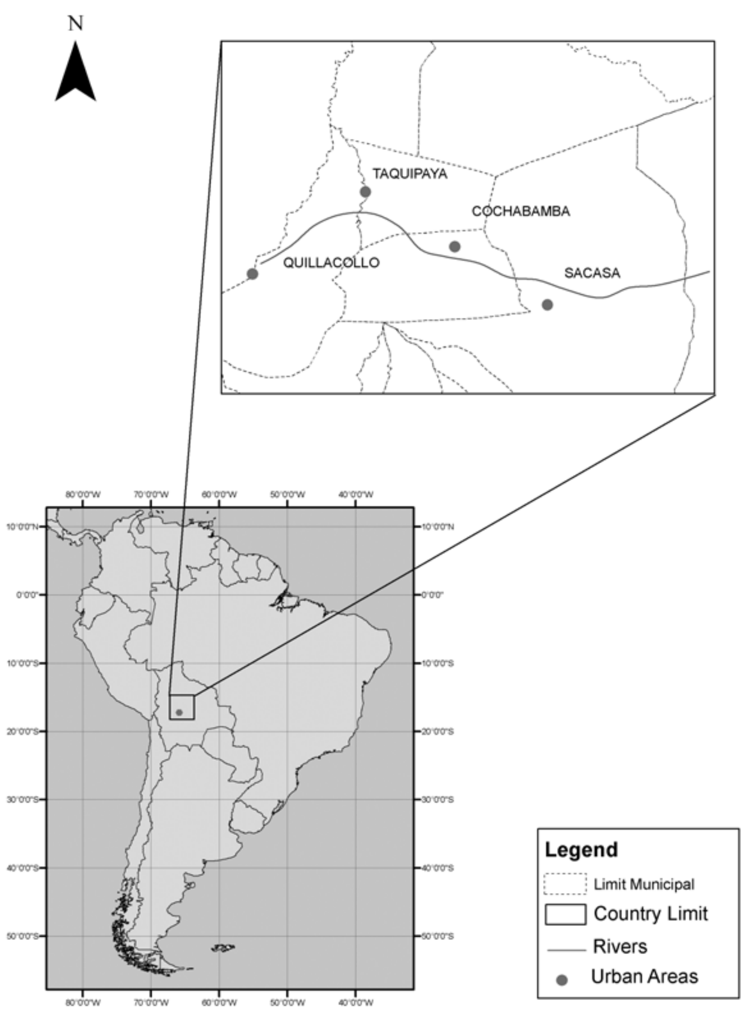


Figure 37: Location of the study area

Topography

The Tunari Mountains are also known as Cochabamba or La Herradura Cordillera. The highest points of the Tunari Mountains are around 5,000 m, and the lowest point is the valley itself with an elevation of 2,500 m. The Tunari slopes are rough and steep, and the valley is flat.

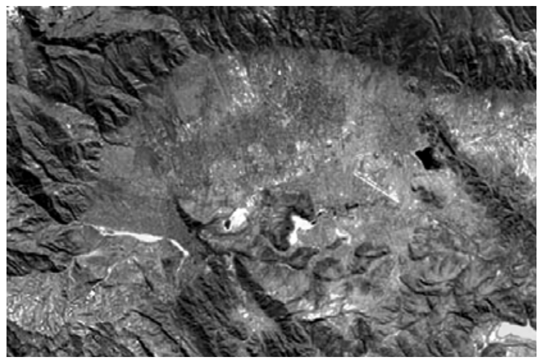


Figure 38: Satellite photo of the Cochabamba Valley and Tunari mountain range
Source: PROMIC (2004)

Drainage Network

The 39 watersheds (Figure 39) in the southern Tunari slopes drain into the Rocha River passing and feeding the Cochabamba Valley. The Rocha River drains into the Mamore River, which is the most important one in the Cochabamba Department (INE, 2003). Thearea belongs to the Amazon Basin.

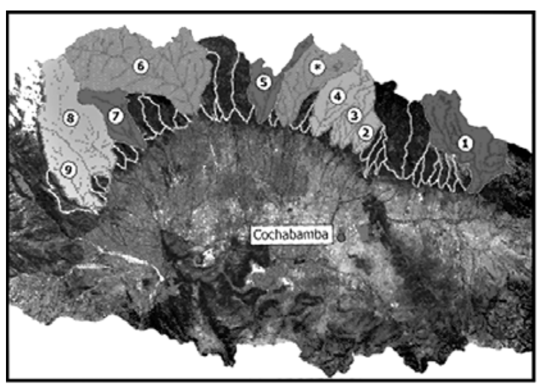


Figure 39: Watersheds in the Tunari Mountains prioritized by PROMIC
Source: PROMIC (2004)

Climatic Conditions

The Tunari mountain range has a peculiar characteristic: it forms a wall where the coldand dry fronts meet the warm north fronts with high water content, and static energy producing high precipitation levels over the cordillera.

In the Tunari mountain range there are places such as Altamachi and Covendo where annual precipitation reaches 5,000 mm, a huge contrast to the precipitation levels in the valley, which are about 400-500 mm. The high values are even greater than values in the Amazon, where the precipitation is about 2,500 mm yearly. This moisture level is comparable to regions in Colombia and Ecuador (CEDIB, 2005).

The temperature varies with altitude, from very cold and perpetual snow in the highest points; to temperate in the valleys, cold to temperate in the premontane forests, and warm in the *yungas* (ecoregions) (Table 27).

Table 27: Climatic conditions in the Tunari region

Agro-productive area	Annual temperature (°C)			Annual precipitation (mm)	Relative humidity (%)		
	Minimum	Maximum	Average		Minimum	Maximum	Average
Closed valleys	11.7	14.4	13.0	941	54	73	64
North valleys	13.7	19.5	16.6	540	54	70	62
Yungas	21.4	26.1	23.7	4,521	75	84	79

Source: INE (2003)

Geology, Mineral Resources, and Soils

The region corresponds to the sub-Andean mountain ranges. This region is a wide group of mountain ranges with valleys in between, running parallel to the Eastern Cordillera.

The area has important ecosystems because of its climate and other biophysical characteristics. There are also oil reserves in the region.

According to its origin the mountain zone can be divided in three areas (Arevalo de la Zerda and Westermann, 2006):

- ***Glacial.*** This area is characterized by the presence and shapes from the last glacial age. The main cover is grasses, and comprises the areas between 3,900 and 5,000 m.
- ***Erosion.*** This area has creeks, rills, and furrows on the hillsides, and has been shaped by intensive erosion processes. It is located between 2,900 and 3,900 m.
- ***Depositional.*** This area is characterized by constant deposition of sediments presenting flat landscapes. The shapes result not only from the water-related deposition processes but also from lacustrine origin. This area has elevations lower than 2,900 m.

Ecosystems and their Plant and Animal Resources

The National Park Tunari (NTP) was created in 1962 to preserve the recharge areas of the aquifers, the natural resources, as well as to prevent inundations and landslides. The original protected area was 240 km^2 and was increased to 3,090 km^{2}in 1991. It is located between 17° 00′ – 17° 30′ S and 66° 42′

W, and altitudes range between 2,200 and 4,400 m. The influence area includes the Rocha-Maylancu Watershed, which includes the Tunari watersheds. The NPT is an important protected area for biodiversity of plants, animals, and birds. The ecoregions of the NPT are: Puna semi-humid,77%, *Yungas*,16%, and Inter-Andean dry forests, 7% (Ibisch and Merida, 2003).

Puna is an ecorregion located in the high Andes from 3,000 to more than 4,600 m. The natural vegetation includes low evergreen forests. It is in this region where most of the human activities are located, which have caused considerable environmental degradation.

The *yungas* (ecoregions) area is in the northeastern slopes of the Bolivian and Peruvian Andes, where evergreen humid forests are located. The vegetation varies according to altitude, which ranges from 1,000 to 4,200 m.

Within the Inter-Andean Dry Forests, there are different ecosystems ranging from dry forest to the large valleys in central Bolivia. The altitude varies from 500 to 3,300 m.

There are also important foreign species such as pine (*Pinus radiata*) and eucalyptus (*Eucalyptus globulus*).

SOCIOECONOMIC SETTING

Demographic Attributes

According to PROMIC (2004) there are approximately 1,000 rural families living on the slopes of the Tunari Mountains, and about 700,000 in the Cochabamba Valley. The Cochabamba Department population is 1,455,711 (INE, 2003), representing 17.6% of the total Bolivian population. The urban dwellers represent 58.8% and the rural 41.2% of the total population.

The population density in the Cochabamba Department is 26.2 people/km^2 , exceeding the national population density of 7.6 people/ km^2. The Cochabamba Department has 16 provinces, with Cercado and Quillacollo having the highest population density of 1,322.3 and 342.8 people/ km^2, respectively (INE, 2003).

Agricultural Labor Force

The potential working population of the watershed area is about 1.06 million. Of these, about 52% are economically active (Figure 40).

Most of the economically active people are engaged in agriculture, livestock, and fishing.

The data from INE (2003) show that there is a higher participation of men (69.8%) in these activities than women (30.2%).

Figure 40: Onion farmers
Source: PROMIC (2004)

Education and Literacy

According to the 2001 census the illiteracy rate in the Cochabamba Department is 14.5%, higher than the national average of 1.3%. The urban illiteracy rate is 6.7% and the rural rate is 27.3%.

The average years of schooling in the Cochabamba Department is 7.35, lower than the country's average of 7.43.

Economic Activities

Acording to INE (2003) the working population classified by activities is composed mainly of workers in agriculture, livestock, and related areas, followed by extractive industries and manufacturing (Table 28).

Agriculture and livestock activities make an important contribution to the gross national product in the Cochabamba Department (Figure 41).

The main conflicts in the region are the result of natural resource exploitation, mainly timber extraction, from primary forests, without any tree replanting. Other areas of concern are oil exploration, with explosions impacting on the environment, and the wells that spill waste into the rivers damaging the ecosystems. Oil exploitation in the Cochabamba Department represents 40.7% of the national production (INE, 2003). There are also gold and asbestos mining operations in the area.

Table 28: Numbers of people working in various activities in the Cochabamba Department

Activity	Total	Men (%)	Women (%)
Armed forces	1,502	97.3	2.7
Public management	7,730	68.5	31.5
Scientist, intellectual, professional	30,115	48.5	51.6
Technician	27,579	63.8	36.2
Office employee	14,885	38.8	61.3
Services and trade	84,890	29.9	70.2
Agriculture, livestock and fishing	170,068	69.8	30.2
Extractive industry, building and manufacturing	96,545	75.8	24.2
Machine operator	29,618	96.6	3.4
Unskilled personnel	41,517	24.0	76.0
Not specified	24,292	42.1	57.9
Total	528,741	58.8	41.2

Source: INE (2003)

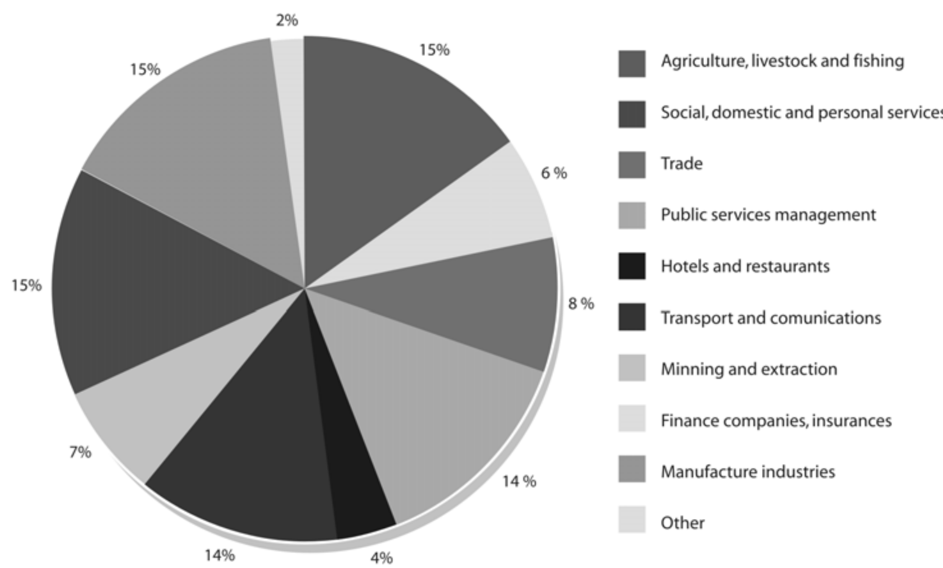


Figure 41: Internal gross product by activity in the Cochabamba Department
Source: INE (2003)

INSTITUTIONAL SETTING

Governance and Organization

In Bolivia environmental management is the responsibility of the Sustainable Development and Environment Ministry that reports to the Presidency. This ministry has three main functions: planning national development and land use, protecting natural resources and the environment, and organizing and promoting participation of citizens.

The second function is the responsibility of the National Secretariat of Natural Resources and Environment. The Secretariat has three departments: Environment, which is in charge of controlling the productive areas that can affect the environment; Natural Resources, which is in charge of land conservation, forestry and management and conservation of watersheds and biodiversity; and Promotion, which is in charge of environmental education and sustainable development promotion (UNEP, 1996).

Policy Framework

The Tunari National Park belongs to the Protected Areas National System (SNAP). The Sustainable Development and Environment Ministry created SERNAP as a means of providing better coordination of activities and to help guarantee integrated management of the national protected areas. TNP is managed by the Cochabamba Department local government.

LAND RESOURCES MANAGEMENT

In the upper part of the watershed where steep slopes are prevalent, the main activities are agriculture and livestock. There are only limited areas where the terrain is appropriate for agriculture (Figure 42).

Figure 42: Agricultural practices on the hillsides
Source: PROMIC

The valley is progressively losing its agricultural potential, and is being replaced by growth of the urban areas.

Agricultural Production

The hillsides of the Tunari Mountains provide mainly subsistence agriculture. The main crops are tubers, vegetables, cereals, and legumes. Despite the decreasing agricultural areas in the Valley, this zone still produces corn, potato, vegetables, and flowers.

Water Availability

The Tunari mountain range receives high levels of precipitation whereas valley precipitation is scarce.

The water from the cordillera is used by communities on the slopes, who derive their livelihoods from agriculture and livestock. The huge urban demands for water in the valley are impossible to satisfy with water collected by the cordillera. As a consequence, water from aquifers is being used to supply the cities.

The presence of farmers in the region has generated conflicts over who has rights to the water sources (CEDIB, 2005).

Water Demand, Allocation, and Use

The water issue has two important components: human-related uses and agriculture and livestock uses.

The population of the cities in the valley (Cercado, Quillacollo, Vinto, and Sacaba) is about 1.5 million. This places immense pressure on valley water resources for human consumption. The urban population needs about 54.8 million m^3 yearly. According to different studies, between 60 and 75% of the human demand is covered by groundwater, meaning that 41 million m^3 are extracted by wells each year (CEDIB, 2005). Only 35 to 40% comes from surface water through the water supply system called SEMAPA. The sources of the SEMAPA system are:

- ***Escalerani:*** 370 l/s—9.5 million m^3/ year—Escalerani and neighboring watersheds and Escalerani Lake. Total available: 11 million m^3/ year, but due to evaporation only 9.5 million m^3 is available for use.
- ***The Escalerani reservoir was constructed in 1980.*** If the dam elevation was raised, then the capacity would increase, however, groundwater exploitation was the preferred choice. Losses in distribution are considerable, reaching as much as 50%.
- ***Misicuni Project:*** It uses the Titiri, Viscacha, and Putucuni watersheds. The project aims to produce 500 l/s, of which 30% will be used for irrigation purposes.

SEMAPA actually covers only 48% of the population, so small groups have created their own systems using groundwater extraction wells.

This situation is worrying, because it is known that in the area only 30% of the water infiltrates to the aquifer and exploitation is higher than the natural recharge rate. The recharge areas of the aquifer are located over the cordillera, where human settlements are established, and the groundwater is used in the valleys, a situation that has created conflicts.

Because water for human consumption and agriculture and livestock activities in the valley is dependent on water production over the cordillera, we cannot overemphasize the importance of conservation of the watersheds in the Tunari.

Challenges related to food, water, and environment

CHALLENGES IN TUNARI WATERSHED

There are many challenges in the Tunari watersheds related to solving problems of the area. Some of the problems are:

- ***Water scarcity.*** Low precipitation, population pressure, poor infrastructure and vegetation cover losses are causes and consequences of the water scarcity in the valley.
- ***Destruction of forests.*** This results from expansion of agricultural lands. which in turn decreases the ability of the watershed to regulate extreme events.
- ***Erosion.*** High erosion rates cause soil losses and decrease soil fertility.
- ***Rural poverty.*** Low education levels, low income, and lack of technical assistance prevent the community from improving their quality of life.
- ***Natural hazards.*** Floods and landslides threaten human settlements.
- ***Poor infrastructure and water use.*** Inappropriate farming techniques and an uneven distribution of water rights, which are concentrated in the lower parts of the watershed, pose serious problems thatneed urgent attention.

Baseline conditions, future outlook, and vision

PARTNERSHIPS FOR TRANSLATING VISION INTO ACTION

PROMIC (2004) has been working for 12 years in five watersheds of the Tunari Mountains: Taquiña, Pajcha, Pintu Mayu, La Llave, and Huallaquea. There are another four prioritized and waiting for implementation of the Watershed Integrated Management scheme: Chocaya, Molino Mayu, Th'ola Pujru, and Pairumani. The program has improved the agricultural production and the income of the population, and has also extended vegetative cover.

RESEARCH AGENDA

Research Priorities

The complete list of research priorities for the Andean System of Basins for CPWF are summarized earlier. The main research topics for the Tunari watersheds areto:

- ***Quantify the hydrologic budget of the watersheds.*** This would help us to recognize water patterns, storage capacity, and other hydrological issues that may contribute to understanding physical processes in the watersheds.

- ***Quantify the sediment budget.*** Together with the hydrological budget, and with the help of mathematical models and sufficient data, we can define the causes and possible solutions to alleviate sedimentation problems.
- ***Determine current land-use patterns and the impact of potential land-use changes on watershed hydrology.*** Models, together with meteorological data, soil, and water samples, maps, and other data can help in the assessment of the consequences of different land-use practices.
- ***Formulate optimal restoration strategies.*** An integral evaluation of the alternatives on land and water use may help to formulate an optimal strategy to restore the ecosystem. Biophysical and economic models plus expert analysis are tools that can address this issue.
- ***Understand the hydrology of the watersheds.*** In order to avoid higher economic risks the interaction between surface water and groundwater must be understand in the region because of the high dependency of human activities on groundwater.
- ***Improve social networks knowledge.*** Conflicts exist between extremely diverse groups, often separated by terrain, but connected as net suppliers or competing users of water. This increases the vulnerability of individual groups and obstructs the path to improvement. Mountain and hill communities are isolated and often marginalized. Lack of efficient, equitable, and sustainable water allocation mechanisms that are acceptable to all watershed stakeholders constrains overall capacity of water to support rural livelihoods.

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The Consortium for Sustainable Development in the Andean Ecoregion (CONDESAN) is a diverse and dynamic group of partners from the public and private sectors who have been working together since 1993, with a shared focus and a synergy of efforts, capacities and resources, to make and assist with concerted efforts in research, training, development, and policy initiatives that promote sustainable socioeconomic progress with the goal of contributing to the equality and well-being of the Andean ecoregion's population.

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