Analysis of the hydrologic sources in the Cotahuasi river basin.

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by

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Preface

The report in front of you is the result of three months fieldwork in the Peruvian Andes and a long period after of collecting and processing the data. For the writing of this report about the hydrologic resources, I had to overcome lots of difficulties. Not only were there the physical challenges of reaching some of the most remote areas of the Peruvian Andes, there was also a language barrier, a collapse of cultures and a delay of months before I received all necessary data.

The excursions into the most remote areas of this distant province of Peru were both astonishing beautiful as severe suffering. Walking three days in a row up to twelve hours a day at altitudes up to 5000 meters is exhausting. Hail, blistering cold and lightning and not changing your cloths for three days in a row doesn't make it more comfortable but the stunning scenery that appeared when the sun came out was amazing. The pure and untouched landscapes that are found in Cotahuasi are scarce and will maybe not stay for long as 'civilisation' reaches the province of La Union.

Before my work started in Cotahuasi I had three weeks of language courses and with the little Spanish I learned back home that was all I got to make my way in Cotahuasi. On my arrival my companion of AEDES told me there had been some changes because a government organisation had come to do the same work as was intended for me. First he wanted to give me a new assignment but soon we decided I was going to join the team of INRENA. Looking back this was in some way ideal and in some way terrible. I had now a big team to cooperate with and a lot more work could be done. On the other hand I lost control of how things were done and had the difficulty of explaining my problems in Spanish if I didn't agree with something.

At first I thought my companion of INRENA, Carlos Romero was a really nice guy and in some ways he is. However I soon found out that there were a few negative things about him. Most important was that he never kept his word. When he told me we were leaving the next day early in the morning we didn't and if he told me nothing he woke me up at 5 am to go on a three day trekking. And although promised a thousand times, it cost me until March of 2007 to finally receive all the data. Well, almost all data, but sufficient to write this report.

In some way it was not all Carlos Romero who was to blame. Of course he had no solid plan, kept no promises and in fact was not up to the job. But it was not easy working under the circumstances. Telephone lines are scarce, roads were not always accessible, guides didn't show up or were completely drunk, salaries were not paid by the headquarters in Lima, employees quitted because of the harsh conditions etc.

In spite of all these obstacles I hope, and think, the report has become a good and easy to read document about the hydrologic resources in the Cotahuasi basin.

Summary

The project was carried out in the Cotahuasi river basin, which contributes to the Ocoña river, one of Peru's most important rivers of the coastal zone. The area is very rugged and remote and characterized by extreme differences in height. It is home to the deepest canon in the world and assigned as protected area because of its richness in biodiversity. The population however is amongst the poorest and least developed of Peru and most of them descend from the indigenous population of Peru.

The objective of the project is to gather information about the quantity and quality of the hydrologic sources in the Cotahuasi river basin to make recommendations for a sustainable use in agreement with the local communities.

Water is present in the forms of glaciers, rivers, streams, springs, meadow wetlands, mountain streams and lakes. In all of the Andes mountain chain glaciers have been declining the past decades and therefore the storage of water as well. The soils are vulnerable for erosion and desertification but are fertile. Climate, vegetation and fauna are very diverse trough the valley which is caused by the differences in height. The valley has been populated for thousands of years and many of the slopes have terraces and irrigation systems to make them suitable for agriculture. Since the coming of the Spanish conquerors the development of the area has ceased and currently one of the major problems is the migration of young people out of the region. From way back the irrigation water was divided equally amongst all users. The Spanish disrupted this system and only recently the partitioning of water starts to improve by the establishment of irrigation commissions and committees. The area is thread by new developments in the way the people use the natural resources. Agriculture and livestock breeding used to be sustainable for centuries but nowadays they are exploited in an irresponsible way.

The hydrologic sources in the basin were measured in co-operation with the national institute for natural resources. They provided a format and carried out most fieldwork. In total 131 lakes, 676 streams, 27 rivers and 556 springs were measured. The reliability of these data is however questionable. Generally the quantity was more important for INRENA than quality. Especially the measurements of the flows of streams and springs can be considered unreliable.

The conclusions are that the irrigation infrastructure is in a poor shape. Not only caused by a lack of maintenance but also by incorrect constructions. The management of the irrigation systems has improved with the establishments of more irrigation commissions and committees. However the lack of young workforce restrains the development of the area. There are too little reliable data available to confirm the supposed decline in the offer of water. In the high and remote parts water is available abundantly. The local population is not enough aware of the vulnerability of the area and the irresponsible way they exploit their natural resources.

To attract young people the area needs a significant economic boost. With a recovered age structure the neglected infrastructure could be improved. The task of monitoring can best me handed over to the local commission and/or committees as this can be done with simple equipment. The population should be informed about the vulnerability of the area and in what way they can contribute to a sustainable development of the area.

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1. Introduction

1.1 Background

The project took place in the protected flow area of the Cotahuasi river which is one of the four basins that make up the Ocoña river basin. The Ocoña river is fed by melting water of one of the highest mountain range of the Andes. Therefore this river is one of the most important rivers on the Peruvian coast with the highest discharge during dry season. The Cotahuasi river basin is an area of approximately 4900 km^2 and is characterized by extreme differences in height, varying from 950 till 6093 meter (Mount Solimana). Most of the basin is very rugged terrain, dominated by canyons, plateaus, ravines, steep slopes, mountain chains and puna (high altitude rolling terrain). It is famous for its richness in biodiversity caused by a unique combination of physical, climatic and biological characteristics.

The province of La Union has a very low population density, the lowest of the Arequipa region. About 17,500 people live in La Union of which approximately 70 percent is centred along the Cotahuasi river. The capital of the province is Cotahuasi with 3,200 inhabitants at an altitude of 2700 meter. Most of the population is descended from indigenous cultures as the Waris, Chankas and Incas. The indigenous language Quechua is still spoken by 97 percent of the people. Still a major problem in Peru is the discrimination of these indigenous people.

The area is one of the poorest of Peru, with a high incidence of illiteracy (34 % of people over 15 years of age) and the lowest life expectancy in Peru (54.33 years, 20 years less then the highest figure of Peru). The main sources of income are agriculture and the breeding of cows, sheep and lamas. For the past decades there has been a high level of emigration out of the Cotahuasi-valley as people seek better income opportunities elsewhere. This resulted in a shortage of able-bodied men in the area. Most of the agriculture in the area is on garden platforms, which turned out to be successful compared to other areas in Peru. However the terraces and the irrigation systems are currently badly maintained which has its effects on the production. The soils in the region are very fragile and poor so erosion and desertification can strike quickly. The agricultural lands are mostly in private hands and primarily of very small size (less than one hectare).

The major threats to the region are (Paparoni, 2002):

- Loss of native and agro-biodiversity, mainly caused by overgrazing and unification of crops.
- Erosion and desertification because of exploitative land use.
- Contamination of water sources from an increase in mining activities, use of agrochemicals and dumping of wastes.
- Climate change, the Andes is one of the areas where the results of the greenhouse effect will be most visible.
- Increasing tourism can be financially beneficial for the local population but can be destructive for vulnerable ecosystems.

AEDES is pursuing a sustainable development of the Cotahuasi river basin. To accomplish this goal more information is needed. One of the subjects little is known about is the hydrologic circle in the area. AEDES wants to obtain a specific representation of all hydrologic sources. With this information problems can be identified and analysed and action can be taken to improve the situation.

1.2 Objective

Gathering information about the quantity and quality of the hydrologic sources in the Cotahuasi river basin to make recommendations for a sustainable use in agreement with the local communities.

1.3 Research strategy

The Cotahuasi river basin is an area of almost 5,000 square kilometres, comparable to the province of Noord Brabant in the Netherlands. The terrain is very rough with extreme differences in height. There are not many roads in the area and all of them are unpaved and sometimes in very bad condition. Bridges are scarce and often not accessible for cars. Reaching the hydrologic sources and executing the required measurements will take a lot of energy and time.
The inventory of the hydrologic sources will be executed by INRENA, the national institute of natural resources. The role of AEDES will be to support INRENA wherever needed. All collected data will be available for AEDES.

As strategy is chosen for a **survey**, because of the following reasons.

- Because of the great extend of the work the research will be more wide than deep.
- The research is more quantitive than qualitive, for every hydrologic source data will be collected.
- The research will be empirical because at the moment little is known about the hydrologic sources in the area.

The sources used for the survey are:
Persons:
For as far possible will the local population be asked for information about the hydrologic sources. In reality this will be difficult because of a communication problem. In the high parts of the Andes Quechua is the main language and for some people the only. The education level is low so only very simple questions in Spanish can be asked.
Reality:
The actual situation of the hydrologic sources will be in-situ measured and investigated. Depending on the type of hydrologic source the following measurements will be executed:

- Determination of location, altitude, perimeter and surface with GPS. This information will be processed digitally with the help of the computer programs MapSource and ArcMap.
- Measurement of the flow with a current meter and a measurement of the wet surface. For small springs a bucket and a stopwatch will be used.
- The major hydrologic sources will be photographed.
- For the determination of the quality of the hydrologic sources is no equipment available. Based on the environment and on information of local people an estimation will be made.

Documents: AEDES has an extensive collection of documentation about the Cotahuasi river basin. Most documentation is also available in a digital version.
Literature: Literature is used to connect the research with existing knowledge of hydrological cycles The only literature taken is the book of Knighton: “Fluvial forms and processes”. In the offices of AEDES is literature available but most about ecosystems and in Spanish. When needed extra literature will be searched for with one of the universities of Arequipa or the UB Twente will be approached.

1.4 Research questions

1. What is the current state of the hydrologic sources?

1.1. Where are the hydrologic sources located within the Cotahuasi river basin?

1.2 For which purposes are the hydrologic sources used?

1.3. What is the quality of the hydrologic source?

1.4. What is the quantity of the hydrologic source?

1.5. What are the most vulnerable and/or valuable hydrologic sources?

2. Which tendencies can be noticed in the state of the hydrologic sources?

2.1. Is there a decrease or increase of the quantity of the hydrologic sources and can a prognosis for the future be made?

2.2. Is there a decrease or increase of the quality of the hydrologic sources and can a prognosis for the future be made?

2.3. Which problems are experienced by the local population?

3. What are the causes of deterioration of hydrologic sources

3.1. What are the influences of humans on the hydrologic sources?

3.2. Which effects can be addressed to the greenhouse effect?

4. How can the maintenance and use of the hydrologic sources be improved?

4.1. Which hydrologic sources needs to be treated with priority?

4.2. Which negative tendencies can be influenced by better management?

4.3. Which knowledge is lacking with the local communities for a sustainable use of the resources?

1.5 Structure of report

In chapter two the Cotahuasi valley is described by means of the natural elements and the human influence. The chapter ends with a list of all major threats to the area.

Chapter three describes the results and findings. First the experiences of the data collection are described, secondly the measured data are mentioned, in the third part they are analysed and last they are discussed.

Chapter four comes with the conclusions, reflections and recommendations.

2. The Cotahuasi river basin

A flow area consists of various elements. There are natural elements like the water, the soil, the climate, the vegetation, geography, fauna. The other major element is the human influence in form of reservoirs, irrigation channels, contamination, forestry, agriculture and stockbreeding. Within the human element organisations and government boards can be find that will try to manage and control the river basin.

The Cotahuasi river basin is part of the Ocoña river basin. Annex I shows the Cotahuasi river as part of the whole river basin of Ocoña and Annex II shows an overview of the sub-river basin of Cotahuasi with the main villages, major roads, altitude lines, rivers and lakes.

2.1 Natural elements

2.1.1 Water

The most essential element of a flow area and of life because it is crucial for the productivity of the soil. It can provide great benefits like irrigation, drinking water, fishing grounds and industrial use but can also cause great problems like erosion and flooding.

In the flow area of the Cotahuasi river basin water is present in various forms.

- Glaciers.
- Rivers
- Springs "manantiales". Water that arises out of the soil surface.
- Meadow wetlands "bofedales". Wetlands with very slow flowing water where special vegetation can grow.
- Mountain streams "Quebradas". Narrow openings between two mountains where water is collected into a stream.
- Lakes or lagoons
- Ground water

In annex III a & b some pictures of springs and bofedals are shown.

2.1.1.1 Glaciers

Although Peru is located relatively close near the equator there are several areas with glaciers found all trough the country. These glaciers are important because meltwater is used for agricultural, industrial and domestic purposes during periods of drought. Especially in the arid coastal areas people depend on the runoff from the mountainous areas.

The flow area of the Cotahuasi river is fed by two glaciers of the Ampato mountain range. The Solimana group and the Firura group both in the east part of the Cotahuasi river basin. In 1962 these glaciers where measured and the collected data are presented in Annex IV. No further research have been carried out to investigate the development of the glaciers on the Ampato mountain chain. This can be explained by the fact that the glaciers of the Ampato are just 4 percent of the surface of all of Peruvian glaciers and are nation-wide of minor importance. The data of 1962 were collected by Concytec, a national research board, and showed a glacier surface of 7,76 km^2 contributing to the Cotahuasi basin.

The development of these glaciers can only be estimated using data of surrounding data. The estimated total surface of glaciers in Peru declined from 2041 km2 in 1970 to 1595 km2 in 1997. This means a reduction of 21,8 % in 27 years time. Small glaciers as the Solimana and the Furira are even more vulnerable and likely to disappear in the coming decades. Because Firura is a very small glacier of only of 1,18 km^2 in 1960 and the relatively low altitudes of between 5140 and 5498 meter above sea level, it is not unlikely that Firura will only be snowcovered during the winter-time and in fact no longer exists as a glacier. Solimana was bigger with 6,58 km^2 and was found higher located between 5100 and 5950 meter.

2.1.1.2 Rivers

As shown in Annex I the Ocoña river is formed by the Marán river, the Cotahuasi river and the Armas river. Very little data exists of all of these rivers. Only at the mouth of the Ocoña river the flow is permanently monitored. Annex V shows the discharge of the Ocoña river from august 2002 till july 2004 as well as the average of the period 1985-2000. The graph shows that 02-03 and 03-04 were very dry years. This was the case in the whole coastal zone of Peru. The year 2001 was a year with abundant precipitation. The graph shows that also the base flow during the winter months declines significantly, even more than the peak flow. Nevertheless the Ocoña river is the river with the biggest permanent flow in Peru. The water of the Cotahuasi river however can hardly be used for human purposes because the river bed is so deeply encised in the landscape. Almost al trough the valley the rivers flows so deep below the plateau's that are suitable for agriculture that the local people are not able to use the river water. Only the narrow coastal plain can fully profit from the hydrologic potential.

The Cotahuasi river is fed by several tributaries. The most important (with their lengths) are :

- Río Huaynacotas (12,52 km)
- Río Pampamarca (16,44 km)
- Río Chuquibamba (11,91 km)
- Río Chococo (6,65 km)
- Río Huacaccara (10,28 km)
- Río Puccnanta (3.97 km)

2.1.1.3 Ground water

Little is known about the amount and distribution of groundwater in the Cotahuasi river basin. However the ground water plays an important role as it is the supply for the many springs and wetlands. Especially during dry seasons the water supply relies heavily on the amount of soil water. The steepness of the landscape indefinitely should have a major impact on the gradients of the water table and groundwater flows but unfortunately there has not been done any research on this topic.

2.1.2 Soil

This important element can provide life if combined with water of good quality. However it is also vulnerable for erosion, fluvial flows, contamination, earth slides, sedimentation of reservoirs, saltification, problems of drainage, etc.

Only the soils in the district of Cotahuasi have been investigated by the National Soil Conservation Program. Since the conditions of soil formation and use during the centuries seem to be fairly uniform in the valley, the results of this investigation provide a good indicator for the complete flow area. The data were collected at elevations between 2300 and 3300 meter which reflects the area where most of the agriculture take place. The conclusions of this investigations are as follows.

- The natural soils are sands and sandy clays.
- At all elevations, cultivated soils in the plow zone (0-30 cm depth) are loams to sandy loams with a low clay content. All have friable consistence and a granular to subangular blocky structure, with abundant fine, medium and coarse pores. Compared to the natural soils they have a higher silt content and less clay and sand. The permeability and capacity to retain water are both good. The chemical properties show a higher portion of organic matter and phosphorus in the cultivated soils and an increased pH level.

The investigation shows that although the soils have been used intensively for several hundreds of years they are still fertile and provide a good source for agriculture. Apparently the management and conservation of soils as practised for ages since the Inca Empire are successful. One of the major influences that still remains was the building of terraces which are still in use in most of the valley.

The Cotahuasi basin is an area highly vulnerable to land degradation and desertification and is considered one of the most fragile zones in the western Andes. Located between the highland deserts of Sechura and Antofagasta the threat of desertification lies on the corner. The extreme differences in height make that erosion can happen easily. The canyons have an average slope between 50 an 70 percent and vegetation is largely restricted to the small oases formed by agricultural terraces. So without the protection of vegetation these soils are very vulnerable and land slides occur regularly in these areas.

2.1.3 Climate

This includes precipitation, temperature, evaporation, cloudiness, etc. These elements have a strong influence on the biological activity.

Peru can be divided into three zones, the very arid coastal zone, the Andes mountain chain and the very humid tropical jungle. The Cotahuasi valley lies on the Western slopes of the Andes, which is the more arid side of the mountain chain.

The river basins on the Western slopes of the Andes can be divided in three zones (Vasquez, 1997).

- The high parts (3000-6000 msl) where the biggest volume of water is concentrated. Precipitation can reach up to 1000-2000 mm a year and usually the mountain tops are (part of the year) covered with snow and ice.
- The medium part (800-3000 msl) is characterised by a soft but precarious climate. Precipitation is usually between 100 and 1000 mm a year.
- The low part (below 800 msl) has an extremely dry climate with annual precipitation at maximum 100 mm but more often close to zero.

The Cotahuasi sub-basin is part of the high and medium parts of the Ocoña river basin. Like in other western valleys intensive agriculture on the basis of rainfall alone is impossible. There is a rainy season that begins in December/January and ends around March/April, which is the summer on the southern hemisphere. Annex VI shows the table of the precipitation-data of four meteorological stations in the province of La Union. Annex VI shows a figure of the average rainfall compared to the average flow discharge at the mouth of the Ocoña river. The flow discharge responds very quick when the precipitation starts to increase in December/January. The same can be said when the rain season is over in March/April.

Another essential characteristic of the climate is the unpredictability of rainfall. Variation of precipitation is substantial and the area has suffered several times of periods of extreme drought. One of the reasons of this unpredictability is the phenomenon of ‘El Niño’, an irregularity in the currents of the Pacific Ocean. During ‘El Niño’ years precipitation on the western slopes of the Andes is abundant. The opposite of ‘El Niño’ is called ‘La Niña’ and causes extreme drought. In the last decade 97-98 was regarded as a strong ‘El Niño’ year, 02-03 was a normal ‘El Niño’ year and 98-99 and 00-01 were both ‘La Niña’ years. The season 04-05 also showed some ‘El Niño’ characteristics. This is confirmed by some Cotahuasinos. Although no data of last years were available locals mentioned that the month January, February and march of 2005 were very wet. The rain season of 2006 was said to be quiet dry.

In both upper and lower parts of the valley the climate is fairly mild. The effects of the tropical latitude (15 degrees south) are mitigated by those of the high altitudes and vice versa. There is however a pronounced temperature difference between day and night that increases with altitude. In the winter season night frost is common in all parts of the valley. In summer only in the high parts the temperature drops below zero. The result of this is that agriculture is constrained in winter.

2.1.4 Vegetation

The vegetation is an important element in the hydrological cycle because it effects the evapotranspiration, the sum of evaporation and plant transpiration. Vegetation works as a buffer, capturing the water longer. Another advantage is that vegetation protects the soil against the erosive effects of water.

The vegetation in the Cotahuasi area is very diverse. In the lower parts crops like mango can be grown as where in some high parts no vegetation at all can be find because of the altitude and poverty of the soils. The diversity of the vegetation is one of the reasons why the area is elected as Protected Natural Area. Initial floral studies (AEDES, 1997 and 1998) have identified 430 species in the Cotahuasi basin. Three species are considered threatened or endangered by the IUCN (World Conservation Union) and 24 by CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora). Because of the long history of agriculture in the valley a wide variety of cultivated plants is found. All kind of types of potatoes, quinoa and maize's grow on parcels and in the wild that have disappeared in other parts of the Andes. The meadow wetlands which are called bofedales have a special biologic value because of their unique ecosystem.

Vegetation zones can be divided according to height.

The lowest zone starts at about 900 meter till about 2300 meter. Rainfall is little in this zone so vegetation is mostly find along the river shores and near springs. Crops that are grown are mainly fruits like mango and grapes for wine. In the dry areas the famous and rare columnar cactuses can be find which can grow up to 10 meters. Outside the vegetated areas the soil is vulnerable for erosion.

The middle zone from roughly 2300 till 3600 meter. Rainfall is still limited in this area and only sufficient during the rainy season from December till march. The rest of the year water is supplied by springs or irrigation channels in the cultivated areas. The plateau's find on this heights are best suited for agricultural use. Trees can be find till about an height of 3000 meters. Especially in the deep and enclosed canons some very special biosphere's can be find with rare shrubs and herbs.

The high part goes up from 3600 till about 6000 meter. Most of the rain falls in these high areas but because of the height and the cold these areas are very hostile. The vegetation found in these areas is adapted to these conditions. It is called Tolares and consists of grasses and mosses. Cows and sheep's can be find on the rough grasslands in the lower areas whereas lama's and alpaca's live in the high parts.

2.1.5 Topography, geology & geography

The steepness and the topography of the terrain affect the way and the speed of the water that flows down the river basin.

The river basin of the Cotahuasi river is located between 14º 40'22" and 15º 35'27" south latitude and between 72º 19'15" and 73º 18'08" west longitude. The total area covers up to almost 5000 square kilometres, comparable with the province of Noord Brabant in the Netherlands. It lies on the western slopes of the Andes, the longest mountain chain of the world and one of the youngest and most active. The Cotahuasi valley lies along the northern edge of the 'Volcanic plateau of Arequipa', a zone of ancient eruption and tectonic uplift. The valley is characterized by extreme differences in height, extraordinary steepness and the deepest canyon in the world. The highest peak is over 6100 meter and the point where the Cotahuasi river joins the Marán river is about 900 meters above sea level. From Cotahuasi (2600 masl) to the closest mountain top (5200 masl) is only 12 kilometres, an average rise of 20 percent. The consequence of this geography is that runoff of water and soil is a potential threat.

The Cotahuasi river and its substitutes are deeply incised in the landscape. Although it has one of the biggest and most consistent flows of Peru most of this water can not be used because it flows tens or hundreds of meters lower than the agricultural grounds. Only in the narrow coastal plain close to the ocean the river water can be used abundantly for agriculture.

2.1.6 Fauna

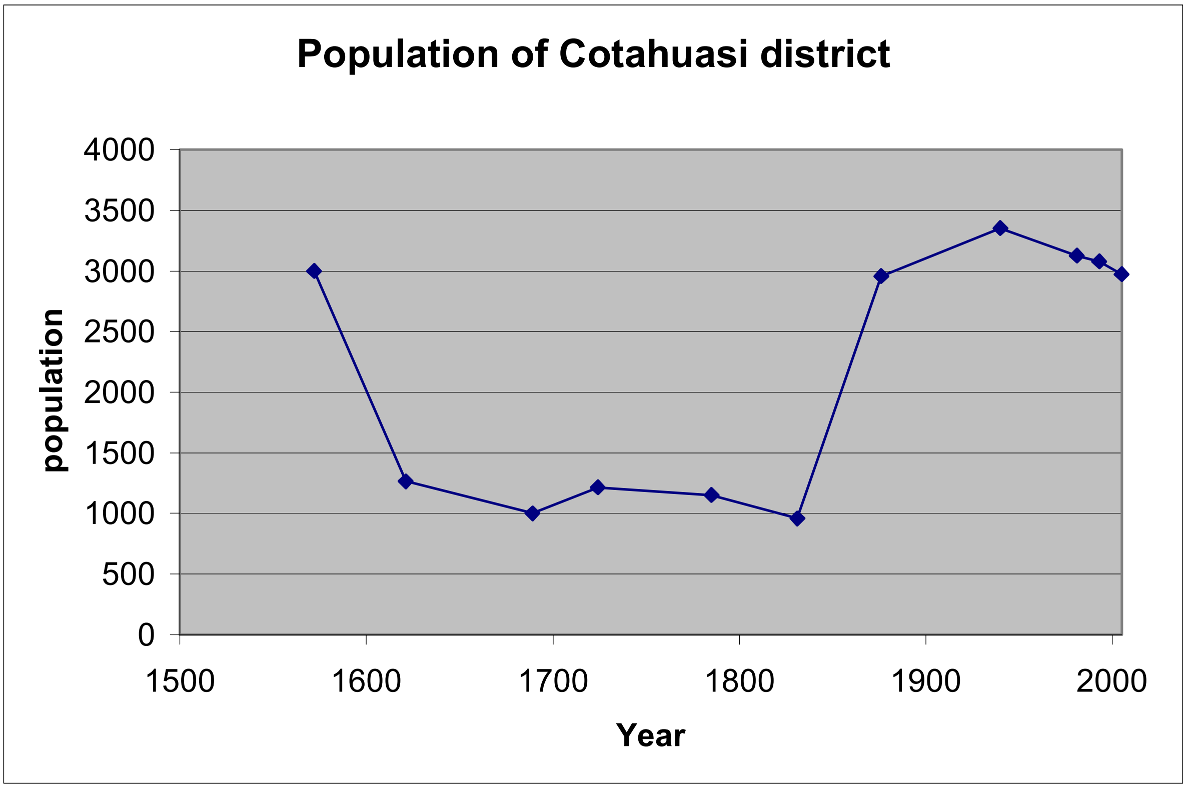
The animal life in an area is not only beneficial for human purposes but also crucial for a natural equilibrium. Normally nature creates a stable equilibrium between flora and fauna. If the equilibrium gets disturbed by man or natural phenomenon's like drought, volcanic eruptions, flooding etc. processes like desertification can take place because of overgrazing.

Originally the grazers of the valley were lama's, alpaca's and vicuna's. Lama's and alpaca's were used for carrying goods over the highlands and their wool. Vicuna's life high up in the mountains and are hard to domesticate. With the coming of the Spanish conquerors new livestock was brought to South America. Mules, cows and sheep quickly gain ground on the original grazers because of their higher profit, in particular the production of milk and ability to carry more load.

2.2 Human influence

2.2.1 The valleys history

Little is known about the valley's earliest inhabitants. Only a few superficial archaeological studies have been carried out and is unlikely that the remains from the initial period have been brought to surface. Investigations showed that the area flourished by the time of the Middle Horizon, from 700 to 900 CE. However it is assumed that people where present long before this period.
During the Middle Horizon the Huari people expanded throughout much of Peru. Originating from the centre of Peru there are clear evidences that they quickly marched to the Southern Highlands, including the Cotahuasi Valley. Most of the irrigation systems and terraces where created in this period or even before this period and are still in use.
After the Huari period the region continued to develop as a wealthy and well organized community. When the Inca empire in the first half of the 15th century started to expand it found a lot of resistance in the Cotahuasi area. Nevertheless the area was conquered and under the control of the Inca's significant improvements in the irrigation system and infrastructure were made.
In 1531 the Spanish conqueror Francisco Pizarro went off a trip which meant the end of the Inca empire. The coming of the Spanish conquerors was devastating for the whole of Peru. The population was reduced from 9 million in 1530 to roughly 600.000 by 1620, a decline of 85 %. This was the result of epidemics of European diseases, forced labour in colonial mines and several wars and violent rebellions. Because of the isolation, high altitudes and scarcity of resources the destruction of the civilisation in Cotahuasi came relatively late. The population graph of the Cotahuasi district (not the province) shows the decline in population after the conquest of the Spanish. The first population count dates back to 1572. Although the reliability is uncertain the devastation is clear. The second count, 39 years later, shows a decline of 58 percent. Based on the sex ratio can be concluded that in 1572 the populations were just beginning to decline. The second count shows a surplus of woman which can be explained by the casualties of slavery in mines. In 1566 the mine of Huancavelica opened and most healthy man from Cotahuasi were forced to move and work in these mines. In the following decades more mines were opened and labourers were conscripted from local villages as in the province of La Union.



Another important development was the establishment of 'haciendas', private agricultural estates. These properties supported the mining industry with the growth of food crops and the supply of mules for transport. The new landowners not only expropriated the land but also the irrigation water that used to be divided equally amongst farmers for ages.
It took until the 19^{th} century when the mining ended for the native population to grow again. Most of their properties however were lost to Creoles, descendants of the Spanish conquerors. Attempts to recover some of the lost properties were mostly without success. The new landowners controlled the economy of the region and most of them focused their business on the wool production and trade. The explosive population growth-figure at the end of the 19^{th} century was not only caused by the end of the mining but also caused by the immigration of Creoles into the area attracted by the profitable wool trade. Most of these immigrants settled in main villages like Cotahuasi and therefore the figure does not represent the growth of the whole region. In the first half of the 20^{th} century the province continued to rely on the wool trade and population growth stabilised at a normal rate. Within the province a movement out of the major settlements took place. Especially the few areas that where not part of 'haciendas' attracted indigenous people who were not willing to work for the new Creole landowners. In the 1980's the Maoist organization Shining Path (Sendero Luminoso) launched a guerrilla war to help the poor farmers against Creole landowners and the government. Most often they used very violent methods to reach these goals. Also in the valley of Cotahuasi the influence and followers of the Shining Path grew. Tension increased and a violent atmosphere was present. In 1988 the confrontation came to a climax when Shining Path attacked the village of Cotahuasi and two landowners were killed. The response of the government was to increase the number of militaries and police. This made an end to the violence in the region but it took till 1992, when the leader of the Shining Path was captured, for the guerrilla war to slowly come to an end.

2.2.2 Recent developments

The last decades show a slow decrease in the population of La Union. The region is one of the poorest and least developed areas of Peru. Annex VII shows some indicators of development. The illiteracy rate is diminishing but still amongst the highest of Peru. There are no reliable data of incomes available. As an indicator of wealth could the used the percentage of thatched roofs. From way back all houses were made of clay with thatched roofs, nowadays the wealthier part of the population has improved their houses with more modern roofs. The figure shows the decline in thatched roofs by district. The figures show clearly an improvement but compared to the state of Arequipa still a huge arrears. Another indicator of development is the percentage of electricity connections which has grown explosively but is still lying far behind on the rest of the state of Arequipa.
The centrally located districts are more developed than the high surrounding areas. However the figures show that the remote parts are catching up with the central parts. The development of the high parts is limited by the remoteness and lack of sufficient infrastructure. Roads are often in a piteous state and are not accessible during the rain season. Even the main road from Cotahuasi to Arequipa is not paved. The trip from Cotahuasi to Arequipa takes therefore about 12 hours. The remoteness of the valley is one of the main reasons of the low development.

Many young people choose to leave the valley to try their luck elsewhere, most of the times in Arequipa one of Peru's major cities with almost one million inhabitants. Because of the outflow of young people the province has a disrupted age structure. Annex VIII shows the population pyramid of La Union compared with that of State of Arequipa. The figure shows clearly the lack of young people. The result is that the working class is too small to maintain the labour-intensive terraces and irrigation systems. Many terraces are abandoned and irrigation channels and reservoirs are in bad condition. Especially in the districts of Quechualla, Tauria and Pampamarca the share of young people is extremely low, about 20 percent of the population is between 20 and 40 years old whereas the average in the state of Arequipa is 34 percent. The districts Cotahuasi and Puyca have the most balanced population pyramids but even these communities lack a sufficient part of young man and woman. In both districts only 26 percent of the population is between 20 and 40 years old. Annex IX shows the development of the age structure from 1981 to 2005. This figure shows that the age structure has been disrupted for the past decades but that there is no further deterioration.

The economy of the area depends on two sectors, agriculture and (upcoming) tourism.

Agriculture

Agriculture is by far the most important source of income for most people in La Union. In 1993 more than 57 percent of the working population was farmer. (INEI, 1993) Most land is divided in very small units. The average size of a parcel is less than a hectare. About 87 % of the production is for own use. (AEDES, Both Ends) Annex X shows the distribution of crops grown in the district of Cotahuasi. This is not an average of the province because there are big regional differences in crops caused by the various climates. Cotahuasi however is the only district were detailed information of crops is monitored. The figure shows that the most grown crop is Alfalfa (35% of the land), a plant that is mostly used to feed livestock. Alfalfa is highly resistant to both frost and drought, and can survive for months without water. However the plants are able to grow fast all year long if enough water is provided. A quarter of the land is used for the production of Kiwicha. This crop is a very good source for all kinds of valuable nutrition and exported to countries like Germany, North America and New Zealand. 21 Percent of the land is used for maize.

The last decade the agricultural sector started to improve partly because of the support of AEDES. Producers were united and a well planned policy was developed to provide the local, national and international markets. With education and training the local farmers were helped to raise their harvests in a sustainable way. Rotation of crops, more efficient (traditional) irrigation methods and new markets like medicinal and aromatic plants were the results of these efforts. The most successful initiative was the establishment of an organic farming program for international markets.

Tourism

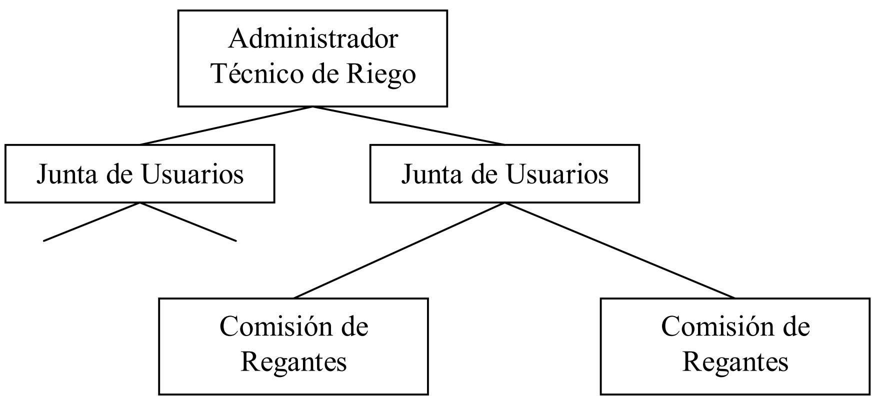
A less developed but quickly growing activity in the basin is the ecotourism sector. Because of its high biodiversity, cultural and historical artifacts, and unique geography, the Cotahuasi basin has a strong potential for ecotourism. During the Inca Empire, the valley was the most direct route between the Inca capital of Cuzco and the Pacific Ocean, and as such was the site of extensive trade and building. This, combined with long-term occupation by its indigenous population, means that today the area is full of archeological artifacts from many different periods, including ancient temple and burial complexes. Another attraction of the Cotahuasi basin is the manner in which man, since pre-Columbian times, has transformed the nearly vertical walls of the canyon into cultivated areas. Throughout the basin, visitors can admire the more than 10,000 hectares or existing and relict garden platforms. As the deepest canyon in the world, the Cotahuasi basin can offer some amazing scenery's and landscapes. The ideal terrain for expert walkers and climbers. The Cotahuasi river is also regarded as a one of the best rivers for rafting in South America and is rapidly becoming popular amongst experienced rafters.

2.2.3 Control of water

Whit the arrival of the Spanish conquerors the efficient irrigation system used by the Inca's disappeared. Because of the decline of the population water was no longer the limiting factor but labour became short. The new landowners expropriated the available water resources for their own lands and irrigated with wasting but labour-extensive methods.
In 1902 the Código de Aguas (Water Code) ratified the private property of irrigation water if these resources where owned for 20 years or more. The remaining water became public property and could be used for collective use. The explosive population growth made the demand for water grow and soon the offer of especially collective water was too little. The villagers started to privatise the agricultural lands and water to ensure their irrigation rights. Another way was buying irrigation water from the landowners for money or labour. This new system demolished the homogeneous structure of the communities. During the drought of 1939 till 1942 disputes, corruption and theft of water became every day issues. In 1941 the Peruvian government appointed an administrator and the first Padrón de Usuarios was established. This was a list of all official landowners with the land that they were allowed to irrigate. The administrator was responsible for the compliance of the assigned rights. The majority of the villagers had no properties and they were the biggest losers of this new system.

In 1969, under the leadership of left nationalist Velasco, the Ley General de Aguas (General Water Law) was introduced. This law made an end to the private property of water in Peru. All water should be divided amongst farmers irrespective of social status or vicinity of the farmland to the water source. In case of scarcity the production of food crops should be given priority. And for every district the use of irrigation water should be planned and monitored. It took until 1979 for the Junta de Usuarios (Consumer Board) to be legally recognized by the Department of Arequipa. Despite being officially recognised by the authorities, Water Consumers' Boards, particularly those in the Andean highlands, received little technical support. The years of violence destroyed many forms of organisation among rural communities, and contributed to increasing the poverty and the isolation of communities in areas of already extreme poverty. The irrigation organisations were some of the few organisations that survived during the times of violence. As peace was re-established in La Unión in 1996, these organisations start to function as intended.

The current organisation of water users consists of an Administrador Técnico de Riego (Technical irrigation administrator), the Junta de Usuarios, 33 Comisiones de Regantes (Irrigation commissions) and 39 Comites de Regantes (Irrigation Committees). Annex XI shows the structure of the organisation.



The Administrador Técnico de Riego
The task of the ATR consists mainly of advising and controlling the Junta de Usuarios. The ATR can support the Junta de Usuarios with advise and help with problems that are too difficult for the Junta de Usuarios. Another important task is the granting of permission to people for the use of ground- or surfacewater.

The Junta de Usuarios
The Junta de Usuarios is an organisation of representatives of all waterusers. All Comisiones de Regantes are represented as well as a representative of the drinking water service and a representative of the remaining non-agricultural users. The Junta has a governing board of nine people which is chosen every two years. The Junta de Usuarios is charged with the collection of water levies and solving problems that can't be solved by the Comisiones de Regantes. The Junta de Usuarios is also responsible for the co-ordination of the activities of the ATR in the district.

Comisiones de Regantes
The farmers of all community are united in a Comision de Regantes. These organisation are responsible for the irrigation system of the community. The most important tasks are the partitioning of irrigation water and the maintenance of the irrigation channels and reservoirs. Each Commission has a president which is elected democratically every two years.

Comités de Regantes
Some Commissions are subdivided in Comités de Regantes. Those committees are responsible for one or two irrigation channels.

This organisational structure has only been functioning in this way for about a decade. Most commissions and committees are established only a few years ago. The system as intended is therefore not working yet as effective as it could be. Some irrigation channels are still poor maintained, elections are not held every two years but people keep their position for up to five years. Another problem is that there is no overview of the exact frontiers of each commission and committee. Some remote areas are not represented at all and for some areas it is unclear to which commission it belongs. The remoteness, limited transport and communication facilities can be seen as causes why the system is not fully functioning as intended.

Besides these formal organisations a few more organisations are involved in the water management of the Cotahuasi river basin.

- The drinking and sewage water company SEDAPAR (Servicio de Agua Potable y Alcantarillado de Arequipa). About 46 percent of the livings in La Union is connected to the drinking water red and only 13 percent has sewerage. These numbers are far behind the average of the Arequipa district which are respectively 76 and 67 percent. There is no shortage of drinking water and quality is within the norms of the World Health Organisation.
- PRONAMACHCS (Proyecto Nacional de Manejo de Cuencas Hidrográficas y Conservación de Suelos) is an organisation of the ministery of agriculture which provides support for the management of river basins in underdeveloped Highland areas. Goal is to improve management in a way that development will be sustainable economically as well as socially.
- CTAR (Conseje Transitorio de Administración Regional) is an organisation that controls all public works. The building of irrigation works is part of the responsibility of CTAR.
- AEDES (Asociación Especializada para el Desarrollo Sostenible) is a non-governmental organisation that is involved in work to promote sustainable development.

2.2.4 Current threats to the land & water resources

Among the greatest threats to the natural resources of the Cotahuasi basin are:

- Loss of native biodiversity due to loss of vegetative cover, overgrazing (concentrated cattle raising), and extraction of bushes and trees for firewood, resulting in population reductions and/or the threat of extinction for some species of native flora and fauna and the reduction, fragmentation and disappearance of ecosystems or specific biotopes.
- Reductions in agro-biodiversity and disappearance of heirloom varieties due to increasing use of new and often exotic seed varieties (generally artificially produced), decreased use of traditional strategies such as seed exchanges among local farmers, and abandonment of higher elevation terraces where native ecotypes are most often cultivated (during the past few years, native varieties have been displaced by 'improved' strains in the basin's intermediate zone, so that today 87% of the agricultural land in the basin is devoted to growing maize and potatoes).
- Accelerating erosion and desertification on agricultural and pasture lands as area inhabitants abandon traditional Andean cultural practices of land management in favour of more market friendly technologies and practices, including elimination of terraces (to facilitate the planting of animal- feed crops and pasture), burning of stubble, abandonment of crop rotation, and changing irrigation techniques, and impacts of these on ecosystem integrity both upstream and downstream in the basin.
- Contamination of water sources from an increase in mining activities (including use of cyanide), including many small mines that would not otherwise exist except for the construction of government subsidized roads, with severe impacts on wild flora and fauna and drinking water quality.
- Contamination of water sources from increased use of agrochemicals and the dumping of solid and liquid wastes into water sources near population centres and cultivated lands.
- Loss of vegetative cover associated with poor use and distribution of water resources, giving rise to the desertification of some natural environments and changes in the ecological processes of others.

2.3 Research approach

The inventory of the hydrologic sources was made in co-operation with a delegation of INRENA (Instituto National de Recursos Hydricos), the national institute for natural resources. The co-ordination was in hands of Carlos Romero hernandez, engineer of INRENA. The processing of data was done by one man and the fieldwork was conducted by 5 to 8 people, depending on the availability of people. The research was carried out during the end of the dry period so the measured quantities could be regarded as the minimum's of the hydrologic sources.

This institute provided a document which was the basis for the research. Annex XII shows an example of these documents. The collected data were as follows.

- General information.
  This includes type of source, the name, the river basin, irrigation district, date and Pfaffstetter code. The Pfaffstetter code is used to divide a river basin in sub-basins to simplify the processing of data.
- Political location.
  This includes the nearest village, the district, province and department.
- Geographic location.
  This includes the geographical co-ordinates and the altitude. The used geodetic system was WGS 84.
- Accessibility.
  The way the source is accessible: a walking trail, un-hardened road, hardened road or no form of access.

According to the type of source the following data were collected.

- For lakes: Surface (m^2), depth (m), height of dam (if present)(m), circumference (m), maximum storage capacity (m^3) and used storage capacity (m^3). If a dam was present the type of dam was noted.
- For springs: If it had a permanent or temporal flow, if and what type of capturing work was present and if it lead to a irrigation channel or storage, the type of spring: filtration, tubular or fissure, place of the spring: the slopes, valley bottom or mountain floor, the quantity of the flow (lts/s) and how this was measured and the location of the measurement.
- For rivers: The minimum and maximum width of the channel (m), the minimum and maximum height of the channel (m), the location of the measurements, the flow (lt/s), the type of measurement and if it was a permanent or temporal flow.
- Water quality.
  This includes pH, conductivity, salt level and temperature.
- Type and rights of use.
  This includes the type of use: for population, for stock, for fishing, for agriculture, for industry, for energy, for mining, for tourism or no use, what the rights of use were and the respective quantities and administrative resolutions.
- Observations
  This includes a written observation, a photograph and a sketch of the situation

Equipment
Geographical co-ordinates and altitude were measured with the use of GPS's. Accuracy's were varying between 10 to 30 meters depending on location and type of GPS. Small flows were measured using a bucket and stopwatch. If possible intermediate flows were measured using a floater. The biggest flows were measured using a current meter. If for some reason measurements were not possible an estimation was made. Amongst the equipment were also a measuring wire, a calculator and maps.

Way of working
Before the actual work was done information was collected with the concerned authorities. In Cotahuasi the ATR was contacted for the overall plan and time schedule of the inventory. The river basin was divided in parts that most of the time coincided with one commission or committee. A time schedule was made and for every area a crew was assigned. When a crew arrived in a certain area a local guide was contacted to bring the crew to all locations and provide additional information as names, use of water etc. Preferably the local president of the commission or committee was asked to help as guide or otherwise a person with knowledge of the local situation. Besides the knowledge of the guides the crew used maps and information of the previous investigation of 1998 as a base for their inventory. All data was collected on the provided forms which were processed in the office in Cotahuasi.

3. Results and findings

3.1 Data collection experiences

As mentioned before the data were noted on the provided documents (Annes XII). During the work this format turned out to contain some indistinct and superfluous issues.

- The type of the source was in some cases not clear. Sometimes it was not possible to define a source as spring, bofedal or quebrada.
- The name of the source and irrigation district was not always known by the guide.
- The river basin, province, state and zone were the same for every source of the inventory. They were however filled in every time again which cost a lot of wasted time and effort.
- The Pfafstetter code and number of source were added in the office and could be left of the form. The same is the case for the storage of lakes which was calculated with depth and superficies.
- The GPS co-ordinates were all read of the display and noted on the form. All type of GPS have the possibility to store location in their memories. This should have been more efficient and could have excluded human mistakes. The reason why this wasn't done is because there were no cables to transfer the data to the computer.

Water quality was not measured at all because there was no equipment available to do the work. However during the fieldwork observations were made of the environment to estimate water quality.

Most often the exact point of origin of the source was high up in the mountains. It took a lot of effort and time to reach up to these points. Sometimes when time was limited the decision was made to estimate the location of origin and measure the flow on a lower location. In other cases flows were not measured but estimated because of difficult circumstances or lack of material. However these estimations were not mentioned on the document as estimations but as measurements. In some cases the data were adjusted in the office to make them look more like measured data.

Initially the fieldwork was scheduled for one month and a half, from the beginning of august till the 20th of september. This was however a great misjudgement. More than once the fieldwork was underestimated and time schedules were not realised. Transport turned out to be difficult in the remote terrain, guides were hard to find, were drunk or didn't show up at all and inventorying an area turned out to take more time than planned. Several times the schedules were adjusted and eventually the last source was measured on the third of november 2006.

3.2 Collected data and findings

In total 131 lakes, 676 streams, 27 rivers and 556 springs were measured in the river basin of Cotahuasi. The following table shows the measurements by district. The district of Sayla is not measured because although it belongs to the province La Union it does not to the Cotahuasi basin. Most measurements were carried out in the northern districts Puyca, Huaynacotas and Pampamarca.

DISTRICT	MEASUREMENTS
COTAHUASI	133
ALCA	129
CHARCANA	45
HUAYNACOTAS	299
PAMPAMARCA	185
PUYCA	308
QUECHUALLA	39
SAYLA	0
TOMEPAMPA	50
TORO	176
TAURIA	15

The lakes cover a total area of almost 14 km^2 and are found only in the northern and south-eastern districts. They store 64 million cubic metres of water at the time of measuring. More than 90 percent of the lakes are located between 4700 and 5000 meter above sealevel. By far the most water is stored in the lakes of Puyca. Several big lakes are found in Puyca, lake Igma is the biggest with a surface of five square kilometres. Other major lakes are Huanzo and

Llanajille, both in Huaynacotas and covering up more than two square kilometres, lake Apalcocha in Tomepampa and lake Lutococha in Puyca. In the district Alca there is a big number of lakes but all of them relatively small. Annex XIII shows a map of the lakes in the basin sorted by total storage volume.

Both with the fieldwork as in the office maps were used which were based on air-photographs and dated back to about 1970. In these maps a distinction was made between rivers and streams. The rivers were measured at 27 points and the streams at 676 points. The major rivers are shown in Annex XIV, all flow discharges more than 1 m^3/s are labelled in the figure. The flow of the Cotahuasi river near the village Tomepampa is 20,38 m^3/s.

The 556 springs together have a total water flow of 3,6 m^3/s. Out of the one hundred biggest springs comes 2,5 m^3/s, the remaining 1,1 m^3/s is divided over 456 springs, some of which are really small. The smallest springs measured have a flow of only 0,01 litre per second. Although this can change during the rain season these numbers are neglectable.

3.3 Data analysis

Analysis of the data shows several obvious mistakes caused by the processing of data by hand. Converting the data in maps using ArcMap showed several sources located outside the boundaries of the province. The data files also contain some altitudes that do not exist in the Cotahuasi basin. Obviously these data have been made by processing by hand. Nevertheless it is remarkable that these mistakes have not been filtered out by the people of INRENA as they are easy to detect. It should be kept in mind that mistakes which are less obvious will not be noticed. For example if the mistake in the co-ordinates is not made in one of the first numbers but in one of the last the location shifts 1000, 100 or 10 meter. These mistakes are hard to detect.

Annex XV shows the main use of the resources. 51 Percent is used for agriculture and 11 percent for other purposes as drinking water, live stock, fishing, tourism or energy. 38 Percent is not used at all. Most unused hydrologic resources are found in the high parts were agriculture is restrained because of the altitude.

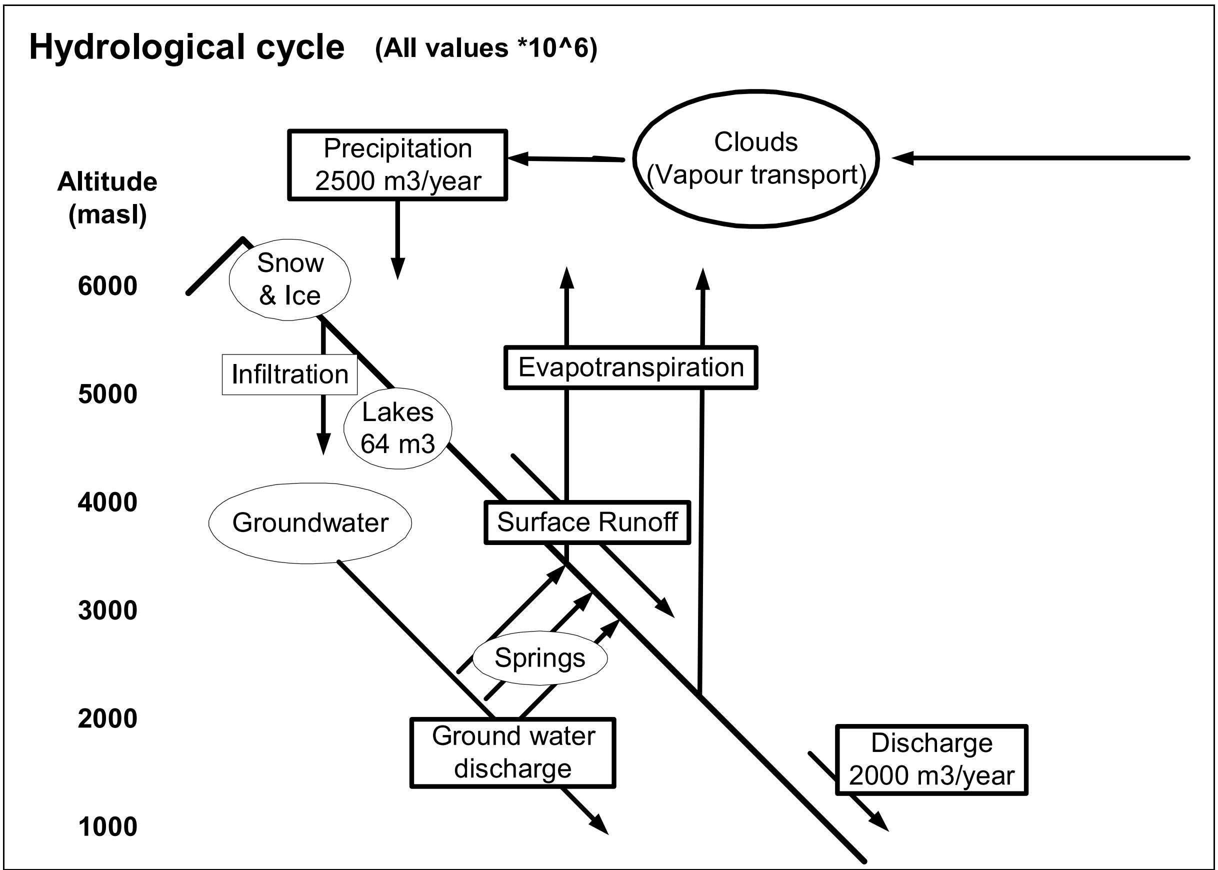
Annex XVI shows the accessibility to the resources. Most sources are accessible by a walking trail (89%), some by road (4% hardened, 5% unhardened) and a minority is not located to any prepared path at all (2%). A hardened road is in this case not an asphalt road but a path of rammed down soil.

3.4 Discussion

The total of water flowing trough the streams is 8,9 m^3/s and water coming out springs is 3,6 m^3/s. The discharge of the Cotahuasi river measured at a point close to Tomepampa is however 20,38 m^3/s. Kept in mind that some springs and streams flow into other streams and are counted double in this way the total flow of water of spring and streams should be higher than the discharge of the river Cotahuasi. Moreover because water from springs and streams is used by people and evaporates. The fact is however that the discharge in Tomepampa, not even the bottom of the valley, is higher than the total flow of springs and streams. Therefore some of these data have to be incorrect. Annex XIV shows the figure of the major rivers and the measured flows. The measurement in Tomepampa is shown as well as two measurements a short end upriver. The total of these two measurements ($17+2,24 = 19,24 m^3/s$) is close to the discharge in Tomepampa. This indicates that these measurements are correct. Moreover the discharge of the Cotahuasi river is known to fluctuate between 15 and 60 m^3/s (Trawick, 1994). My experiences in the field confirm the conclusion that the measurements of bigger flows are the most reliable. The majority of flows in the high and remote areas are estimations. As the river is fed by streams and springs this means the flow measurements of springs and streams are incorrect, or that not all springs and streams are measured.

A comparable inventory of hydrologic resources on a smaller scale was done in 1998 and led by Freddy Motta, the ATR of Cotahuasi. This research doesn't make a distinction between springs and streams. Only 184 locations were measured and according to Freddy Motta the reliability of the data is very low. A comparison between the 1998-data and the current data turned out to be impossible. Only in a few cases location and name corresponded but by far insufficient to make a reliable comparison. Moreover the offer of springwater depends on the precipitation that has fallen in the year before. These exact precipitation data are not available either. Therefore a trend in the offer of water from hydrologic sources can not be made.

The following figure shows the hydrological cycle of the Cotahuasi river basin. The annual precipitation and discharge data are rough estimations based on the data of annexes V, VI and XIV. Precipitation is strongly related to altitude in the region. By dividing the basin in areas with similar altitudes and assigning an annual precipitation based on the measured data an estimation of total precipitation of the valley is made. Total discharge is estimated by extrapolating the measurement of September to the other months based on the Ocoña discharge.



4. Conclusions & Recommendations

4.1 Conclusions

The lakes contain enormous amounts of water which in potential can be used for irrigation. In the largest lake of Huaynacotas, Lake Huanzo, a water outlet has been build but this construction is blocked by sediment and out of use. There is a lack of knowledge for creating such constructions.

Many irrigation channels and reservoirs are currently in poor shape. This is caused not only by insufficient maintenance but also because of wrong constructions. Apparently the necessary knowledge for the solid construction of irrigation systems is not present with the local population.

The once effective irrigation system has disappeared since the coming of the Spanish. Not only the infrastructure but also the irrigation schedules and partitioning have deteriorated. The last decade the poor situation of the region was noted by government and other organisations and initiatives have been started to improve the region. The organisation and management of the hydrologic resources has improved but the migration of young people has a strong negative effect on the region because of the lack of a young workforce.

The claimed decline of water in the region can not be confirmed by data. The fact that temperatures are rising and glaciers are melting is solid. The precipitation however has been unpredictable for decades and reliable data to determine a trend are not available. A comparison between the inventory of hydrologic sources of 1998 and this inventory is not possible either. There are too many distinctions between the two inventories to compare them. Moreover the offer of water during the dry season depends strongly on the amount of precipitation in the rain season before and these data are not available.

In the high and remote parts of the valley, especially in the north, water is abundantly available. Most of this water is not used for any purpose and flows directly into the Cotahuasi river. In potential this water can be used to irrigate the agricultural lands below. This should demand a considerable investment in the irrigation system.

The vulnerability of the environment is not realised by the majority of the population. Garbage is dumped everywhere, water is polluted and used inefficient. Because of the characteristics of the area problems like erosion and desertification could easily occur.

4.2 Reflections

The co-operation with the people of INRENA had both advantages and disadvantages. All measurements in the field could never been done without INRENA. Also the fact that they were native Spanish speakers and knew the Peruvian culture was helpful. On the other hand the data that was collected is not as reliable as should be. The attitude of many Peruvians is to give preference to quantity before quality. This also counts for INRENA, however they tried to awake the appearance that all data were perfectly reliable. It should have been better to indicate the reliability of data, to make a distinction between measured data and estimated data. The processing of the data by hand was also not the best way. It not only took lots of time, during the manual work errors were created which should not have happened if the data were processed by computer.

4.3 Recommendations

To become attractive for young people the area needs a significant economic boost which can not be created only by the agricultural sector. Therefore new opportunities should be searched for as tourism and (new) low-tech industries like food processing and textiles. To improve the tourism sector three improvements are most important: the construction of a hardened road to Cotahuasi, better provision of information for tourists in Cotahuasi as well as in Arequipa and improvements of the accommodations. The land is not suitable for intensive agriculture because of the extreme differences in height. Therefore the production of common agricultural products like maize and wheat can be profitable for the local market but can not compete in the long run with low-land, intensive agriculture. To create an export market for agricultural products, the sector should focus on specialization on typical Andes crops like Kiwicha or special types of maize's. Important is that new developments will be sustainable for man and environment.

The task of monitoring the hydrologic sources can best be handed over to the several irrigation commissions and committees. All locations of hydrologic sources are noted so lists can be made of the most important sources belonging to a certain commission or committee. With quiet simple methods the flow of these sources can be measured on a weekly or monthly basis. With detailed data of the flow during the year the management of the area can be optimised. Crops could be adjusted so they better match the offer of water during the year. The distribution of water could also be improved if the available water is monitored. And if there is a positive or negative trend in the offer of water in the long term the management can notice this and adapt to it. The co-ordination of this monitoring could be in hands of the Junta de Usuarios or the ATR.

The irrigation infrastructure should be improved. Therefore not only the amount of labour for maintenance should increase. Also the knowledge of (channel)constructions should improve. The aim should be to first improve the present infrastructure which is in poor state. Later the unused hydrologic sources in the high and remote parts could be connected and contribute to the irrigation system.

To maintain the ecological value of the area people should become aware of its vulnerability. The sense should be created that on the long run nature can only be used in a sustainable way. The major issues should be to prevent the dump of garbage in the nature as this can harm tourism, to make people aware of the scarcity of water to promote efficient use and to inform the population of what harm pollution can do to the health of people and animals and to their crops. To reach this goal information should be provided in the form of posters or workshops about sustainable land use.

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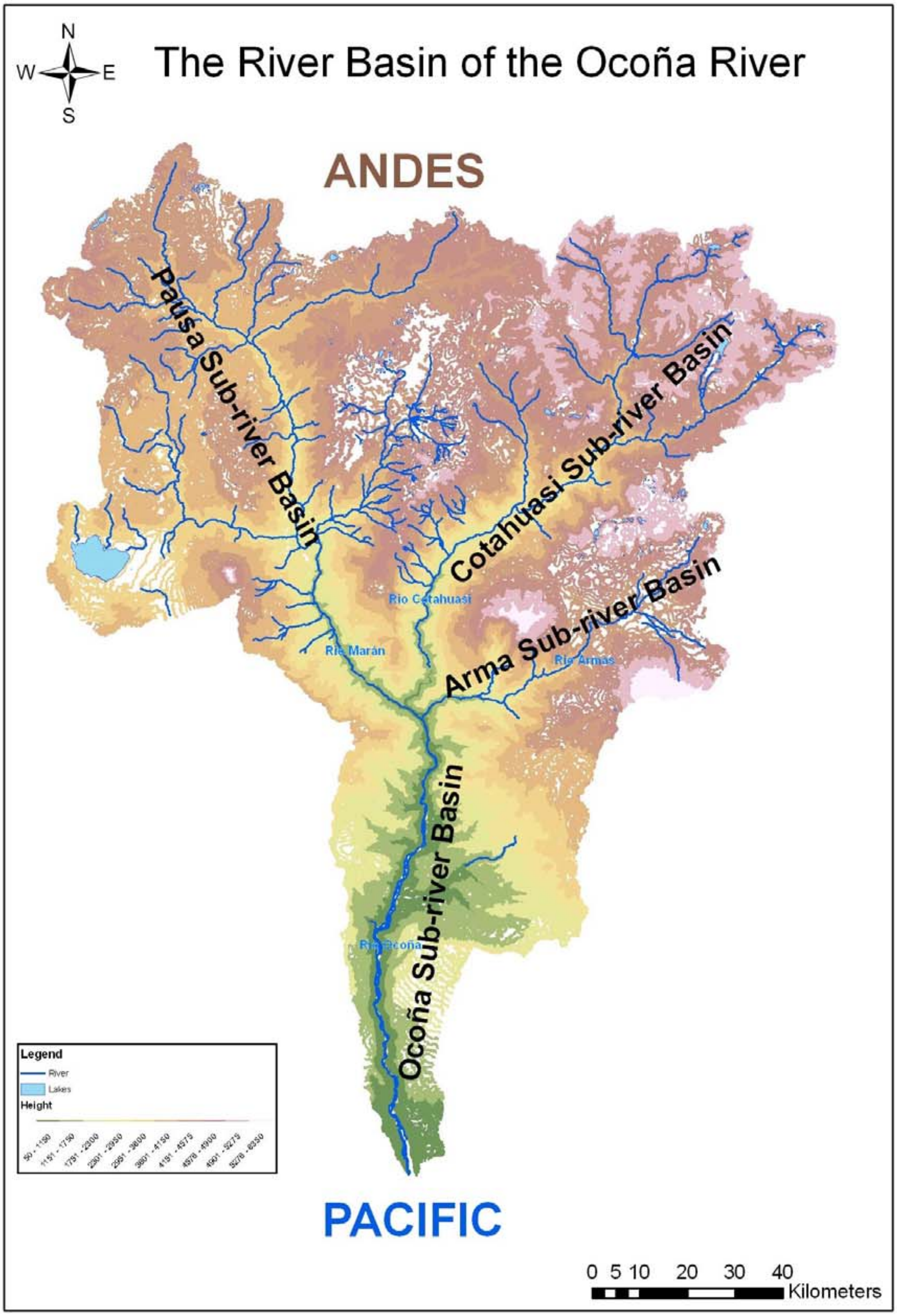
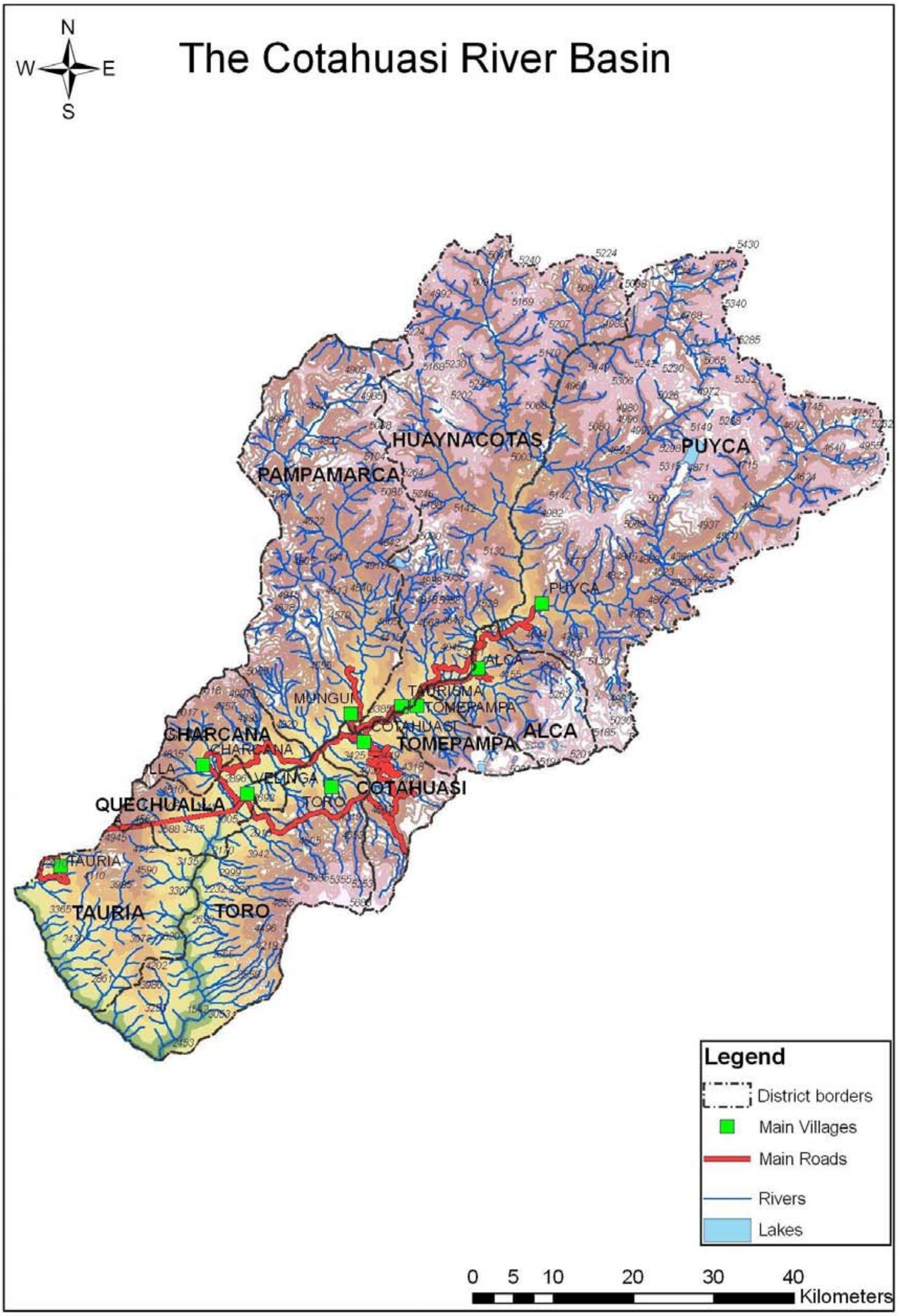
Annex I The River basin of the Ocoña River

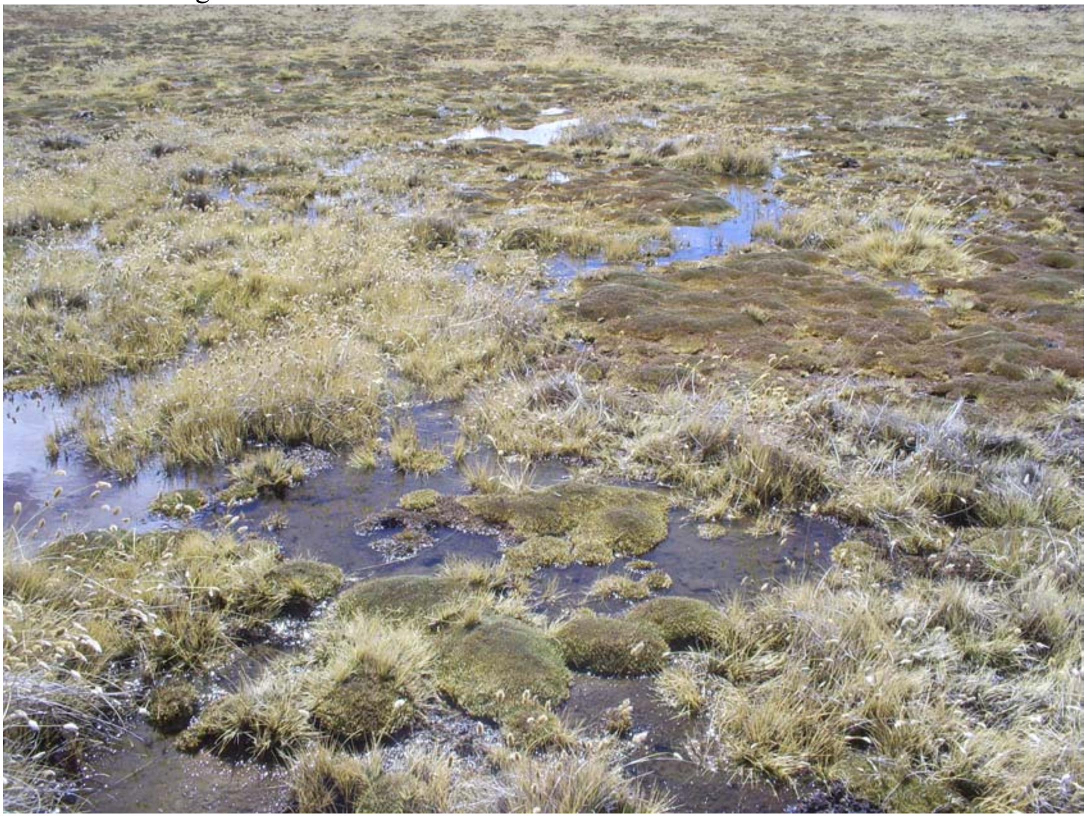


Annex II The Cotahuasi sub-basin



Annex III-a Images of springs

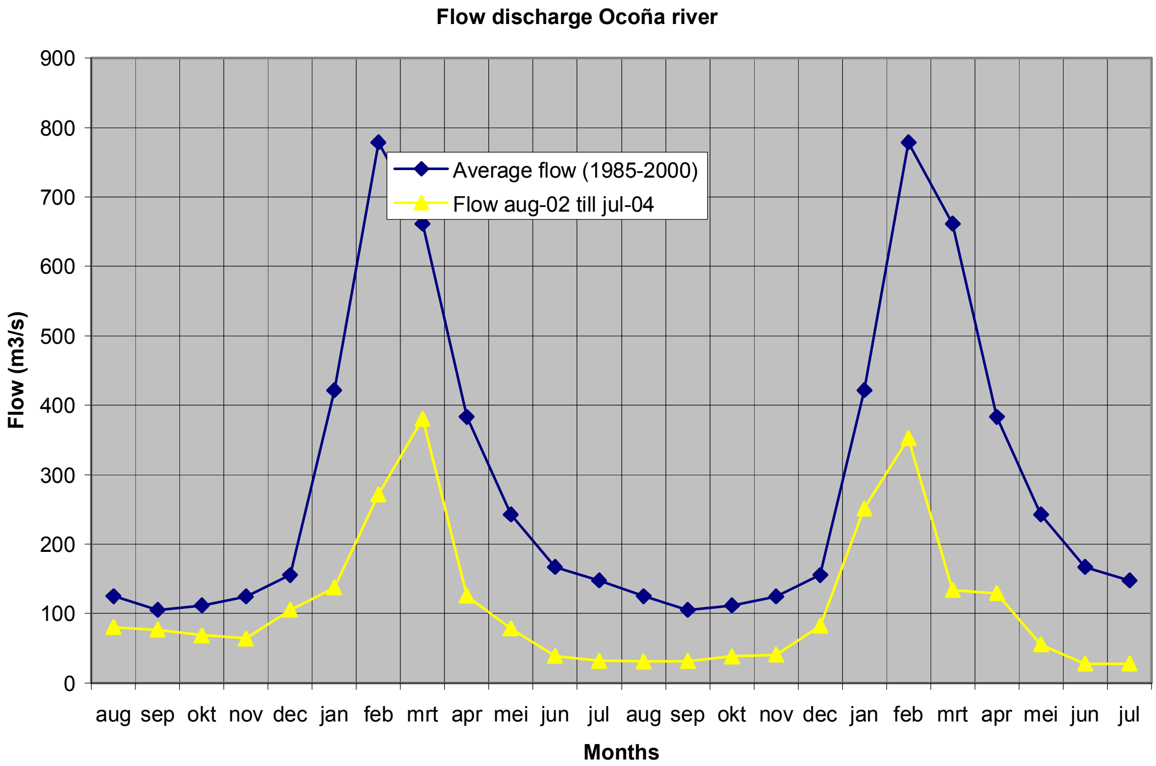
Annex III-b Images of bofedal's

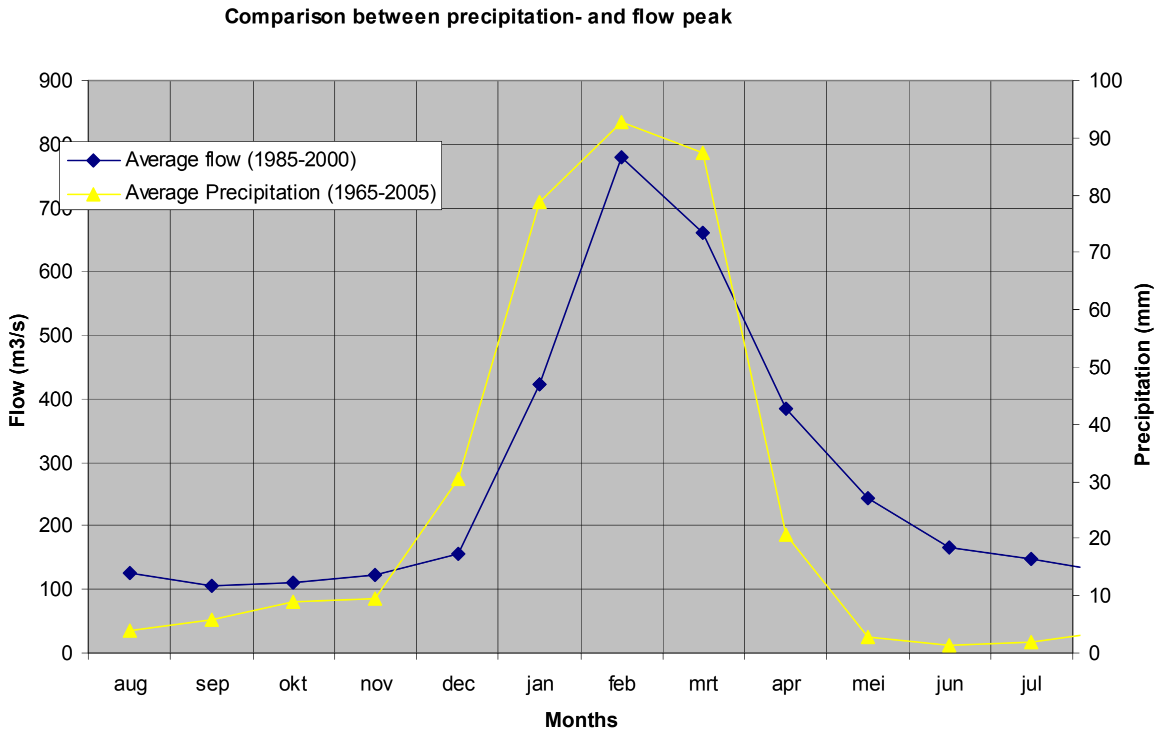


Annex IV Glacier data

Data of glaciers on the Ampato mountain chain which contribute to the Cotahuasi river basin (1962)												
Name	Group	South latitude	West longitude	Area (km2)	Average width (km)	Average length (km)	Maximum length (km)	Orientation AC	Orientation AB	Altitude max	Altitude med	Altitude min
Yanaranra	Solimana	15º 23” 29’	72º 53” 03’	0,71	0,5	1,4	1,4	N	N	5800	5475	5225
Ccaño	Solimana	15º 23” 56’	72º 53” 37’	0,78	0,6	1,3	1,5	N	N	5700		5260
Solimana	Solimana	15º 23” 96’	72º 53” 80’	1,92	1,1	1,7	1,9	NW	N	5950	5700	5325
	Solimana	15º 23” 59’	72º 54” 50’	0,8	0,7	1	1	NE	NE	5750	5550	5325
Puccaorco	Solimana	15º 23” 47’	72º 54” 85’	0,79	1,2	0,6	0,8	NW	NW	5750	5525	5325
	Solimana	15º 23” 64’	72º 55” 10’	0,29	0,4	0,7	1	NW	NW	5700	5550	5300
Yaretay	Solimana	15º 23" 38’	72º 55” 86’	0,42	1	0,4	0,6	NE	NE	5500	5410	5300
Yaretay	Solimana	15º 23” 38’	72º 56” 07’	0,33	0,5	0,6	0,7	W	W	5518		5275
	Solimana	15º 23” 50’	72º 56” 40’	0,3	0,5	0,6	0,8	NW	W	5375	5200	5100
Iglesiayoc	Solimana	15º 23” 66’	72º 56” 61’	0,24	0,6	0,4	0,5	NW	NW	5275	5190	5100
			Total:	**6,58**					**Average:**	**5631,8**	**5450**	**5253,5**
	Firura	15º 13” 25’	72º 37” 92’	0,22	0,4	0,6	0,7	NW	NW	5450		5250
	Firura	15º 13” 38’	72º 38” 11’	0,18	0,6	0,3	0,3	S	S	5450		5275
	Firura	15º 13” 71’	72º 38” 28’	0,24	0,3	0,8	0,8	N	N	5498		5250
	Firura	15º 13” 67’	72º 38” 56’	0,33	0,5	0,6	0,7	NW	NW	5475	5350	5215
	Firura	15º 14” 21’	72º 38” 83’	0,21	0,3	0,7	0,8	NW	NW	5400	5280	5140
			Total:	**1,18**					**Average:**	**5454,6**	**5315**	**5226**
			Total	**7,76**								

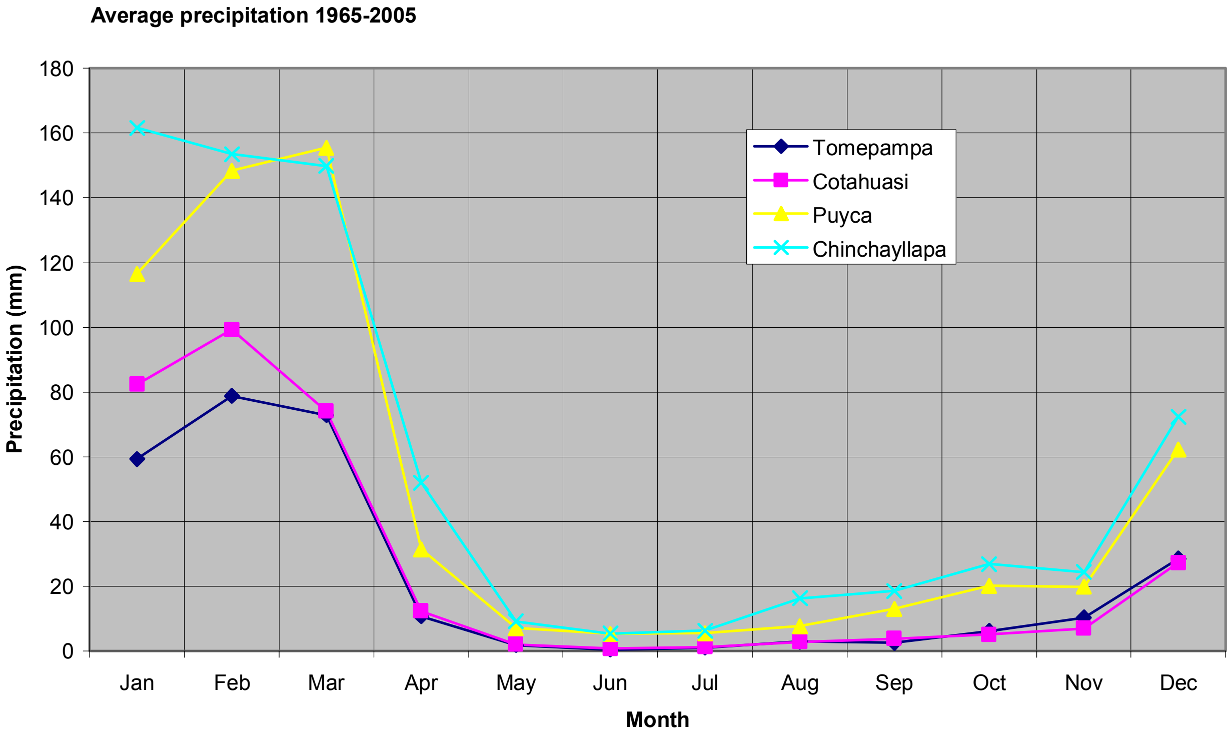
Annex V Ocoña flow discharge



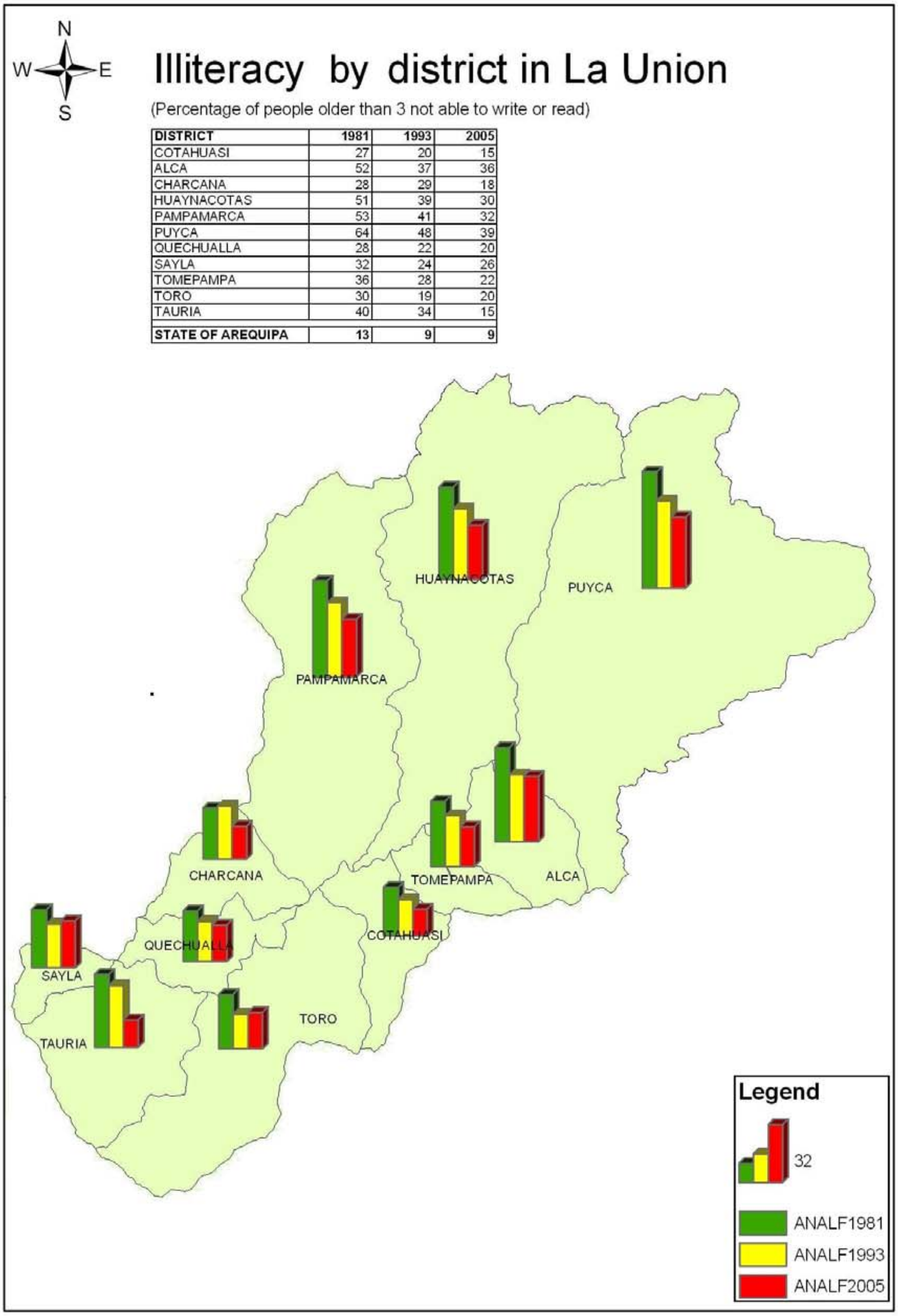


Annex VI Precipitation data of the Ocoña river basin

Station	Height	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Ocoña	58	0,1	0	0	0	0	0,1	0,3	0,8	0,7	0	0,1	0	2,1
Urasqui	330	0	0,3	0,3	0	0,1	0	0	0	0	0	0	0	0,7
Pausa	2530	61,8	63,4	50,4	7,5	1,7	0,6	1,2	2,3	2,1	3	2,2	17,2	213,4
Tomepampa	2650	59,3	78,8	72,9	10,8	1,9	0,5	1,1	3	2,6	6,2	10,4	28,6	276,1
Lampa	2715	60	63,1	61,9	13,2	1,9	0,5	2,1	1,4	5,6	3,8	3,2	16,6	233,3
Cotahuasi	2883	82,4	99,3	74,1	12,4	2,1	0,8	1,3	2,9	3,9	5,1	7	27,3	318,6
Carhuanillas	3000	114,1	154,2	146,1	34,6	0,9	0	0,7	2,2	3,7	9,7	12,9	27,6	506,7
Yanaquihua	3130	39,3	57,4	35,2	1,8	0,5	0,4	0,3	1,6	0,8	1,4	2,9	10,1	151,7
Salamanca	3203	75,9	90,5	72,8	12,4	1,3	1,3	2,4	4,7	4,2	6,3	7,6	25,4	304,8
Incuyo	3298	76,3	106,6	92,7	26,6	0,9	0,1	0,9	0,5	3,9	10,4	5,1	31,1	355,1
Chaviña	3310	128,5	155,7	171,4	35,9	5,7	0,9	1	4,2	11,8	13,4	12	51,8	592,3
Puyca	3362	116,5	148,4	155,5	31,5	7,1	5,3	5,5	7,7	13,1	20,2	19,9	62,3	593
Lucanas	3400	106,7	117,5	145,5	40,6	5,1	1,8	2,3	5,5	7,9	13,7	13,4	34	494
Orcopampa	3779	98,4	100,3	84,5	30,1	4	1,5	3,3	5,4	8,9	12,5	23,1	53,4	425,4
Chinchayllapa	4100	161,6	153,5	149,8	52	9,2	5,4	6,3	16,3	18,6	26,9	24,4	72,4	696,4

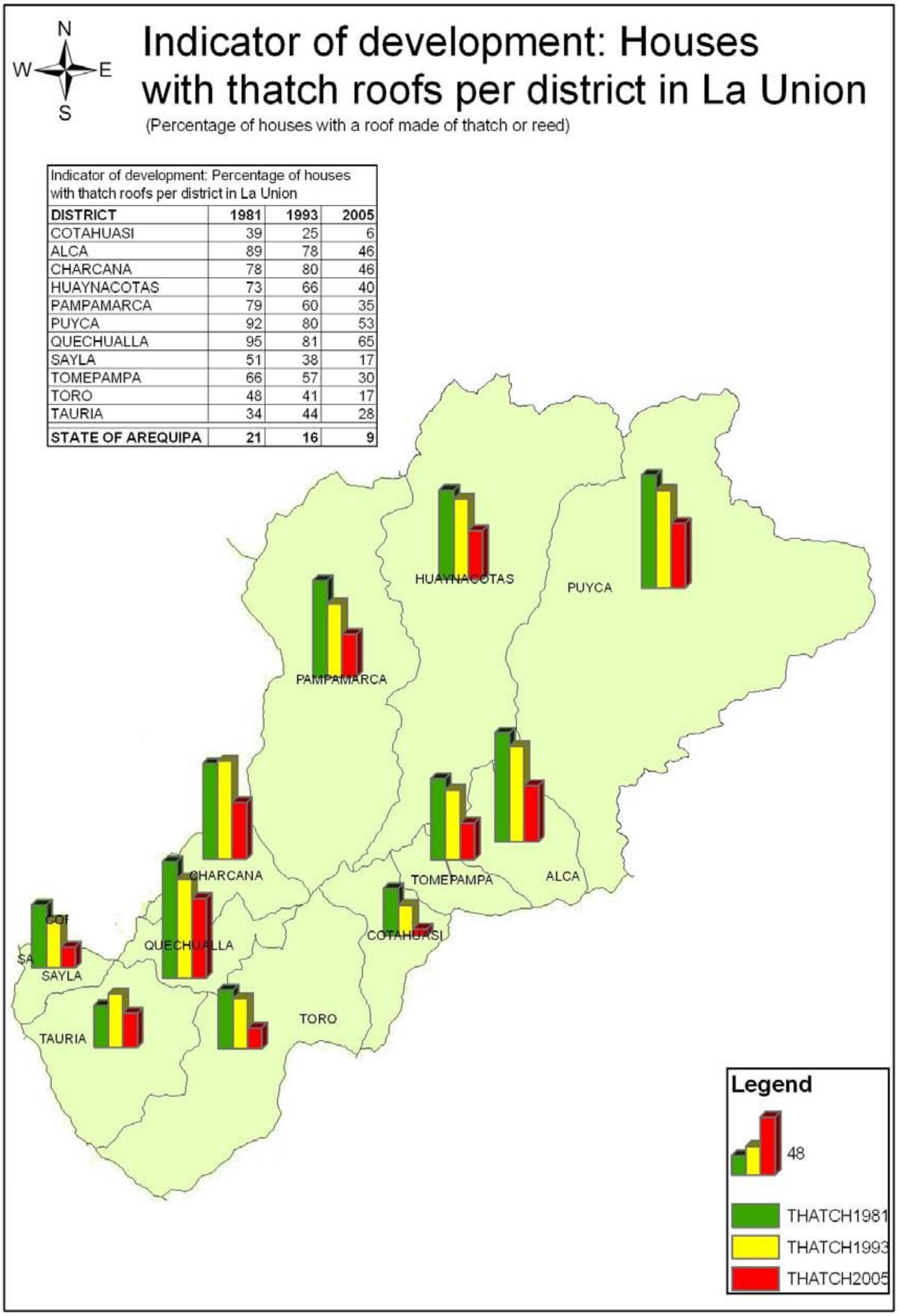


Annex VII-a Development indicator: Illiteracy



DISTRICT	1981	1993	2005
COTAHUASI	27	20	15
ALCA	52	37	36
CHARCANA	28	29	18
HUAYNACOTAS	51	39	30
PAMPAMARCA	53	41	32
PUYCA	64	48	39
QUECHUALLA	28	22	20
SAYLA	32	24	26
TOMEPAMPA	36	28	22
TORO	30	19	20
TAURIA	40	34	15
STATE OF AREQUIPA	13	9	9

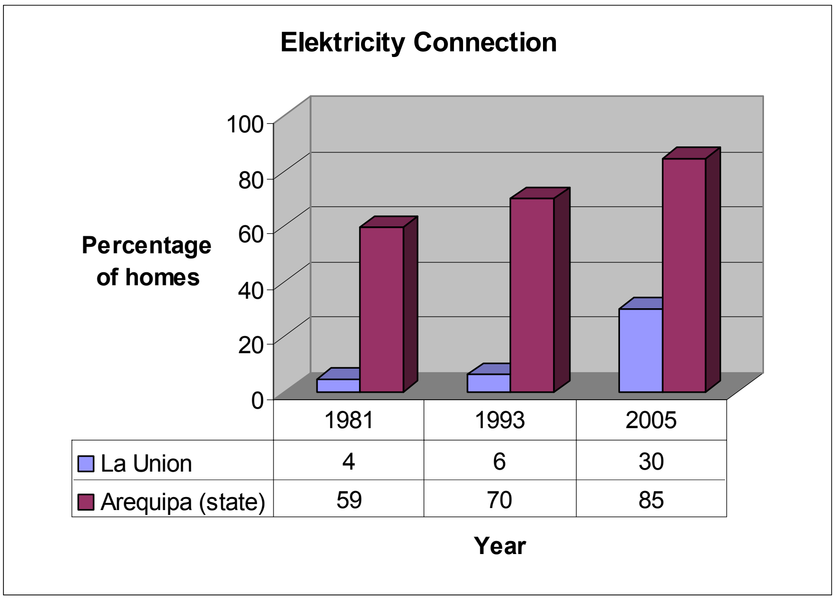
Annex VII-b Development indicator: Percentage of houses with thatch roofs



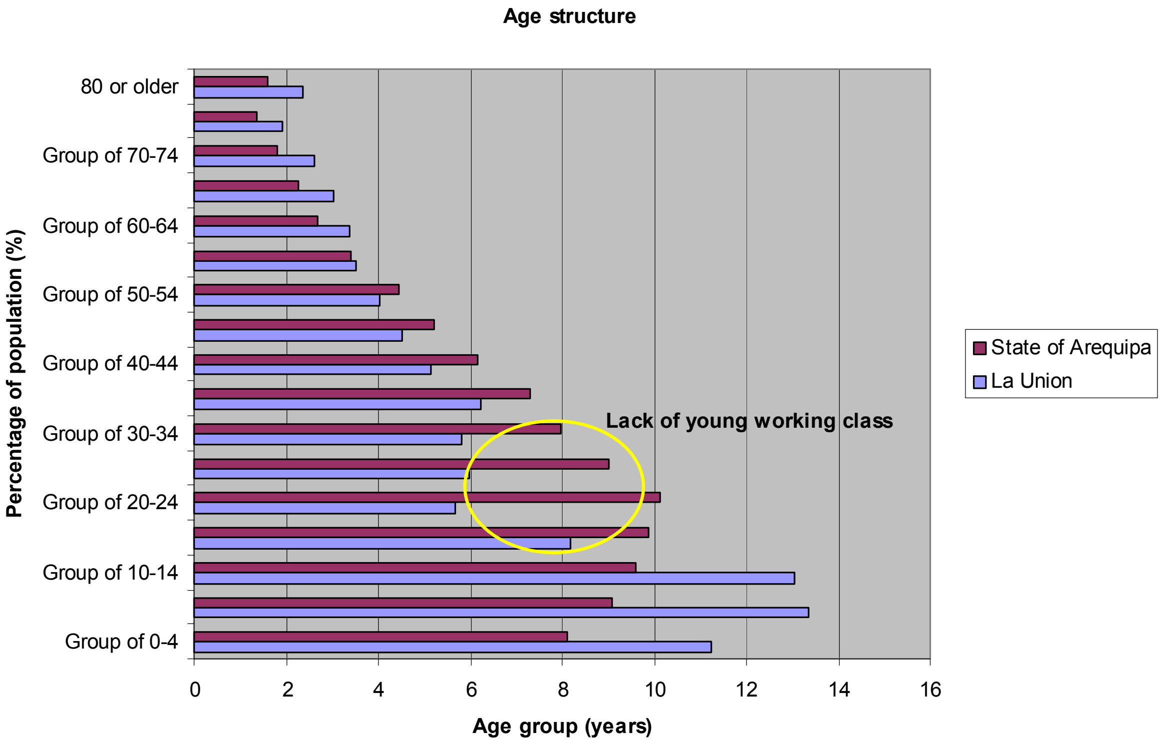
Indicator of development: Percentage of houses with thatch roofs per district in La Union

DISTRICT	1981	1993	2005
COTAHUASI	39	25	6
ALCA	89	78	46
CHARCANA	78	80	46
HUAYNACOTAS	73	66	40
PAMPAMARCA	79	60	35
PUYCA	92	80	53
QUECHUALLA	95	81	65
SAYLA	51	38	17
TOMEPAMPA	66	57	30
TORO	48	41	17
TAURIA	34	44	28
STATE OF AREQUIPA	21	16	9

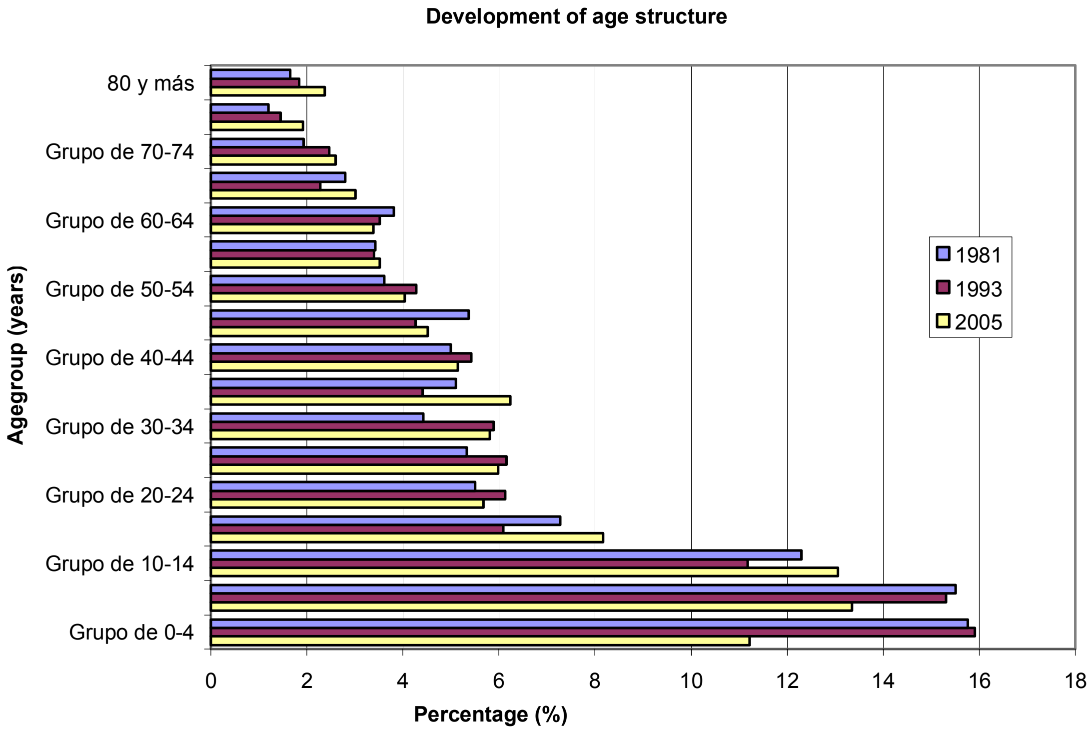
Annex VII-c Development indicator: Percentage of homes connected to the electricity network



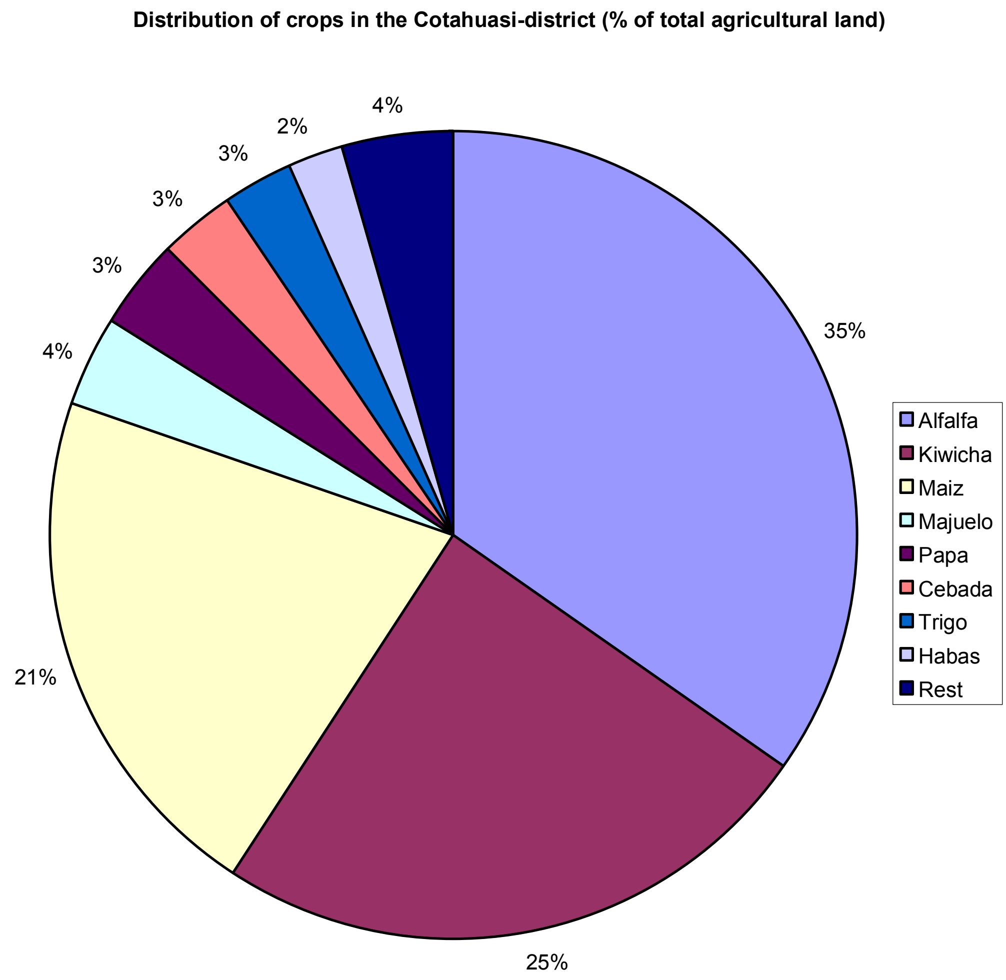
Annex VIII Age structure of La Union and the state of Arequipa



Annex IX Development of age structure



Annex X Distribution of crops



Annex XI Overview of irrigation commissions and committees in La Union

District	Irrigation commissions	Irrigation committees
Cotahuasi	Cotahuasi - Piro	Toma corira
		Estanque Occara
		Estanque Cascahuilca
	Quillunza	Chumpullo
		Huayllaccocha
	Chacaylla - Chayme	
	Reyparte - Peccse	
	Cachana	Reyparte - Armancca
	Chaucavilca	Anchapacha
		Ccasiancca
		Estanque Tarayoc
Huaynacotas	Taurisma - Chaclla	Chaclla
		Tulla - Anchasco - Puca - Puca
		Taurisma - Collota
		Teneccacca
	Huaynacotas	Tarhuara - Huacay
	Antabamba	Piramarca
		Pomacocho
	San Jose de Luicho	
	Visbe	
Tomepampa	Tomepampa	Huayhuanca
		Aranjuez - Huayhuanca
	Locrahuanca	
	Achambi	
Alca	Alca	Calle - Nueva
		Cahuana
		Huillac
		Yumasca
		Alca - Ayahuasi
		Ayahuasi
		Lucha
Puyca	Puyca	Suni
		Chincayllapa
		Pettce
		Churca
		Meclla - Ccaclla
		Huactapa
		Maghuancca
Pampamarca	Pampamarca	Santa Rosa
	Ccochapampa	
	Mungui	Acorca - Pomacocho
	Lancaroya	
	Huarhua	Yarqui
Toro	Toro	Pampacocha
	Ancaro	
	Siringay	
	Llallihua	
	Caspi	
	Huachuy	
	Cupe	
Charcana	Charcana	
	Andamarca	
Quechualla	Quechualla	Picha Cayhuini
	Huanuca	
	Velinga	Allancay
		Palcapampa

Annex XII Document for fieldwork

MINISTERIO DE AGRICULTURA
STITUTO NACIONAL DE RECURSOS NATURALI

INTENDENCIA DE RECURSOS HIDRICOS
DIRECCION DE RECURSOS HIDRICOS

INVENTARIO DE FUENTES DE AGUA SUPERFICIAL - FICHA DE CAMPO

FORMATO UNICO
LAGUNAS / PRESAS - MANANTIALES / AGUAS DE RECUPERACION - RIOS / QUEBRADAS

A. DATOS GENERALES

TIPO DE FUENTE			dd mm aaaa
		FECHA DE INVENTARIO	
NOMBRE DE FUENTE			
		CODIGO PFAFSTETTER CUENCA	
CUENCA		(Nivel)	8 7 6 5 4 3 2 1
DISTRITO DE RIEGO		NUMERO DE FUENTE INVENTARIADA	

B. UBICACIÓN POLITICA

ANEXO, CASERIO		PROVINCIA	
DISTRITO		DEPARTAMENTO	

C. UBICACIÓN GEOGRAFICA

ZONIFICACION UTM (HUSO)	
COORDENADA - UTM. NORTE - Y [m]	
COORDENADA - UTM. ESTE - X [m]	
ALTITUD [m.s.n.m.]	

D. ACCESIBILIDAD (Marcar con X)

CAMINO PEATONAL	
CARRETERA SIN AFIRMAR	
CARRETERA AFIRMADA	
NO EXISTE	

E. CARACTERISTICAS DE LAGUNA / PRESA

AREA DE SUPERFICIE LIBRE DE AGUA [m2]				PROFUNDIDAD MEDIA [m]		CAUDAL DE SALIDA	[lt/s]
ALTURA DE PRESA [m]				LONGITUD DE CORONA [m]		TIPO DE AFORO (1)	
ALMACENAMIENTO MAXIMO [Hm3]				ALMACENAMIENTO UTIL [Hm3]		COORDENADA - UTM. NORTE - Y [m]	
PRESA RUSTICA		DE CON-CRETO		PRESA DE MAMPOSTERIA PIEDRA		COORDENADA - UTM. ESTE - X [m]	
PRESA DE TIERRA		SIN PRESA		OTRO [....]		ALTITUD [m.s.n.m.]	

F. CARACTERISTICAS DE MANANTIAL / AGUAS DE RECUPERACION

CAUDAL PERMANENTE		CAUDAL INTERMITENTE				CAUDAL DE SALIDA	[lt/s]
SIN OBRA DE TOMA		TOMA RUSTICA		TOMA DE CONCRETO		TIPO DE AFORO (1)	
SALIDA A CANAL DE CONDUCCION		SALIDA A ALMACENAMIENTO				COORDENADA - UTM. NORTE - Y [m]	
DE FILTRACION		TUBULAR		DE FISURA		COORDENADA - UTM. ESTE - X [m]	
DE LADERA		DE FONDO DE VALLE		DE PISO		ALTITUD [m.s.n.m.]	

G. CARACTERISTICAS DE RIO / QUEBRADA

ANCHO DE CAUCE :	MINIMO [m]		MAXIMO [m]		CAUDAL AFORADO [lt/s]
ALTURA DE CAUCE :	MINIMA [m]		MAXIMA [m]		TIPO DE AFORO (1)
UBICACIÓN GEOGRAFICA DE PUNTO DE AFORO (UTM) :					FRECUENCIA ANUAL DE CAUDAL :
NORTE		ESTE [m]		ALTITUD [m]	CONTINUO ___ ESPORADICO ___

(1) **V** = VOLUMETRICO; **C** = CON CORRENTOMETRO; **F** = CON FLOTADOR; **V** = CON VERTEDERO; **O** = OTRO […………………………………………………………]

H. CALIDAD FISICA DEL AGUA

pH		CONDUCTIVIDAD (mS/cm)		TIPO DE EQUIPO	
SALES TOTALES [ppm]		TEMPERATURA (°C)		MARCA	

I. TIPO Y DERECHOS DE USO

TIPO DE USO (2)		TIPO DE USO (2)		TIPO DE USO (2)	
TIPO DE DERECHO (3)		TIPO DE DERECHO (3)		TIPO DE DERECHO (3)	
VOLUMEN ASIGNADO [M3]		VOLUMEN ASIGNADO [M3]		VOLUMEN ASIGNADO [M3]	
CAUDAL ASIGNADO [lt/s]		CAUDAL ASIGNADO [lt/s]		CAUDAL ASIGNADO [lt/s]	
Nº RESOL. ADM.		Nº RESOL. ADM.		Nº RESOL. ADM.	

(2) **S/U** = SIN USO; **PO** = POBLACIONAL; **PE** = PECUARIO; **PI** = PISCICOLA; **AG** = AGRICOLA; **ID** = INDUSTRIAL; **EN** = ENERGETICO; **MI** = MINERO

(3) **L** = LICENCIA; **P** = PERMISO; **A** = AUTORIZACION; **R** = POR REGULARIZAR

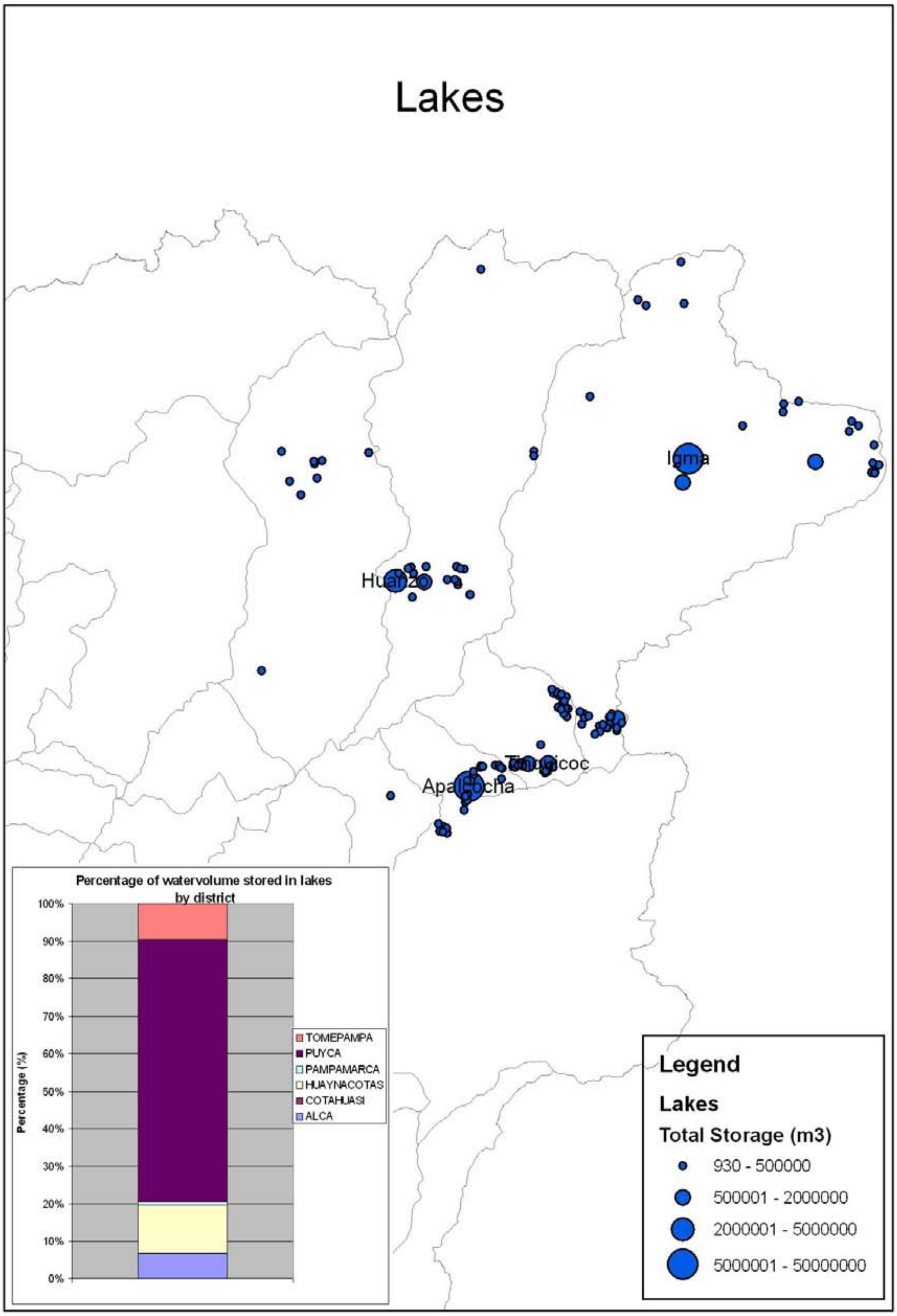
OBSERVACIONES

CROQUIS	FOTOGRAFÍA

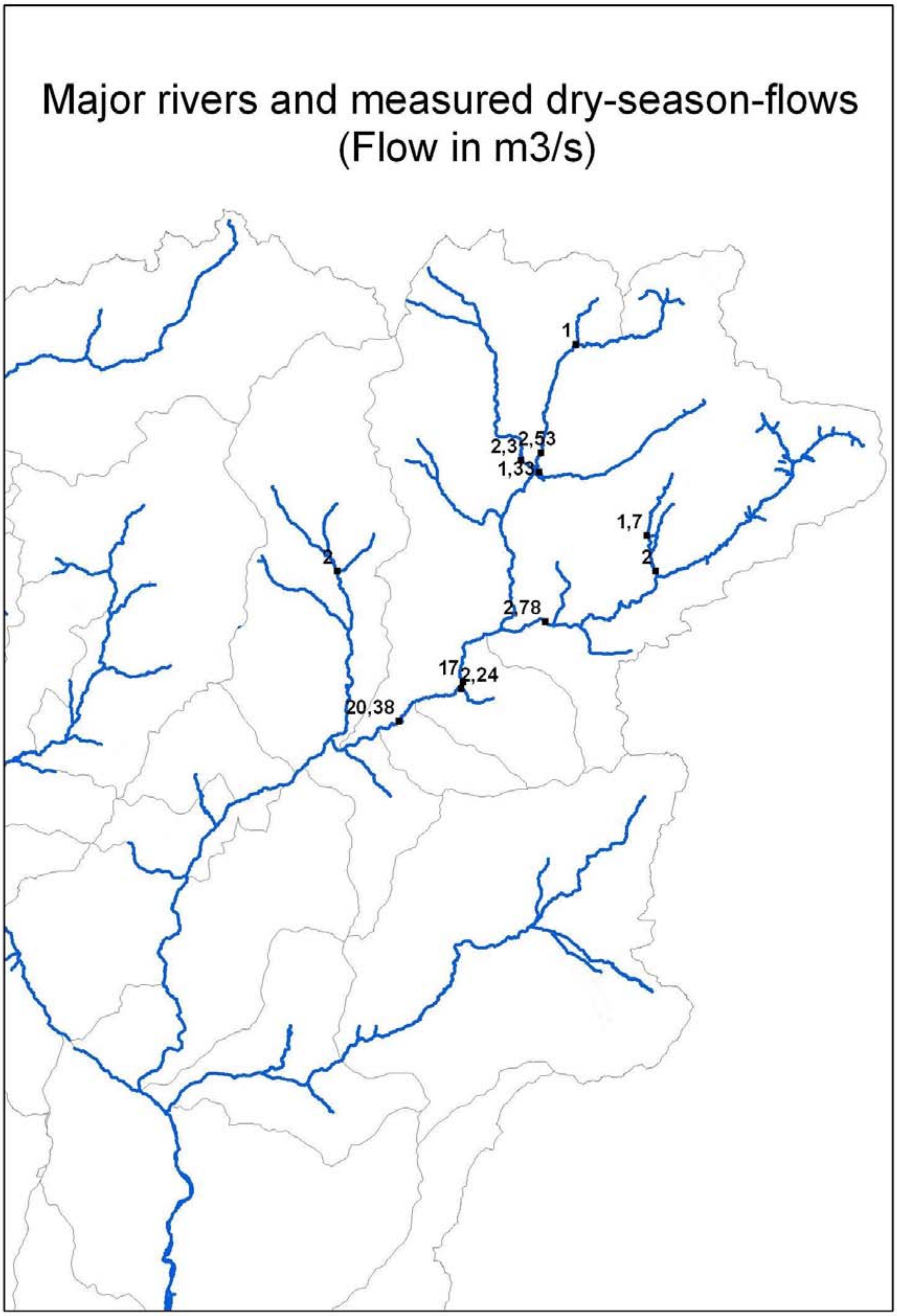
TECNICO RESPONSABLE (Nombres, Apellidos, F ……………………………………………………………………………………………

ING. RESPONSABLE (Nombres, Apellidos, Firma ……………………………………………………………………………………………

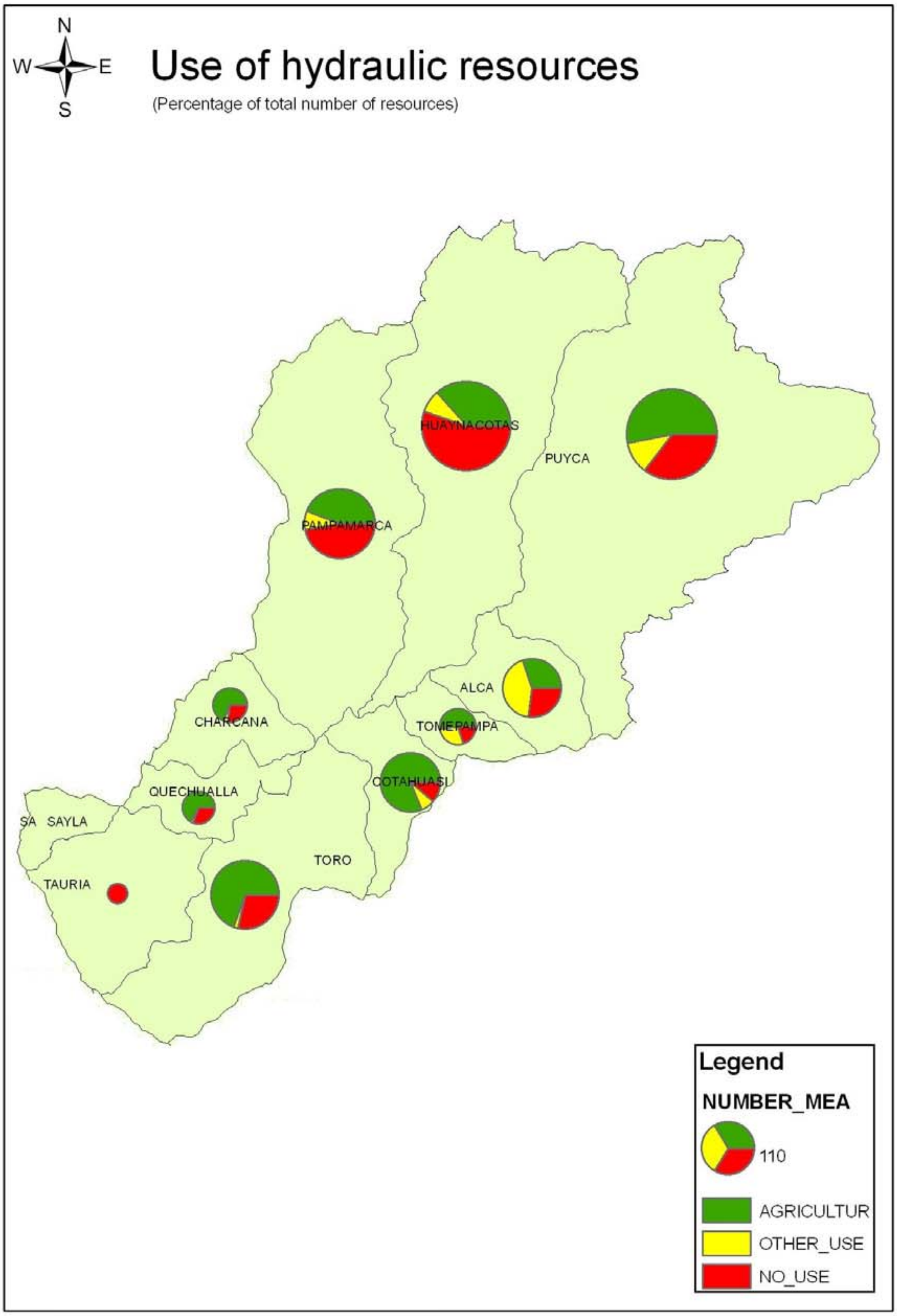
Annex XIII Lakes



Annex XIV Rivers



Annex XV The use of the hydrologic resources



Annex XVI The access to the hydrologic resources