VULNERABILITY AND ADAPTATION TO CLIMATE CHANGE IN THE PERUVIAN CENTRAL ANDES

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ABSTRACT

The present research attempted to establish the relationship between the climate variability of a river basin located in Peruvian Central Andes (Mantaro river basin), and a subset of the main socioeconomic activities in this river basin: agriculture, generation of hydroelectric energy and health sectors, from the perspective of integrated basin management, and with a broad participation of the community.

Future climate scenarios were generated for the region and the population future vulnerability was analyzed, which allowed to formulate general adaptation measures to reduce this vulnerability, which will hopefully be incorporated into the local and regional development planning.

INTRODUCTION

The Geophysical Institute of Peru, in coordination with the National Council of Environment, CONAM, through the Program of National Capacities Building for Impact of Climate Change and Air Pollution Management, PROCLIM, developed the pilot study "Integrated Local Assessment of the Mantaro River Basin", as part of the activities related to the study of vulnerability and adaptation to climate change.

The main objective of the study was to systematize and to extend the knowledge about climate change in the Mantaro river basin, and to evaluate the climatic, physical and social aspects of its vulnerability, as well as to identify viable adaptation options for the agriculture, hydroelectric energy and health sectors, to be incorporated into local and regional development planning.

The Mantaro river basin is located in the central Andes of Peru, and includes territories of Junín, Pasco, Huancavelica and Ayacucho regions (Figure 1). The Mantaro river is one of the most important rivers of the region, its volume depends on the precipitations throughout the basin, on the level of Lake Junín, and the lakes located below the glaciers in the western and eastern mountain ranges. In the Peruvian Andes, the Mantaro river basin has the best hydrometeorological records, including one of the meteorological longest historical series of Peru (Huayao, since 1921).

The Mantaro river basin is very important, because its hydroelectric plants produce nearly 35% of the electrical energy of the country, the agricultural production of its valley is the main source of food for Lima, and its population surpasses 700,000 inhabitants. Therefore, it is important to assess the impacts of climate change and propose adaptation measures.

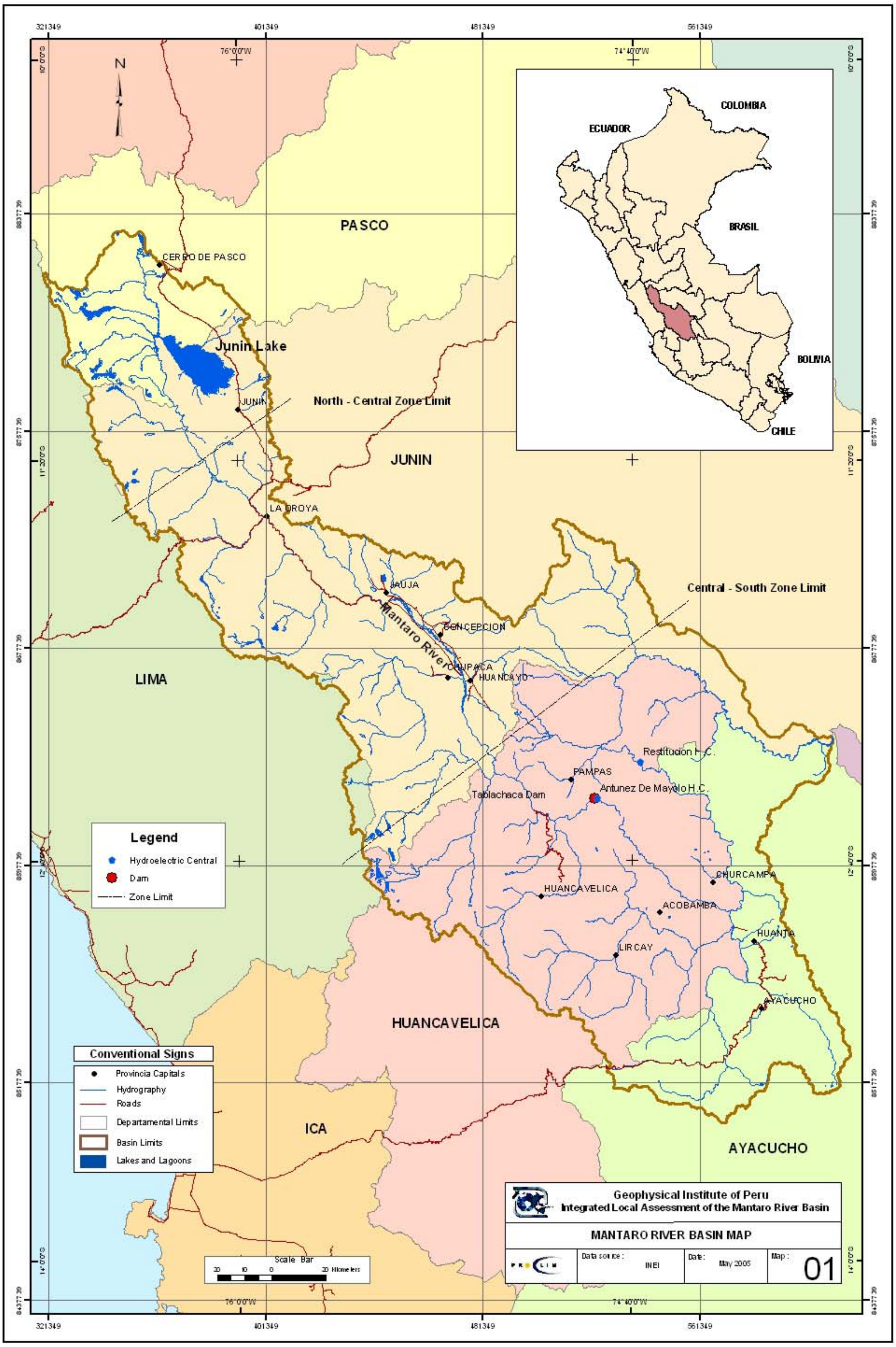

Figure 01: Administrative and political map of the Mantaro river basin

METHODOLOGY

This research was done within the framework of an integrated local evaluation of the river basin, which is an interdisciplinary process that combines, interprets and communicates knowledge of diverse scientific disciplines so that the chain of cause-effect of a problem can be evaluated with a synoptic perspective (Rotmans and Dowlatabadi, 1998). Thus, in the development of the study in the Mantaro river basin, two parallel interdisciplinary working groups were formed.

The first group (Group A) made the analysis of the climatic characteristics of the river basin, mainly referred to rainy and dry periods, their relation with the El Niño phenomenon, teleconnection[1] mechanisms and the relation between the physical processes on the meso and local scales with the monthly, seasonal and/or interannual variability of the main meteorological variables (rain and air temperature). The results were used to identify the meteorological phenomena that have historically affected the population of the river basin. The climate change analysis was based on the analysis of the observed trends in precipitation and air temperature, as well as the frequency and intensity of freezes. The fundamental part was the development of future climate scenarios, information that later was used for the analysis of the future vulnerability of the population.

The second group (Group B), analyzed the present and future vulnerability in the river basin, considering three socioeconomic sectors that were prioritized in this study, and using the information generated by Group A. In a series of workshops, the high-priority sectors were selected, and after the analysis of present and future vulnerability, the adaptation measures to climate change for each one of these sectors were elaborated. The sectors prioritized were: agriculture-forest-cattle, generation of hydroelectric energy and health, and were chosen by their sensitivity to changes in the climate. Due to the absence of data and information in the agriculture-forest-cattle sector, it was replaced by the agricultural sector.

The research was of an interdisciplinary and interinstitutional nature, and its fundamental tool consisted in participative workshops with the collaborating institutions and the local population, which made numerous and useful contributions not only to the recollection of information, but to the analysis, data modeling and application of results. An important goal of the study was to incorporate the climate change as a high-priority subject in the regional agenda, at institutional and grassroots organization levels, and the population in general. Thus, the population of the river basin had to be not only subject of study, but an acting part in the development of the research.

The first step for the development of the study, was the design and development of a diagnosis that served as baseline for the study of the river basin, and provided the “big picture” of the reality of the basin, not only from a socioeconomical perspective, but also cultural and biophysical. Furthermore, it provided with information on the ancestral and current knowledge of the environmental reality, as the population perceives it.

The diagnosis allowed to incorporate the main natural hazards identified in the river basin - droughts, freezes and superficial geological phenomena- into the elaboration of the adaptation proposals, considering water resources as the transversal factor of the study. Also, it was vital to take into account that the capacity of the human systems to adapt and to face the probable consequences of climate change depends on factors not necessarily dependant of climate, like technology, education, information, creativity, innovation, access to financial resources and institutional capacities.

[1] Teleconnection: (i) A linkage between weather changes occurring in widely separated regions of the globe. (ii) A significant positive or negative correlation in the fluctuations of a field at widely separated points. Most commonly applied to variability on monthly and longer timescales, the name refers to the fact that such correlations suggest that information is propagating between the distant points through the atmosphere (As defined by the American Meteorological Society www.ametsoc.org)

The results of this diagnosis became both a source of information and a tool for the validation of the study. With this information, the river basin was divided in three zones of analysis: northern, central and southern zone (Figure 1), based on climatical, physiographical, hydrological, socioeconomic and institutional differences.

The northern zone is the least populated one in the basin. It contains the National Reserve of Junín and most of its territory is occupied by Lake Junin, also called Chinchaycocha, the second largest lake of Peru after Titicaca. Around the reserve, an interesting experience has developed with the cultivation of maca (Mincetur, 2004; Portugal, 2003) for export. Nevertheless, this zone faces serious problems related to contamination from mining, mainly by heavy metals settling in the lake waters,

The central zone – in which the so-called “Mantaro valley" is located – is the most populated one, and includes the main cities of the basin. Most of the agriculture of the basin takes place in this zone - mainly oriented to supply the coastal cities with products like potato, artichoke, carrot, barley, etc. I, it is the commercial axis of Mantaro, and agglutinates the largest amount of goods and services offered in the river basin.

The southern zone, which has the greatest poverty indices in the basin, has the largest amount of agricultural land, and crops like potato, barley, olluco, oca and tuna are cultivated. The population has little access to services like potable water and electricity, even though this zone is where the main hydroenergetic infrastructure is located.

CURRENT VULNERABILITY IN THE MANTARO RIVER BASIN

The vulnerability of the population is strongly associated with poverty, since poor people have little resources to be able to overcome adversities of different types. Frequently, the poor population is located in ecologically fragile areas, including areas of low agricultural potential and, in many cases, they are "intruders" in urban areas (Ekbom and Bojö, 1999).

This situation is explained by the fact that poor people lack the resources to relocate themselves or to take provisory measures against precarious environmental conditions. In addition, the low level of education and political marginalization - among other factors - reduce the potential for access to infrastructure and social assistance, and thus, their health risk is increased. Comparatively small additional expenses, as the health treatment of a family member, or the replacement of a roof after a storm, can be enough to seriously weaken the economic and social stability of a family, in a vicious circle of debt.

The socioeconomic vulnerability is amplified by factors that we have called critical vulnerability amplifiers in the Mantaro river basin, whose main characteristics are presented in Table 1.

Table 1: Critical vulnerability amplifiers in Mantaro river basin and main characteristics

Critical vulnerability amplifiers	***Characteristics***
Structural crisis of the land	Low rural income Degradation of traditional production systems Rural depopulation Diminution of harvests by presence of agricultural plagues and diseases Lack of water for agricultural use
Increasing and disordered urbanization	Unplanned urban growth Deficient habitational infrastructure / lack of basic services

	High risk by exposure to pluvial drainage problems and floods Houses located in highly vulnerable zones (river beds, etc.)
Displacement, migration and conflicts over use of resources	Environmental risks (contamination) and climate variations contribute to elevate the rates of migration when fundamental resources diminish. Land and water conflicts (domestic, agriculture or energy use). Search of opportunities Authorities indifference

These factors are associated with poverty, which is a decisive factor for the lack of resilience of the population. Additionally, the population of the Mantaro river basin is vulnerable to numerous meteorological and geodynamic phenomena, that constantly act against the security and well-being of the population, and these hazards would possibly be exacerbated by climate change (UNDP, 2005), increasing even more the risks for the population.

In order to estimate the current socioeconomic vulnerability, six factors were taken into account: two of economic character (familiar income and agricultural fragility), three of social character (rate of illiteracy, access to potable water and sewage systems, and suitable housing conditions) and one of human occupation of the territory (population density). Using these, a sensitivity index was constructed, and it was conjugated with the risks of extreme temperatures and precipitations and external geodynamic phenomena, information that was used in the analysis of the present and future vulnerability of the three prioritized sectors of the investigation: agriculture, generation of hydroelectric energy and health.

Current vulnerability in the agricultural sector

Agriculture constitutes the most important economic sector in the Mantaro river basin according to the fraction of the economically active population (EAP) dedicated to it, which is 54,6%. Although commercial and service activities are more important in pecuniary terms, for the purpose of this study the EAP is a more relevant measure, since it assigns a stronger weight to the population.

There are approximately 339.065 hectares of agricultural land, 29% of which are under an irrigation system, and 71% are dependent on precipitation. One of the main characteristics of agriculture in the Mantaro river basin is the existence of the “minifundio” (private ownership of less than 0,5 hectares), and small property (0.5 hectares – 4.9 hectares), both representing the 85.7% of the producers. The southern zone of the Mantaro river basin concentrates the greatest land parcellation (57%), whereas in the central zone this value amounts to 41%.

Agriculture is directly related to food security through production and generation of financial resources to acquire food. Climatic variations have direct and indirect influences in food production, since variations of temperature, irregularity of precipitation and the occurrence of extreme climatic events like freezes and droughts increase the pressure on the agrarian resources and reduce the quality of the land dedicated to the agricultural production, affecting their yield.

For the analysis of the present vulnerability in this sector, two representative crops were chosen: maca, for the analysis in the northern zone of the river basin; and potato, for the analysis in the central and southern zones.

Records of precipitation accumulated during the agricultural year (September-April), mean temperatures and frequencies of freezes (also between September-April) were used in representation of the climatic variations; and production, harvested surface and yield in representation of the socioeconomic variables. A recurrent problem in the analysis was the short duration of the time series used[c1].

The results indicate that the correlation of the agricultural indices with precipitation is not as strong as expected, whereas the correlation with mean temperature and freezes frequency is larger and negative. The reason for the negative relation with temperature is not obvious and would be associated with a greater incidence of plagues and diseases with warmer temperatures.

In the northern zone, maca has a particular interest, due to its good yield in the zone and its potential for exportation. The correlation analysis between maca and the mean temperature, indicates a significant negative relation. This result would reflect the relation between the temperature and the incidence of plagues and diseases, as mentioned previously. Also it could be due to the preference of this crop for temperatures, reason why warmer temperatures could reduce the yield of the crop.

For potato, in the Central and South zones of the river basin, we have found that reduced production, cultivated surface and yield are expected, when the temperatures are warmer - due to the greater incidence of plagues -, when the frequency of freezes is greater - since the freezes can kill the crops -, and when the precipitations are smaller - since it is more difficult to fulfill the hydro plant requirement.

The correlation coefficients associated with precipitation are smaller than expected, probably because the Mantaro is a controlled river basin, with numerous dams. Part of the water required by the crops is provided by irrigation, so the impact of the precipitation variability on the irrigated land water provision is probably smaller thanks to the handling of the dams. The correlation with the yield is zero, which suggests the variations impact of the rain on the total production occurs through the control on the harvested surface[c2].

Current vulnerability in the hydroelectric power sector

Although the Mantaro river basin produces nearly 35% of the electrical energy of the country, the electrical energy coverage in the homes in the basin is very low, for example, the southern zone produces 96% of the hydroelectric energy generated in the river basin, and only 17.7% of the homes count with this service.

The Mantaro Hydroenergetic Complex is the most important center of hydroelectric generation of the country, located in the province of Tayacaja, department of Huancavelica, and belongs to the ElectroPeru company. It is conformed by the Tablachaca hydroelectric dam, and central power stations Santiago Antúnez de Mayolo and Restitución (Figure 1).

The energy generated in both central power stations is transmitted towards the Campo Armiño Substation from where transmission lines transfer the energy to transformation and distribution centers of all the country, including Lima (the capital city), mining centers and main industrial companies. For that reason, any factor that affects the energy generation, affects not only the Mantaro river basin, but also a great part of cities, mining centers and main industrial companies of the country.

The data of hydroelectric energy generated in the hydroelectric power stations of Mantaro and Restitución have been correlated with precipitation data in the stations of Upamayo, Huayao and Mejorada, located in the North, Central and South part of the Mantaro river basin, respectively. Also the correlations between the useful volume of the Junín lake and natural volumes in the La Mejorada station, were calculated[c3].

The values of the correlation between the precipitation and the generation of energy are small and have negative signs. Nevertheless, if the trends in the series are removed[c4], the correlations improve considerably (Table 02), mainly in the Mantaro hydroelectric power station.

Table 2: Correlation coefficients between precipitation (mm/year) and the hydroelectric energy generation (GWh/year) in the Mantaro. Period of data: 1995-2003. Data source: ElectroPeru, IGP. Analysis: IGP

	With trend		**Without trend**	
	Mantaro Hydroelectrical Central	Restitución Hydroelectrical Central	Mantaro Hydroelectrical Central	Restitución Hydroelectrical Central
Upamayo precipitation	-0,22	0,09	0,14	0,28
Huayao precipitation	-0,10	-0,19	0,21	-0,03
Mejorada precipitation	-0,04	-0,15	0,16	-0,01[c5]

Significant positive correlation exists between the useful volume of the Junín lake and the energy generated in the Mantaro and Restitución hydroelectric central. Similarly, good correlations are observed between the energy produced in the Mantaro and the volume of the Mantaro river in La Mejorada station.

These results indicate that there is a dependency between the amount of energy that is generated in the Mantaro river basin and the amount of accumulated water in the Junín lake, as well as the volume of the Mantaro river measured in La Mejorada station.

Current vulnerability in the health sector

The occurrence of extreme climate events in the basin often becomes a leading factor of changes in the health of the population. In the Mantaro river basin, these changes are indirectly related to variations in the precipitation and air temperature, which affect the main economic activities, agriculture and cattle, thus placing the population in a situation of high vulnerability. This situation is aggravated by the lack of basic services, as potable water and sewage.

In the case of gastrointestinal diseases, their occurrence is independent of the air temperature and precipitation levels, since the correlation factor is negligible for both parameters. Nevertheless, the main cause of its presence in the basin would be the restricted access to potable water and sewage services, indirectly related to the probable effects of climate change. On the other hand, it is possible that, with warmer air temperature due to climate change, the number of bacteriological agents that develop due to the interaction between the contamination in foods and waters and the air temperature could be increased.

For infectious diseases such as malaria - transmitted through the bites of infected mosquitoes - numerous studies made in tropical countries indicate (McGranahan et al., 1999) that the seasonal changes in the climate of a region, rather than high annual temperatures or rain, play the main role in the appearance of epidemics. Thus, for a breakout of a malaria epidemic, an increase of air temperatures throughout the year is not a necessary condition, but an increase of air temperature and higher precipitation in the season in which the mosquitoes transmitting the disease reproduce. In the Mantaro river basin, the reported cases of malaria are imported from the tropical forest zone of Oxapampa and Satipo mainly, by reasons for work and/or tourism, and most of the registered cases appeared during June and July, where the factors of raised air temperatures due to the strong insolation and lack of cloudiness in this period, and the presence of precipitation in the tropical forest, are factors that promote the reproduction of the mosquito.

The group of diseases related with respiratory infections, appears with much greater incidence during the dry season, between May and August, when the minimum air temperatures are lowest. Thus, these diseases are inversely correlated with the minimum air temperatures, so an increase in the minimum air temperatures would produce a decrease of the morbidity and mortality related to these diseases. On the contrary, an increase in the occurrence of freezes or low air temperatures in the river basin would elevate the number of cases.

During the last years increasing concern to analyze the level of ultraviolet radiation of the Mantaro river basin has arisen among numerous groups of investigators (Suárez 2000, Suárez and Contreras, 2003). These researchers concluded that the ultraviolet radiation in the basin is very high due to reduced concentrations in the ozone layer, the small zenith angles in the region, the cloudless sky during the months from May to September, as well as its location above 3,000 masl. Although the data are still limited, it is known that the cases of skin cancer, cataracts (clouding of the crystalline lens) and pterignon (conjunctive hypertrophy characterized by a vascular weave appearance) have increased considerably in the basin.

FUTURE VULNERABILITY IN THE MANTARO RIVER BASIN

The future climate scenarios estimated for the river basin for the year 2050, using statistical downscaling, indicate an increase of 1.3°C and 1 g/kg in air temperature and specific humidity, respectively, and a decrease of 6% in relative humidity in the Mantaro river basin during the rainy months, of December to February. Also, the precipitation would diminish by 10%, 19% and 14% in the northern, central and southern zones of the basin, respectively. These results are consistent with the trends estimated from historical climate information for the period 1950-2002. These results were crossed with the socioeconomic information projected to 2050 (Instituto Geofísico del Perú, 2005c), in order to estimate the future vulnerability in the prioritized sectors.

The main hazard to the population in the basin, is related to the lack of water, which would affect the existing ecosystems in the basin, and also the increase of air temperature by more than 1 °C, which, due to the glacier melting, could cause increased landslides, mainly at the feet of the glaciated mountains, erosion, and surface run-off. The conjunction of these elements could alter the fragile ecosystem of the basin, harming the numerous species that live there.

The impact on the population, however, will be dominated by urban expansion and the increasing demand of water and land resources. Thus, it is the socioeconomic aspects that would determine the future vulnerability in the basin.

For the analysis of the future socioeconomic vulnerability, the future projections in the six variables analyzed in the current socioeconomic vulnerability were considered: familiar income, agricultural fragility, rate of illiteracy, access to potable water and sewage, suitable housing conditions and population density.

The changes in these six variables between the current and the future will be a measure of the change in socioeconomic vulnerability. The analysis indicates an increase in the socioeconomic vulnerability, mainly tied to the increase in the population density, which will entail to an increase in the demand of basic services, like potable water availability, which is already scarce and that, with climatic change, will probably diminish. In addition, the reduction in precipitation would imply less water for agriculture, which, added to the increasing land division, would make the sector more vulnerable.

The analysis of the future vulnerability was also made in separately for each prioritized sector, considering the future climate scenarios.

Future vulnerability in the agricultural sector

Projections indicate that agriculture would pass to a second level of economic importance after the activity of commerce and services, in terms of the economically active population participation, which would only be 31,5%. Nevertheless the agrarian structures, the main crops and cattle, will be maintained (IGP, 2005c).

According to the results of the current vulnerability, the interannual variability in precipitation has a marginal effect on the crops, except when strong droughts occur, like the one that occurred during 1991 and 1992. An average decrease in precipitations between 10 to 20%, like that projected for the year 2050, would have the effect of a prolonged drought that could not be lessened by the management of dams and reservoirs, since evidently these cannot provide water indefinitely. Therefore, the effects will be felt by both irrigation agriculture and by rain depending systems.

The air temperature variations, irregularity in precipitations, and climate extreme phenomena, will increase the pressure on the agrarian resources and will reduce to the quality of the zones dedicated to the agricultural production and its yield. The agriculture land dependent of rain would be especially harmed. However, lands under irrigation would also be affected, mainly by the social conflicts between the users of potable water, water for irrigation and water for the generation of hydroelectric energy, which would alter the already fragile social panorama of the river basin.

The raise of air temperatures could allow the cultivation of some products at higher altitudes, although always with the limitation of a smaller water availability. On the other hand, the maca cultivation, which requires low air temperatures, could be seen seriously affected by the disappearance of areas with this range of temperatures.

An indirect effect of the rise of air temperature could be an increase in the incidence of plagues and diseases in the crops. If we assume that the observed positive trend in the freeze frequency will persist, the vulnerability of the crops would increase even more.

Future vulnerability in the hydroelectric power sector

As we mentioned, although the Mantaro river basin generates a large fraction of the electricity energy of the country, the coverage of the energy service for homes in the river basin is insufficient. The future estimates indicate that the situation will improve for the year 2050. Nevertheless, the deficit will still be considerable, as it is shown in Table 03, which makes a comparison between the present and future deficit.

Table 3: Current and future deficit of electrical energy service in Mantaro river basin homes. Source Ministerio de Energía y Minas, 1998, INEI, 1994a,1994b, 1994c, 1994d. Analysis: IGP.

Zones	***Current deficit in energy service in Mantaro family units 2005 in %***	***Future deficit in energy service in Mantaro family units 2050 in %***
North	50,9	27,6
Central	37,2	21,5
South	82,3	67,0
Mean	56.8	38.7

The rain estimations for the year 2050 indicate that the rain deficit in the northern zone of the river basin would be 10%. Due to the dependency of the amount of energy that is generated in the Mantaro river basin on the amount of accumulated water in the Junín lake, we can assert that in a next future the amount of hydroelectric energy generated in the river basin will be negatively affected.

The national population projections indicate that the population would have an increase of 50% for the year 2050, thus implying that the necessities of electrical energy would be increased, at least in the same proportion. This situation, combined with the precipitation deficit, and therefore, of energy in the river basin is serious.

Future vulnerability in the health sector

The potable water deficit in the homes and the unacceptable hygienic conditions will continue being the main causes of diseases, that will put in risk the well-being of the population, with women being those more exposed to water related diseases, due to their traditional tasks of washing, agricultural irrigation and water recollection.

The lack of public sewage networks in the Mantaro river basin will continue being still greater than the potable water deficit. According to projections, in the southern zone of the basin, more than 50% of the homes will continue without potable water, and 60% not connected to sewage systems, negligible less than in the present. The increase of air temperatures would favor the appearance of infectious focus[c6] by exposing excretes and dirt water. The more prolonged drought periods would affect the potable water availability for the population.

On the other hand, the river basin receives high levels of UV radiation through the year, and it is reasonable to expect a greater amount of days with cloudless skies in drier conditions, which will produce greater intensity of radiation in some years, with negative effects on the population, mainly in skin and eyes.

ADAPTATION MEASURES IN THE MANTARIO RIVER BASIN[c7]

The formulation of the adaptation measures for the Mantaro river basin took place in numerous workshops and working meetings with the participation of the main actors of the basin – representatives of the regional governments, public and private institutions, NGOs, etc. - and water (use, distribution and management) was identified as the cross-sectional factor that connects the three prioritized sectors. For that reason, its integral management with the support of all the involved actors is vital in the adoption of adaptation measures proposals presented.

The human systems capacity to adapt and to face the probable consequences of the climate change, depends on factors not necessarily related to climate, like technology, education, information, creativity, innovation, access to resources and institutional capacities. Actions such as the territorial ordering of the basin and the redistribution of the increasing population, are part of the baseline of necessary management that must be taken into account to appropriately incorporate adaptation measures into the local and regional development plans, which must go accompanied by institutional strengthening and the support and action of the involved actors in the basin.

For the elaboration of the proposals of the adaptation measures, in addition to the future climate scenarios and the socioeconomic projections, the risk factors identified in the river basin -

droughts, freezes and superficial geology phenomena - were considered. For each prioritized sector, structural and non-structural measures were proposed.

The structural measures are referred to the physical intervention by the development or reinforcement of engineering works, which seek to minimize material damages. The non-structural measures correspond to actions based on an efficient use of resources, related to educative actions, or of legislative application of management and organization, that are complemented with the structural measures, and that promote the organization, the institutional fortification and the public information of the actors involved.

The amplitude of the river basin, and the coexistence of very diverse economic and social systems was an obstacle for a more detailed development of the adaptation measures, which were oriented towards the three prioritized sectors identified at the beginning of the study: the agricultural sector, generation of hydroelectric energy and health.

The agricultural sector involves the largest number of economically active population in the Mantaro river basin, and its reality is broad and complex. Thus, the structural and non-structural measures are numerous and general[c8], and, nevertheless vital for the development of the basin. The stakeholders that should be involved in the implementation of these measures are not limited to the Ministry of Agriculture, and local and regional governments, but include pedagogical institutions, universities, farming institutes, professional unions and schools, farmers communities farmers, etc.

The structural adaptation measures are mainly referred to improving the capacity of water storage, and the construction and improvement of irrigation systems. Associated to these, are forestry oriented measures, such as the implementation and development of forestation and reforestation programs, and, on the other hand, the reinforcement, extension and modernization of the hydrometeorological observation systems, for the generation of baseline information for the study and forecast of adverse meteorological phenomena.

The non-structural measures reflect in many cases negative socioeconomic and cultural aspects of the Mantaro river basin that must be reverted: regulation of migratory agriculture and the implementation of a law of land inheritances; the rescue of own and suitable technologies for the zone: update of the Andean technology in diversification, crop rotation and land rest periods, promotion of the agroforestation, etc.; the use of advanced technologies: use of registered seeds; normativity and fulfillment of existing laws, like those referred to dangerous pesticides; education and sensibilization in the uses of water, management of natural pastures, integrated plague management, etc.

Other non-structural adaptation measures were those referring to the implementation of a monitoring and forecast system: for freezes and droughts; the development of research studies related to plagues and diseases; and finally, the related to institutional aspects: improvement of the interinstitutional management between institutions related to land and water use, agrarian research and extension, local capacity building for risk management, and the exchange of basic information between the institutions.

The hydroelectric energy generation is affected by the lack of rain. Therefore, with a decrease in rain, the cost of its generation increases, with the consequent increase of the cost to the consumers. This situation would affect not only the basin, but a great part of the country, including important cities and industrial companies supplied by the Mantaro hydroenergetic system. The main actors in the implementation of these adaptation measures are: the Ministry of Energy and Mines, hydroelectric energy generating companies like ElectroPeru and ElectroAndes, the regional and local governments, the education sector, and the main users of the generated energy.

The structural adaptation measures are mainly referring to the use of alternative systems of energy generation: use of bioenergy in rural zones, use of solar panels, implementation of three-phase power supply for industry, etc; they also refer to the improvement of the electric network in the river basin, especially in the southern zone. And finally, to the reinforcement, extension and modernization of the hydrometeorological observation systems for the generation of basic information for the study and forecast of adverse meteorological phenomena.

The main non-structural adaptation measures, are those referred to enhance capacities: permanent population capacity building in the good use of the electrical energy; in the research sector: the development of research programs for the generation of electrical energy using alternative power sources; and, similar to the agricultural sector, the implementation of monitoring systems and forecast for droughts.

The adaptation measures related to institutional issues, are also very similar to those developed for the agricultural sector: the improvement of the interinstitutional management between institutions related to the generation of hydroelectric energy, and the exchange of basic information bases between institutions.

The adaptation proposals for the health sector are directly related to the subject of sanitation (water and sewage networks). Thus, the subject of the quality of potable water, its correct use and suitable planning and management, are subjects that cannot be separated from a suitable management of the health sector in the basin. The main actors in the implementation of these measures are the Ministry of Health with their attention centers: hospitals, basic health units, the regional and local governments, etc., Ministry of Education, etc

The structural measures of adaptation for the health sector are mainly aimed to improve the infrastructure of public health, and the services of health, with emphasis in gastrointestinal and respiratory diseases. Complementarily, the direct participation of the health sector in the urban design and the implementation and installation of UV radiation measurement equipment in the different zones of the river basin. Also, those related to the care of the skin and other zones of the body to the UV rays exposure, like the increase of shaded areas in schools, swimming pools and recreation zones for children, etc.

The non-structural adaptation measures are mainly directed towards the prevention, with the implementation of services such as early cancer detection (mainly of skin), early detection of ocular diseases (cataracts and pterinon). Also the measures related to capacity building programs oriented to the medical personnel, mainly in the evaluation of diseases related to the indirect effects of the climate change; health population capacitating, specially with respect to the best care of children; UV exposure risks, among others.

Finally, and like in both previous sectors, the articulation of the health sector between institutions, such as hospitals, municipalities and schools, mainly in the planning of integral campaigns of health for the population is considered very important.

GLOSARY

Maca *(Lepidium meyenii walp.)* .- The only brasicaceas domesticated in the Andes. It is adapted to very cold ecological conditions, characterized by average temperatures between 4 and 7° C, high solar irradiation, frequent freezes, strong winds and acid grounds. It has high nutritional and medicinal value, and is consumed in flour form and prepared in soups, desserts, breads, cakes, etc.

Oca *(Oxalis tuberosa Moll)*.- Andean tuber. In fresh it is consumed cooked, generally previously exposed to sun, and dehydrates like "ccaya" or "uma ccaya". Also candies and jams are made. Its stem constitutes excellent forage for cattle.

Olluco *(Ullucus tuberosus Caldas)*.- Andean tuber. It is the most spread specie, after the potato, between the consumers of the coast of Peru. It is consumed in two forms: fresh and dehydrated

Tuna *(Opuntia Ficus)*.- Cactaceous, in Peru their fruits are destined to the human consumption in fresh form, and for the elaboration of regional products (sweeties, boiled must). Pencas are used like forage, being a very valuable resource at times of drought and low forage availability for the cattle.

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