TWINLATIN

Twinning European and Latin American River Basins for Research Enabling Sustainable Water Resources Management

Final Report

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Some of the National agencies or public organisations active involved in the research activities have been: DGA, CIEP and CONAMA from Chile; ANA and Cuareim River Commission from Brazil; MVOTMA and MGAP from Uruguay; INETER from Nicaragua; CRC and Universidad del Valle from Colombia.

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Executive summary

The strategic objective of TWINLATIN was to fill gaps in knowledge and methods in order to enable implementation of a harmonised IWRM approach in Latin American river basins, addressing the European Water Initiative and using the European Water Framework Directive as a guiding reference approach. In this context an important focus was to enable and perform assessment of climate change effects on the hydrological regime, water availability and water quality of the seven river basins. The project also addresses the objectives of the EU Water Initiative; improvement of water quality and availability for poor communities as a means to reduce poverty, enabling water authorities to propose actions that have been thoroughly analysed from all perspectives; surface water availability, surface water quality, groundwater availability and quality, sustainability criteria, as well as domestic, agricultural, industrial and hydropower stakeholder interests.

The pilot river basins in TWINLATIN were: The Baker river (Chile), the Catamayo-Chira river (Peru-Ecuador), the Cauca river (Colombia), Lago de Nicaragua (also called the Cocibolca lake, Nicaragua), the Quarai/Cuareim river (Uruguay-Brazil), the Thames river (UK) and the Norrström river (Sweden). The research and development work focussed on the Latin American rivers, but RTD was also carried out for Norrström. The Thames River was used as a reference case.

Decision making tools are needed in the Latin American countries and transfer of such tools have been a major objective of the project. Such tools are major components necessary for a successful analysis of climate change and human development scenarios, effects of measures and development of preliminary river basin management plans.

TWINLATIN focused on solving problems and priorities identified at local and regional level and on creation of networks for implementation of results. In this sense public participation and stakeholder involvement were key elements, assuring that the RTD activities focussed on local priorities. At the same time, the partners have been striving to create communication structures that can and will be utilised after the termination of the project.

The work within TWINLATIN was initiated in September 2005 and was finalised during the spring 2009. Work has been conducted within ten work packages, each resulting in a final work package report as well as other deliverables:

- WP1 Current Status and Stakeholder Structures
- WP2 Monitoring and database construction
- WP3 Hydrological regimes and Extremes
- WP4 Public participation
- WP5 Sustainable Management Strategies
- WP6 Pollution pressure and impact analysis
- WP7 Classification of water bodies
- WP8 Change effects and assessment of vulnerability
- WP9 Optimal Actions and their Socio-Economic Impact
- WP10 Twinning activities

All reports have been made available to the public on the project's web site (www.twinlatin.org).

The river basins in TWINLATIN are all medium-sized, ranging from 13.000 km^2 (the Thames basin), to 26.700 km^2 (the Baker basin). With the exception of the Cauca river the Latin American basins are transboundary. Transboundary issues were prioritised in the Catamayo-Chira and the Cuareim/Quarai basins, although also the Cocibolca and Baker basins are transboundary. The climatological characteristics vary considerably between the basins. Three of them are temperate (Baker, Norrström and Thames), while the Cauca, Cocibolca, and Cuareim/Quarai basin are tropical/subtropical. The lower parts of the Catamayo-Chira basin is semi-arid. In terms of population the basins differ widely, from densely populated basins such as Thames and Cauca, basins with medium sized populations (from 600 000 to 1,5 million inhabitants) as Catamayo-Chira, Cocibolca and Norrström, and small populations as in Cuareim/Quarai (60 000) and very low in the Baker basin . The Norrström, Cauca and Catamayo-Chira are heavily modified by hydropower infrastructure. The Baker basin plans of building five hydroelectric power stations over the next fifteen years have created heated discussions in the country. Domestic water supply and associated water quality issues are important issues in the Thames and Cauca basins and increasingly so also in the Cocibolca basin with future plans for provision of drinking water to Managua city. Eutrophication is main environmental problem in the Norrström basin. Industrial, domestic and agricultural pollution are problem areas in four of the Latin American basins. The exception is the Baker basin which is still pristine. Erosion and sediment release is a major pressure factor in the Latin American basins, targeted within the project in the Cocibolca, Cauca, Cuareim/Quarai and Catamayo-Chira basins.

The extent and availability of existing data and monitoring infrastructure varied between the pilot basins. The report of WP 1 covers compilation of history, current knowledge, the status of the river basins regarding hydrology, water quality, water availability, used demands, political structures, policies, and stakeholder structures. This information was the basis for the execution of all work packages.

Early in the project it was agreed that IVL should look into the possibility of assisting twinning organisations in Latin America with the development of a common database structure based on ArcGIS/ArcHydro. During the first and second year, a number of information exchange and twinning events resulted in implementation of harmonised geo-database structure in the LA basins for the geographic/thematic information of the different case study basins.

The partners of the transboundary river basins in TWINLATIN, who include the managing authorities, have developed far-reaching strategies for assuring continued sustainable use of data and results after TWINLATIN. The Cuareim-Quarai river basin (Uruguay-Brazil) has been selected as a successful example for Water Resources Management between the two countries and the Local Coordination Committes created years ago are now working in a co-ordinated way and in line with Federal and State policies in Brazil and Uruguay. The Catamayo-Chira basin (Ecuador-Peru) is another successful example of coordination and cooperation between countries.

The project has contributed substantially to filling of monitoring data gaps, thus allowing the partners to work with modelling, actions, climate change analyses, economic assessments, on a level of detail and quality that was not possible prior to the project. The monitoring conducted in TWINLATIN was incorporated in the plans and regular monitoring activities at the responsible national organisations, and have catalysed strengthened and extended monitoring plans for the coming years, after the project. This has been a major achievement of TWINLATIN. No further monitoring was planned in the Thames basin as part of TWINLATIN, while monitoring was carried out in Norrström, as a basis for improved nutrient modelling.

The hydrological modelling activities in Work Package 3 addressed problems and areas in the pilot basins prioritised by stakeholders. All Latin American partners chose to model at least one sub-basin, usually selected by importance and/or data availability. Data availability was the main reason to not model at the entire basin scale. Apart from the Catamayo-Chira case, all partners chose to model at a daily time step. In the end, six different hydrological models were used by Latin American partners under WP3, ranging from a simple water balance to a large-scale distributed model. At Norrsröm, the activities performed were addressing eutrophication of the Baltic Sea and Lake Mälaren (the latter provides drinking water for 1,5 million people). In order to improve the modelling of phosphorus transport in the Norrström basin, flow proportional measurements of P were conducted. Part of the modelling activities in the Norrström basin also focused on microhabitat modelling. The objective of this work was to assess habitat suitability as a biological quality indicator for selected species of fish, useful in ecological status assessment. A continental approach can provide a wider regional context for some of the problems faced, in particular water deficit. It can also provide an opportunity for climate change impacts to be examined and compared at the continental, regional and basin scales. Therefore, the Global Water AVailability Assessment (GWAVA) model was applied to the South American continent, enabling a broader regional picture of hydrology and spatial extents of water scarcity.

The SWAT model was successfully applied to the Lonquimay basin in the Biobío, representing the major intra- and inter-annual variability of flow values in the basin relatively well and thus enabling first assessments of the possible impacts of climate change scenarios in a mixed-regime (rainfall and snow-fed) river basin from central Chile. Outcomes from such assessments can be used to foresee potential impacts under similar climate change scenarios in similar sub-basins of the **Baker**. **Catamayo-Chira**: Application of the SWAT model to four sub-basins of the Catamayo-Chira basin proved successful in three cases, as it did for the overall basin. The results obtained can be considered a useful tool for management and planning activities, by allowing a first assessment of the impacts on water and sediment production due to soil use and climatic changes in the basin. **Cauca**: The HBV/IHMS model was applied to the Tulua sub-basin in the Cauca. For the validation period, HBV/IHMS model performance was relatively poor. One of the model's potential applications as a management tool for hydrology is the generation of a series of short, medium and long-term forecasts for tributaries to Salvajina Dam, as well as flow generation at ungauged sites. **Lake Cocibolca:** Three modelling approaches were adopted in the Lake Cocibolca basin. The simple annual water balance method revealed that water resources are especially scarce in the north-western part of the basin during the dry season. The monthly water balance modelling using WASMOD had relatively low efficiency criteria indicating that there are high uncertainties in the input and/or validation data. Uncertainty estimation was important because the data quality and availability were often low. The daily hydrological modelling using WATSHMAN had problems, because of data limitations and high spatial and temporal variability. The MGB-IPH model was used at **Cuareim-Quarai** basin, which was adapted to include hundreds of small farm reservoirs and rice fields. It was successfully applied and results of the model analysis have already been presented to both stakeholders in the basin, and government institutions. The National Water Agency is using results of the model to support decisions concerning water permits. MODISM, a water allocation model, is recommended for management of the basin water resources. Examination of the SWAT results reveals that the model tends to underestimate the high flows. It is, however, recommended for use as a tool to validate daily data of precipitation and flow, and to model erosion and water quality in a basin with diffuse source pollution. The good hydrological modelling results at **Norrström** have allowed achieving better and satisfying Nutrient modelling. SWAT model was satisfying calibrated and validated using Swedish parameters/conditions. However, more data is needed in areas such as: soil parameters, soil nutrient content. Another key result from the work done at Norrström is that IVL have set up two stations for flow proportional measuring of Nitrogen and Phosphor. Need for improved modelling of the P cycle and better estimates of the internal load of Phosphorus from Lake Mälaren are substantial in the basin to have a better understanding on how the eutrophication process affect the water quality conditions.

Strengthened Public Participation and stakeholder involvement was the main outcome of WP 4 and one of the main achievements of TWINLATIN. In all basins the WP 4 efforts have produced substantial advances in PP and SI structures as well as in the public and stakeholder awareness on water problems and the IWRM process. The participatory process conducted in WP 4 created spaces for dialogue and reflection among stakeholders and groups of interest of the basin, as well as between researchers and government officials. The main lesson taught by the process is that collaborative and coordinated work is the main way to address the complexity of the IWRM. As mentioned the partners of the transboundary basins have carried out the tasks of ambitious dissemination plans in their respective basin. The communication plans prepared during the first year of the project were implemented in all basins with some corrections and/or changes requested by stakeholders. Of special interest are the activities in the Catamayo-Chira and Cuareim/Quarai river basins, where the transboundary dimension add another difficulty to water management. Gender actions were one the objectives at Catamayo-Chira project and a number of gender related meetings, workshops and other technical activities have been carried out in the basin, significantly strenthening the awareness of women regarding water related problems and their capacity and possibility to participate in the management process. A milestone in the TWINLATIN public participation efforts was the organisation of the international workshop " Public participation and gender in water Management". Co-ordinated by UNIGECC and IVL during May 2008 in Piura – Peru.

WP 5 focussed on sustainable management strategies. The current river basin management structures in the five basins differ, due to the diversity and complexity of the institutional and legal frameworks of the different countries. There are also important differences in their history and regional evolution. Different management systems meet in transboundary basins creating yet another level of complexity. Therefore, it is difficult if at all possible to jointly, for all the pilot basins, draw general conclusions relating to needs and recommendations on management strategies. For each country however, this has been done. During the International Workshop on Sustainable Management Strategies held in Montevideo, Uruguay (June 2008) the management strengths and weaknesses of the countries of each basin were identified, and proposals and recommendations for improvements developed. These results provide a general and summarized vision of the current management situation in the basins and help to assimilate, compare, and analyse issues common to all. The conclusions and recommendations were produced by leading scientists and water management officials from the countries participating in TWINLATIN, and will therefore be integrated in future national management strategies, and have with considerable weight in the development of these strategies. The proposed management systems include various components of development or improvement towards an integrated management of the water resources. In the concept of integrated management, the different uses of water are interdependent and have to be considered in an integrated system. In the same way, problems in different areas have to be analysed in a systematic and planned way and the projects that are undertaken have to take into account the hydrological, biological, chemical, physical, and socio-economic consequences.

The countries will advance in the management and shared management of basins if they as far as possible take advantage of the strengths they have and confront their weaknesses. The process is long-term, in which the effort has to be put on modifying the aspects of the water management that are inadequate, preferably in stages, with a reasonable period of time given for each stage. As has been shown in some of the TWINLATIN river basins, an important first step for transboundary rivers is to share collection and use of data, so that a jointly accepted information-base is built.

In WP 6 – Pollution pressure and impact analysis, emission inventories were carried out to collect data on large and medium sized point sources (industrial, municipal waste water treatment plants). Erosion and sediment delivery to water bodies is considered to be the main contributor of nonpoint source pollution in the TWINLATIN basins (with exception for the Baker river). Together with sediments, nutrients and pesticides also reach the river system. From this perspective, spatially and temporally explicit modelling of erosion and sediment delivery is a natural starting point for addressing non-point source pollution. Such modelling has been carried out using the WATEM-SEDEM model in most of the TWINLATIN basins (the Cauca, Cuareim, Catamayo-Chira and Cocibolca basins). Diffuse point sources have also been assessed using the SWAT and/or WATEM-SEDEM models in all Latin-American basins as well as in the Norrström basin. Delivered maps assessing prioritised areas of actions have been produced for all the Latin-American basins and for Norrström. Examples of these prioritised areas are given below.

The main **impact** of diffuse pollution in the Catamayo-Chira basin is the sedimentation of the Poechos reservoir. The contribution of different source areas/micro basins in terms of sediment production and following river export have been identified.

For the Norrström basin the resources were concentrated on the tasks relating to improvement of modelling of nutrient transport to Lake Mälaren, in order to provide highest possible maximum benefit of the work to the end-users. Eutrophication of the Baltic Sea and Lake Mälaren poses a serious environmental problem with increased algae blooms and oxygen depleted bottoms. Nutrient loads had earlier been modelled for many of the tributaries to Mälaren, but not for the areas directly adjacent to the lake, drained by small creeks and ditches, in total an area of more than 3000 km^2. The TWINLATIN project has resulted in calibrated and validated nutrient modelling, by using new flow-proportional measurements. The model results show that the nutrient loads from the area nearby Lake Mälaren measured as averaged areal loads (kg/ha) does not differ in magnitude from the other twelve tributaries.

The effort in the Cuareim/Quarai basin concentrated on the effect of dams on fish communities. It was concluded that the number of species in the Cuareim River Basin has not diminished since 1950 up to 2006. The number of species is similar in the principal channel but also in the creeks. The diversity and equitativity indexes also indicate that the basin is quite homogeneous.

WP 7 – Classification of water bodies: A first categorisation scheme was established in the LA river basins and a first practical classification of the water bodies at the basin scale was carried out.

For the Baker river basin a total of 17 river types considered as representative for the Baker River basin were established, of which - after an estimation in function of a pressure analysis - the conclusion was reached that the majority of the different types have segments under a probable reference condition status. The Baker Basin still presents exceptional conditions (in comparison with many other basins in the world) which allowed for an experimental definition of reference conditions.

For the Cuareim/Quarai basin (the Uruguayan side), the project activities were oriented to advance the knowledge on ecological status of the water bodies in the Cuareim River basin and to contribute with information for definition of a Monitoring Plan. The methodology used was inspired by the EU Water Framework Directive, with the necessary adaptations to the characteristics of the basin. Combining three layers of information for the Uruguayan territory: altitude, contributing area and geology; 17 classes were obtained and therefore the river reaches were grouped by expected similar natural characteristics. For each class one reference station should be established. Some of these classes were small in area so they should be further analysed to justify the need of a reference site. The water quality-quantity monitoring conducted in WP 2 and used as basis in WP 7 was carried out at 4 locations, 3 in the main channel and one on Brazilian territory and thus allows preliminary conclusions as follows:

- The quality of the Cuareim River in general is good.
- Some variables show an increase in the relative concentrations closer to the mouth of the river.

A water body typology in the Cuareim-Quaraí River Basin (Brazilian side) was established. Rivers were grouped in 20 typology regions in the basin through 4 hydromorphological parameters. Type-specific reference conditions for each water body type were established using the best available data. Two classifications of water bodies were performed based on the combined analysis of a series of layers representing different types of human pressures. These two classifications schemes clearly show that the main economic activity developed in the basin, rice production, constitutes the principal human pressure on the ecological status of water bodies.

Currently, almost no field data is available which would allow for a characterization of the different water body ecosystem types in the Cocibolca Lake Basin. In TWINLATIN a first approximation for the "reference land cover conditions" was used to establish "reference" spatial erosion patterns and magnitudes under natural land cover in the basin (forest). These "natural" micro-basin or river reach contributions can then be deducted from the results obtained from the "current land use" erosion & sediment maps, in order to obtain a view of where human-induced sediment delivery is high. This would indicate the areas where mitigation/prevention actions may be most effective, and therefore their inclusion in a priority list for action can be considered.

In the Catamayo–Chira basin, a river segment categorisation has been carried out for the first time, based on a GIS analysis. The approach followed the methodology established in the EU WFD. 32 water body types were identified for the Catamayo/Chira basin, as a basis for establishment of reference conditions and assessment of the ecological quality of the water bodies. Due to logistic limitations, the practical classification was carried out only in the River Quiroz sub-basin. As a result of this preliminary process, fifteen stations were assessed in three biological/ecological sampling campaigns. The results of the sampling campaigns are available and will be the base for future research on ecological status. In the Cauca basin, twenty-three (23) types of water bodies were established through cross referencing of the included variables. This first classification of water bodies is done by combining variables such as the drainage area, altitude and type of soil, according to map overlaying to determine a class in which the typology is identified. According to the above classification, there are 23 types of classifications. By combining data on reference variables and degrees of pressure, the results show that 58% of the water bodies in the pilot Bugalagrande basin show contamination. This is a situation that in general terms, represents the status of the entire Upper Cauca Basin, where agricultural activities and population settlements generate the greatest pressure on water bodies.

WP 8 – Change effects and vulnerability assessment: The vulnerability of water bodies to environmental changes and external pressures can be assessed by means of expert judgement, monitoring, analysis of historical data sets and modelling approximations. The approach followed in the TWINLATIN project built mainly on the use of the mathematical models developed in WP 3 and WP 6. Future anthropogenic pressure and changes in water demand were forecasted, and the hydrological, chemical and biological/ecological effects of these changed conditions were predicted using GIS and modelling techniques. Large-scale changes that were analysed were climate change, land use change, changes in agricultural and forestry practices, urbanisation, and hydropower development. Change effects and vulnerability assessments have been made for the mainland South American continent, in addition to those for the TWINLATIN basins, using a grid-based modelling approach (GWAVA) which enables a consistent methodology to be applied across the continent.

In the TWINLATIN project, all partners agreed to use a harmonized approach in the context of the analysis of climate change effects. Therefore, in all Latin American basins future scenario projections were created with MAGICC/SCENGEN version 4.1 that then could be used for comparison with baseline scenarios.

The methodology that was proposed in WP 8 for assessing land use changes was based on three important steps: The identification of historical land use changes within the study area, data collection and geo-database construction, the generation of plausible future land use scenarios and the modelling of the potential impact of Results from WP 8 was integrated in activities of WP's 3, 6 and 9 in order to assess the potential impact of these plausible scenarios on availability and quality of natural resources (e.g. water, soil). as well as the associated societal impacts.

A vulnerability assessment was carried out in the LA basins. Vulnerability is defined as the extent to which a natural or social system is susceptible to sustaining damage from for example climate change.

The Description of Work for WP 9 followed closely the methodology recommended in the guide for implementation of economic analyses of the EU Water Framework Directive. The tools included in this guiding reference were the focus of the workshop in April 2007 in Santiago, when work in WP 9 began, as well as in the Spanish guide that was elaborated. All river basins have with different ambitions followed this guide and have completed the economic analysis of water uses, the cost-recovery analysis and the baseline scenario. These in turn have served as input for their selection of actions to address the major water problems in the basins. It is mainly here where the focus has differed from that of the Water Framework Directive. A common problem in most of the river basins is principally water quantity rather than water quality. The actions have therefore been chosen in order to address this problem and to find a price for water. Further, even though there are water quality problems which need to be addressed such as in Cocibolca, the information is poor. Proposed actions have for example been connection to municipal services, construction of dams, change of cultivation patterns, improvement of agricultural technology etc. Further in the Baker river basin, the water problem has neither been water quantity nor quality but the possible use of the river basin to produce energy with a large hydropower dam. Here the focus was on estimating the economic value of the loss of landscapes. In two of the river basins there has been a strong involvement of stakeholders also in the economic analyses (while in other basins SI have focussed on e.g. participative modelling, pressure and impact assessment, or management strategies). In for example Cuareim-Quarai various meetings have been held with stakeholders to receive their views and to make them participate in decisions-making. The participation was high and experiences positive.

The WP 9 objectives have been fulfilled in most river basins. No river basin developed a full program of cost-efficient actions accompanied by a socio-economic impact analysis. The reasons are mainly problems to find detailed data on costs and effects for each action, and the fact that the problems have been more directed to water quantity. The efforts in WP 9 have been a first attempt to transfer knowledge and to define and agree on a common methodology in the Latin American river basins. The results presented are in general positive. Despite scarce information and different problem approaches the results are a significant achievement which can be extended and used in other river basins.

The efforts in WP 10 – Twinning, were expanded considerably compared to the original plan. The twinning workpackage served all other workpackages. Courses, on the job training, workshops, exchange of experts, etc; were organised within this package, addressing needs identified within the other workpackages. From the project kick-off meeting (October 2005), twinning activities were discussed and during the first progress review meeting held in Coyhaique meeting (March 2006), the first main training focus was identified. This was the need for identifying a joint database strategy.

The ArcHydro database structure was decided as the topic for the first training course activity in the project. This course was held at IPH Brasil, in Porto Alegre – Brasil, in April 2006. From this first activity a number of other twinning activities were carried out.

The legacy of the project will be the use of data, results, methods and participatory approaches by the authority partners and by water management stakeholders in future water management and in follow-up research projects. This legacy has been intensely promoted by the twinning activities.

A permanent dialogue has been established that will continue after the project. Twinning activities have been continuous in the project, with active participation of all partners. These activities have contributed significantly to filling of gaps in knowledge and methods and to implementation of a more integrated water management approach in the LA basins.

A considerable part of the progress that was made in the different basins would have been very difficult to achieve without the intensive twinning activities that have taken place. Twinning has clearly allowed the development to reach much further than would otherwise have been possible.

Overall project conclusions:

- In spite of divers existing structures for water management in the twinned river basins all partners and stakeholders found the European Water Framework Directive a good framework for development of methods and tools for implementation of integrated water resources management.
- TWINLATIN has by collaboration with the major public stakeholders in each basin and each partner country significantly contributed to the transfer of research results and methods to major stakeholder institutions in the countries of the twinned river basins.
- Advances in research and knowledge have been achieved in several fields, such as improved hydrological modelling and pollution pressure modelling and water body characterisation, methods for and results on impact of climate and societal change on water flow and pollution, and improved knowledge on the economics of water use and action cost-effectiveness. Throughout the project and with increased intensity in the second half, stakeholders from

‘grassroots’ to national authorities have been involved in discussions on research methods, results and abatement measures.

- A harmonized approach for assessment of climate change impact (baseline and scenarios) was developed, providing the basis for future projections and adaptation analysis. Methods have been transferred, adapted, used and disseminated in the participating countries. Results have also been disseminated to other countries by presentations at workshops and conferences.
- A matrix identifying the management strengths and weaknesses of the countries of each basin was developed, as well as proposals and recommendations for improvements. The matrix provides a general and summarized vision of the current management situation in the basins and helps to assimilate, compare, and analyse issues common to all. The proposed management systems include various components of development or improvement towards an integrated management of the water resources. As has been shown in some of the TWINLATIN river basins, an important first step for transboundary rivers is to share collection and use of data, so that a jointly accepted information-base is built.
- TWINLATIN has been well connected with other EU and regional initiatives and has served as a catalyst for identification of problems and needs in non-EU river basins to improve IWRM. A number of publications and participation in different forum assured the dissemination of knowledge and findings to other regional initiatives.
- Twinning has significantly raised the competence level of the third country partners, as well as that of stakeholders and end-user water authorities in all countries. In some areas, the European partners have benefited from ambitious development work carried out by third country partners. Language difficulties and the efforts needed for translation and basic technological support have required more resources than anticipated, but the general conclusion of the consortium is that the advances clearly outweigh these difficulties.

The R&D conducted in the project resulted in improved methods, modelling tools and knowledge. Knowledge has been disseminated through conferences, workshops, media appearances, meetings with end users, research papers and the website. The active participation of local water authorities and other end users assure practical use of the tools and knowledge gained through the project. Some of the tools improved such as GWAVA, SWAT, Watshman are marketed by partners on a commercial basis, while tools developed by university partners will be publically available.

Partners in the project

Table below shows the partners involved in TWINLATIN:

Partner name	Team Leader	short name	Country
IVL Swedish Environmental Research Institute, Project Co-ordinator	Sam Ekstrand	IVL	Sweden
Centre for Ecology and Hydrology, Wallingford	Helen Houghton-Carr	CEH-W	UK
Department of Geology-Geography, K.U. Leuven	Gerard Govers	KULeuven	Belgium
Center for Environmental Sciences, University of Concepción	Patrick Debels	EULA	Chile
Instituto de Pesquisas Hidraulicas, University Rio Grande do Sul	Beatriz Camano	IPH	Brasil
Dirección Nacional de Hidrografía	Silvana Alcoz	DNH	Uruguay
Centro de Investigación y Estudios en Medio Ambiente, Universidad Nacional de Ingeniería	Sergio Gámez	CIEMA	Nicaragua
Management Unit for the Bi-national Catamayo-Chira river basin	Mercedes Alonso/Isabel Filiberto	UNIGECC	Perú-Ecuador
Corporación Autónoma Regional del Valle del Cauca	Amparo Duque	CVC	Colombia

1. Introduction

An important part of the TWINLATIN objective is to build capacity to carry out IWRM in all the five LA river basins, building on European approaches to water resources management with the Water Framework Directive in focus, as well as on third countries expertise and experience. Decision making tools are needed in the LA basins and transfer of such tools have been a major objective of the project. Such tools are major components necessary for a successful analysis of climate change and human development scenarios, effects of measures and development of preliminary river basin management plans.

By twinning the five basins from LA basins and the two from Europe and tying together water researchers with key expertise and knowledge on these rivers, a critical mass of experience and knowledge has been mobilised.

To reach the strategic objectives of TWINLATIN, a number of research activities tasks on hydrology, modelling of pollution flow, impact assessment, socio-economics, scenario analyses and action efficiency, impacts of changes and vulnerability have been carried out. Based on existing analysis on climate change the effects on the hydrological regime, on water availability and water quality have been modelled and the economical consequences analysed. Sustainable management strategies have also been identified in each of the LA basins. TWINLATIN was designed to enable and facilitate twinning in all fields of activity in order to fill gaps in knowledge. The strong component of public participation and stakeholder involvement focused on that each component had local ownership. The river basins selected represented a wide variety of conditions, addressing also transboundary water problems. Thus, the applicability of the WFD approach varied for the third country basins.

2. Brief description of the river basins

The river basins in TWINLATIN were: The Baker river (Chile), the Catamayo-Chira river (Peru-Ecuador), the Cauca river (Colombia), Lake Cocibolca, Nicaragua), the Quarai/Cuareim river (Uruguay-Brazil), the Thames river (UK) and the Norrström river (Sweden). The research and development work focussed on the Latin American rivers, but RTD was also carried out for Norrström. The Thames River was used as a reference case.

BAKER BASIN

The Baker river basin is located between latitude 45°50' S and 47°55' S, on the Eastern slope of the Patagonian Andes (Southern South-America). It occupies a total surface area of approximately 26.726 km2. Of these, slightly less than 6.000 km2 (22%) are located in Argentina's Province of Santa Cruz, while the remaining part is located in Chile's Aysén Region. It is the second biggest basin in Chile in terms of surface area, and the most important in terms of mean annual discharge (approx. 1.100 m3/s according to DGA). Annual precipitation varies from approx. 2000 mm/year in the west to approx. 600 mm/year in the east. Traditional economic activities in the area are based on the important agricultural potential (mainly livestock) and on the abundance of (native) forest resources. The Baker river basin acquires special relevance due to the fact that it is considered to contain Chile's major remaining hydroelectric potential. Recently, plans were announced to build five hydroelectric power stations in the Patagonian region over the next fifteen years, meaning a total investment of USD 2.8 billion. Two of these projects, to be executed in the Baker river basin, would provide a total capacity of 1310 MW. Significant contributions of the TWINLATIN project, aimed at filling knowledge gaps and providing the basis for the establishment of an integrated water resources management plan.

CATAMAYO-CHIRA BASIN

The Catamayo-Chira has an extension of 17200 km2 in total, from which 7212 km2 are in Ecuador and the remaining 9986 km2 are in Peru. The river springs from the Occidental Andean mountains at an altitude above 3600 m and flows to the Pacific Ocean. The confluence of the Catamayo and Macará rivers is the starting point of the Chira River. There are about 1479 km2 officially protected areas in the basin (8% of the total surface area), being another 12% considered as potential conservation areas The predominant activities are agriculture and small-scale business with few but incipient agro-industrial activities. The border area is characterized by high emigration rates due to the harsh socio-economical conditions, which in many cases has led to important local nuclei of extreme poverty: this population is one of the poorest in the country, with 73% living in poverty. Combined unemployment and underemployment amount up to 70%, and only 22.5% of the households have access to running water, and 24.2% to sewage systems. The main interest areas for research within the TWINLATIN project are the Establishment of a monitoring program, the assessment of Erosion and transport of sediments, Climate change and future development and the Contamination pressure and analysis

CUAREIM/QUARAI BASIN

This is a transboundary river basin shared by Brazil and Uruguay, with the main channel of the Rio Cuareim being the border between the two countries. Rio Cuareim is a tributary on the left bank of the Rio Uruguay and is part of the River Plate Basin. The Rio Cuareim Basin has a drainage area of about 14 800 km2, of which approximately 6 700 km2 (45%) are in Brazil and 8 100 km2 (55%) are on the edge of north-western Uruguay. The total length of the main channel is 351 km and the difference in elevation between the source and its mouth is 326 m. The average altitude is less than 200 m and there is an average slope of 0.93 m/km, with the steepest slopes located in the first quarter of its course. Average annual precipitation is between 1,300 and 1,500 mm, all provided primarily by frontal systems with an almost uniform seasonal distribution (in summer 20 %, in autumn 22 %, in winter 24.5 % and in spring 23 %), with marked variation from year to year. Throughout most of the basin, shallow soil limits storage capacity, which leads to a rapid response and heavy runoff during intense rains. In most sub-basins of the Cuareim river basin, the grow of rice is limited by the availability of water. The water available for irrigation from intakes is strongly affected by the distribution of water through each month, which was not taken into account in the monthly time-step model used.

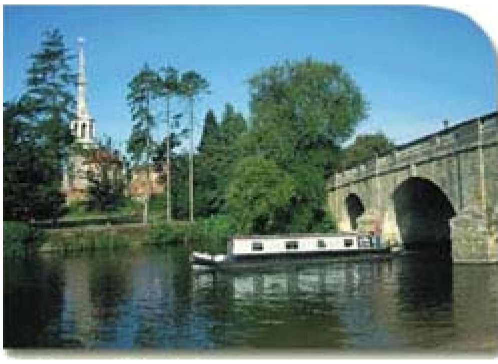
CAUCA BASIN

The Cauca River Basin cover an area of 63,300 km^2 and represents 5% of the total national territory, in which take seat 183 municipalities, with a population near the 10 million inhabitants representing 25% of the total population of the countryFrom an economical point of view, the Magdalena-Cauca system is considered to be the most important river system in Colombia. The Cauca river basin itself has a total extension of 62 000 km2. The area under focus in the TWINLATIN project corresponds to the management units representing the Upper Cauca basin, located in the Departments “Cauca” and “Valle del Cauca”, and covering an extension of approximately 22 000 km2. Human activities in this area are diverse, and so are the management problems: the Cauca River frequently hits the news due to the contamination of its waters, and because of problems related with water availability. Deforestation in the upper watersheds leads to biodiversity loss and severe land degradation (erosion), and causes downstream problems such as increased flooding and sediment transport during downpours, with sedimentation of irrigation channels and periodic interruptions in the provision of drinking water for the City of Cali as a consequence. During the dry season, downstream water users (irrigation sector) are severely affected by water scarcity. Contributions of the TWINLATIN project, aimed at filling knowledge gaps and providing the basis for the establishment and improvement of integrated water resources management plans.

COCIBOLCA LAKE

Located in the Southwest of the country, Lake Nicaragua (also known as Lake Cocibolca) is the largest lake in Central America with an area of 8 250 km2 (and volume of 108 km3). It is located 24 km from the Pacific Ocean and drains into the Caribbean Sea at San Juan del Norte via the Río San Juan. It is a freshwater lake inhabited by a variety of species usually associated with saltwater, such as shark and swordfish. The Cocibolca Lake is one of the 40 largest lakes in the world by both surface area and volume. Its origins are both tectonic and volcanic. The total drainage area of the basin is 17 300 km2. The average monthly evaporation rate is estimated to be 1200 mm. The run off to the Río San Juan is about 460 m3/s. The most important problems are: erosion, point sources pollution, polluted runoff, and toxic discharges from industry. Specific pollution pressures come from industrial and agricultural activities (Mining, Pesticides). The lack of scientific information is a strong obstacle to evaluating different alternatives and projects in the area. A strong interest in creating a better knowledge on this Lake is expressed in the Environmental Plan developed by the government for the 2006-2026 period. Due to its high importance in terms of water availability for the production of drinking water, and due to the presence of multiple, important user groups in its basin the lake urgently needs a water resources conservation program to assure good quality drinking water as well as sustainability of the other uses, under both present and future conditions of anthropogenic (and climatic) pressure.

THAMES BASIN



The Thames basin in the UK covers an area of 13,000 km^2, representing 4% of the UK land area. However, it houses one fifth of the UK's population with 12 million people, and generates more than one quarter of the GNP. This creates intense pressure on the natural environment through the demand on land for homes, offices and other developments, stress on the basin's water resources and waste disposal. In particular, the Thames has had a long history of pollution, especially in the London area. Campaigns have been aimed at improving water quality, attacking, firstly, gross organisc pollution and, latterly, nutrient enrichment. However, whilst river water quality may be improving, groundwater pollution is a progressively more important issue with nitrate concentrations in groundwater across the Thames basin continuing to increase slowly. Two study catchments, the 235 km2 Lambourne and its neighbour, the 170 km2 Pang, will be used as representative twinning catchments for the purposes of TWINLATIN, rather than trying to consider the whole 13,000 km2 Thames basin, as it will be easier to understand how the WFD may best be applied on these smaller, intensively studied sub-catchments. In order to enable the project to consider lessons learnt from implementation of the WFD to the Pang and Lambourne catchments within the Thames basin, CEH will build upon work undertaken by them already for the UK Environment Agency (CEH, 2002). No further research work will be carried out for the Thames. Instead, the lesson learnt and methods developed will be used to assist decision makers in the other case study basins to move towards better IWRM.

NORRSTRÖM BASIN

The Norrström river basin covers an area of 22.600 km2, and includes two of Sweden's largest lakes. Mälaren with an area of 1000 km2, and Hjälmaren which is slightly smaller. The river basin and Lake Mälaren has it's outlet to the Baltic sea through central Stockholm. Lake Mälaren supplies drinking water to a large part of the Stockholm region. During the last years an increase in the nutrient load has repeatedly caused heavy algae blooms during the summer months which decrease the quality of the raw water that is processed for drinking water production in a few large treatment plants. A considerable part of the Swedish nutrient transport to the Baltic Sea is attributed to the Norrström river basin. Also the concentrations of CDOM (coloured dissolved organic matter) mainly caused by leakage from logged forest areas cause disturbances in the production of drinking water. Other problems are high copper concentrations at the outlet to the Baltic Sea as well as high concentrations of other metals and POPs in parts of the river basin. The western parts of Lake Mälaren are highly eutrophicated. Several of the tributaries have so high concentrations of nutrients and levels of primary production that oxygen deficit occur frequently, as well as fish death and sub-lethal reproduction damage on fish. The main focus under TWINLATIN project is the assessment of eutrophication.

3. Work Packages activities and Results

3.1 WP1 Current Status and stakeholder structures

The main aspects included in the WP1 – Current Status and Stakeholder Structures, report are: compilation of history, current knowledge, the status of the river basins regarding hydrology, water quality, used demands, political structures, policies, stakeholder structures, etc. were the input to other WPs mainly in aspects such us networking and implementation of results. Water availability and water quality problems have also been documented. The WP1 finished during the first year (end of April) but updates have taken placed and all information is now available at the TWINLATIN web site (www.twinlatin.org). The status of the river basins as described in the WP 1 report is summarised below.

BAKER

The Baker River acquires special relevance due to the fact that it is considered to contain Chile's major remaining hydroelectric potential. Recently, plans were announced to build five hydroelectric power stations in the Patagonian region.

Due to the large surface area covered by the basin, its geographical isolation and low population density, baseline information for the basin is scarce:

- The available meteorological and hydrometric network does not allow for a detailed view on basin meteorology or hydrology, and is definitely insufficient for basin-scale modelling efforts. The strong precipitation gradients observed across the basin, combined with basin & sub basin topography, make that even at the sub-basin level measuring networks would have to be extended in order to allow for modelling applications such as rainfall-runoff modelling, erosion modelling etc. No bathymetric data is available for hydrodynamic modelling of e.g. the Baker River, or for the most important lakes

- Currently, historical changes (last century/decades) in the contributions from glacial melt to river hydrology of the different glacier-fed subbasins is difficult to evaluate, due to the absence of historical limnigraph data on such subbasins. A limnigraph was recently established on the Nef River by the IRD (France) and DGA, but a calibration curve for the instrument still has to be established.

- In the last decade, baseline information on terrestrial fauna and flora has been extended. However, knowledge about aquatic ecosystems remains rather restricted. A detailed analysis of the diversity of aquatic ecosystem types (water body typology) at the basin level is lacking at the moment. Baseline information for the establishment of reference conditions is only available from a limited number of measurements, done at a limited number of sites, for a small number of parameters.

- Currently, no information is available on human-induced changes in sediment load in the river network (e.g. to overgrazing), and of its relative importance in the total sediment balance.

- An evaluation of the potential impact of future climate change on the basin's water resources has not been made.

- An analysis of the economy of the basin and its relation to/dependence on water resources is not available.

- Impact of the historic forest fires (beginning of the 20th Century) on the different affected basins/watersheds and its water resources have not been thoroughly evaluated.

Taking into consideration the formerly mentioned knowledge gaps, it can be concluded that the generalized lack of baseline information for the basin constitutes a major knowledge gap which complicates the thorough evaluation of the potential impact of hydropower development in the basin, and of other future development plans in the basin.

CUAREIM - QUARAI

The Cuareim river basin is a bi-national river basin shared by Brazil and Uruguay.

The main environmental conflicts in the basin are related to the use of its water resources: water availability and water quality. Some localized problems of poor water quality have been identified due to the effluents generated from the cities of Artigas/Quaraí. This information was just the result of two water quality campaigns, so that statement was no more than the situation at two specific moments in time. There were no systematic water quality measurements.

In both countries the main regulatory features to implement the national water resources policy are alike. Difficulties to manage the water resources in a coordinated manner are not due to a lack of legislation or institutions: the flaws are mainly based on implementation aspects. The Binational Commission plays a good role for the signing of agreements but does not have technical capacity to supervise its implementation. The difference in importance given by each country to the basin contributed to the difficulties found in the coordination. An agreement among the two Chancelleries of both countries and the Commission of the Cuareim River was signed in May 6, 1997, called "Complementary adjustment to the Cooperation Agreement between the Government of the Oriental Republic of Uruguay and the Government of the Federative Republic of Brazil for the utilization of the Natural Resources and the Development of the River Basin". In it, it was agreed among others, a maximum water quota to each country of 0.2 l/s/km2, to authorize direct intakes from the Cuareim river. Nevertheless, there were difficulties in the practical implementation of what it was agreed.

Most of the control (that as a matter of fact is quite effective) of the use of water in the basin is being done by the users, who denounce irregularities.

Since this is a cross-border basin, a Uruguayan – Brazilian Committee was constituted for the Development of Cuareim river and this in turn, constituted the Local Coordination Committee (CCL for its Spanish acronym), which is made up of: in the Uruguayan side: Artigas Shopping Center; IMA; OSE, DNH; the Association of Rice Producers of Artigas; and in the Brazilian side: the Association of Rice Producers of Uruguayaza; Rural Union of Barra do Quaraí; Prefecture of Uruguayaza; EMATER Quaraí; CORSAN Quaraí; IRGA Quaraí; Municipal Prefecture Quaraí; Aquapan. The Basin Committees (Brazil) was not in operation in the Cuareim river basin (this management tool has been approved and is being used in other Brazilian basins, achieving the management of the water resources in a decentralized and participative manner) while in Uruguay the Irrigation Assessing Committees actively participate in the water allocation process.

Therefore the principal weaknesses of the existing institutions in the basin and the way they manage the water resources are: the lack of adequate implementation of rules; management is still country-focused and not regarded as a shared matter; there are differences in intensity of controls, registration of rights and inventory of works; information exchange between competent offices is still slow and scarce; and competent offices in each country first need effective coordination among themselves, in order to allow for coordination with their peers in the other country.

With respect to management plans in the basin, no management plan (neither quantity nor quality) has been implemented, but isolated studies were carried out on this matter.

There were planned monitoring networks to measure water quality data and other environmental data, but they were implemented neither in the left nor in the right margin. There was a need for an extensive and systematic monitoring program.

Finally, in general terms, all available information of the basin were dispersed in different organizations so to gather this information in a unified and structured database was recommended.

COCIBOLCA

The Lake of Nicaragua has been considered for the last approximately 40 years for the Government, through the current Nicaraguan Company of Aqueducts and Sewer Systems, as potential source of water supply for human consumption, and in different moments they have developed punctual studies of the resource and defined reception areas. However until now there is not a law initiative or promulgated ordinance that specifies thas this lake is reserved for drinking water supply.

At the same time, due to the population growth, changes of soil use in their basin and industrial activities, there is a presumption that Lake Cocibolca is entering in a eutrophication process that puts in much risk the biodiversity of the Lake as well the use of its waters without more treatment.

The municipalities inside the basin have growing interest in use of waters of the Lake Cocibolca to satisfy their drinking water supply demand and initiatives of micro basins management are in develop as well campaigns of sensibilization and the financing search for install drinking water plants. That is to say they have more concern for the prevention and the control of the contamination of the Lake Cocibolca.

MARENA, in the State of the Environment in Nicaragua 2003, indicates that Lake of Nicaragua, the main fresh water body of the country, it is subjected to a slow process of contamination as a consequence of the economic activities that are carried out in its basin"

Currently, there are serious management issues in Nicaragua and in the selected basin. One of the elements affecting the different decisions is the absence of a Territorial Zoning Law nationwide, which has an effect on the chaotic growth of the cities, producing a negative impact in the basin.

The main problems related to this aspect are: lack of liaison between planning and public investment, weak bonds between territorial zoning and the reduction of social vulnerability and poverty, absence of urban planning, lack of definition and coordination of normative and institutional framework for urban development, and institutional management weaknesses at national level.

In spite of the aforementioned difficulties, all the municipal institutions have designed their environmental management plans of their territory, which include work components that contribute to mitigate the environmental impacts in the basin; however, these efforts are carried out virtually without budget, and some town councils define small amounts that do not represent a solution to the problems.

It is important to mention that most of the environmental actions are being developed by the Municipal Environment Committees at local level (CAM for its Spanish acronym) where all local institutions are represented; however, it is the NGO’s which perform important activities on this subject.

CATAMAYO-CHIRA

The management of the hydrological resources at the Catamayo - Chira cross-border basin faces a problem which does not greatly differ from the current international panorama characterized by lack of quality information, the absence of tools to manage such information, the limited technical and technological capacities of competent institutions and lack of clarity about their competences, as well as the existence of a population that is barely sensitized, barely informed and barely participative of the management processes. In the recent years a series of changes have occurred in the binational river basins which have to do with legal, institutional, financial and operational structures. With the purpose of reaching the IWRM goals, is necessary to harmonize the interests and dynamics of the population with the surrounding dynamics where they live so that the decisions are taken are in agreement with these changes.

In the case of this river basin it is necessary to take into account:

- The binational process from the Peace agreements between both countries,
- The decentralization that is a slow process developing in Peru and Ecuador that it will bring important changes in the resource management.
- The Water Laws, very old in both countries, will have to be changed or be adapted to the new circumstances.
- The appearance of new concepts on water treatment has to be taken into account, such as the environmental services and payments for them, the ecological flow, the Early Warning Systems, the applied GIS, the processes of territorial ordering, the creation of institutional platforms, etc.
- With the complex present situation and with the little existing information within TWINLATIN we will have to make projections of short, medium and long term, considering possible political-normative, technical and economic scenarios about the future evolution of the main variables.
- The preparation of these will have to be adjusted to the specific requirements of the population and the river basin itself, trying to satisfy its necessities.

Within the work of the Binational Project Catamayo Chira an identification of stakeholders has been made, its profile, level of participation, existing habits of communication, social networks, respected leaders, etc. On the basis of this map of actors, the proposal within the Public Participation Plan has three strategies:

- The conformation of a Binational work group by work package conformed by the institutions with competitions in the topic.
- The spread of information generated for rising awareness
- The socialization of proposals in those groups identified by the Project.

CAUCA

Great achievements have been made in the Alto Cauca Basin by minimizing the pollution pressure of the river Cauca and its tributaries; nonetheless, an efficient culture on environmental management has not been consolidated as a consequence of multiple situations that have direct relation with the diversity of actors, the extension of the territory, the economic crisis in the region, crisis of governance and low level of participation of the different social actors.

In general terms, this deficient environmental management compromises the whole environment, bringing huge consequences against the ecosystem and natural resource sustainability.

In Colombia, there are neither committees of farmers with irrigation rights nor water administration meetings formally established; however, there are some organizations with current structuring process.

According to provisions in Decree 48 dated January 15, 2001, which modifies Article 7 of Decree 1768 of 1994 and the Articles 1 and 2 of Decree 1865 of 1994, the Regional Autonomous Corporations have three planning instruments: the Triennial Action Plan, the Annual Investments Operation Plan, and the Regional Environmental Plan. The latter, with a 10 year duration, must be collectively proposed, with the participation of the different social regional stakeholders, and from there, set the environmental commitments and responsibilities for each stakeholder.

Considering Colombia's position as the leader of the region in the regulation of legal participative instruments, the process for the 2002-2012 Regional Environmental Plan was developed respecting the legal terms of the different mechanisms of citizen participation in effect in Colombia: Law134 of 1994; Law 70 of 1993 and Regulatory Decree 1745 of 1995.

Environmental management scenarios allowed participation, action and coordination by the different institutional, entrepreneurial, and community stakeholders. Some of these scenarios originate from the standards, while others are created by the stakeholders within the environmental management consolidation process in the Department of Valle del Cauca, and their goal is to facilitate the achievement of development sustainability.

For this reason, the 2002-2012 Regional Environmental Plan "Committed Participation" follows the basic principles of participation in environmental management described in the "Guidelines for a Policy for Citizen Participation in Environmental Management".

3.2 WP2 Monitoring and Database Construction

Setting up operational monitoring programmes constitutes a major step of the WFD and the IWRM processes.

The specific objectives of this work have therefore been:

- To compile all available data from current and earlier monitoring programmes in the river basins, as well as all GIS data layers available for each basin and required for the achievement of the project's objectives (meteorology, hydrology, water quality, etc). A project database will be designed and built for each one of the partner basins, for this purpose.
- To compile a list of priority substances for the **TWINLATIN** complementary monitoring programmes in each one of the river basins
- To design and implement a monitoring programme adapted to the specific conditions and problems of each river basin, running during two full years, providing the data sets required for construction, calibration and validation of the modelling tools described in the following WP's, and for the ecological status analysis in WP08.

Database construction (Implementation of environmental database)

At the TWINLATIN workshop held in Chile in March 2006, it was decided that IVL should look into the possibility of assisting twinning organisations in Latin America with the development of a common database structure based on ArcGIS / ArcHydro for storing river basin management information. This database should be in the form of a personal geo-database, which is an ESRI standard for storing spatial and tabular data in a Microsoft Access database. Activities continued after the first course organised 9-11 may 2006 at IPH – Brazil, where the Hydraulic Research Institute at the Federal University of Rio Grande do Sul. The professionals involved in this training activity were in contact mainly through e-mail, skype and telephone. As a result of this Twinning activity, each of the LA basins has developed a harmonised database structure being one of the main achievements of TWINLATIN.

The basic aspects of the ArcHydro concept were effectively implemented in several of the TWINLATIN case study basins.

ArcHydro Database Structure. ArcHydro is a geospatial and temporal data model for water resources that operates within ArcGIS. ArcHydro has an associated tool that populates attributes of the features in the data framework, interconnect features, and support hydrologic analysis. It provides systematic and efficient project execution and the potential to reuse data on subsequent projects in the same area.

Catamayo-Chira
Prior to TWINLATIN a centralized environmental database of the River Basin did not exist, even if most of the needed information already was created. A geographic database is now available in Access format and with de ArcHydro Model structure.

Cauca

In the work done to develop the TWINLATIN Project, the different organizations existing in the Upper Cauca River basin worked together in order to establish a common data set for the study zone to facilitate the development of activities within the different Project packages.

Cuareim

A **binational geodatabase** for the Cuareim River Basin was developed in the framework of TWINLATIN, used and updated during the project. This database was the base for the development of all TWINLATIN Working Packages.

Cocibolca

A Geo-referenced Environmental Information System for the Cocibolca Basin was constructed. With this database, the information resources related to the case study area –with their spatial, thematic and temporal components- are structured and stored.

Baker

An approach similar to that of the Cocibolca Lake Basin was used also for the Baker basin implementation in Cocibolca occurred through intensive EULA Twinning support).

Monitoring activities

NORRSTRÖM

Eutrophication of the Baltic Sea and Lake Mälaren, the latter providing drinking water for 1,5 million people, poses a serious environmental problem with increased algae blooms and oxygen depleted bottoms. Estimates of the total losses of phosphorus from the area ranges from 103 to 280 tonnes/year and these large uncertainties suggests that there is a need for improved modelling of the phosphorus cycle as well as better estimates of the internal load from Lake Mälaren, which can be substantial. The fixed-interval sampling means that the accuracy is suffering during periods with high flow rates and during the snow-melt in the spring when phosphorus is flushed out at high concentrations. The combination of high flow rates and high concentrations is giving rise to a substantial amount of the annual mass transport during short periods of time. One way to overcome this problem is flow-driven sampling at fewer but representative locations. This will lead to more accurate quantification of total loads and a better understanding of the dynamics of phosphorus (and nitrogen) losses from agricultural land.

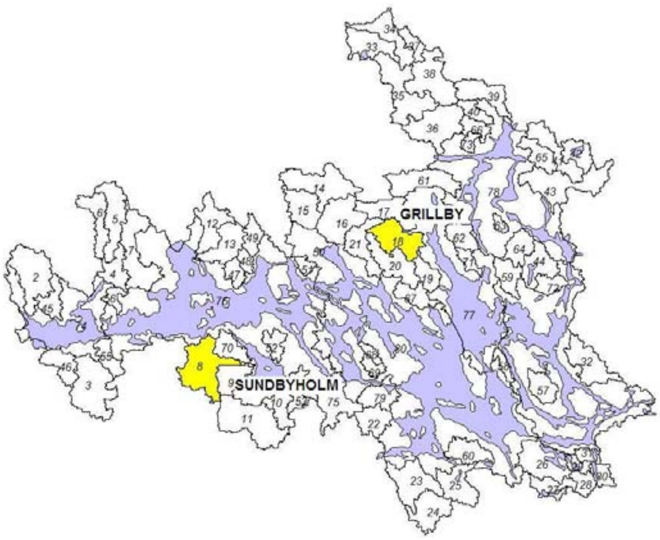


Figure 1. Lake Mälaren catchment as represented in the SWAT-model. Sub-basin division coincides with the Swedish national division system. The catchments where the flow-driven sampling stations are located are indicated with yellow.

Distributed hydrological modelling of nutrient transport for the area nearby Lake Mälaren is carried out in the TWINLATIN-project and to support the modelling efforts flow-driven sampling were performed at two relatively large catchments that are dominated by agricultural land with streams draining directly to Lake Mälaren.

Results and discussion

Flow-driven sampling of total phosphorus and nitrogen were performed from June/July 2007 to June 2008 at two stations located at the outlets of the streams that drain the Grillby and Sundbyholm catchments, respectively.

Phosphorus

The measured phosphorus concentrations at the flow-driven sampling station in Grillby were very low during the five-month period from July through October 2007 and typical values are 10 µg/l. As the first large peak flow occurred in the stream in the beginning of December the phosphorus concentrations rose dramatically up to values over 300 µg/l. The amount of phosphorus flushed-out of during this first peak flow event was a significant contribution to the annual load. The four larger peaks flow events from January and onwards were associated with high concentrations of phosphorus although with somewhat lower peak values (about 200 µg/l) compared to the first flow peak of the winter season in December.

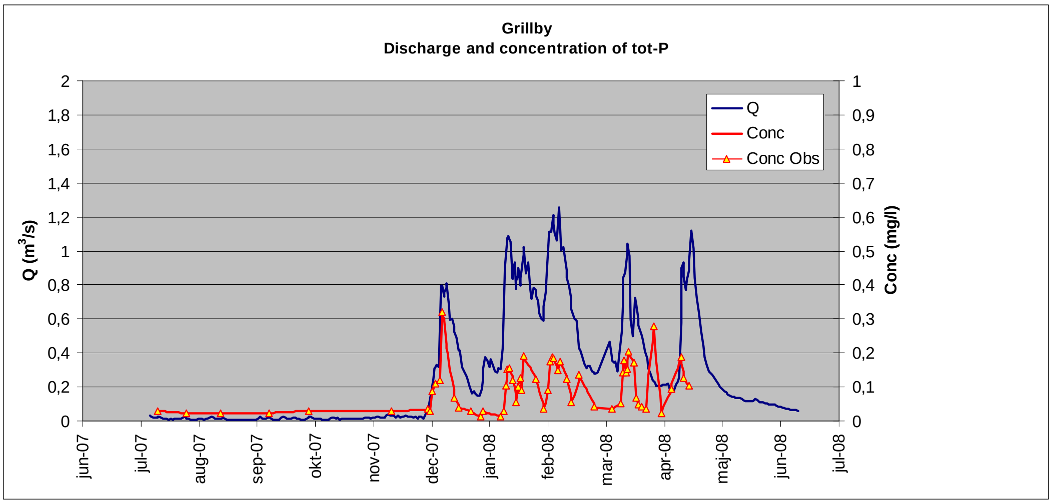


Figure 2. Discharge and concentration of total phosphorus at the flow-driven sampling station in the Grillby catchment.

For the Sundbyholm catchment the dynamics of phosphorus flush-out is showing a similar pattern and the most pronounced increase in concentrations was also here associated with the first peak flow event of the winter season in December 2007. The peak concentrations of more than 500 µg/l were much higher in the Sundbyholm catchment than in Grillby. Small flow peaks does not give a significant increase in the phosphorus concentrations and this pattern was also observed in Grillby. A major difference between the two catchments are that the "background concentrations" during the winter period is proportionally higher in Sundbyholm than compared with Grillby and this might depend on several different factors or a combination of these, such as differences in land use, soil type, crop type, location and area used for agriculture, fertilizing practices, livestock density etc.

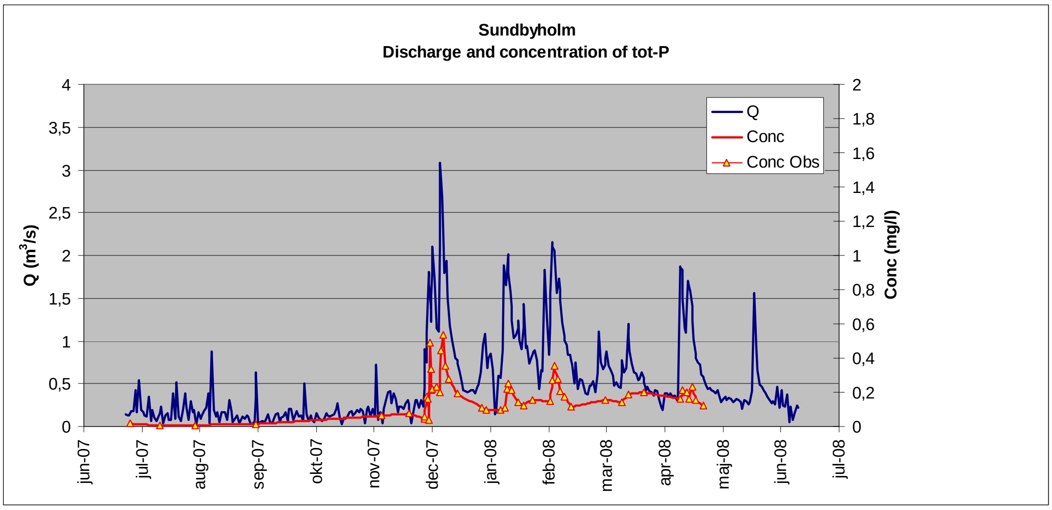


Figure 3. Discharge and concentration of total phosphorus at the flow-driven sampling station in the Sundbyholm catchment.

Nitrogen

In addition to the phosphorus measurements total nitrogen was also sampled but no detailed analysis is presented here since the focus of the TWINLATIN research in the Norrström basin was on the quantification and dynamics of phosphorus losses for modelling purposes. The measured nitrogen concentration in the two catchments exhibits very different patterns. In Grillby the highest concentrations were found during the low flow period from July to November 2007 where the concentration is very high and typically around 10 mg/l whereas the concentrations drop to about 6-7 mg/l from January and onwards. The lowest concentrations of about 5 mg/l were observed during the peak discharge events. In Sundbyholm the nitrogen concentration during the low flow period until November 2007 was around 0,5 mg/l and the variation is very small. From December 2007 the concentrations rises with a factor 10 to around 5 mg/l thus coinciding with the high flows during the winter season.

Total loss of phosphorus and nitrogen

The total loss of phosphorus and nitrogen from the Grillby and Sundbyholm catchments for the sampling period is presented in Table 1.

Table 1. Total mass transport of phosphorus and Nitrogen

Catchment	Measurement period	Phosphorus, tot-P (kg)	Nitrogen, tot-N (kg)
Grillby	2008-07-15 to 2008-04-11	585	32561
Sundbyholm	2008-06-15 to 2008-04-21	2117	50143

The areal loss per unit agricultural land from the Grillby catchment with a size of 40 km^2 and occupied with 66 % agricultural land was 0,22 kg/ha for the sampling period. From the Sundbyholm catchment with a size of 85 km^2 and with 52 % occupied by agricultural land the loss of phosphorus was 0,48 kg/ha for the sampling period. Based on these figures an estimate of the areal loss on an annual basis should be 0,3 kg/(ha*year) for Grillby and 0,6 kg/(ha*year) for Sundbyholm.

Conclusions

It is shown that flow-driven sampling of phosphorus (and nitrogen) is an efficient and reliable method for quantification of nutrient losses from agricultural watersheds since the total loads can be calculated with high accuracy and the complex dynamics of phosphorus losses is captured. A limited number of peak flow events during the winter and spring of 2007-2008 accounts for the majority of the annual loss of total phosphorus from the agricultural catchments of Grillby and Sundbyholm to Lake Mälaren in central Sweden. With traditional monthly monitoring the risk of missing such peaks is evident. It is evident from both catchments that the first high flow event of the winter season exhibits the highest concentrations of phosphorus measured during the sampling period. This flush-out is attributed to high flow events occurring when rain fall on already saturated soils giving high sediment loads with an increased transport of particulate phosphorus.

THAMES

The Thames Basin is an extensively monitored river basin. Long records exist for most hydro-meteorological variables. These have been collected primarily through routine monitoring programmes operated by the Agency and its predecessors. Data are also held by a variety of other organisations, many concerned with research e.g. CEH.

A recent example of a research project in the Thames basin is the thematic research programme called LOCAR funded by the UK Natural Environment Research Council. The objective of LOCAR is to study key water resource issues in the lowlands of the English chalklands. LOCAR examines surface and groundwater supplies, changes in water quality and their impacts on fisheries and wetlands in five intensely instrumented catchments, including the Pang and Lambourn tributaries of the Thames.

The Thames basin is also a representative river basin in the HarmoniRiB project funded by the EU (see references list). HarmoniRiB aims to harmonise techniques for assessment and use of uncertainty information in integrated water management using data from a network of European representative river basis. Clearly, the objective of the project gives it strong links to the TWINLATIN and TWINBAS projects and, like the twinning projects, the relevance of the project to the implementation of the EC Water Framework Directive is high.

The new Thames Regional Telemetry System enables the Agency to have faster access to more accurate and detailed environmental information to assist with flood forecasting and the management of droughts, pollution and environmental protection, and water resources generally, throughout the Thames basin.

The Thames basin is intensively monitored for rainfall and river flow, as well as other hydrometeorological variables. Past/current monitoring activities in the basin are described under the "*Meteorology*" and "*Hydrology*" sections. Parts of the basin, particularly tributaries of special interest like the Pang and the Lambourn, have amongst the most spatially intensive and highest quality hydrological networks in the UK, and current/future monitoring activities in these sub catchments are described in the "*Future monitoring efforts*" section.

Spot samples are taken at about 5000 sites in the Thames basin to monitor water quality. There are also data on river habitats and macro-invertebrates. The majority of the gauged flow data for the Thames basin is artificially influenced by abstractions or discharges upstream. Abstractions and discharges are also monitored by the Agency, but much of this information is confidential, though the licensed amounts can be obtained for research purposes. There is no routine manual monitoring of river sediment loads for either the Pang or the Lambourn, nor regular bulk sampling for suspended solids, nor continuous measurements of river turbidity. There is random sampling of effluent discharges and spatial investigations of pollution incidents

Identification of priority data needs

State indicators measure the quality and quantity of natural resources e.g. quantity of river flow, chemical river water quality.

Assessing the state of the environment at a point in time is a very complex undertaking. Lack of any previous comprehensive or fully integrated means by which the state of the environment as a whole has been assessed is, in part, because many of the standards which apply to environmental materials have evolved independently to protect against specific risks. The different aspects of the state of the environment can be differentiated by distinguishing between the three environmental media: water, air and land.

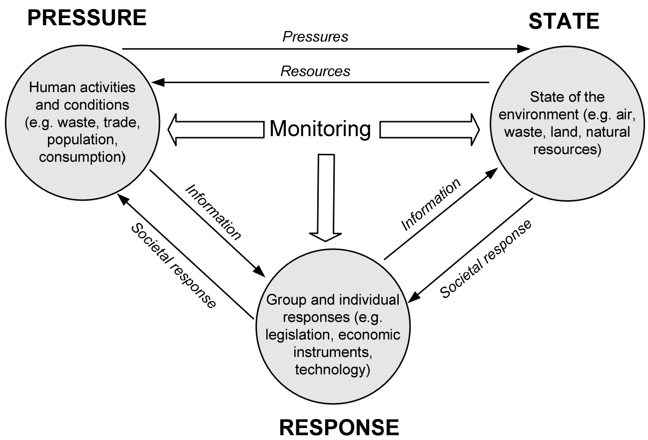


Figure 4. State-pressure-response framework used by the Agency

The pressures on the environment arise from both controllable and non-controllable sources. Some pressures relate to geographical position, the nature of the countryside, population density and distribution. Some pressures arise directly from controlled releases of substances to the aquatic environment, to the atmosphere and into and onto land. Pressures also arise from the abstraction of materials from the environment, most notably that of water from both surface and groundwater sources.

The response indicators illustrate actions or activities intended to address the current state of the environment, or the pressures acting upon it. The trend in these indicators over time is classified as: improving or positive progress; change uncertain or mixed; or deteriorating or no/unfavourable progress. The results to date, and the predicted future trends, illustrate the intense pressure that the basin's environment is under. The information is used to help formulate and update Local Environment Agency Local Plans (LEAPs) which are management plans for identifying, prioritizing and solving local environmental issues, and River Basin Management Plan (developed under the Water Framework Directive) to identify any changes in water quantity that are required to achieve a healthy aquatic ecosystem in the Thames basin.

BAKER

The TWINLATIN monitoring efforts in the Baker Basin were oriented - at least to a considerable extent - towards (i) a better understanding of ecosystem functioning, and (ii) the establishment of reference conditions. Together with the results from the identification of pressure sources, this typology can be used in the future for further optimizing the design of the monitoring campaigns.

Freshwater biodiversity

During January 2006, an extensive freshwater biodiversity monitoring campaign was executed by researchers from EULA, in the framework of the research activities of the Centre for Research on Patagonian Ecosystems CIEP. The campaign makes part of (Ph.D.) research at EULA, which is associated to both the TWINLATIN project as well as the small-grant DIUC project "Spatial Patterns of Freshwater Biodiversity in the Aysén Region".

Objectives of the monitoring specifically with respect to the TWINLATIN project were: (**1**) to characterize the diversity and distribution of water body types (this includes an aggregation of the most similar aquatic ecosystems, in order to provide information for checking compliance of future environmental standards based on water body typology – in case it works); (**2**) the identification of reference conditions at different water bodies (and see if there is a relation with theoretically derived water body typology; (**3**) the identification of water bodies currently under pressure; (**4**) the incorporation of biological parameters/reference data in future water quality standards for the Baker River Basin ; **(5)** providing information for the establishment of the Secondary Water Quality Standard for the Baker river.

More than 50 stations were sampled during this January 2006 campaign. Besides the biological parameters (benthonic macro invertebrates, periphyton and bird fauna (field observations)), the following physicochemical parameters were measured: Conductivity, pH, Dissolved Oxygen, Temperature, visual Turbidity, Turbidity and Color. Measurements of depth and speed were also carried out.

Additionally, a limited amount of monitoring on the presence of native fish species in lake ecosystems is being executed in the framework of a collaboration with a DIUC project entitled "Spatial & Temporal Patterns of the Native and Non-native Lacustrine Fish Fauna of the Aysén Region: an Approach based on Community and Population Levels", which is also associated to the EULA, CIEP & TWINLATIN research activities on the Baker River Basin and wider Aysén Region.

In the context of TWINLATIN, the General Water Directorate DGA of the Aysén Region was capable – through the support of EULA – to install 2 turbidimeters with data logger in the Baker River basin. The information obtained from these instruments is currently subject to a validation process by part of central DGA (in the city of Santiago) and is expected to be available for use and for incorporation in the Basin databases.

In collaboration with the CIMAR 14 campaign of the CIMAR-Fjord Program of the National Oceanographic Committee (CONA), samples were taken on board of the investigative ship AGOR Vidal Gormáz, in the zone near Caleta Tortel (mouth of the Baker River), Baker Canal, Mitchell Fjord, until the most exposed zone of the Messier Canal. This is the first study in Chile that analyzes, through a geochemical organic focus (isotopes and fatty acids), the destiny that the organic material has contributed by the rivers, in an ecosystem of canals and fjords in the Chilean Patagonia. The study acquires special relevance in the light of the planned hydropower development on the Baker River, which has led to international controversy.

A Paleolimnologic Monitoring of the Baker Basin lakes which will provide a better idea will be obtained on the influence of important historical pressures (forest fires, overgrazing) on the past and current status of these lake ecosystems, and on background and perturbed erosion rates in these parts of the Baker Basin.

Macro-invertebrate Sampling: extending the 2006 and 2007 campaigns

At each sample sight the following variables were determined *in situ*: (b) physical-chemical parameters of the water column (b) Physical parameters of the river: A visual characterization of the substrate bottom was carried out. The samples of benthic macro-invertebrates (>500 µm), carried out in the stations covered a sample area of 0.6 m^2 with six samples per sight. Below it is presented some general results from the campaigns conducted during 2006 and 2007.

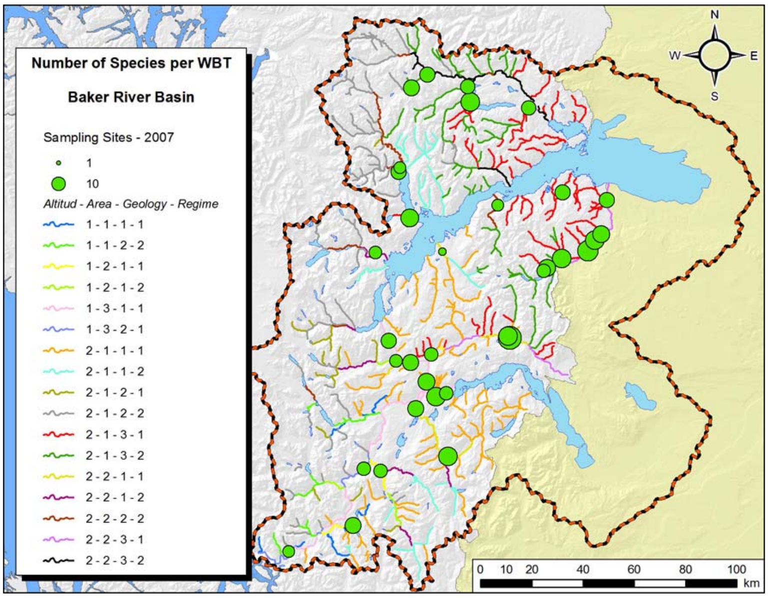


Figure 5. Species richness at the different sampling sites. Background shows the water body typology determined under Work Package 7.

CUAREIM - QUARAI BASIN (Brazilian partner)

Environmental database construction

A **binational geodatabase** for the Cuareim River Basin was developed in the framework of TWINLATIN, used and updated during the whole project. This database was the base for the development of all TWINLATIN Working Packages.

All historical meteorologic data that was only available in paper was digitalized in the framework of TWINLATIN, therefore the database (ArcHydro structured) has all the historical pluviometric and hydrometric records in the basin.

Monitoring activities under TWINLATIN

Some of the main conclusions from this data gathering were:

- The pluviometric monitoring network is not uniformly distributed in the basin and there is only one flow gauging station in the main stream. The quality of the available data varies.
- There is no data of high flows during storm events in tributaries of the Cuareim river (there are only at one specific point at the Cuareim River). Existing low-flow data are not reliable in some cases.
- With respect to real-time hydrometeorology data in the basin, there are gauging stations on the left margin (CTM) but not on the right one. It would be important to add real-time gauging stations on the right margin, especially upstream of Artigas and Quaraí cities, in order to improve the existing preliminary hydrological forecast system.
- Some conflicts have arisen within the Uruguayan territory due to extra need of water (applications for more water-use rights or direct intakes without authorization), that have been resolved with the active participation of the DNH and the Irrigation Assessing Committees.
- There is just a first and partial assessment of the basin's water-quality current condition. Some localized problems of poor water quality have been identified due to the effluents generated from the cities of Artigas/Quaraí. This information is just the result of two water quality campaigns, so that statement is no more than the situation at two specific moments in time. There are no systematic water quality measurements.

- The consequences of the use of agrotoxics for growing crops in the water quality are not known on the left margin (Uruguay) (there is not enough field information to have a diagnosis of the basin in this respect). On the right margin (Brazil), the concentration of total phosphates is above accepted limits. It is important to pay attention to this issue, especially when the use of fertilizers is a common practice in the basin. It is believed that in the Uruguayan territory the problem could be similar, based on similar land uses and common production practices. With respect to metals, mercury and Cadmium have been found in the Brazilian territory with values higher than those allowed. It is likely that similar results would be obtained in the basin in Uruguayan territory.
- During storm events, polluted urban runoff from the cities of Artigas/Quaraí is considerable. This phenomenon occurs with a return period of 2 years. On the other hand during droughts, there may be a considerable decrease in flow and therefore reduced capabilities of auto depuration.
- There are planned monitoring networks to measure water quality data and other environmental data, but they have been implemented neither in the left nor in the right margin. **There is a need for an extensive and systematic water quality monitoring program.** On the left margin (Uruguayan territory) no agrotoxic testing has been performed (in the Brazilian margin there are only localized measurements).

The monitoring under TWINLATIN focused on the determination of some of the general water quality parameters (conductivity, dissolved oxygen, etc); dissolved salts; solids; organic matter; nutrients; microbiologic; and inorganic elements.

The most important output from this transboundary basin was the establishment of the agreement between the TWINLATIN partners - DNH and IPH - to carry out a joint monitoring program in the river, considering water quantity and quality aspects. The main objective of the agreement between IPN and DNH were:

- Get information on water quality of the Cuareim River
- Generate the necessary information for the establishment of a permanent monitoring and management plan for the Cuareim River's basin
- To contribute to the knowledge on how rice irrigation systems work, so to use that information to optimize and improve the management of water resources in the Cuareim River Basin.
    - To determine low flows and their relationship to the area of installed rice fields in the Cuaró River subbasin of the Cuareim River basin
    - To determine the flow and the volume of water that returns to the stream from an irrigated field at the Cuareim River basin

This has been the first monitoring activity done in coordination between both countries in the basin.

In the framework of TWINLATIN, four sampling stations were chosen:

Point 1: Source of the Cuareim River, located on Brazilian territory
Point 2: Upstream the Cities of Artigas-Quarai
Point 3: Downstream the Cities of Artigas-Quarai
Point 4: Paso Paypaso

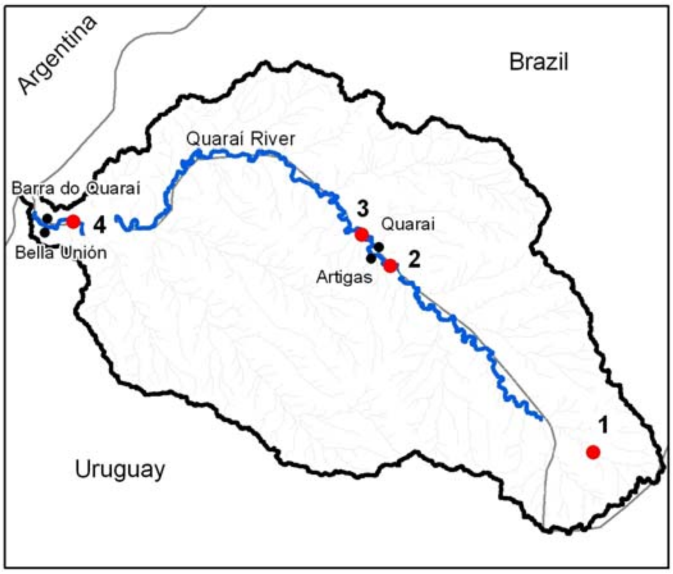


Figure 6. Location of the sampling stations (Points 1,2,3, and 4)

As point 4 is located on Brazilian territory, this point was monitored just by IPH. The other 3 points were monitored by both partners in parallel. During the time period October 2006 - February 2008, DINAMA and DNH (Uruguay) and IPH (Brazil) did 10 monitoring campaigns under the TWINLATIN framework. DNH-DINAMA participated on 9 of the 10.

CUAREIM - QUARAI BASIN (Uruguayan partner)

A **binational database** for the whole basin was implemented, sharing information between the two partners (IPH (Brazil), DNH (Uruguay)). It is a georeferenced database using ESRI Geographic Information System. The ArcHydro Dabase Structure was used as had been agreed by all partners. Metadata was associated to the data.

The **water quantity monitoring** was a pilot study that helped determine the value of the return flow from an irrigated rice field to the creek. This information could be taken into consideration at the time of granting water rights as was done in WP3. More research should continue in this area, for which funds and equipment are needed.

Regarding **water quality monitoring,** a total of 9 monitoring campaigns were completed during the project. In spite of the difficulties to carry them out, being a binational work, it has to be said that for the first time both Brazil and Uruguay in the Cuareim River basin worked together in this issue, and many lessons have been learnt to devise a sustainable monitoring program. There is still very little knowledge about the water quality of the Cuareim River. TWINLATIN Monitoring Program has contributed to it but there is a long way to go. In general, the water quality of the Cuareim River is good but this is based on a low number of observations, so the monitoring has to continue and be improved based on the recommendations outlined in the report.

1) Data base construction: New information was added to the database, in particular satellite images, water quality data, and soils data. The database has been the source of data to all the work done in the different Working Packages. A step-by-step methodology was created for the preparation of metadata and shared with partners.

2) Water Quality Monitoring: New water quality campaigns were done by DNH and DINAMA (09/10/2007, 06-07/11/2007, 08-09/01/2008, 26-27/02/2008). As before, sampling was done following the protocols of the Department of Water Quality Assessment (DECA) of DINAMA. Those protocols are based on the International Program of Environmental Global Monitoring System (Operating Guide GEMS Water, 3rd Ed, 94,1). Lab tests were done at DINAMA. Data of all the 9 campaigns were analyzed. To do the analyses it was necessary to combine the quality data with water quantity information, for which a characterization of the state of the Cuareim River at the time of each water quality sampling was done. The water quality feature class for the geodatabase was prepared. As stated in WP4, DINAMA presented to CCL Artigas a letter from the National Director of the Environment (Uruguay) requesting it to promote a meeting with the ANA (National Water Authority) of Brazil to continue with the water quality monitoring, even after the TWINLATIN project is over, for sustainability of the program.

3) Water Quantity Monitoring: The Cuareim River basin is one of the basins in Uruguay in which there is an intensive use of the water resources, mainly for rice. Rice is grown in summer, and needs big volumes of water, so for basins that are far from water bodies the construction of irrigation systems capable to store water during the year and distribute it during the rice season is necessary.

There are also other systems, when closer to important streams of water, that withdraw water with pumps, directly from the river, and then the water is distributed.

In both cases, the water is transported (from the reservoir or from the pumping site) to the fields through excavated channels and it is distributed by them through lateral outlets. In the case of small reservoirs, generally the fields are downstream, so that the distribution channels can transport the water by gravity without the need of additional pumping. Based on the inventory of the National Directorate of Hydrography (DNH), in 2002 the Cuareim River Basin had 92 reservoirs and 35 direct intakes.

The region has large climate variability over the year and between years.

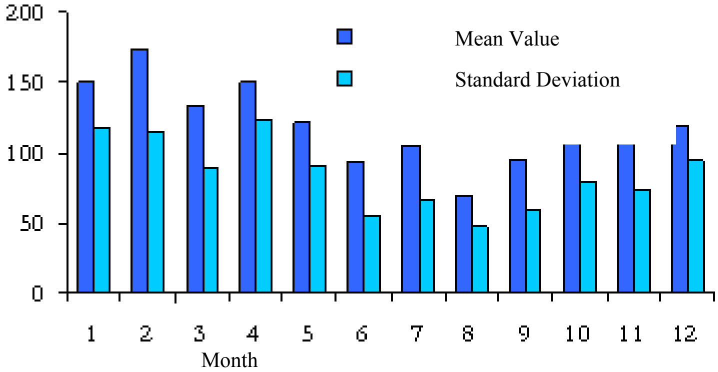


Figure 7. Variability of the mean precipitation (mm per month) for 1970-2005, at Artigas, operated by the National Directorate of Meteorology

Although the water permits are granted as a function of what the water is used for, the Management Agency of the water resources in Uruguay does not know the real demand of crops or the effect of the irrigation system on the hydrologic cycle. In particular, in the Cuareim River basin it is believed that the irrigation systems increase downstream low flows.

The rice sector have recurrently been expressing the need to determine the positive or negative effect of dams and irrigation systems on streams. The office of DNH in Artigas held many meetings with the directors and associates of the Association of Rice Growers of Artigas (ACA), to determine the water systems that could comply with the necessary technical requirements to produce a water balance for a typical irrigation system in the region. With the backing of the ACA four ranches were visited and one chosen on the Cuaró River basin. The owner of the irrigation system of the selected pilot study area allowed the installation of gauging structures, of monitoring instruments for data collection, and he also collaborated with personnel and machinery for the construction of the structures and by measuring the precipitation in the area.

The objective of this was:

- To contribute to the knowledge on how rice irrigation systems work, so to use that information to optimize and improve the management of water resources in the Cuareim River Basin.
    - To determine low flows and their relationship to the area of installed rice fields in the Cuaró River subbasin of the Cuareim River basin
    - To determine the flow and the volume of water that returns to the stream from an irrigated field at the Cuareim River basin

The activities in the pilot project of Cuaró River Basin was used to determine the flow and the volume of water that returns to the stream from an irrigated rice field. Precipitation data used for the analyses was obtained by the producer in the pilot area. Potential evapotranspiration data was delivered by INIA (Salto). Using flows measured outside the rice season, during the period 27/09/2007 - 20/10/2007, a hydrologic model of continuous simulation and with daily-step precipitation was calibrated (HEC-HMS). It modeled the basin without the presence of the rice fields and the irrigation. Flow measurements were taken 28/11/2007 to 31/1/2008. The flows returning from the fields to the creek were calculated as the difference between the modeled flow and the observed one in the periods without precipitation events and with irrigation.

Based on the objectives stated previously, an irrigation system was chosen, where flow measurement instruments were installed. The pilot study was done for the rice seasons 2006-2007 and 2007-2008.

The chosen irrigation system withdraws water from the reservoir using a siphon, then this reservoir cannot let pass the required minimum flow of 0.4l/s/km^2 established by the authority, and it can be then concluded that during the two-year study the total runoff of the basin was stored.

The monitoring that was devised at the beginning of the work had 4 points of measurement:

- Point B - outlet of basin with no intervention
- Point C - at the irrigation channel, at the entrance of the rice field
- Point D - at the river channel before receiving the lateral contributions from the rice field
- Point E – at the outlet of the pilot study

This monitoring scheme to measure flows at points B and D, needed the construction of dikes and spillways. Unluckily, although these were constructed, they did not resist several precipitation events that occurred.

Siphon of the reservoir

Siphon outlet and beginning of the distribution channel

Siphon in operation, water entering the distribution channel

Distribution channel in operation, with lateral outlets to the fields

Figure 8. Photos of the irrigation system

In **Figure 16**, it can be observed at the beginning of the rice season that the measured and observed hydrograms respond differently to the precipitation events. This difference may be due to the initial retention of the planted area at the outlet of the basin. From then, it can be observed that the flows that should decrease in a long period without rain, on the contrary increase, occuring an important flow return from the fields. Ahead, there are two more periods without rain, when new flow-returns occur.

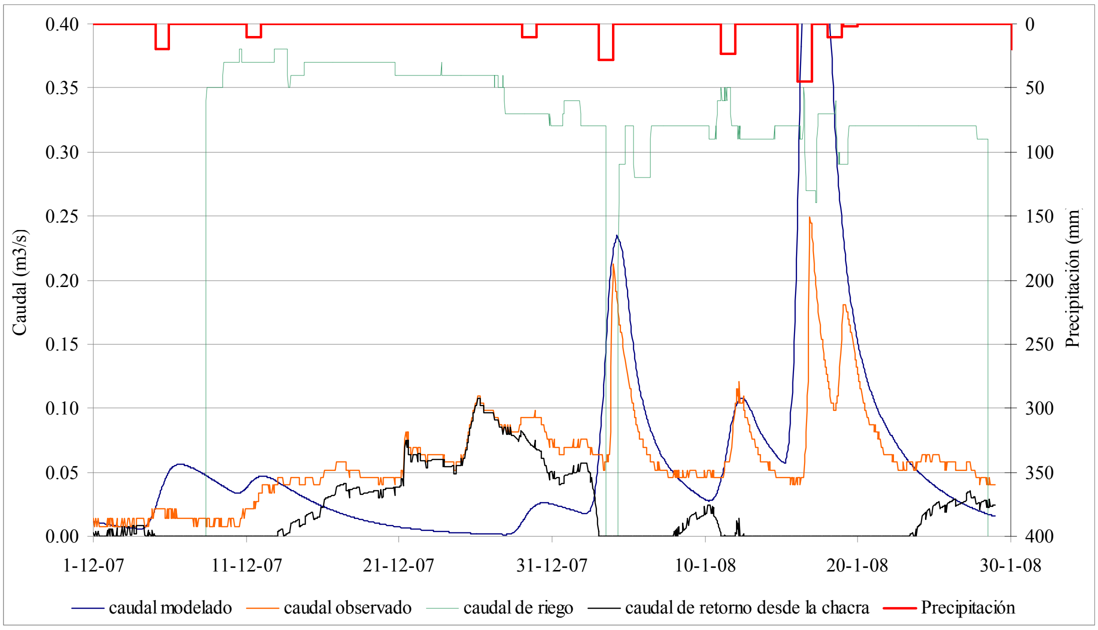


Figure 9. Results from the model and return flows from the field during the rice season 2007-2008. Left axes: flow in m3/s, Right axes: precipitation in mm. From left to right in the reference legend, we have: modeled flow, observed flow, irrigation flow, return flow from the field, and precipitation.

Finally in **Table 2**, the final results of the calculated return flows are presented, being 12% for the rice season 2006-2007 and 7% for 2007-2008. From that Table it can also be observed that the irrigation demand varies from 7700 to 7200 m3 per hectare, a lower value than the one generally used in irrigation projects (usually a demand of 14000 m3/ha is used).

Table 2. Results of the calculated return volumes

Season	***Planted (ha)***	***Irrigated total volume (*1000 m3)***	***Return volume (*1000m3)***	***Percentage***	**Applied irrigation per ha (1000m3/ha)**
2006-7	88	681	83	12%	7.7
2007-8	202	1461	107	7%	7.2

Water Quality Monitoring
Sampling done by DINAMA (National Directorate of the Environment) and DNH (National Directorate of Hydrography) in Uruguay followed the protocols of the Department of Water Quality Assessment (DECA) of DINAMA. Those protocols are based on **the International Program of Environmental Global Monitoring System (Operating Guide GEMS Water, 3rd Ed, 94,1).** This is the mechanism of the United Nations (UN) to coordinate the monitoring activities and environmental evaluations done by specialized UN Agencies and by national and international institutions. The variables that were monitored, grouped into categories according to GEMS Water Program were:

- **General Water Quality:** Temperature, Conductivity, pH, Dissolved Oxygen, % of Oxygen Saturation, Turbidity, and Total Suspended Solids, **Dissolved salts:** Alkalinity; **Nutrients:** Nitrate, Nitrite, Ammonium, Ammoniac, Total Nitrogen, Kjieldal Phosphates and Total

Phosphorous; **Organic matter:** Biochemical Oxygen Demand (BOD5); **Microbiologic contamination:** Fecal or Thermoresistant Coliforms; **Inorganic contaminants:** Aluminum and Zinc.

In addition, other measured variables not included in the GEMS Water Program were:

- Chemical Oxygen Demand (COD); Total solids (TS), total fixed solids (TFS) and total volatile solids (TVS); Total Suspended Solids (TSS), Volatile Suspended Solids (VSS); Total Dissolved Solids (TDS), Fixed Dissolved Solids (FDS) and Volatile Dissolved Solids (VDS)

Figure 10. Field campaigns for streamflow measurement and water quality sampling at the Quaraí river basin

The analyses were done at the laboratory of the National Directorate of the Environment (DINAMA), Environmental Laboratory Department, following internationally validated methodologies, based on the Standard Method for the Examination of Water and Waste Water; 21st edition; 2005. Quarterly monitoring campaigns were made to cover the possible seasonal variation for the different analyzed variables.

Conclusions

Water Quality

- In general, the water quality of the Cuareim river is good
- Some variables show an increase of the relative concentrations closer to the mouth of the river
- Some variables show a strong association with the volume of water present at the time of the sampling.

As a continuation of the work done in TWINLATIN, it is necessary to:

- Select an expanded number of monitoring stations, with a basin approach.
- Modify the frequency of the sampling.
- Monitor other variables such as majority ions that characterize water bodies, or biocides (chlorinated and phosphorated), Halogenated Organic Compounds, etc., in addition to those that have been monitored.
- Include sampling of sediments.
- Continue with the monitoring to improve the data series in terms of quantity and quality
- Relate biological data with environmental data.
- Standardize the methodology of sampling and analysis of samples.

Research on the contribution of nutrients from the basin to the water bodies should be prioritised, with the objective to clarify if the high levels of total phosphorous is a natural characteristic of the basin or an anthropogenic impact.

Considering that Cuareim is a bi-national river, shared by Brazil and Uruguay, it is **essential to coordinate between the two countries**. It is a considerable challenge to be able to define and implement a monitoring program for the Cuareim River. During TWINLATIN, work was done in a coordinated, but parallel way. There is not yet real cooperation between the two countries to carry out a joint monitoring. Even though there are no clear signs of low water quality in the Cuareim River, it is the responsibility of both countries to maintain its quality, and if problems are detected they should be corrected in a shared and joint work. The important pressure that agriculture is having on water quantity will also be affecting the water quality.

In spite of the difficulties to carry out the monitoring during the project, it has to be said that for the first time both Brazil and Uruguay in the Cuareim River basin worked together in this issue, and many lessons have been learnt to devise a sustainable monitoring program.

Water Quantity

Monitoring of the uses of the water resources as the one presented in this study requires important investments in the construction and maintenance. These investments and activities must be done with funds and equipment that the Water Authority in charge of managing and controlling the use of the water resources and the university research centers currently do not have.

The measurement of flows in irrigation channels with the approach used in this work would be difficult for large flows from areas of more than 300 ha of rice. It is recommended that the monitoring of flows of a channel is done by measuring flows and constructing a curve stage-flow that could be verified with hydrodynamic models.

The value of the return flow from the irrigated fields with the methodology used can be estimated to 10% of the applied volume.

COCIBOLCA LAKE

Identification of priority data needs

Because the very low industrial activity in the basin the priority were the substances produced by agriculture, livestock, land use and domestic waste water. Nutrients, turbidity, dissolved oxygen and changes in land use were priority aspects to take in account in the monitoring program in the Lake Cocibolca.

A state-pressure-response framework, like the one used for Thames basin, in dimensions according to the reality and needs in Lake Cocibolca basin, was identified as suitable tool for the management of the basin. At Cocibolca two different DPSIR chains were analysed: 1) erosion as a pressure; sedimentation as an impact (driver= soil use); and 2) pesticide pressure and impact

Monitoring under TWINLATIN

Since September 2006, through the Project TWINLATIN Cocibolca, personnel of the Direction of Water Resources of INETER, every two or three months made measurements of liquid and solid flows on the main 6 rivers of the eastern side of the basin and on San Juan and Frio rivers too (see Table 3). Samples of waters are collected and transported to CIEMA water quality laboratory to determine physical and chemical characteristics of that river waters.

Table 3. Rivers, station code and initial date of solid and liquid measurements

#	River	Measurement points	Code	First sampling date
1	San Juan	2	690102 690112	15-11-2006 14-11-2006
2	Malacatoya	1	690501	29-09-2006
3	Mayales	1	690801	28-09-2006
4	Acoyapa	1	691001	28-09-2006
5	Oyate	1	691201	26-09-2006
6	Tepenaguazapa	1	691302	27-09-2006
7	Camastro	1	6920009	29-09-2006
8	Frío	1	690114	14-11-2006
Total		9		

CIEMA has collected water quality data during the TWINLATIN Project, from records of drinking water wells, and river water samples collected by INETER during the measurements of flow and sediments.

There are data from 89 wells, 17 river points, 3 creeks and 6 lake points. Figure 11 shows spatial distribution of these points and Table 4 indicates the date of first sampling.

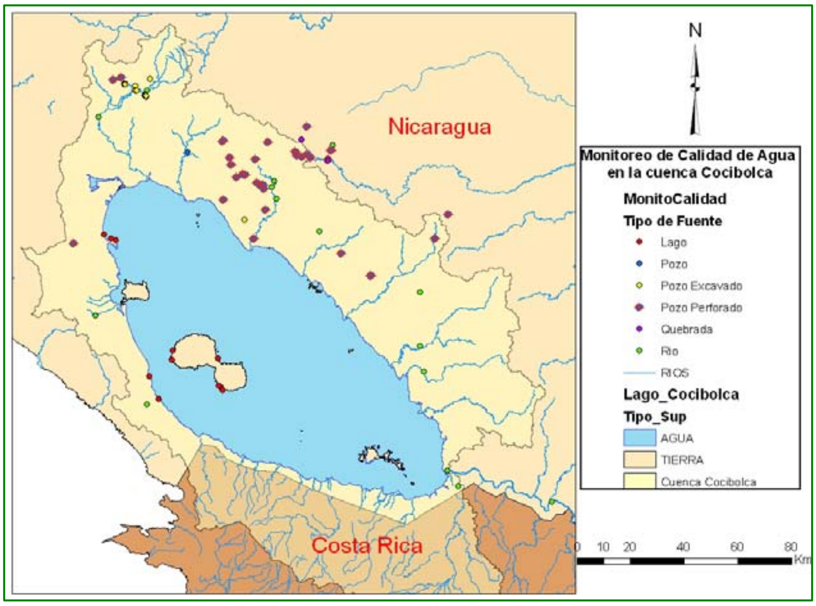


Figure 11. Physical Chemical water quality sampling points

Table 4. Number of sampling points and rivers sampled

#	River	Number of sampling points	Type of analysis	First sampling date
1	San Juan	2	FQ	14-11-2006
2	Malacatoya	2	FQ	18-11-2006
3	Mayales	3	FQ	08-06-2006
4	Ochomogo	1	FQ	01-05-2007
5	Acoyapa	1	FQ	28-09-2006
6	Oyate	1	FQ	26-09-2006
7	Tepenaguazapa	1	FQ	27-09-2006
8	San Miguel	2	FQ	16-03-2004
9	Kinuma	1	FQ	16-03-2004
10	Camastro	1	FQ	29-09-2006
11	Las Lajas	1	FQ	01-05-2007
12	Frío	1	FQ	14-11-2006
Total		17		

Table 5 shows a list of parameters measured in samples collected from different waters sources in different time periods by differents agents (CIEMA, NICANOR).

Table 5. Water quality parameters measured in samples

Parameter	Lake Cocibolca (CIEMA) (2006-07)	Rivers	Creek	Wells	Lake Cocibolca (NICANOR) (2004-07)
Total Arsenic (As)			X	X	
Carbon Dioxide	X				
pH		X			X
Conductivity		X			

Turbidity		X			
Color		X			
Alkalinity		X			
Bicarbonate		X			
Total Hardness		X			
Calcic Hardness		X			
Calcium		X			
Magnesium		X			
Chloride		X			
Ferrum		X			
Nitrite		X			X
Nitrate		X			X
Sulphate		X			
Sodium		X			
Potasium		X			
Fluoride		X			
Phosphorus		X			X
Nitrogen		X			X
Suspended Total Solids		X			
Total Solids		X			
Dissolved Oxigen					X
Chlorophyll					X
Temperature					X
BOD 5					X
Ammonium					X

In addition to this, through a twinning effort with EULA, a field campaign was conducted to obtain sediment cores for 210Pb from the Lake and the Las Canoas reservoir. Results from these cores (analysis to be conducted) will aid in the interpretation and validation of the results from the erosion modelling application conducted by means of the WATEM-SEDEM tool.

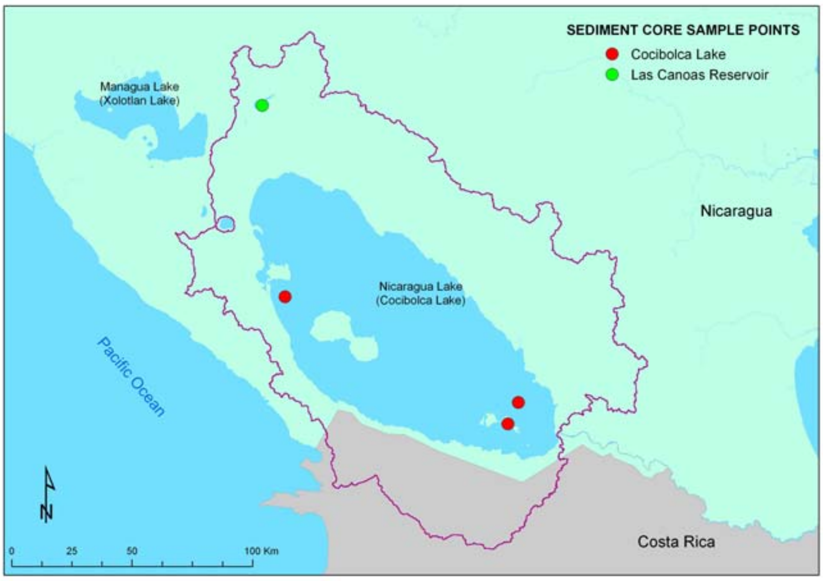


Figure 12. Sites in the Cocibolca Lake Basin where the sediment cores have been taken

Results from all monitoring efforts were incorporated in the Georeferenced Environmental DataBase System for the Cocibolca Lake SIGACC, based on the ArcHydro time series model. Data has been made available to the water authority INETER for future work on the Cocibolca Lake Basin. The information will also constitute a valuable input for the Nicaraguan "Country Environmental Assessment", to be conducted in the first half of 2009.

CATAMAYO-CHIRA

Identification of priority data needs

The Catamayo Chira is a river basin that has been intensely studied in its lower parts, due to the hydraulic infrastructure of the Poechos reservoir. In spite of this, there are gaps of quality information within the river basin and a lack of continuity in the registry of certain parameters (meteorological, hydrological, sediments, hydrogeology, flooding limits, water uses, etc.).

Priority substances for monitoring

For the Catamayo Chira River Basin, a systematic water quality monitoring program that fulfilled the requirements of the Peruvian and Ecuadorian water quality laws and regulations had not been put in place before the project. The main objective of the TWINLATIN water quality monitoring program was to monitor the parameters that these laws identify. Some of these parameters (physical and chemical, microbiologic, biochemical) were being monitored in some sites of the river basin by different institutions, but a periodic monitoring program with consented parameters, technical protocols, time frames and frequencies was needed, in order to offer a more holistic and systematic perspective of the actual water quality status.

Heavy metals had never been monitored (due to the lack of budget) by the responsible institutions. These were going to be priority substances for the TWINLATIN water quality monitoring program since they posed a potential problem for the area and it was suspected that the concentration of some of these substances could be exceeding the recommended maximum safety limits.

Although the participant institutions had equipped laboratories for carrying out the physical, chemical, biochemical and microbiological analysis, there were no laboratories in the area having quality certifications for carrying out the needed analysis. The task had to be commissioned to outsiders laboratories, in Lima, in Peru, and Cuenca, in Ecuador.

Monitoring under TWINLATIN
The primary goal of Catamayo Chira water quality monitoring program has been to provide information about the water quality condition of the river. This has allowed the establishment of a baseline of water quality, to use it as a reference point for the determination of the changes that might be occur to the water system in the future and to be taken into account by decision makers.
Specific objectives of the program were to:

- Monitor the condition of the water courses in the Catamayo Chira River;
- Identify problems related to source water quality;
- Evaluate the effectiveness of existing activities to prevent or remediate water contamination and
- Evaluate if applicable water-quality goals, standards and guidelines were being met.
- Increment the technical and technological capacities of the local competent institutions creating a binational structure around the topic of water quality of the basin for the experience and information transfer

The number and distribution of the elected monitoring sites is shown in the Figure 13. Sites were chosen coming to a consensus with the Peruvian and Ecuadorian participating institutions. The list was subject to changes along the timeframe of the project with the aim of improving representativeness of the sites.

Altogether, the Catamayo Chira Monitoring Program included 28 sites to be monitored. These sites were chosen in accordance to the following criteria:

- To use existing monitoring sites, with functional equipment to measure the river flow and with good accessibility all along the year
- To monitor each subbasin
- To establish a well distributed program taking into account the variability of climates, land use, population, human impacts and budget limitations.

- To identify the potential influences of activities on the surrounding land and water (mainly, to identify the influence of the point sources).

Figure 13. TWINLATIN monitoring sites

The parameters monitored in the Catamayo Chira Water Quality Monitoring Program were:

A. - Physical: Temperature, Hydrogen potential, Dissolved solids, Smell, Colour, Turbidity, Floating material and foams, Greases and oils, Electric conductivity.

B. – Chemical: Dissolved Oxygen, BOD_5, Total Nitrogen, Nitrates, Nitrites, Sulphates, H_2S, Relation Nitrogen - Organic Phosphorous, Ammoniac, Cyanide, Chlorine, Chloride, Phenolic compounds, H_2S

C. – Microbiological: Total coliform, Fecal coliform

D. - Heavy Metals: • Arsenic, • Barium, • Cadmium, Magnesium, Zinc, Copper, Iron, Chromium, Mercury, Lead, Manganese

The above was the final list consented by the Peruvian and Ecuadorian participant institutions. This list was changed during the project because it was adapted to the real needs of the program, depending on the results of the first monitoring campaigns. In the frame of TWINLATIN project, seven quarterly samplings were done at every monitoring site.

In the frame of TWINLATIN, seven monitoring campaigns were done, in the following dates:

First monitoring campaign	: July – August, 2006
Second monitoring campaign	: October, 2006
Third monitoring campaign	: Mars, 2007
Forth monitoring campaign	: August, 2007
Fifth monitoring campaign	: November, 2007
Sixth monitoring campaign	: Mars, 2008
Seventh monitoring campaign	: June, 2008

Analysis and data processing procedures

In the Catamayo Chira River Basin, as a binational river basin, there was a need of developing a binational institutional structure related to water quality. Among other tasks, this institutional structure or committee should work for the homologation and uniformization of the water quality monitoring procedures, the organization of the monitoring campaigns, the transference of information and the sustainability of actions. This would include the harmonization of the list of parameters, the sampling procedures, the analyzing protocols and the data processing activities.

The Catamayo Chira project, in the frame of TWINLATIN, started this process and created a binational technical working group that conducted the monitoring work. The group was conformed by the following institutions:

- Dirección Regional de Salud Ambiental (DESA - Sullana). DESA is a decentralized organ of the Dirección General de Salud, the Wealth Peruvian Minister (DIGESA). Its functions are the authorization of every spill of waste waters in the river, the determination of limits of pollutant concentration in water and the vigilance and control of water quality of natural rivers.
- Subcomisión Ecuatoriana para el Aprovechamiento de las Cuencas Hidrográficas binacionales Puyango – Tumbes y Catamayo Chira (PREDESUR). It is responsible of the planning and execution of works for the promotion of integral development of sectors and subsectors of economy of the south region of Ecuador.

The available TWINLATIN budget was destined, initially, to complement the budgets of the water quality responsible institutions participating in the program. This allowed the monitoring of additional sites and parameters (as heavy metals) that normally were not reached because of budget limitations.

Results from the monitoring

In general, the values of the parameters measured in the field (temperature, dissolved oxygen, electric conductivity and pH) correspond, with punctual exceptions, with normal values of water quality. The monitoring sites present well oxygenated waters and this fact shows a good ecological potential of the river and a good auto depuration capacity. Total solids values oscillate between normal ranks and increase downstream. This behaviour is shown by most parameters, as the waters of the river receive the effluents of human activities. In the case of electric conductivity, the increase of the value is proportional to the increase of dissolved solids and reflects the level of mineralization and the presence of salts. Values are especially important from P06 station until the main outlet of the river.

At some stations, the parameter dissolved oxygen presents alarming values, below 2 mg/L. This is due to the elevated concentration of organic mater in the river. The anoxia in these sites supposes a serious impact for the living conditions of aquatic flora and fauna of the river, and is a especial problem in the Puente Viejo of Sullana, where this situation is permanent.

Total solids and turbidity are closely related and measure the level of "clarity" of the river. These are important parameters because affect directly the uses of water, the treatments that the water will need for those uses and the aquatic life. The values of solids and turbidity increase downstream, as waters collect the sediments from the slopes of the basin and the dusts from pits and other areas where materials explorations near to rivers are done. These kinds of activities generate elevated punctual values that could limit some uses of water, as in the case of P-14, in the Chipillico river, and raise the price of the depuration treatments.

The presence of sulphates, nitrates and phosphates in water is due, probably, to the influence of human activity, principally to the agrarian and domestic activities. The concentrations that appear in the results are lower than the legal maximum limit. Nevertheless, due to the agrarian character of the river basin and to the potential impacts that these substances could have, it is necessary to continue the monitoring of these parameters in the agrarian areas of the basin.

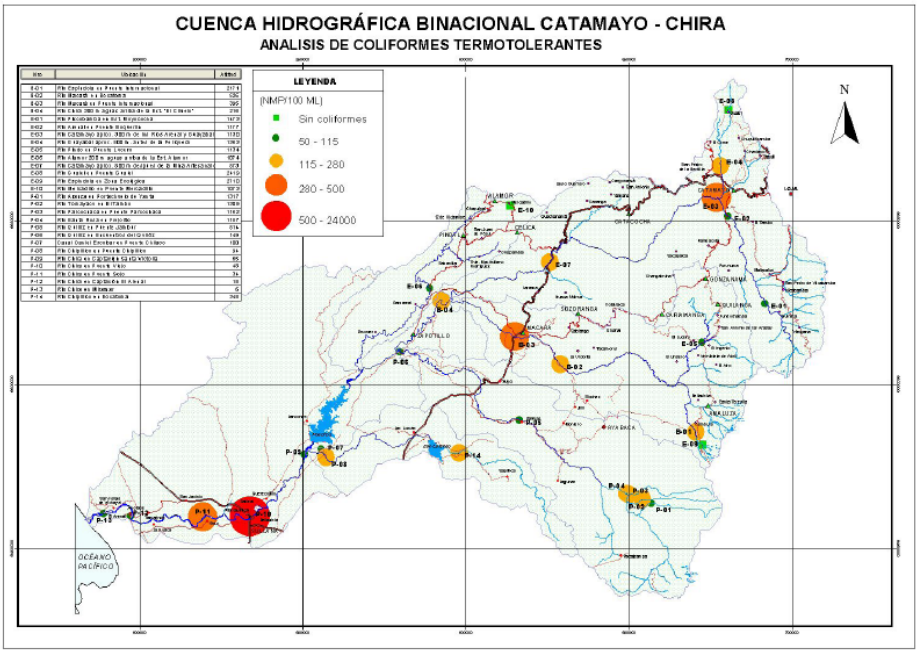


Figure 14. Results of coliform bacteria analyses

With regard to oils and greases, indicators of domestic human activity, their presence is significative in points with vehicular transit or accessible areas that population uses for diverse objectives as cleaning up.

Magnesium, manganese, iron and arsenic concentrations were low that does not represent risks for the uses of water. It is important to remind that because of the geological condition of the river basin, the water presents a tendency to have concentrations of salts and other chemical elements naturally. This is the case of Barium that presents values that deserve a further research. The probable cause of theses values is the presence of natural deposits of baritina that, by mineralization, can produce, in raining conditions, similar concentrations to those founded in some campaigns. The rest of heavy metals monitored don't present significant values.

The most significant parameter in the river basin is the microbiological. The presence of termotolerant coliforms shows clearly the occurrence of domestic sewerage spills, without any previous treatment, to the river. This is the principal problem related to water quality in the river basin and a risk for human and livestock health. Furthermore, this contamination of water presumes the existence of other infectious parasites for humans, case that will have to be studied with more detail. Diarrheic diseases, parasitosis, infantile malnutrition and other diseases of the dermis are some of the problems associated frequently to the direct ingest of this water that population do without any previous treatment. These risks are particularly dangerous to the health of children of less than five years. Next page presents a map that shows the distribution of the microbiologic results in the river basin.

Observations on the sustainability of an operational monitoring plan

Sustainability of operational monitoring was the main issue addressed to ensure the perdurability of TWINLATIN water quality actions in the river basin taking into acount differents fronts: **Institutional component (**This would take the form of a binational committee, representing the main institutions in both sides of the river basin, with legal competences in the water quality field); **Economical component (**The activities of the program have been included in the second phase of the Catamayo Chira project and this ensure the continuity of actions in the following years); **Social component, a** set of social communication activities related to water quality in the river basin were planned and developed in the frame of TWINLATIN. This was carried out participatory with other related institutions and NGO's working on the same field and in the same area, to ensure the creation of synergies and to reach bigger objectives.

CAUCA

Identification of priority data needs

Priorities set by the TWINLATIN Project framework have the following scope in terms of monitoring:

- Improvement in the quality of the water model through the establishment of constant kinetics in experimental form in the Cauca River.
- Establish the pilot projects of erosion and integrated gestion of the Water Resource in the basins of Bugalagrande y Tuluá Rivers.
- Complement the monitoring of sediments to improve the pilot projects of the erosion models and the quality of the water for the integrated management of the water resource, in the basins of the Bugalagrande and Tulua Rivers, sub basins of the Cauca River, located in the middle zone of Valle del Cauca. In these basins, the exploitation pressure on river materials and water resources is high.

Monitoring activities included:

- Water quality monitoring from the upper part until to Salvajina, in order to have consolidated basin information
- Sediment monitoring for the Bugalagrande and Tuluá River Basins
- Monitoring of main basin discharge sources
- Quality and Fog monitoring in the Tuluá River Basin

The Cauca River basin covers jurisdictions under CVC and CRC, the environmental authorities. Therefore, information management and development of project priorities have to be defined by the two Corporations.

Hydrology modeling and water quality work will continue in the sector corresponding to the valle of the Cauca River, between Salvajina and La Virginia, given the fact that Salvajina Dam has modified the regime.

River drag material overexploitation has been identified as a problem by CVC Management. Another problem encountered is the considerable demand of water quantity and quality at the higher part of the Upper Cauca sub-basins. This situation calls for development of projects that improve mining zoning and effficiency in use of available water.

The priorities selected for these studies are the Bugalagrande and Tuluá Rivers, two important sub-basins of the Cauca River. River sediments were monitored in the first basin. Results obtained on sediment production in the pilot Bugalagrande basin were useful for erosion studies of diffuse source contamination (WP06 work package). The quantity and quality of water present in the fog (horizontal precipitation) was assessed in the second basin in order to study the possibility of implementing fog water collection systems for the better use of water resources in areas where water availability is scarce or none. The results of these studies can later be replicated at other sub-basins.

Priority substances for monitoring

Cauca River Critical Parameters. In 2003 CVC, with the support of Universidad del Valle, identified critical parameters for water quality monitoring. Results obtained in this study are a powerful tool for the selection of parameters to be more frequently monitored by CVC in order to evaluate water resources quality in a more representative manner. The Cauca River common and non-common parameters were defined as critical for the evaluated usages, being No. 1 the section having the largest amount of critical parameters (The section between the Hormiguero Bridge and Mediacanoa). These are the critical parameters identified:

- Dissolved Oxygen
- BOD_5
- DQO
- Suspended solids
- Turbidity
- Color
- Phosphates
- Ammonia nitrogen
- Iron
- Manganese
- Total coliforms
- Fecal coliforms

These critical parameters include those associated with water quality (DO, BOD_5, DQO), suspended materials (S.S.T), nutrients (Phosphates and Ammonia nitrogen), Metals (Iron and Manganese) and pathogens (Total and Fecal Coliforms).

Water demand satisfaction in the pilot basin was complemented by monitoring the quantity and quality of fog water. Horizontal precipitation information using fog measuring devices was collected in the highly foggy study zone. The following parameters were analyzed to determine the quality of water for human consumption: Turbidity, Color, Hardness, Total Iron, Nitrites, Sulphates, Total Coliforms, E-Coli, Fecal Coliforms and pH.

Monitoring under TWINLATIN

Considering the current status of the Cauca River Basin, it is important that the environmental authorities continue with ambitious monitoring efforts in the study area.

Joint meetings were held between Corporación Autónoma Regional del Valle del Cauca CVC and Corporación Autónoma Regional del Cauca CRC, to determine monitoring activities to be implemented. It was concluded that it is necessary to jointly monitor water quality in the study section to document the river water quality and to apply the water quality modelling in the Bugalagrande and Tulua River Basins which have been chosen as pilot basins for scenario analyses relating to erosion modeling and integrated water resources management.

Monitoring sites

According to monitoring sites presently established by environmental entities, Table 6 shows monitoring sites where physical-chemical water quality information is updated:

Table 6. Monitoring sites

Station	Corporation	Status
Before the Vinagre River	CRC	Presently being monitored.
Before the Piedras River discharge	CRC	Presently being monitored.
Before the González settlement (before the entrance to Popayán)	CRC	Presently being monitored.
Julumito, exiting Popayán	CRC	Presently being monitored.
Entrance to Salvajina Dam	CRC	Presently being monitored.
Salvajina exit (vehicle bridge over the Cauca River on the road Morales – Suárez)	CRC	Presently being monitored.
La Balsa bridge	CRC	Presently being monitored.
Before the Palo River	CRC	Presently being monitored.
Hormiguero Bridge	CRC	Presently being monitored.
19 stations over the Cauca River	CVC	Presently being monitored.

Monitoring the main quantity and quality pressure sources:

Sediment monitoring in the Bugalagrande River basin in order to have data for the implementation of a layer erosion model is made on sites chosen for suspension sediments. These are El Placer station and site known as Puente Nuevo. Liquid and solid measurements were made during a 2 month period (May – June, 2008), taking samples every 2 days on average. The horizontal precipitation monitoring project in the Tuluá River pilot basin includes the installation and operation of 6 fog measuring devices in the upper part of the basin. Figure 15 shows the installation and arrangements of devices used to measure and use the water resource represented by fog in the zone.

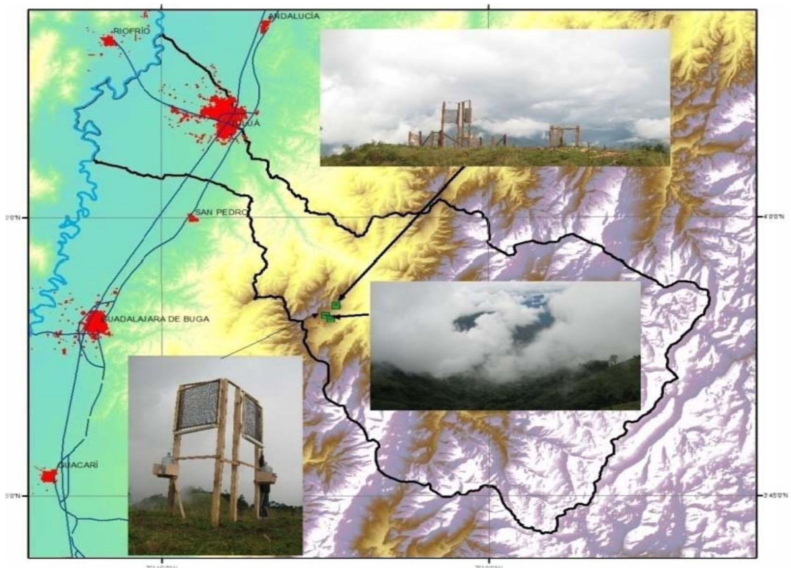


Figure 15. Location of fog measuring devices in the Tulua River Basin

Parameters monitored

Physical-Chemical and Bacteriological Quality. Measurements included in the proposed monitoring are those previously described as critical parameters. Of these parameters monitored by CRC, the following are not analyzed: Iron, Manganeso and Ammonia Nitrogen.

Sediments. Another component added is sampling of suspension sediments (Concentration of water sediments) in order to monitor erosion processes in the basins. The pilot basins used are the Bugalagrande and Tuluá River basins.

Data processing and analysis

Information processing on the physical-chemical and bacteriological Cauca River water quality, as well as the main pressure agents, will be used to optimize the Cauca River Water Quality Modeling.

CVC has been working on the integrated management of water resources project for the Cauca River basin. The representative basin is denominated Zone 2 in the geographic valley, considering the following criteria:

- This basin has historical hydroclimatologic information which is basic to reconsider location of new stations.
- The lower part of the basin has an intermediate population of more than 190,000 inhabitants and active agricultural practices that jointly generate pressure and conflict in water resources usage.
- Water resources production starts at an altitude of 4,000 meters above sea level (high barren plateau) until an elevation of 1,400 meters, where the last important tributary is located. That is the location of the hydrometric station of Tuluá-Mateguadua, which is in charge of characterizing natural regime flows.
- There is a hydrometric station located before the Cauca River mouth (Tuluá-La Rafaela station) that monitors intervened regime flows. This can also be considered a permanent water quality gauging station.
- In the mid lower part of the basin there was a meteorological station owned by IDEAM (Botanical Garden). This station can be refurbished for the new monitoring network.

In the framework of the water resources integrated management for the Tulúa River basin, it is required to optimize water distribution. In order to take advantage of fog as a water resource, fog metering devices will be installed to evaluate its availability in terms of quality and quantity.

On the other hand, in the pilot basins of the Tuluá and Bugalagrande Rivers, samples and analyses of suspended solids will be used for pilot erosion modelling.

Data quality & metadata issues

Selected partners comment on the issues of data quality and metadata generation. The contributions to this chapter with regard to the proposal for selection of a metadata standard and profile for future work in the Latin-American case study basins were mainly prepared at EULA/CIEMA, with support from DNH.

EULA/CIEMA/DNH

The discussion on data quality and metadata issues which is given below mainly originates from the problems encountered during the construction of the environmental database, and the use of the data sets in the work for the different work packages in the case of the Nicaraguan study basin (Cocibolca Lake). However, as similar problems occur in many other river basins, or can even be considered to be universal, we feel it is of general interest in the context of the reporting on the TWINLATIN activities, and with regard to the outreach of the project results to include this discussion here.

Data quality

A considerable problem encountered during the construction of the georeferenced environmental database for the Cocibolca Basin (the so-called "SIGACC"), as well as during the execution of the different research activities under TWINLATIN, was the inexistence of, or the lack of readily available, good and high-quality input data sets covering the entire study area.

The need for metadata – an introduction

The experiences from the TWINLATIN work on the Cocibolca Basin clearly show how the lack of readily available and consistently structured documentation for the existing datasets (**metadata**) has complicated the advances during the project execution towards the achievement and delivery of durable, high-quality results from research for which a broad acceptance by a wide group of stakeholders can easily be guaranteed, and which therefore can serve for real-world decision-making.

Therefore, during the execution of TWINLATIN, at EULA-Chile/CIEMA-UNI an analysis has been made of the literature with regard to the creation of documentation for geographic/thematic data sets, as well as with regard to related standards, data profiles and available tools. Additional twinning between EULA/CIEMA and DNH also provided input with regard to the use and interoperability of selected metadata generation tools. In what follows we provide the reader with both a basic introduction and the most important conclusions obtained from this research.

Metadata are commonly defined as: "data about data". They describe the content, quality, format, etc. associated to a resource, and constitute a mechanism for characterizing data and services in such a way that users (and applications) can locate and obtain access to those data sets that best serve their specific purposes.

Analysis of metadata standards, profiles and editing tools under TWINLATIN

As a conclusion from the work conducted under TWINLATIN, we highly recommend the **systematic generation of metadata in all future efforts** in the twinned (and other) river basins. For this purpose, the **ISO 19.115** international standard needs to be the reference. We currently recommend the practical implementation of this standard for the data sets for the Cocibolca Lake Basin (and other TWINLATIN basins) by means of the Spanish Data Profile **NEM ("*Nucleo Español de Metadatos*").**

Whereas an exhaustive analysis of standards, profiles and tools for the generation of metadata could be conducted under TWINLATIN, unfortunately due to time and logistical constraints the production of metadata for the generated datasets for the Cocibolca (and other partner) basin(s) could only be started in the last phase and should therefore urgently be continued in the ongoing post-TWINLATIN efforts. The following figure shows the different metadata elements that should be included in a data source's description, according to the NEM (figure in Spanish).

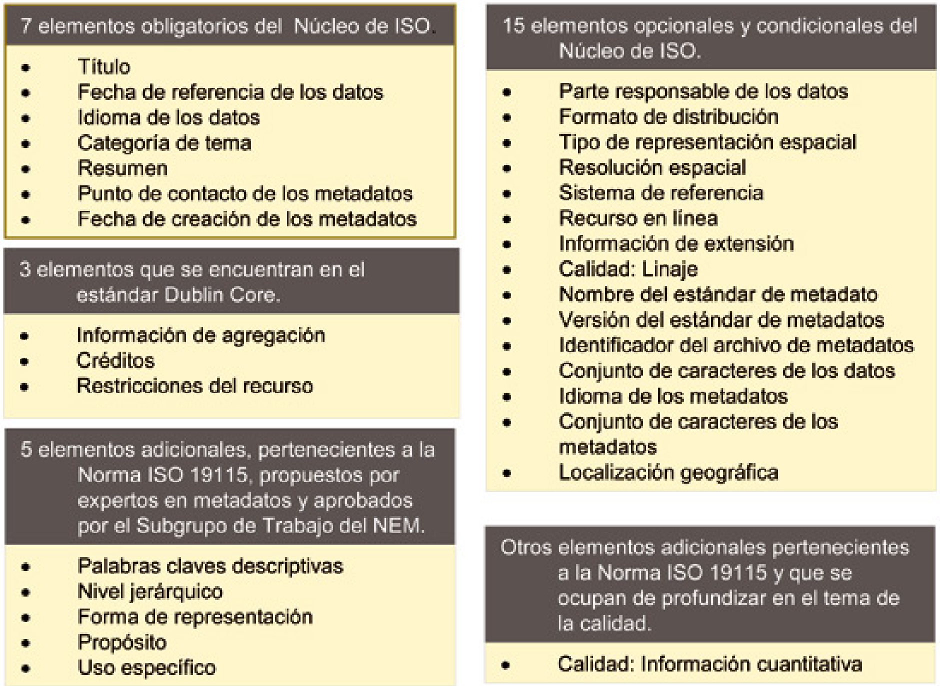


Figure 16. Elements to be included in the metadata according to the Spanish Metadata Profile NEM ("Nucleo Español de Metadatos")

DNH

In Uruguay, collections of metadata exist under the FGDC and ISO 19115 standards (being the latter a generalization of the former). Currently, the Interinstitutional Group that is working in the IDE (Uruguayan Spatial Data Infrastructure) is assessing, and it is practically a fact, the adoption of the NEM profile (Núcleo Español de Metadatos - Spaniard Nucleus Metadata), which is a synthesis of the ISO19115 standard, and by transitivity will be transparent to the FGDC format.

In the framework of TWINLATIN, we will work with the **NEM profile, so to comply with the ISO standard** and at the same time, we will enrich it with the **FGDC format, that is the one adopted by ESRI tools** (GIS environment in which the geographic information has been managed in a geodatabase in this project. As part of the project, a setp-by-step methodology has been created for the preparation of metadata as well as metadata was created for the feature classes, rasters and tables included in the Cuareim River Basin Geodatabase:

3.3 WP3 Hydrological modelling and extremes

The requirement to manage water resources in an integrated and sustainable manner has become a driving force behind the use of models for understanding of how basin hydrology will be affected by change. Accurate hydrological modelling is a necessary basis for all Integrated Water Resource Management (IWRM) phases. Considerable research efforts are needed to enable hydrological modelling in some of the Latin-American basins, and depend very much on local conditions (ranging from tropical to polar climate zones), observed or expected problems and the availability of historical datasets in each basin.

The main objectives of this WP were:

- To contribute to the understanding of the importance and interaction between different key processes in the generation of water and contaminant flows, and of their relation with specific human activities (soil & water use) in the study basins, through the application of physically-based and/or spatially distributed mathematical models.
- To assess the dynamics of the flooding problems in the Quarai, Catamayo-Chira and Cauca river basins and create a basis for flooding scenario modelling based on climate change effects in all basins, through GIS based monitoring and modelling tools.
- To provide validated modelling tools, as well as results from the application of these tools, required for identification of corrective actions and their impact as well as for assessment of actual and future ecological status of the water bodies.

Hydrological modelling applications have five principal stages, once the model itself is selected, namely: data collation and pre-processing, model set-up and configuration, calibration, validation and evaluation. The model is then ready to use for whatever purpose it has been developed and implemented. Data requirements may differ considerably, but are often extensive. Ideally, a long-term, wide-ranging, systematic monitoring system will have been in place in the basin, with a quality-controlled database, maintained by the central authority with the mandate to disseminate the data to users as required. Unfortunately, this is rarely, if ever, the case, and WP2 was charged with compiling and assessing all available data from current and earlier monitoring programmes in each basin, in order to design and implement a monitoring programme for TWINLATIN, with the aim of providing the data needed for other WPs, including WP3.

It should be noted that data are of many different types and originate from many different measuring devices and different sources. In simulating the behaviour of a catchment and river system, the hydrological model integrates these data, and inconsistencies can lead to errors in the computations, which may or not be evident in the output. Investigation of data and model uncertainty is largely beyond the SCOPE of TWINLATIN, though was examined as part of the modelling activities in the Lake Cocibolca basin.

Approach to hydrological modelling

In each of the Latin American river basins, a questionnaire was used to identify the problems to be solved and, therefore, the most urgent research needs under WP3. This had the added benefit of guiding the TWINLATIN partners, several of whom had little experience of hydrological modelling at the start of the project, thorough a thought process to assist them in clarifying the various issues to be considered in model selection, development and application. The questionnaire sought information on the reasons for modelling, the spatial and temporal scales for the modelling, and the data that were or would be available (see WP2 report). Recognition of the aims, data and resources available for the hydrological modelling lead to a choice of appropriate model(s).

In some basins, obviously, these changed through the lifetime of the project, as a result of developments in other work packages and also external factors, such as different priorities identified by stakeholders during public participation activities. Tables 7 summarises the final outcomes from this exercise, together with other issues such as the exchange of modelling experience between basins, the relevance of the modelling approaches to other non-TWINLATIN basins, and the wider applicability within the Latin American region.

The table reveals that there is a lot of similarity between the current water uses in each basin, the priority issues to be addressed during TWINLATIN generally, and WP3 specifically, and the future application of the modelling.

Table 7. Approach to hydrological modelling

Issue	**Baker Chile**	**Catamayo-Chira Ecuador-Peru**	**Cauca Colombia**	**Lake Cocibolca Nicaragua**	**Cuareim/Quaraí Brazil-Uruguay**
Area (km^2)	26,726	17,200	62,000	24,000	14,800
Transboundary?	yes	yes	no	yes	yes
Why model?					
Current water uses	Water supply, irrigation, mining, conservation	Water supply, irrigation	Water supply, irrigation (coffee, sugar cane), industry (paper)	Water supply, fishing, navigation, conservation, tourism	Water supply, irrigation (rice fields)
Priority issues	Lack of data, glacier/ snowmelt issue, HEP development	Water demand, WQ/ sediment, reservoir siltation, deforestation, intensive agriculture	WQ, pollution from industry & intensive agriculture, waste disposal, water rights	Water availability, WQ/sediment, deforestation, intensive agriculture, waste disposal, navigation, water rights	Water availability, WQ, urban flooding, low flows/ droughts, small farm dams, water rights
Modelling applications	Land use/ climate change	Land use/ climate change impacts on WQ/erosion	Land use/ climate change	Land use/ climate change	Water resource scenarios, land use/ climate change
Data availability and modelling time interval					
Data availability	Very poor in Baker, mixed in amount & quality in BioBío	Poor amount & quality	OK amount of data, quality poor	Poor amount & quality	Global datasets available, local data mixed in amount & quality
Time interval	Daily	Monthly	Daily	Daily/monthly/ annual	Daily
Spatial scale	1 sub-basin of Biobío	Basin & 4 sub-basins	1 sub-basin	Basin & 1 sub-basin	Basin & 1 sub-basin
Model selection					
Choice of model	SWAT to Lonquimay sub-basin of BioBío to further develop snow/ glacier/ TWINBAS work	SWAT to 4 sub-basins in upper & mid basin, & outlet	HBV/IHMS to basin – for TWINLATIN work to Tulua sub-basin of Cauca	Simple WB & WASMOD WB for basin WATSHMAN-PCRaster in Mayales sub-basin & GLUE uncertainty	SWAT, MODSIM to Tres-Cruces sub-basin MGB-IPH large-scale distributed hydrological model to basin
Data requirements	Topography, met data, rain, snow, flow, land use, soils (daily)	Topography, met data, rain, flow, land use, soils (monthly)	Topography, met data, rain, flow, soils, veg (daily)	Topography, met data, rain, flow, soils (daily)	Topography, met data, rain, flow, land use, soils, veg, x-sections,reservoir & small farm dam data (daily)

where: HEP – hydroelectric power, WQ – water quality, WB – water balance, x-section – cross-section

Table 8. Hydrological models used during TWINLATIN WP3

Model	Description	Basins
GWAVA	Large-scale distributed model	South American continent
HBV/IHMS	Hydrodynamic forecasting model	Cauca
MGB-IPH	Large-scale distributed model	Cuareim/Quaraí
MODSIM	Water allocation model	Cuareim/Quaraí
SWAT	Physically-based rainfall-runoff model	Biobío, Catamayo-Chira, Cuareim/Quaraí, Norrström
WASMOD	Water balance model	Cocibolca
Water balance	Water balance model	Cocibolca
WATSHMAN	Distributed rainfall-runoff model	Cocibolca

Issues unique to the Baker basin were the general lack of data, including glacier and snow melt information, for modelling to assess the impacts of hydropower development in a predominantly natural basin. Whilst "data" *per se* subsequently proved to be an important issue for many of the basins, as it is indicated, the implications for modelling in the Baker within the timeframe of TWINLATIN were particularly significant, as it quickly became clear that meaningful spatially distributed hydrological modelling was simply not feasible. Instead, an alternative strategy was implemented, developing a hydrological model for the snow-fed Lonquimay sub-basin in the Biobío river basin, thereby further developing the work started under TWINBAS. Experience gained from this effort can then be transferred to the Baker basin as part of future, post-TWINLATIN, activities.

Apart from the Baker, all Latin American partners chose to model the entire basin, in addition to at least one sub-basin, usually selected by importance and/or data availability. Apart from the Catamayo-Chira, all partners chose to model at a daily time step. In the end, six different hydrological models were used by Latin American partners under WP3, ranging from a simple water balance to a large-scale distributed model, as listed in Table 8. SWAT was used in three of the basins, who benefitted greatly from the exchange of knowledge and experience. Despite the model being used, common data requirements in the basins included topographic data, meteorological data, flow data, and land use and/or soils data.

Each of the TWINLATIN study basins varies dramatically in terms of climate, geography, hydrological response and the issues faced by the inhabitants e.g. flooding, water quality, sustainable water resources, soil erosion and development, amongst others. Basin-scale modelling ambitions focus on specific localised issues. A continental approach can provide a wider regional context for some of the problems faced, in particular water resources. It can also provide an opportunity for climate change impacts to be examined and compared at the continental, regional and basin scales. Therefore, the Global Water AVailability Assessment (GWAVA) model (Meigh *et al.,* 1998; Meigh *et al.,* 1999) was applied to the South American continent (excluding Nicaragua) enabling a broader regional picture of hydrology and spatial extents of water scarcity to be examined. The continent-wide approach means that a consistent methodology can be applied across four of the subject basins in the TWINLATIN project (Baker, Catamayo-Chira, Cauca and Quaraí/Cuareim) as well as the regions in between.

NORRSTRÖM

In the TWINLATIN project only the closest area around the Lake Mälaren has been modelled, the contributing watersheds to Lake Mälaren have already been modelled in the TWINBAS project. Figure 17 shows the area that has been modelled and the meteorological stations that were used.

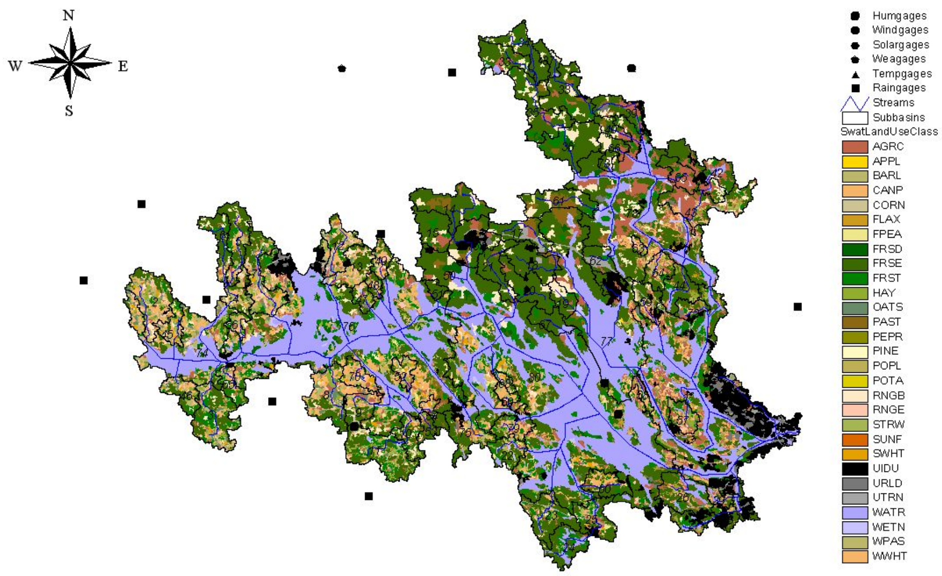


Figure 17. The Lake Mälaren and its surrounding land use

Natural Setting

The Norrström River Basin covers an area of 22.600 km^2, which corresponds to about 5% of the area of Sweden. The basin includes two of Sweden's largest lakes: Mälaren, which has an area of 1000 km^2, and Hjälmaren, which covers approximately 500 km^2. The number of people living in the area is approximately 1, 2 million. In the Norrström Basin, forests and mires dominate the landscape and cover about 70% of the surface area.

Norrström river basin is one of the most studied areas in Sweden, much because of its location in a densely populated area with its outlet to the Baltic Sea in Stockholm. The basin is commonly divided into 12 tributaries, all with outlets in Lake Mälaren. Administratively, the Norrström basin belongs to 31 municipalities, and is a part of six different counties. The closest area around Lake Mälaren covers 4900 km^2 and is dominated by forest.

Hydrology

Agricultural areas occupy an additional 20%, while lakes cover around 10 % of the Norrström basin (Wallin et al., 2000). The Mälaren and Hjälmaren lakes are connected through the Eskilstunaån River. The outlet of Lake Mälaren to the Baltic Sea is situated in the centre of Stockholm. The Lake Mälaren has 10 major tributaries (Arbogaån, Kolbäcksån, Hedströmmen, Köpingsån, Svartån, Sagån, Örsundaån, Fyrisån, Råckstaån and Eskilstunaån), which together contribute approximately 80 % of the total inflow. Lake Mälaren consists of several bays and islands and has been divided into six well-defined basins. The westernmost basin, Galten, receives 46 % of the total inflow, while the other sub-basins receive between 11 and 24 %. During the last 30 years the water flow at Norrström has been 164 m^3/s in average. The precipitation shows greater variation than the water flow, which shows regular variations. Average annual precipitation for period 1961 to 1990 was 618 mm in Västerås and 541 mm in Uppsala. The monitoring of Lake Mälaren started in the mid 1960's. During the late 1960's and early 1970's there were large improvements in chemical composition and biological status.

Water Resources

Mälaren provides drinking water to 1, 5 million people and is also the recipient of the wastewater from the surrounding cities and industries. Advanced sewage treatment and continuous monitoring of water quality is thus of utmost importance.

Lake Mälaren is both an important transport route for oil and chemical products and an appreciated recreational resource. Both lake itself and its tributaries have been stepwise dammed since 1943. For instance, 24 hydropower stations are situated on Svartån, Arbogaån, Kolbäcksån and Hedströmmen and many more dams and ponds control water flow in Norrström basin.

The major problem is nutrient transport, causing eutrophication both in smaller rivers and lakes as well as in Lake Mälaren and in the Baltic Sea. The contribution of agricultural land to the net load on Lake Mälaren is significant since large agricultural areas are located in the nearby area, with direct drainage to the lake and with very little retention. This has a large impact on the total nutrient transport to the lake. However few studies have been conducted on the importance of the area close to Lake Mälaren, so far most studies have been focused on the surrounding tributaries. The area near Lake Mälaren is 4900 km^2, i.e. about 20% of the total Norrström river basin, of which 2416 km^2 is open land and 1338 km^2 forest and wetlands. According to recent data, the total load from agriculture could be as high as 280 ton phosphorus and 3400 ton nitrogen from the whole basin. The measurements are however scarce and the real figures could be both higher and lower.

Table 9. Input data to the AVSWAT model and its resolution.

Classification	Type of data	Resolution
Meteorological	Precipitation	Daily
Meteorological	Min & max temperature	Daily
Meteorological	Air humidity	Daily
Meteorological	Wind speed & solar radiation	Daily
Stream flow	m^3/s	Daily

There are several different monitoring programs in the Norrström river basin regarding water quality. The Swedish University of Agricultural Sciences (SLU) is data host for the national monitoring program initiated by the Swedish EPA. This data has high quality and accuracy and was therefore used in the modelling.

Hydrological modelling in Norrström subbasins

The Norrström river basin is divided into 12 different tributaries (subbasins) of which Hedströmmen, Köpingsån, Sagån, Svartån, and Örsundaån have been hydrologically modelled within the TWINBAS project. The subbasin Lake Mälaren has been modelled within the TWINLATIN project. Considering the best available data regarding land use, water flow and nutrient measurements, the modelling period for the different subbasins in the Norrström basin was set to 1996-2001. This period was then divided into two periods, calibration year 1996 –1998, and validation year 1999 – 2001. The first six months of each period was used as a “warm up” period to avoid errors related to initial conditions. By running the model for six months the model is more likely to better represent the area than it would be from the start when it comes to initial parameters for variables like soil water content, infiltration rate and soil chemistry. The agrohydrological year (July to June) was used in order to encompass both main water flow episodes and important agricultural management operations.

Results of hydrological modelling in Norrström subbasins

Calibration results from Lake Mälaren

The subbasin of Lake Mälaren has been modelled for water flow. The subbasin of Lake Mälaren has three locations where daily measurements of water flow were available, which increased the accuracy in the calibration. Unfortunately these locations were not optimal from a calibration point of view since they were not evenly distributed in the subbasin. Figure 18 shows the location of the measurement station in the subbasin of Lake Mälaren. The station near Stockholm was not used due to difficulties in modelling the water flow from Lake Mälaren. The statistical values for Lake Mälaren are shown in Table 10. The calibration period was set to July 1996- June 1998 and climate data set including point sources was created for the period 1 January 1996 to 31 December 1998. The simulation period lasted three years but the first six months were used as a “warm-up” period to avoid initial errors related to initial conditions.

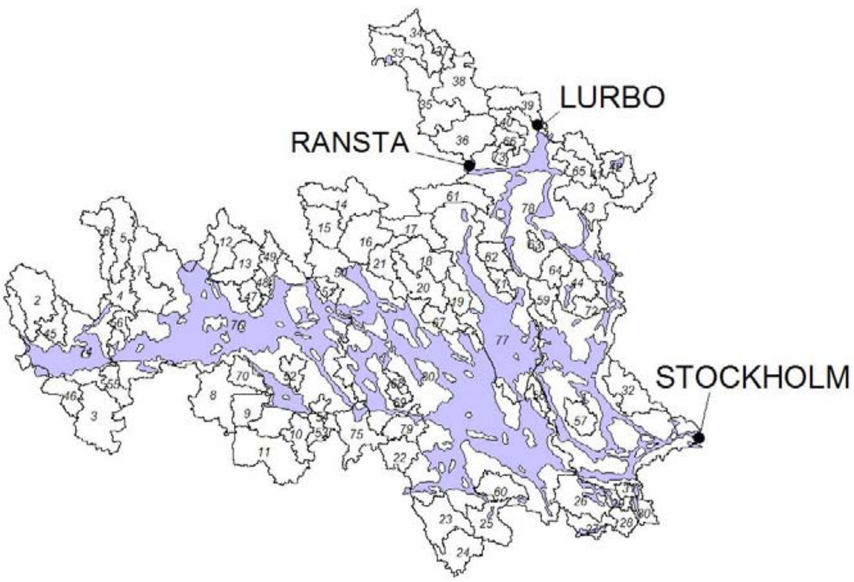


Figure 18. Measuring stations used in the modelling.

The Figure 19 shows the dynamics of the model for the measuring station Ransta for the whole period 1996-2001. The results show good adjustment to dynamics but some problems due to snow melting parameters.

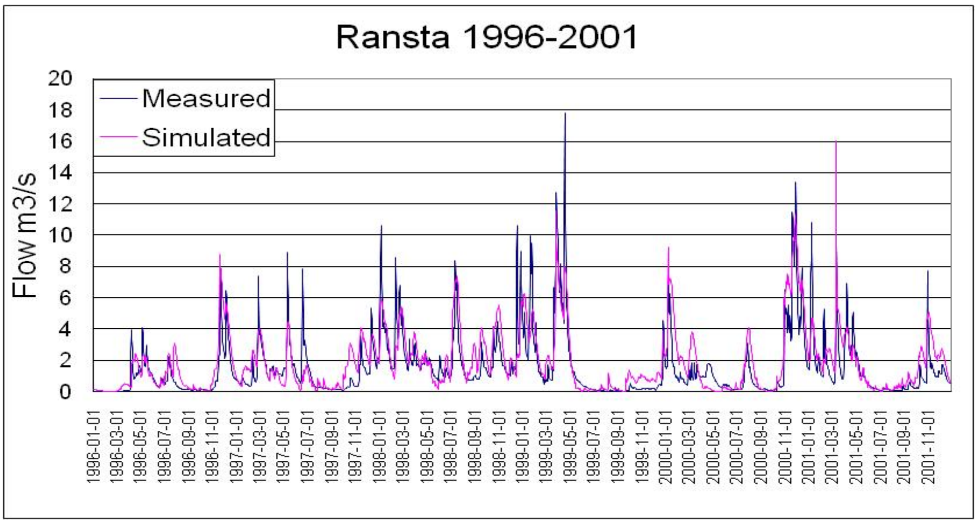


Figure 19. Measured and modelled water flow at Ransta measuring stat ion 1996-2001

Table 10. *Hydrological results for Lake Mälaren.*

		Lake Mälaren	
Calibration		**Ransta 1996-1998**	**Lurbo 1996-1998**
	Coefficient of determination (R^2)	0,56	0,59
	Nash-Sutcliffe model efficiency (Reff)	0,49	0,54
	Deviation of water flow volume (Dv)	0,16	0,21
Validation		**Ransta 1999-2001**	**Lurbo 1999-2001**
	Coefficient of determination (R^2)	0,74	0,68
	Nash-Sutcliffe model efficiency (Reff)	0,6	0,65
	Deviation of water flow volume (Dv)	0,35	0,21

Validation

A good correspondence between the measured and simulated water flow is necessary to model the water quality. If there is too large of differences between the model results and the measured results the pressure modelling will suffer in reliability, since much of the phosphorus leakage is influenced by intensive precipitation and water flow.

Although calibration is a time consuming task and sometimes very difficult depending on the accuracy of input data such as soil types and amount of calibration points, it is preferable to use “nested watershed” approach, which is associated with calibration at several stations whenever possible. The results are thereby improved and uncertainties reduced. In Lake Mälaren this was however not possible, this made the calibration more difficult.

Results from flow proportional measurements conducted by IVL

To further improve the pressure modelling two flow proportional measurement stations have been set up in the surrounding area of Lake Mälaren. The geographical locations of the two stations are shown in Figure 20. Measurements were only being conducted during one year, between 2007 and 2008. This makes it hard to calibrate and validate the water flow for the stations, especially since the two stations are located on different places than the Stabby and Ransta which both are located in the northeast. On the other hand the different geographical location constitutes a good test for the earlier water flow modell settings. The results from the flow proportional measurements helps also to get a better understanding of the nutrient loading from the agricultural areas around Lake Mälaren.

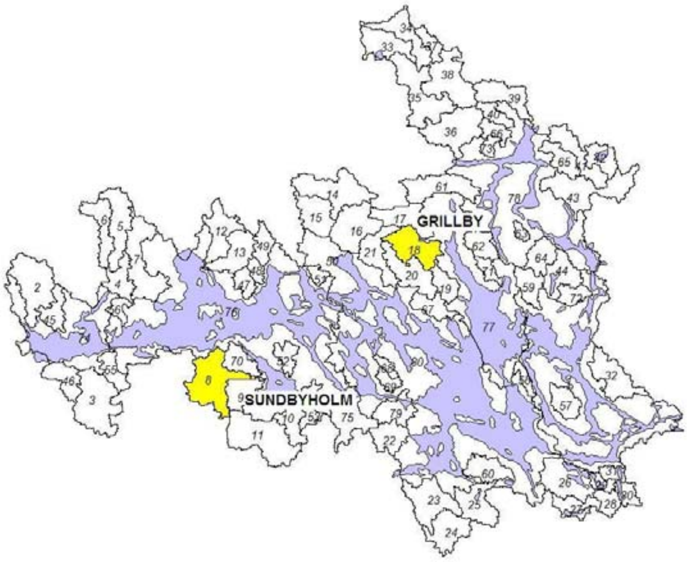


Figure 20. Lake Mälaren catchment as represented in the SWAT-model. Sub-basin division coincides with the Swedish national division system. The catchments where the flow-driven sampling stations are located are indicated with yellow.

The hydrological result for the Ransta subbasin for the period 2007-2008 was satisfying, and validates the result for the earlier model parameters for the calibration and validation period. The prerequisites for the flow proportional measurements are different, where both Ransta and Lurbo receives water flow from upwards located subbasins, Sundbyholm and Grillby are the sole subbasin for the water flow.

Even though the prerequisites for the two subbasins for flow proportional measurements, differs from the location for the flow measurements stations used during calibration and validation period, the hydrological results were satisfying for the Grillby and Sundbyholm station after some minor calibration. The result for the calibration year is shown in Table 11 below and Figure 21.

Table 11. Results for flow proportional measurements and Ransta

		Lake Mälaren		
Results	**2007-2008**	**Grillby**	**Sundbyholm**	**Ransta**
	Coefficient of determination (R^2)	0.61	0.59	0.66
	Nash-Sutcliffe model efficiency (R_{eff})	0.48	0.55	0.60
	Deviation of water volume (D_v)	-0.17	0.01	-0.20

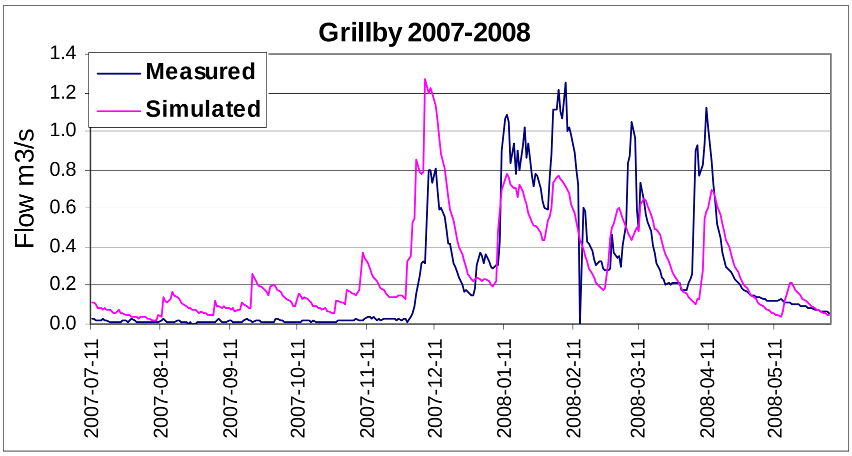


Figure 21. Hydrological results for Grillby

Limitations

Modelling should give feedback to existing monitoring programs, data collection and database development.

1. **Predefined delineation**

   In areas where watershed delineation into sub-catchments already exists it would be preferable to use predefined watershed delineation. This is now available in a later version of the SWAT model, this version was however not available when the project started.

2. **Application of SCS CN method in Sweden**

   In Sweden the use of SCS Curve Number (CN) method for runoff calibration is limited and national or regional databases relating a Curve Number to local land use and/or soil types are not always available. Surface runoff seldom occurs in Sweden's flat landscape (Grip & Rodhe, 1991). In Sweden, surface runoff is more often the cause of saturated soils or freezing processes that lowers the soil conductivity, than a result of intense precipitation. Hence the recommended CN value is something that must be revised when calibrating the model, since they often result in too high simulated values for surface runoff.

3. **Soil maps**

   Existing soil maps are of rather low resolution. Additionally, data and soil types from Swedish Geological Investigation are rather poorly described regarding texture and soil physical properties. Combination of this data with data from Eriksson et al. (1997) and Wiklert et al. (1983) study is an improvement but further efforts and mapping of Swedish soils are needed to facilitate model applications at the watershed scale.

4. **Lake Modelling**

   The SWAT model build to model watersheds and nutrients and not to model lakes as first priority, therefore the lake modelling within SWAT is not its biggest strength. When modelling areas with a large proportion of lakes it can therefore be hard to calibrate the water flow from the lakes.

5. **Tile drainage**

   Data regarding distribution of tile-drained fields in a GIS format is not available. One third of Swedish arable land is assumed to be drained, but the drainage that the farmers usually have is not digitised and information is lacking on higher scales such as municipality or regional levels.

6. **Physical characteristics of water bodies.**

   Data concerning physical characteristics of streams and lakes is scarce. This made it very hard to model the area of interest since the Lake Mälaren constitutes such a big fraction of the total area. The knowledge of the fluctuations of water level in Lake Mälaren is also scarce.

7. **Water flow monitoring**

   As concluded above, more than one point where water flow is being measured considerably improves the accuracy of the results. The use of "nested watershed" gives better model results and a lower amount of uncertainties. In the modelled area this was not possible and due to the geographical locations of water flow measurements.

Discussion of hydrological modelling results

The hydrological results were satisfying; the major difference between the calibration and validation period was that the validation had a higher correspondence. This is explained by the difference in precipitation between the two periods. The validation period therefore has higher statistical results, which shows that the model is not incorrectly calculated. In all subbasins there are some peaks that are missed. This may be attributed to many reasons such as a low resolution of precipitation, lacking information of drainage, scarce measurements, and information concerning the soils hydraulic conductivity. In the beginning of each period there was a low response that can be explained by the lack of knowledge of the initial soil and climate parameters of each model run. This also motivates the use of the agro-hydrological year and thereby letting the model run for six months before comparing the results.

An important precondition for pressure modelling is satisfactory modelling results of water flow and dynamics. Considering the coarse resolution of some input data layers, specifically soil profile data, and the low amount of monitoring stations for water flow, the achieved results regarding water flow were of sufficient quality to proceed with the nutrient modelling. The conclusions that can be drawn from this work package regarding the hydrological modelling are that it is possible with available data to get a good overview of the situation and produce reliable data.

Support to CIEMA and INETER, Nicaragua

IVLs support to CIEMA and INETER regarding hydrological and water balance modelling continued during 2007 and 2008 with visits to Nicaragua, email and telephone contacts, as well as a substantial work effort carried out from Sweden and in Nicaragua, carried out mainly by Ida Westerberg. The results are mainly described but the effort is also mentioned in WP 10 –Twinning activities.

The main results for the hydrological modelling activities in the Lake Cocibolca basin are the characterisation of the precipitation regime and the calculation of the water balance; the latter is required by the new National Water Laws in Nicaragua and a priority for the end user INETER. Through a substantial effort of structuring, quality control and analysis of the climate data a consistent database was created in TWINLATIN as a sound basis for further study.

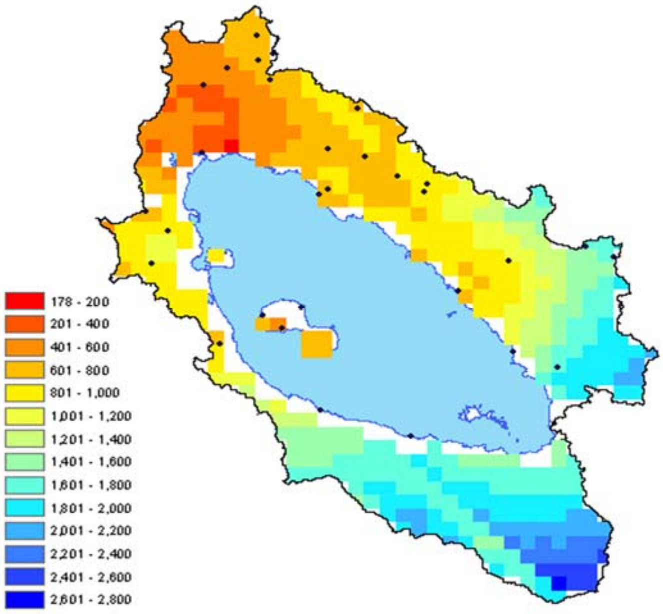


Figure 22. Mean annual run-off in mm in 2000-2005 calculated as a long-term water-balance. Not valid in the Costa-Rican (SE) part of the basin as there were no precipitation data there during this period.

The quality and availability of precipitation and particularly discharge data (which contained many missing values and few high-flow data) limited the possibilities for modelling and underscored the need for uncertainty analysis. The water balance of the basin was estimated comparing the results of a long-term water balance based on satellite-derived evaporation data from the MODIS-project[1] and interpolated mean annual precipitation, with that of a monthly water-balance model. In the future it would be important to assess the water balance at sub-annual scales too, but some idea can be given by the interpolated mean monthly precipitation; water resources are especially scarce in the north-western part of

[1] Mu, Q., F. A. Heinsch, M. Zhao, and S. W. Running (2007), Development of a global evapotranspiration algorithm based on MODIS and global meteorology data, *Remote Sensing of Environment*, *111*(4), 519-536.

the basin during the dry season (Dec–April). There were no complete years of discharge records during the period 2000-2005 for evaluation of the simple water-balance method. But a comparison with the monthly water-balance model application in the Mayales sub-basin showed that mean annual runoff for the long-term water balance was higher (around 700 mm in 2000-2005) than the uncertainty bounds of the monthly-scale water-balance model (around 150-400 mm). Possible explanations could be that there is deep seepage from the groundwater directly to the lake in the Mayales sub-basin or that MODIS-evaporation is underestimated. It could also be that the monthly water-balance model is predominantly calibrated with low and medium-sized flows.

The feasibility of daily-scale hydrological modelling was also assessed in the Mayales sub-basin through the application of the distributed WATSHMAN-PCRaster model within GLUE. Data limitations and high spatiotemporal variability made daily-scale hydrologic modelling problematic. Given the uncertainties in the simulations, modelling of un-gauged catchments and scenario modelling on a daily time scale do not appear feasible. Daily-scale modelling could be a useful tool for quality control, as an evaluation of the coherence and quality of the hydro-meteorological data.

Recommendations for the future

Daily scale hydro-meteorological analysis using interpolated precipitation is not recommended (if the density of precipitation stations is not very high); given the spatiotemporal correlation structure a 4–5 day timescale would be the shortest possible for meaningful interpolation of precipitation. Larger data availability on a monthly time scale favours monthly or yearly analysis. A thorough revision of discharge data should be carried out to remove outliers, and rating-curve data analysed to assess uncertainties in discharge data. In this process it would be important to establish the highest measured discharges included in the rating curve to know which discharge data are based on the extrapolated parts of the rating curves. If possible more high-flow measurements should be made to reduce uncertainty in peak flows. Frequent rating measurements also make it possible to change rating curves more often and improve the calculation of discharge from gage height. Scenario modelling of land-use change effects could not be recommended with the present data-quality problems. Land-use change effects can be expected to be seen in the dynamics of the peak flows; given the high climate variability and the high uncertainty in peak discharges such effects would be hard to detect in the data. It is highly recommended to use uncertainty estimation in future modelling studies in the basin.

Support to DNH, Uruguay

A hydrologist from IVL (Tony Persson) prepared and conducted a two-week on-the-job training effort at DNH – Uruguay in October 2007). Part of the work time was put on WP 10 – Twinning, and part on this WP. The objective was to implement a model system for reservoir management and granting of water rights in the Cuareim River in northern Uruguay.

Support to UNIGECC, Peru-Ecuador

An agronomist/modeller from IVL (Peter Wallenberg) prepared and conducted a two week on-the-job training course at UNIGECC in Piura, Peru (2 weeks, October 2007). The activity was aimed to support UNIGECC with completing the setup of hydrological input files for the SWAT modelling software and solve problems encountered when attempting to run the model. The model setup was completed successfully and the modelling was carried out without further problems. Part of the work time was put on WP 10 – Twinning, and part on this WP.

CEH-W

South America continental modelling

South America has a total land area of 17.8 million km^2. The continent extends across some 67 degrees latitude from tropical, sub-tropical and temperate climates. It is characterised by diverse landscapes and habitats of the Amazonian rainforest, the Pantanal wetland and the Andean mountain chain that runs almost the entire length of the continent. The Andes are important in regulating the eastward movement of moisture onto the continent from the pacific giving rise to the arid Patagonian steppe, as well as the presence of glaciers and icefields. The water balance of this continent is of special importance to the global hydrology as well as to the 346 million inhabitants (FAOSTAT) and reported to account for 28% of the total world freshwater resource (FA0, 2003).

Development of water resources is variable throughout the continent. Argentina and Brazil have reasonably well-developed water resources infrastructure with reservoirs for water supply and hydropower generation. The most notable scheme is the Itaipu Hydropower plant on the border of Paraguay and Brazil which, in 2007, provided an estimated 91% of total energy needs of Paraguay and 19% of the Brazilian electricity demand (source: Itaipu Binational http://www.itaipu.gov.br).

Each of the TWINLATIN study basins varies dramatically in terms of climate, geography, hydrological response and the issues faced by the inhabitants e.g. flooding, water quality, sustainable water resources, soil erosion and development to name but a few. Basin-scale modelling ambitions focus on specific localised issues. However, it is hoped that, from a water quantity perspective, a continental approach will provide a wider regional context for some of the problems faced, in particular droughts and water resources. It will also provide an opportunity for climate change impacts to be examined and compared at the continental, regional and basin scales.

The aim of applying a global-scale model in TWINLATIN is to provide a broader regional picture of hydrology and spatial extents of water scarcity. The Global Water AVailability Assessment (GWAVA) model (Meigh *et al.,* 1998; Meigh *et al.,* 1999) enables water use to be superimposed on top of the water supply (runoff), thus enabling water scarcity and/or abundance to be examined.

The model is, of course, limited in the approximations made by discretising the land surface into 0.5 degree cells and this will impact most greatly on the small catchments (those occurring on the western Andes). The continent-wide approach does, however, mean a consistent methodology can be applied across four of the subject basins in the TWINLATIN project (Baker, Catamayo-Chira, Cauca and Quaraí/Cuareim) as well as the regions in between. Particular advantages will be apparent when examining changes in climate through the application of Global Circulation Model (GCM) outputs as well as examining demographic changes which also impact at the national level.

Global Water Availability Assessment (GWAVA) for South America

The **G**lobal **W**ater **A**vailability **A**ssessment (GWAVA) model (Meigh et al., 1998) combines a detailed hydrological model with the water resources system on a 0.5 degree grid enabling spatially distributed assessments of water availability to be made. The GWAVA model has been applied to the South American continent on a spatial resolution of 0.5 degrees and the model is driven by monthly precipitation, temperature and potential evaporation data. Water demands are computed on a monthly basis and modelled streamflow outputs are also monthly.

Effects of change can be examined through the changes to the simulated streamflow hydrograph available at each cell and through a suite of water availability indices which compare the available freshwater to the demand in that cell. The model scheme allows the user to apply simple adjustment factors to the driving rainfall or to examine more complex patterns of change obtained from outputs of global climate models (GCMs) and, thus, can be used to examine relationships between precipitation and runoff generation at the cell and basin scale, and the combined effects of changing temperature and precipitation on soil moisture. Building upon this, scenarios of population growth can be used with and without climate change scenarios to understand more fully the relative importance of each effect.

Inputs

Along with climatological data to drive the model, information on land cover, soil texture, mean elevation and drainage direction must be specified per grid cell as well as information on the location and capacity of lakes, wetlands and reservoirs if required. Sub-grid information on elevation bands are computed from a digital elevation model for cells with a mean elevation greater than 2000 m to run the mountain snowmelt sub-model. The annual water demand per cell is estimated from rural and urban populations, livestock numbers and industrial water use all of which are obtained from global datasets. Monthly water demand arising from irrigation is modelled and requires additional inputs of crop location, planting calendar, area and crop types. To examine climate change impacts, changes in the mean monthly precipitation, potential evaporation and temperature are also required and are typically obtained from global or regional climate model simulations.

Data requirements

GWAVA requires wide ranging inputs of data both to drive the rainfall-runoff model and in order to estimate the anthropogenic water demands at the scale of the grid cell. The data are largely derived from existing global datasets and a number of methodologies have been developed to incorporate these.

Table 12. Summary of data requirements and sources for GWAVA

Parameter	Source name	Resolution	Source reference
Physical parameters for runoff estimation			
Monthly precipitation, temperature gridded data 1901 – 1994	Climate Research Unit (CRU) TS2.1	0.5 degrees monthly	Mitchell & Jones, (2005)
Soil Texture	Digital Soil Map of the World and Derived Soil Properties		FAO (1995)
Land Cover	Global Land Cover Characteristics (GLCC) Database	0.042 degrees	USGS (2005)
Routing network	Based on DDM30	0.5 degrees	Döll & Lehner (2002)
Elevation	Hydro1k DEM	1km	USGS (2000)
Glacier location, percentage ice	Digital Chart of the World	coverage	ESRI (1993)
Lakes, wetlands and reservoir	Global, Lakes and Wetlands Database (GLWD)	Coverage	Lehner & Döll (2004)
Demands			
Human populations	Gridded Population of the World	2.5 arc minutes	CIESIN *et al.* (2000)
Urban fraction	Global Rural-Urban Mapping Project (GRUMP)	5 minutes	CIESIN *et al.* (2004)
Livestock populations	Gridded Livestock of the World	5 minutes	FAO (2007)
	FAOSTAT	national	
Irrigation - cropping locations, areas,	Global Map of Irrigation Areas - version 4.0.1	5 minutes	Siebert *et al.* (2007)
calendars & crop types	FAO-AQUASTAT	national	
Data to validate water withdrawals	FAO-AQUASTAT	national	
Data for scenarios			
Climate change data from GCMs/RCMs	Various GCM/RCM outputs available from IPCC-DDC.org	Various	
Population	World Population prospects	national	

Scenario modelling

As with all hydrological models, one important objective of applying a model is to use the model to then try and understand how the catchment with behave under different conditions. The GWAVA model was developed to enable various type of scenarios and, in particular, climate change scenarios to be examined.

The latest set of Global Circulation Model (GCM) experiments run for the recent Fourth Assessment Report on Climate Change (IPCC, 2007) are available via the IPPC data distribution website (www.IPCC-DDC.org). However, limitations remain in the way the data can be used. In line with understanding changes in the seasonal deficits of water, the impact study will focus on examining the effects of changes in the mean monthly precipitation, temperature and potential evaporation derived from GCMs centred on 2020, 2050 and 2080. In the GWAVA scheme, these changes can be provided as inputs to GWAVA so that climate change scenarios can be examined easily. Aswell as running climate change scenarios two demand scenarios of increasing demand for domestic water supply will be developed and examined.

Results

The two key model outputs are the monthly streamflow series generated at each cell and the water availability indices (WAIs). Other supplementary maps can be produced to examine changes to low flows and standard deviation of flows in cells.

Water availability indices

Comparisons on a cell by cell basis of water yield and demands can be made in different ways. The simplest Type 1 index divides the annual volumetric water yield by the annual volumetric demand; however, this does not capture the seasonal or inter-annual variation in water demand and supply. The Type 2 index calculates the actual supply available for use, estimated as the driest month in each year which occurs with 90% reliability. This value, termed Qdryav, can also be plotted to examine changes to low flows. This value is compared to the minimum monthly demand i.e. assumes demands are constant throughout the year. The Type 3 index for surface water is found by calculating the 90% reliable flow for each month of the year separately, rather than calculating a single value based on the driest month in each year. The index is then the minimum (over all months in the year) of this value minus the demand in the same month. This index reflects the critical point in the year whether or not there are variable irrigation demands. The index is expressed as a volume, with positive values indicating an excess of supply over demand and negative values a shortfall. An advantage of this index is that it helps to distinguish areas where demands are large and there is a large shortfall (for instance) from those where both supply and demands are small and, therefore, the shortfall is small. Thus, areas of large-scale water availability problems are picked out from those where the problems are relatively small-scale. The Type 4 index was developed so that results could be expressed as a ratio which ranges from -1 (negligible water available to meet demand), though zero (available water meets demand), to 1 (available water exceeds demand).

Examples of these outputs produced for South America are plotted in ArcGIS and shown in Figure 23.

Table 13. Summary of water availability indices for surface water, groundwater and combined sources as computed in GWAVA

	Index	Definition
Surface water only	SWAI–type 1	Total annual runoff / Total annual demand
	SWAI–type 2	90% reliable driest month runoff / Minimum monthly demand
	SWAI–type 3	Minimum over all months of: (90% reliable monthly runoff – Demand for that month)
	SWAI–type 4	(SWAI–type 3) / (90% Reliable monthly runoff + Demand for that month)
Ground water only	GWAI–type 1	Annual groundwater yield / Total annual demand
	GWAI–type 2	Minimum monthly groundwater yield / Minimum monthly demand
	GWAI–type 3	Minimum over all months of: (Monthly groundwater yield – Demand for that month)
	GWAI–type 4	(GWAI–type 3) / (Monthly groundwater yield + Demand for that month)
Combined	TWAI–type 1	(Total annual runoff + Annual groundwater yield) / Total annual demand
	TWAI–type 2	(90% Reliable driest month runoff + Minimum monthly groundwater yield) / Minimum monthly demand
	TWAI–type 3	Minimum over all months of: (90% Reliable monthly runoff + Monthly groundwater yield – Demand for that month)
	TWAI–type 4	(TWAI–type 3) / (90% Reliable monthly runoff + Monthly groundwater yield + Demand for that month)

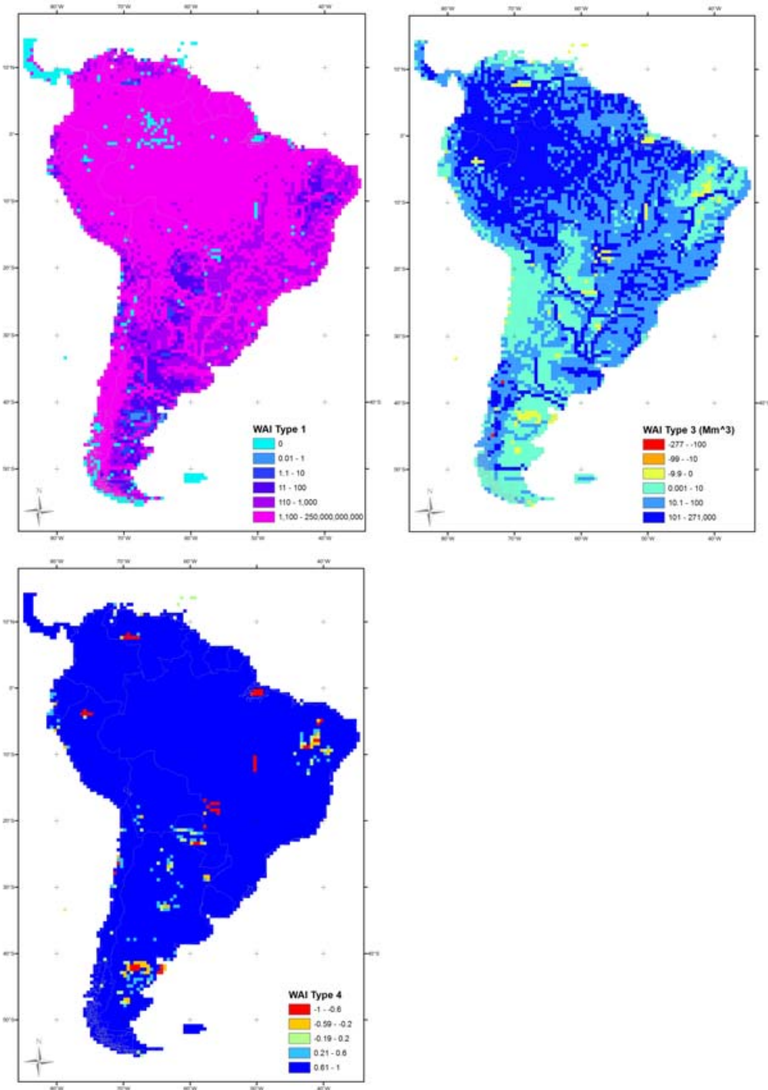


Figure 23. Maps illustrating a) WAI Type 1 b) WAI Type 3 and c) WAI Type 4 for South America computed for the baseline period 1961-1990

Baseline period

The model was run for a baseline period of 1961 to 1990. It should be noted that landcover, and all information used to compute the water demands, are assumed to be constant over the baseline period with data used to derive the water demands centred on 1990. The straightforward Type 1 index is shown as a simple ratio of the annual demand to runoff where 76 cells have an annual deficit of water. As expected the cells with highest runoff volume, i.e. those in the main river channel, have flows considerably in excess of demands annually. In the second plot (Figure 8.10b), the Type 3 index is plotted. The more complex Type 4 index which compares the water availability to the demand such that across most of South America the demand is met (A positive value for the Type 4 index shown as blue on the map indicates a ample supply of water to meet demand whereas a negative value denoted by orange and red indicates cells insufficient water to meet demand i.e. water stress with red indicating a more severe deficit). Overall for the baseline period, there are 152 cells experiencing water shortfalls with two main clusters of cells: one in north-east Brazil, a region of intense agriculture, and the second in southern Argentina, plus another smaller grouping in Paraguay. Water supply in southern Brazil, Argentina, Uruguay and Paraguay is supplemented by the use of groundwater pumped from the large regional Guaraní aquifer. In these simulations however, no account has been taken of water supply by groundwater and these maps should be treated as a worst case view if groundwater were to become unusable due to either insufficient recharge or contamination.

Evaluation of hydrological modelling

The GWAVA model has been applied to South America on a half degree grid. It has been calibrated at 43 locations against observed monthly streamflow records and has been rerun for the baseline period 1961–1990. The model has reproduced monthly flows reasonably well across a range of climates and flow regimes. Some particular issues were encountered in capturing the large wetland area of the Pantanal; whilst ultimately a reasonable annual water balance was achieved the seasonal outflow from the model was not captured and is due largely to the simplicity of routing algorithm used within GWAVA. It has not been possible to make a proper assessment of the model in basins whose regime is characterised by glacial melt and, in particular, the Baker basin for the following reasons:

- 0.5 degrees too coarse to resolve the basin accurately enough;
- Scarcity of independent information to validate the input precipitation;
- Presence of the very large Lake General Carrera obscuring the effects of snowmelt as viewed from the very downstream gauging station at La Colonia.

Summary and recommendations

Whilst the GWAVA modelling scheme is designed to be a generalised approach capturing large-scale hydrological processes, there are a number of improvements that could be made to refine the model:

- A finer spatial resolution on the western Andes watersheds would enable more accurate modelling of the mountainous and small catchments through a more detailed river routing network and fewer errors between the gridded and natural basin areas;
- A better approach of implementing large wetlands into the model using the existing method, developing a large-scale inundation model, or perhaps incorporating an empirically-based solution.

The calibration procedure could also be improved by the use of a multivariate approach to model optimisation when examining nested sub-basins, and this would overcome some of the problems of propagating errors from basin to basin that were encountered.

In terms of the estimates of water demands and water scarcity mapping, the accuracy of the results depends largely upon the availability of data both to validate the model and as inputs. Better information on the cropping patterns in South America is needed and mapping of crop types with climate and altitude would lead to a more realistic distribution of particular crop types (and hence the crop coefficients) across the region.

Incorporating information on groundwater supply and, if available, groundwater availability would enable a fuller examination of water resources availability for South America to be carried out. Again this is in possible within the GWAVA scheme but relies on the availability of data, ideally standardised across the continent.

BAKER

Meteorological data

Due to the complicated climatological conditions and the isolated geographic location of the Baker River Basin, the monitoring network is relatively poorly developed in comparison to many other Chilean Basins. The meteorological network within the basin consists of eight stations for which daily rainfall data are obtained.

The spatial distribution of the measuring network shows that the stations are mainly located at lower elevations, generally in the vicinity of urban settlements. The current measurement network does thus not cover the altitudinal gradients that most certainly exist within the basin. This fact complicates the establishment of water balances at the (sub-)basin level, and immediately limits possibilities for modelling applications. Time series for the different stations are highly discontinuous and, even for those years for which information is available, data gaps are common and considerably large.

Implications for modelling

It became clear that meaningful spatially distributed hydrological modelling applications for the Baker River Basin (suggested in the planned activities for WP3 in the original DOW) - using the outcome from the priority setting exercise done under WP1 (based on an analysis of potential conflicts, knowledge gaps and the existence of other past/ongoing/upcoming projects) and considering the results from the analysis on data availability for the Baker Basin under WP2 (now also including the newly available datasets from Endesa) - were not feasible under TWINLATIN due to the non-representativeness of the available input information providing very limited possibilities for model calibration and validation. This conclusion takes into account EULA's previous experience in hydrological modelling under limited conditions of data availability (e.g. TWINBAS where modelling was successful but data availability – though also limited - was much better; see Stehr *et al.,* 2008).

It was further also perceived that the outcome from such a modelling exercise is currently not the information most needed by the stakeholders, for the general purpose of immediate and near-future decision-making in the basin.

Considering the former conclusions with respect to the current feasibility of a distributed modelling approach in the Baker Basin, an alternative modelling strategy was implemented: based on the slightly better data availability (allowing calibration and validation) for certain snow-fed sub-basins in the upper part of the Biobío Basin (see TWINBAS WP4, in which non-snowfed sub-basins in the Central Part of Biobío were modelled), and due to the similarity of processes of these sub-basins with many sub-basins in the Aysén Region (and the Baker River Basin), it was decided to develop a modelling application for the snow-fed Lonquimay sub-basin in Biobío.

Experiences gained from this effort can then be used to evaluate the potential future usefulness of transferring the applied modelling approach to the Baker River Basin, as well as to plan further (post-TWINLATIN) developments which will be required in the Baker Basin in order to allow for the successful implementation of such a modelling approach. In this sense, considerable advances have been obtained in the modelling of the Lonquimay sub-basin (using the SWAT model), a manuscript on results of this modelling effort has been prepared, and results from the exercise are documented in this report. In addition, a presentation on results from this work at the last SWAT User Conference has been made.

Choice of model

Within the framework of TWINLATIN, the SWAT model is being applied to the Lonquimay Basin (to gain experience and insight in minimum input data requirements for future applications for the Baker), Norrström Basin, and Catamayo-Chira Basin. Exchange of information and practical experience in both directions (twinning) has facilitated implementation in the different basins.

Selection of SWAT for application under TWINLATIN is thus based on, amongst others, that good user documentation which facilitates transfer to interested stakeholders (e.g. DGA); and availability of snowmelt module, which is highly relevant for the modelling of Andean / Patagonian basins.

Useful outputs consist of:

- daily and/or monthly evaluations of water balance components at different points of interest within the basin;
- possibility for analysing impacts of change scenarios e.g. climate change.

In the latter context, future applications of SWAT within the Baker River Basin may be useful to analyse how climate change might impact (sub)basin hydrology in this area. For this purpose, however, use of the SWAT model and its snowmelt component should first be trained in sub-basins where a minimum of input data availability exists. For this purpose, under TWINLATIN, the Lonquimay Basin is being modelled, and possibilities (including evaluation of minimum data requirements) for meaningful transfer to the Baker River Basin are being analysed.

Scenario modelling

Climate change scenarios

As a first approximation, under TWINLATIN climate change scenarios for the Baker River Basin will be prepared based on output from the MAGICC-SCENGEN v4.1 scenario modelling tool, as part of a harmonised approach towards scenario generation which will be followed by the different TWINLATIN partners. In the case of the Baker Basin, this information will allow for a basic, preliminary and semi-quantitative assessment of the potential impact of climate change on water resources in the basin. In a similar way, information will also be obtained from the MAGICC-SCENGEN tool for the Lonquimay Basin (Biobío). This information will be more directly used to perturb observed meteorological time series for this basin, which can then be used for a quantitative impact assessment (sensitivity analysis of the hydrological model) by means of the SWAT hydrological model application.

Output from MAGICC-SCENGEN will consist of change signals (reference period 1961-1990) for temperature (absolute change) and precipitation (% change) for the future 30-year time window 2071-2100 (mean values). Obtained change signals will be used to perturb a baseline for temperature and precipitation for the Lonquimay Basin, in order to perform an analysis of the sensitivity of the hydrological model to meteorological (climate) input datasets and as such make a first evaluation of the potential impacts of plausible climate change scenarios on (sub)basin hydrology.

Table 14. Model output parameters

	Parameter	Level
1	Total amount of precipitation (mm H_2O)	HRU; Sub-basin
2	Irrigation (mm H_2O). Amount of irrigation water applied	HRU
3	Potential evapotranspiration (mm H_2O)	HRU; Sub-basin
4	Actual evapotranspiration (soil evaporation and plant transpiration) (mm H_2O)	HRU; Sub-basin
5	Soil water content (mm H_2O)	HRU; Sub-basin
6	Water that percolates past the root zone (mm H_2O)	HRU; Sub-basin
7	Recharge entering aquifers (total amount of water entering shallow and deep aquifers) (mm H_2O)	HRU
8	Deep aquifer recharge (mm H_2O)	HRU
9	Water in the shallow aquifer returning to the root zone in response to a moisture deficit during the time step (mm H_2O)	HRU
10	Irrigation from shallow aquifer (mm H_2O)	HRU
11	Irrigation from deep aquifer (mm H_2O)	HRU
12	Shallow aquifer storage (mm H_2O)	HRU
13	Deep aquifer storage (mm H_2O)	HRU
14	Surface runoff contribution to streamflow in the main channel (mm H_2O)	HRU; Sub-basin
15	Transmission losses (mm H_2O)	HRU
16	Lateral flow contribution to streamflow (mm H_2O)	HRU
17	Groundwater contribution to streamflow (mm H_2O)	HRU; Sub-basin
18	Water yield (mm H_2O)	HRU; Sub-basin
19	Leaf area index at the end of the time period	HRU
20	Average daily streamflow into reach (m^3s^{-1})	Reach
21	Average daily streamflow out of reach (m^3s^{-1})	Reach
22	Average daily rate of water loss from reach by evaporation (m^3s^{-1})	Reach
23	Average daily rate of water loss from reach by transmission through the streambed (m^3s^{-1})	Reach

In addition to this, temperature and precipitation time series (0.5º x 0.5º grid cells) for both the reference period 1961-1990 and the future time window 2071-2100 from the Chilean RCM exercise "Study of the Climatic Variability in Chile in the XXI Century" (CONAMA-DGF, 2006) are made available for the Baker Basin. These time series can also be used for a finer resolution change effects assessment. In this study, the HadCM3 GCM (mean resolution 300 x 300 km) was used to indirectly force the regional simulations: the atmospheric model that is forced at the surface level with the output from this model is HadAM3, which represents very similar characteristics but at a major spatial resolution. Output from this last model finally is used to force the regional simulations which are executed with the PRECIS model, at a spatial resolution of 25 km. The different output variables from this model (e.g. mean, maximum and minimum temperature, and precipitation) are available for each grid point within the spatial domain 18°S – 57°S and 62°W – 85°W. Three 30-years time series are available for each point: the reference climate and two future climatic time series for the period 2071-2100, corresponding to the A2 and B2 emission scenarios, respectively (see Figure 24).

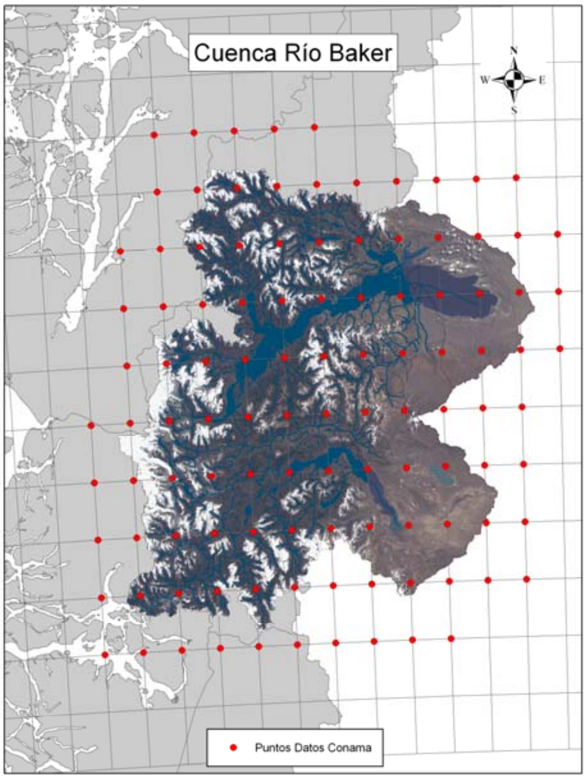


Figure 24. Grid points from the RCM run conducted by DGF- CONAMA (2006); at each point a 30-year daily time series (2071 – 2100) is available

Model development

Overview

As previously mentioned, in the context of TWINLATIN, the rainfall-runoff modelling application focuses on one sub-basin of Biobío, namely the Lonquimay Basin (455 km^2). Through the application of the previously described SWAT model, monthly and annual water yield at the sub-basin level can be obtained and can be used later on to assess the impact of change scenarios on basin hydrology. Groundwater flows will not be explicitly modelled (detailed hydrogeological data which would allow the application of a separate groundwater model are lacking), but it is possible to derive the magnitude of the exchange between surface and groundwaters through analysis of the water balances calculated by SWAT.

Through the modelling of the Lonquimay Basin, TWINLATIN will thus set the basis for future modelling efforts in the Baker River Basin. The location of the Lonquimay Basin occupies approximately 2% of the total surface area of the Biobío Basin.

Model set-up

The hydrological cycle as simulated by SWAT is based on the following water balance equation:

$$WYLD = PP - ET - \Delta SW - (PERC - GWQ)$$

Where: *WYLD* is the water yield of the (sub)basin (*WYLD* includes surface runoff, lateral flow and base flow), *PP* is precipitation, *ΔSW* is change in soil water content (vadose zone), *PERC* is flux to the groundwater and *GWQ* is baseflow contribution to the river discharge.

The subdivision(s) of the basin enables the model to reflect the influences of local characteristics (e.g. soil type, land use type, etc.) on the different components of the water balance.

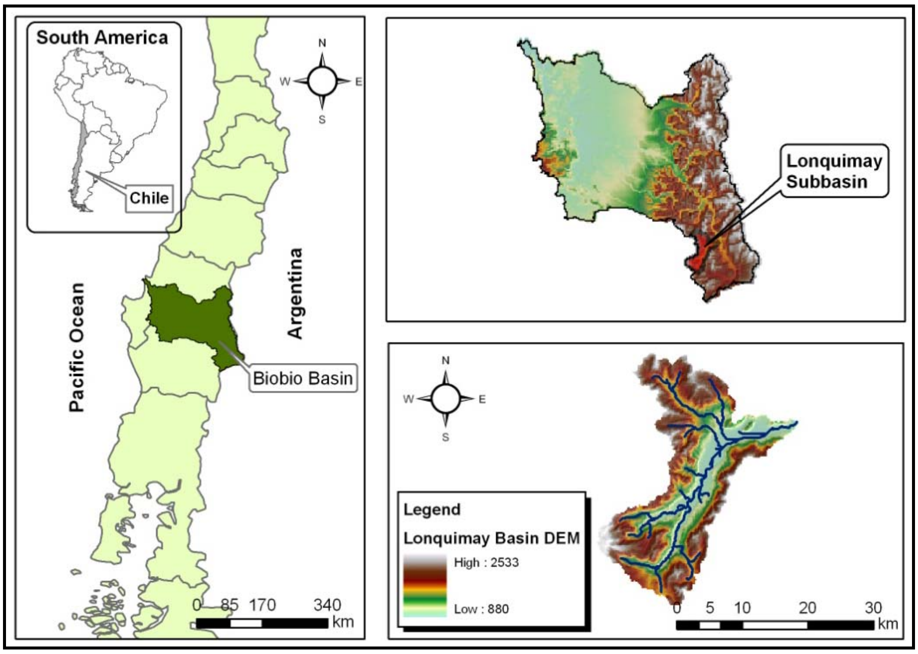


Figure 25. Location of the Lonquimay sub-basin within the Biobío Basin

Climate

The climate of a basin provides the moisture and energy inputs that control the water balance and determine the relative importance of the different components of the hydrological cycle. The climatic variables used by SWAT consist of precipitation, air temperature, solar radiation, wind speed and relative humidity. Minimum requirements (i.e. in case of the use of the SCS Curve Number (CN) technique for runoff, and the Hargreaves equation for evapotranspiration) are: daily precipitation, and minimum and maximum daily temperature. The data can be input from records of observed data, or can be generated by means of a stochastic weather generator. Currently aavailable input data for the Lonquimay Basin consist of 11 years of daily precipitation and temperature time series observed at six stations. Data from one limnigraph is available for calibration and validation. The SCS CN and the Hargreaves method are thus used, together with the observed time series, for the modelling of runoff and evapotranspiration, respectively, in the Lonquimay Basin.

Hydrology

Precipitation may be intercepted and held by the vegetation canopy, or fall to the soil surface. Water on the soil surface will infiltrate into the soil profile or flow overland as runoff. Runoff moves relatively quickly towards a stream channel and contributes to short-term stream response. Infiltrated water may be held in the soil and later evapotranspirated, or it may slowly make its way to the surface-water system via underground paths. The potential pathways of water movement simulated by SWAT in the HRU.

For the modelling of the Lonquimay Basin, the model is set up in such a way that the following components are considered in the calculations: precipitation as rain and snow; snow accumulation and melt, surface runoff, transmission losses; infiltration, soil storage, evapotranspiration, sublimation, lateral flow and percolation, shallow and deep aquifer, return flow and streamflow.

Evapotranspiration

Evapotranspiration is a collective term for all processes by which water in the liquid or solid phase at or near the earth's surface becomes atmospheric water vapour. Evapotranspiration includes evaporation from rivers and lakes, bare soil, and vegetated surfaces; evaporation from within the leaves of plants (transpiration); and sublimation from ice and snow surfaces. The model computes evaporation from soils and plants separately as described by Ritchie (1972). Potential soil water evaporation is estimated as a function of potential evapotranspiration and Leaf Area Index (LAI; area of plant leaves relative to the area of the HRU). Actual soil water evaporation is estimated by using exponential functions of soil depth and water content. Plant transpiration is simulated as a linear function of potential evapotranspiration and LAI. More details (equations, additional references, etc.) can be obtained from the SWAT Theoretical Manual.

Lateral subsurface flow

Lateral subsurface flow, or interflow, is the streamflow contribution which originates below the surface but above the saturated zone. For calculation purposes, the (unsaturated) soil profile can be subdivided into a maximum of 10 layers. In this way, variability in soil characteristics such as conductivity can be accounted for (if such information is available). Lateral subsurface flow in the soil profile (0-2 m) is then calculated simultaneously with the redistribution of water within the soil profile. A kinematic storage model is used to predict lateral flow in each soil layer. Typically, under limited availability of information on the variability of soil characteristics within the vertical soil profile, a single soil layer is used for modelling. This is thus, consequently, also the case for the Lonquimay Basin model application.

Surface runoff

Surface runoff, or overland flow, is flow that occurs along a sloping surface. Using daily rainfall amounts, SWAT simulates surface runoff volumes for each HRU. Surface runoff volume for the Lonquimay Basin is thus computed using the modified version of the CN method (USDA Soil Conservation Service, 1972) incorporated in SWAT. In this method, the curve number varies non-linearly with the moisture content of the soil. The curve number drops as the soil approaches the wilting point and increases to near 100 as the soil approaches saturation.

River network

The river network in the implementation of SWAT for the Lonquimay Basin is generated from the Digital Elevation Model (DEM), using a minimum contributing area of 5 km^2. The extracted river network was compared with official shapefiles from the DGA, and a very good correspondence between “real” and “extracted” river network was observed.

Within the SWAT application, two types of channels are considered: the main channels and the tributaries. Tributary channels are minor or lower order channels branching off the main channel within each sub-basin. A tributary channel drains only a portion of the sub-basin and does not receive groundwater contribution to its flow. All flow in the tributary channels is released and routed through the main channel to the outlet of the sub-basin. SWAT automatically calculates the attributes for each channel from the DEM and uses these to determine the time of concentration for the sub-basin.

Transmission losses (i.e. losses of surface flow via leaching through the streambed) may occur in ephemeral or intermittent streams. SWAT uses Lane’s method (USDA Soil Conservation Service, 1983) to estimate transmission losses. Losses are a function of channel width, length and flow duration. Both runoff volume and peak rate are adjusted when transmission losses occur.

Baseflow

Baseflow is the volume of streamflow originating from groundwater. SWAT partitions groundwater into two aquifer systems: a shallow, unconfined aquifer which contributes return flow to streams within the sub-basin, and a deep, confined aquifer which contributes return flow to streams outside the sub-basin

(Arnold *et al.*, 1993). Water percolating past the bottom of the root zone is partitioned into two fractions, and each fraction becomes recharge for one of the aquifers. In addition to return flow, water stored in the shallow aquifer may replenish moisture in the soil profile in very dry conditions or be directly removed by plants. Water in the shallow or deep aquifer may be removed by pumping. In the current model application for the Lonquimay Basin, no pumping is considered. The model considers transfer from the shallow to the deep aquifer by means of a parameter called "Deep aquifer percolation fraction". As no information regarding the properties of shallow and/or deep aquifers for the Lonquimay Basin was available, the model parameters were calibrated.

Flood routing

As water flows downstream, a portion of it may be lost due to evaporation and transmission through the bed of the channel. Another potential loss is removal of water from the channel for agricultural or human use. Flow may be supplemented by rainfall on the channel itself and/or addition of water from point source discharges. Flow is routed through the channel by choosing between a variable storage coefficient method (Williams, 1969) or the Muskingum routing method. In the Lonquimay Basin application, the variable storage coefficient method was chosen for flow routing. Water abstraction points in this sub-basin of Biobío are limited, so as a first approximation no water extraction was modelled. The calibrated/validated model can then later be used to assess the impact of abstraction on water availability in other sub-basins.

Spatial Scale

The SWAT version integrated in ArcView3.2 is semi-spatially distributed: the user uses several options to set the level of detail or spatial scale, in accordance with the specific requirements of a particular application. For the application to the Lonquimay Basin, a 90m x 90 m DEM was used as a basis for the delineation of the basin. Automated extraction of the river network was done by using a threshold value of 5 km^2 for the upstream contributing area. A total of 45 sub-basins were defined, 44 of which were close to the different intersections in the river network, and one which was close to one point where limnigraph data are available (outlet of the whole basin), a requirement for calibration and validation purposes. A total of 87 HRUs were generated within the different sub-basins.

Temporal Scale

Considering the availability of input data at the daily time scale, a time step of one day was used for the model calculations. Output data are also generated at the daily level. The daily data can then be aggregated to the monthly or annual level, in order to obtain the corresponding water balances and runoff volumes. In TWINLATIN, monthly data are used to evaluate model performance. Aggregation of output data at the monthly time scale gives a clear overview of the inter-annual and intra-annual variability of the water yield of the different sub-basins.

Validation

Time series from the 1996-2002 period were used for model validation. Again, the first three years of data from these time series are used for model warm-up. Evaluation of model performance is thus based on output for the 1999-2002 period (Figure 26). Table 15 shows results for different periods of model evaluation.

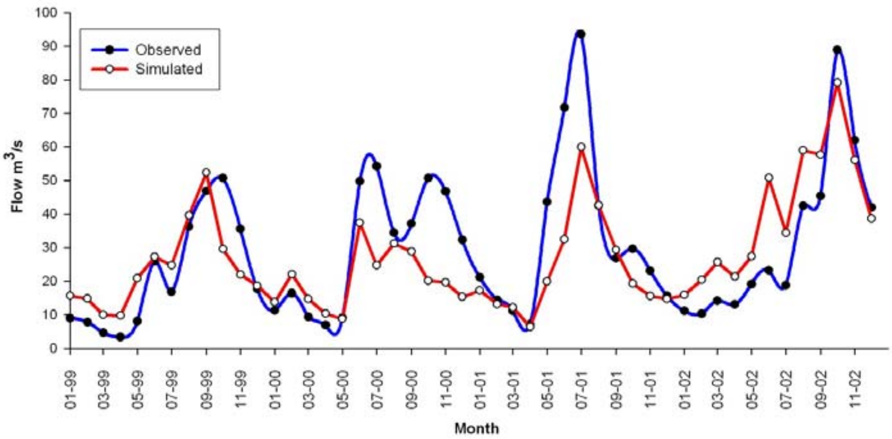


Figure 26. Monthly observed versus simulated flows at the Lonquimay gauging station during validation

Table 15. Statistical indicators of model performance (monthly output) calculated at the outlet of the Lonquimay Basin, considering different periods of evaluation

Index	Validation						
	Su[1]	A[2]	W[3]	Sp[4]	SA[*]	WS[**]	All
EF	-1.27	0.32	0.34	0.38	0.36	0.36	0.56
R^2	0.24	0.32	0.35	0.77	0.37	0.51	0.57
PBIAS	-39.01	3.08	2.2	29.55	10.96	15.87	7.86

[1]: Summer; [2]: Autumn; [3]: Winter; [4]: Spring; *: Summer – Autumn**;** **: Winter – Spring

Snow Cover Area (SCA) validation

The MODIS snow cover products are one of the many geophysical products derived from MODIS data. Global snow extent has been mapped by MODIS since shortly after the launch of the Terra satellite, and a global, daily snow-cover map has been produced since February 2000. The MODIS snow cover products are provided daily and as 8-day composites at 500 m resolution over the Earth's land surfaces, using an algorithm based on the normalised difference of a visible and a shortwave infrared band (Hall *et al.,* 2002). The MOD10A2 products (Figure 27) are composites of eight days of snow maps in the sinusoidal grid, produced by compositing from two to eight days of the MOD10A1 and MYD10A1 snow products. An 8-day compositing period was chosen because that is the exact ground track repeat period of the Terra and Aqua platforms.

To validate the snow cover area estimated by the model, the MOD10A2 snow product (Hall *et al.* 2006, updated weekly) was used. Firstly, imagines were reprojected (WGS84 UTM 19S) using the MODIS Reprojection Tool (MRT). Basin imagines were reclassified as (1) snow and (0) no snow, and then aggregated at the monthly time scale.

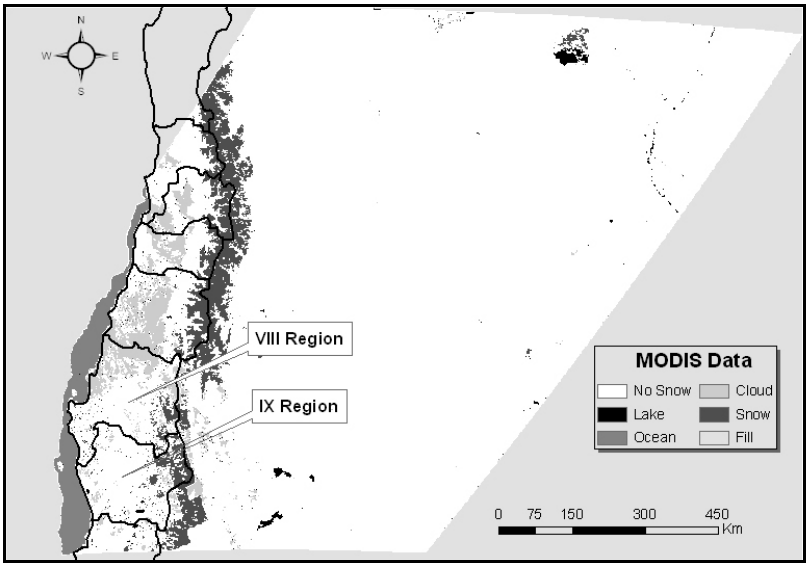


Figure 27. MOD10A2 images

Considering the limited existing overlap between locally observed time series for the Lonquimay basin and available MODIS imagery, three years of MODIS images (2000–2002) could be used for the SCA validation. Cells with snow presence in each sub-basin are counted for each month and multiplied by the cell area, as to obtain the snow area for the sub-basin. Then, sub-basins were reclassified as (1) snow or (0) no snow. Snowpack was calculated using values obtained for snowfall, snowmelt and sublimation. As in the case of MODIS, model values were also reclassified as (1) snow or (0) no snow for each sub-basin; in this case a zero value was assigned only if snowfall, snowmelt, sublimation and snowpack were zero. After reclassification, values from the modelling results were subtracted from the MODIS-based results; a zero value indicates that the image and model are in agreement, -1 indicates that model results reveal snow presence whereas the MODIS image does not, and 1 indicates that model does not estimate snow whereas the MODIS image signals the presence of snow. Figure 28 summarise the results of the comparison exercise.

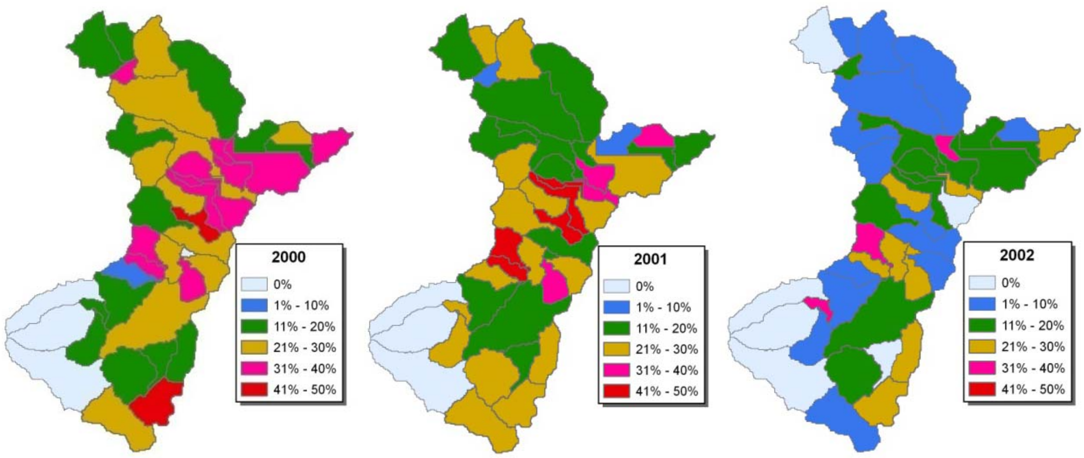


Figure 28. Percentage of disagreement between monthly model outputs and MODIS imagines, for the different sub-basin. For 2000 only the months from March to December are considered.

Summary and recommendations

The hydrological component of the Soil and Water Assessment Tool SWAT was applied to a sub-basin of Biobío located in the Andes of south-central Chile. The very limited availability of traditional input and calibration and validation datasets for this sub-basin is typical of many Andean (sub)basins in Chile. Results obtained from this model application for the Lonquimay basin show a good to satisfactory general model performance in terms of representation of long term or annual mean discharge at the basin outlet.

Besides the traditional calibration and validation based on river flow, MODIS snow products were used to evaluate the representation of snow cover extent as it is generated by means of the calibrated SWAT model snow routine. Although a reasonable description of snow cover extent could be obtained under most circumstances, the present case study shows the limitations inherent to modelling under situations of low station density in areas with high (topography-induced) precipitation gradients. Location and density of monitoring stations undoubtedly play a determinant role in the general accuracy of model results, and the present case study provides an example quantitative indication of how good a model may perform under limited availability of input meteorological datasets. Improvements in model behaviour may, however, still be obtained in future work through the incorporation of an improved description of basin soil types and characteristics (especially for those parts of the basin that can be reasonably assumed to have a very thin or non-existing soil cover), as well as through the use of differential seasonal temperature lapse rates (analysis of temperature data obtained from MODIS produced a different lapse rate value for the different seasons).

By applying the necessary caution in the interpretation of the results (see also Chapter 9 for evaluation), the model can indeed already be used to make a first assessments by means of model simulations of the possible impacts of climate change scenarios in a mixed-regime (rainfall and snow-fed) river basin from central Chile, and conclusions from this assessment can be used to foresee potential impacts under similar climate change scenarios in similar sub-basins of the Baker (see WP8 report).

Especially with regard to its usefulness for the Baker Basin, future work should also more explicitly address the aspect of glacier melt contributions. For this purpose, the glacier melt module proposed by Schaper *et al.* (1999) can be adapted and incorporated in SWAT.

In the current work, the MODIS snow products have been used for validation purposes only. This has allowed gaining improved insight into the performance of the SWAT model and of its snowfall– snow melt routine. Future efforts may be directed towards the incorporation of MODIS information directly into the process of model parameter calibration itself, in an attempt to further improve model results. Such incorporation would depart from the inherent assumption that the MODIS representation of snow cover is good.

With regard to the water authorities in the Baker River Basin (and in general), the following recommendations can be made:

- Well-thought and strategic (long-term/goal-oriented) improvements in the hydrometeorological monitoring networks should urgently be considered (longer time series are generally required for model calibration and validation, and maximum benefits from improvements in the monitoring network will not be obtained immediately; even so such improvements should not be postponed); such improvements can be balanced and combined – out of cost considerations - with the search for alternative data sources such as, for example, those generated from remote sensing. In order to evaluate the potential importance of such alternative data sources, additional research will be required.

Capacity building in the use of hydrological models for government stakeholders has been conducted in the past (e.g. in the Biobío Basin under TWINBAS). For the Chilean case, in the immediate future, however, the execution of modelling work is mainly situated within the academic or consultant environment, where specific modelling tasks can be conducted upon request by water stakeholders and authorities. The outcome from such work is clearly of high interest to the water stakeholders, who can use information from the modelling in their decision-making. Conducting the modelling applications at government institutions themselves, however, may be feasible in the future; under current conditions, government organisations will typically lack staff – or available staff will lack time - to conduct such modelling work themselves. This may change in the near future, as modelling support for decision-making becomes more and more required. Creating awareness among government stakeholders with regard to the possibilities and limitations of modelling work, however, is important, as it will help them to better evaluate the real value of model outcome, and to better direct and specify requests for consultancy work or research. Attention has been given to this aspect under TWINLATIN (e.g. through the public participation workshops), and this awareness building should also be further developed in ongoing and future interactions between academics and authorities (or other basin stakeholders). Providing training on simplified modelling case studies may also be helpful in this sense.

Support to CIEMA

Through the analysis of available data sets which should allow model applications (calibration & validation) in the different subbasin of the Cocibolca Lake Basin in Nicaragua, EULA further assisted CIEMA in the development of the Cocibolca Lake modelling strategy under the TWINLATIN project.

CUAREIM - QUARAI (Brazilian partner)

Choice of model

The hydrological model chosen to be applied in the Quaraí river basin is the large-scale distributed MGB-IPH model.

MGB-IPH is a large-scale distributed hydrological model that was developed to be applied in large South American basins, and having in mind situations of low spatial and temporal data availability typical to this region. The MGB-IPH model is composed of modules for calculation of soil water budget, evapotranspiration, flow propagation within a catchment, and flow routing through the drainage network. The drainage basin is divided into elements of area (normally square grids) connected by channels, with vegetation and land use within each element categorised into one or more classes, the number of vegetation and land use types being at the choice of the user.

Water quality modelling capabilities were also added to the MGB-IPH model recently, including calculation of both point and diffuse sources of pollution, advection and change of concentration along the rivers and reservoirs (Larentis *et al.,* 2008).

The MGB-IPH model was chosen because it is a hydrological model that can be applied to large basins, taking into account the spatial variability in precipitation, land use, vegetation, soil types and relief. Another important reason for choosing this model is the large experience the Brazilian TWINLATIN members of the project have in applying this model in South America (Allasia *et al.,* 2005).

Tests in other parts of the Uruguay basin, of which the Quaraí/Cuareim river is a tributary, have shown that the MGB-IPH model can be applied to estimate streamflow in ungauged basins if its parameters can be calibrated in a nearby catchment with similar characteristics (Collischonn *et al.,* 2007a).

Another important reason for choosing MGB-IPH model is the possibility of including the hundreds of small reservoirs and rice fields explicitly in the simulation, by programming special modules to represent both types of hydrological elements. This development was done in the context of the TWINLATIN project because of the unique aspects of the Quaraí basin hydrology and due to the lack of information on the actual water use in rice fields in this region.

Data requirements of the MGB-IPH hydrological model are: digital elevation model (DEM); land use; vegetation classes; soil types; river cross-sections; reservoir characteristics; rainfall; streamflow; water quality data; temperature; humidity; atmospheric pressure; radiation; and wind velocity.

To classify areas of rice fields, a new satellite image data source was used, obtained from the CBERS program. CBERS stands for China-Brazil Earth Resources Satellite and was born from a partnership between Brazil and China. It has three sensor types and images can be free downloaded from www.cbers.inpe.br. CBERS images were used because of free availability for several different dates in this region.

Reservoirs influence river flows and reservoir characteristics, at least its volume, should be known in order to simulate the basin's hydrology. There are several hundreds of small reservoirs distributed in the Quaraí/Cuareim river basin, on both sides of the country border. Since the basin streamflow is very flashy and baseflow is low, the reservoirs are needed to guarantee water during the rice growing season (summer). Most of these reservoirs are small and entirely built and contained within individual land properties, and some of them were constructed along ephemeral or first-order streams. Local inspection during the start of the TWINLATIN project revealed that many of the reservoirs do not have any hydraulic structure to maintain minimal flows in the streams.

A solution to this problem was found by obtaining a relation between inundated area and volume based on data of those reservoirs for which both information items are available. This relation is further explained in section 6.5.1, where the model development is more deeply described.

Water quality data are scarce in the Quaraí/Cuareim river basin. Unlike other rivers in the Brazilian southernmost state of Rio Grande do Sul, the Quaraí is not monitored by the state environmental institution (FEPAM). In Uruguay the agency responsible for the environmental monitoring of river is DINASA, which also has very limited information on water quality of the river Cuareim or its tributaries. Due to this general lack of data on water quality, the monitoring programme during the TWINLATIN project was largely focused on this aspect. Five field campaigns with water quality sampling and streamflow measurement were undertaken during the TWINLATIN project. These campaigns and the results obtained are described in the WP6 report.

Scenario modelling

Scenario modelling was necessary from the start of the hydrological modelling acitivities in the Quaraí river basin. This is due to the fact that observed streamflow time series are strongly influenced by the presence of reservoirs and by water abstractions for rice irrigation.

Table 16. Hydrological scenarios analysed in the Quaraí river basin (marked cells refer to aspects that were included in the model during each scenario).

Scenario	Reservoirs	Reservoir	River water	Return flow	Climatic	Land use	Objective
1	X	X	X	X			Model calibration; actual situation
2							Natural situation of the basin
3	X						Analyse effects of reservoirs
4	X	X		X			Analyse effects of reservoirs and reservoir abstractions
5	X	X	X				Analyse effects of return flows
6					X		Analyse effects of climatic change
7						X	Analyse effects of land use change

Simulation of small reservoirs in the MGB-IPH model

One of the most important hydrological characteristics of the Quaraí river basin is the high number of small reservoirs for which the proper data on volume and operation are normally missing.

Figure 29 presents the inputs and outputs considered for each reservoir, where *Qi* means streamflow entering the reservoir from upstream; *E* means evaporation; *P* means direct precipitation over the reservoir surface; *Qv* means water spills during high flows and *Qd* means water abstractions for rice field irrigation.

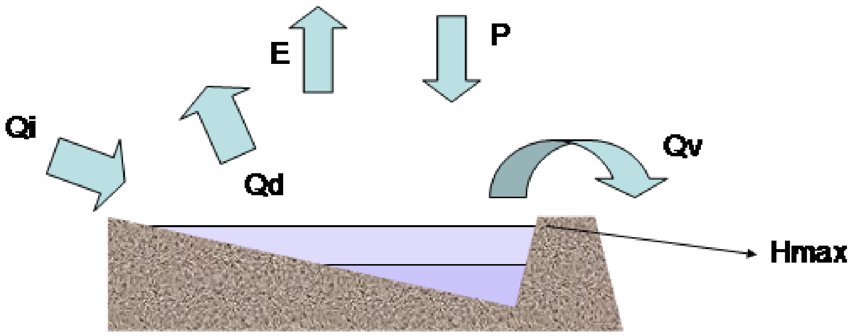


Figure 29. Water balance variables considered in the simulation of a reservoir.

For each rice field included in the model a similar approach was applied in the simulation as in the case of reservoirs. Every rice field larger than 10 ha was included explicitly in the simulation. A total number of 477 rice fields were identified after the image classification, filtering and vectorisation of the rice fields. Each field received a identification number.

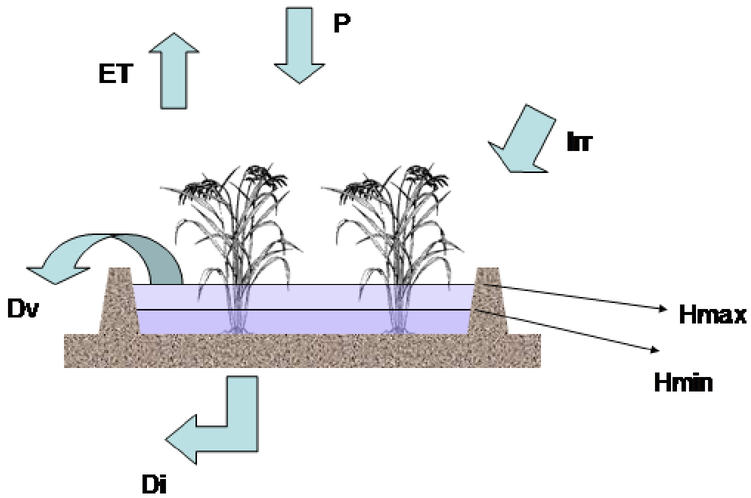


Figure 30. Scheme of water fluxes in a rice field: rainfall (P); irrigation (Irr); evapotranspiration (ET); infiltration losses (Di); spilling losses (Dv).

Rice cultivation period

The overall time of rice cultivation in South Brazil is close to 100 days. Irrigation of rice fields starts in October or November. Irrigation in every rice field can start in a different day. To represent this variability in the hydrological model simulations, a probability distribution of the day of irrigation start was created, using a uniform distribution starting at 15 October and ending at 16 November. Every individual rice field starts its irrigation period on one of those days and the irrigation period extend for 100 days. The end of the irrigation period occurs in January or February.

Evaluation of hydrological modelling

The hydrological modelling will provide the basis for analysis in several other work packages. Due to the unique characteristics of the Quaraí river basin, particularly the high number of small farm dams and reservoirs, and the intensive use of water for irrigation, it was not a simple application of a hydrological model. It was necessary to adapt a hydrological model to include hundreds of reservoirs and rice fields. Therefore the model that was chosen was the MGB-IPH model, which source code is developed in IPH and can be adapted to handle those characteristics.

Several limitations of the modelling work have been detected during the activities. The first one and probably the most important is the low availability of hydrological data. Rainfall gauging stations are relatively sparse and time series show several periods with data missing. Streamflow is being collected routinely only in one single gauging station. Both Brazil and Uruguay monitor the same point, located close to the bridge between Artigas and Quaraí. At this point the drainage area of the basin is more or less one third of its whole size at the river outlet at Barra do Quaraí.

Streamflow data were found for another location on a tributary of the river Quaraí, the river Tres Cruces, at Javier de Viana. However this gauging station showed only a short period of valid data and could be used only for model validation. Another gauging point is urgently needed in the lower reach of the Quaraí river and at some of its tributaries to permit a clear understanding of the actual effects of water abstractions over the basin.

During the modelling activities several assumptions had to be made concerning the size of reservoirs and the amount of water used for irrigation, because information was not available. A linear regression was used between reservoir surface area and its total volume, since surface area could be easily obtained from satellite images. There is obviously a large uncertainty associated with this assumption. Every one of the more than 400 reservoirs larger than 3 ha found in the basin should have an estimate of volume somewhat better than that obtained by the linear regression function.

Another arbitrary assumption that was made during the modelling work was the definition of connections between rice fields and water sources, which was done based on proximity rather than actual field information. This should be improved for a next phase of hydrological modelling work in the basin.

Water quality data were completely absent in the basin and the first known sampling activities were undertaken during TWINLATIN, and will be discussed in the WP6 report.

Results of the model analysis were already presented to the public, including stakeholders in the basin, and government institutions. The National Water Agency (ANA) is using results of the model to support decisions concerning water permits, and the water authorities in the state Rio Grande do Sul asked for simulations of the effects of large reservoirs in the basin.

Summary and recommendations

Future hydrological modelling in the basin should be based on better hydrological data. Therefore it is strongly recommended that at least two more flow gauging stations should be established in the Brazilian side of the basin. One should be on the lower reach of the river Quaraí, as close as possible to its mouth, but free of the backwater effects of the river Uruguay. The other should be placed on one of the main tributaries of the Quaraí downstream of the city. This recommendation will be transmitted to the National Water Agency, which is in charge of hydrological measurements in Brazil.

Another recommendation refers to the lack of information that exist concerning the volume and operation rules of the small farm reservoirs. It has been shown during the hydrological modelling work that those reservoirs exert a considerable influence on streamflow. However the real extend of this influence is dependent on the actual size of the reservoirs. The estimates based on the linear regression between area and volume used for this study should be limited to the minority of the reservoirs.

One of the most important obstacles to hydrological modelling in the Quaraí river basin is related to the lack of knowledge of the actual locations where water is being abstracted from the rivers. It is strongly recommended to elaborate an inventory of water users in the basin and to include very detailed information on how much and where water is be taken from the rivers of the basin.

CUAREIM - QUARAI Basin (Uruguayan side)

Description of basin

The Tres Cruces creek is one of the most important tributaries on Uruguayan territory of the Cuareim River which is a tributary of the Uruguay river, and border between Brazil and Uruguay. The Tres Cruces creek basin has an area of 1.466 km^2 and is entirely located in the Artigas department (Figures 31).

Figure 31. Location of the Tres Cruces creek

The main objective of this work is to take a first step in managing the granting of water rights considering the global system in the Tres Cruces creek basin. The outlet of the basin is where the Tres Cruces creek reaches the Cuareim River. The purpose of the study specifically includes:

- To implement, calibrate and validate a distributed daily-step hydrologic model that will quantify the water resources (SWAT);
- To implement a generic simulation model of operations of a hydraulic system, as a decision tool to be used for the hydrological simulation of irrigation network systems (MODSIM);
- To evaluate and make recommendations on how to manage water resources and grant water rights.

Model development: SWAT

The land uses were identified from a satellite image of the 2005/06 rice season. In this image it was possible to distinguish the following land uses in the Tres Cruces creek basin: Water (WATR), Pasture (PAST), Native forest (FRDS) and Rice (RICE) (Figure 32).

The soils map at scale 1:1,000,000 in the Tres Cruces stream basin shows four dominant soils: Arapey, Itapeby, Cuchilla de Haedo y Curtina.

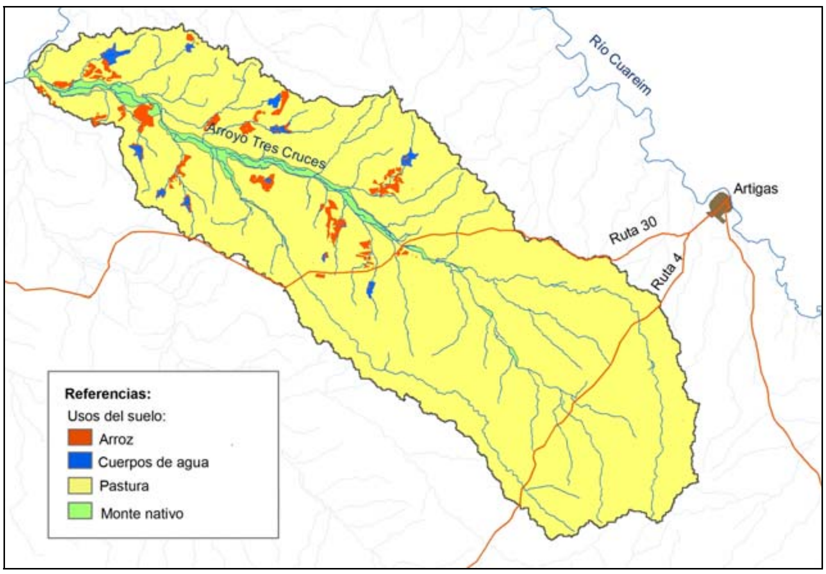


Figure 32. Current land uses (Red: Native Forest, Yellow: Pasture, Orange: Rice, Green: Water)

Model development: MODSIM

This section describes the implementation of the MODSIM generic model of simulation of operations of a system and corresponding management.

MODSIM is a generic operations simulation model for a hydraulic system developed as decision support and used to simulate hydrological networks systems in a basin.

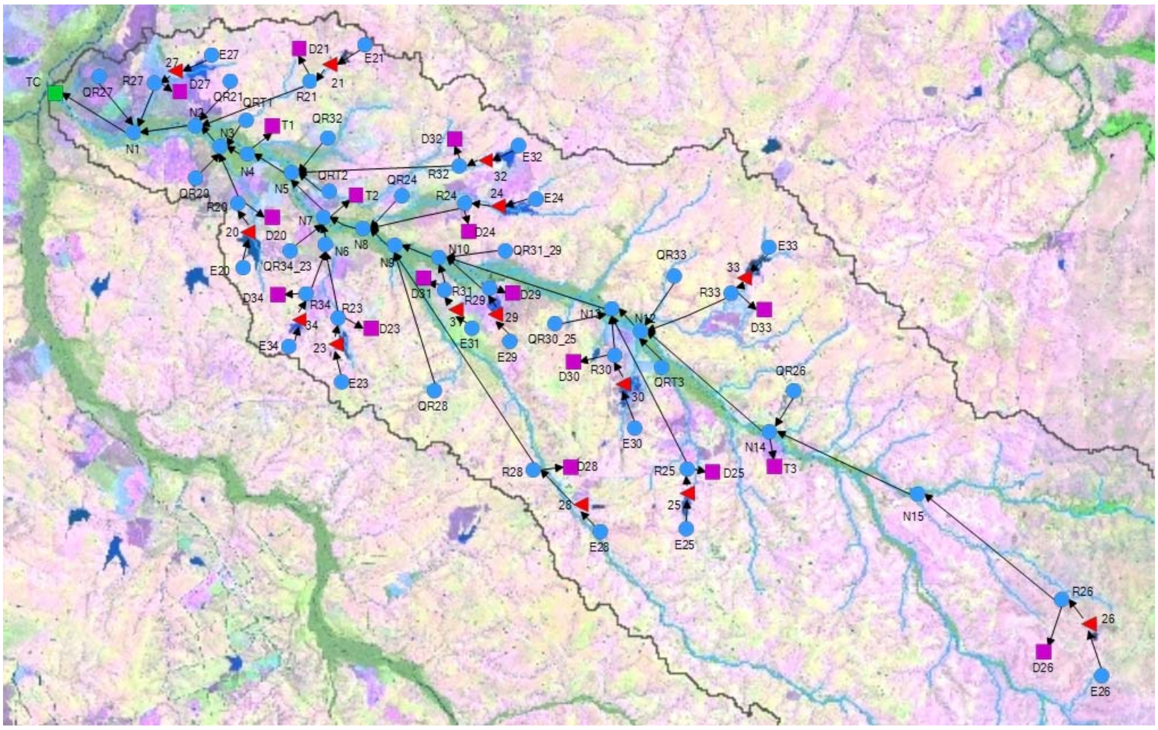


Figure 33. Hydrologic configuration system for the Tres Cruces creek basin in MODSIM

The input data to the model correspond to the period January 1932–December 2007, as it is the period with data for both raingauges with influence in the basin. The simulation was carried out for the period November 1960–October 2007, the non-calendar year in which it is assumed that the reservoirs get filled out for the irrigation of rice and because the period 1960-2007 is considered to be long enough to run the model. A monthly-step was chosen because of the climate available information.

Two types of demands were considered: reservoir demands and direct intake demands.

Evaluation of SWAT daily hydrological model

The daily hydrologic model SWAT was implemented, calibrated and validated in the Tres Cruces creek basin. The calibration and validation that were carried out are not very encouraging (Nash-Sutcliffe efficiency 0.43 and R^2 0.45), attributing those results to the quality of the information used. Likewise, the flow data have a runoff coefficient of 0.29, much lower than the calculated with the monthly-step Temez model (0.45), which would indicate that the flow is being underestimated, because it is a basin with a concentration time less than 24 hours with only three daily measurements.

To assess the amount of water there is in the basin it is recommended to use the monthly-step Temez model (with four parameters against the 27 in SWAT).

Evaluation of climate change scenarios

A runoff elasticity study was carried out to evaluate climate change. Small changes to the input data were made and changes in runoff were calculated. Figures 34 and 35 present the curves that show the variation of the average, percentiles and permanence curves.

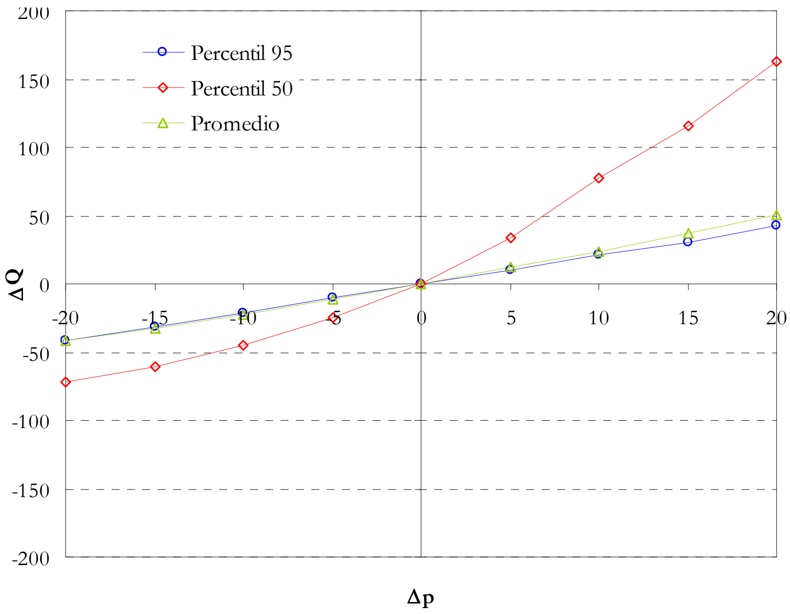


Figure 34. Relationship between a variation in precipitation and the corresponding variation in runoff. Green: Average. Red: Percentile 50. Blue : Percentile 95

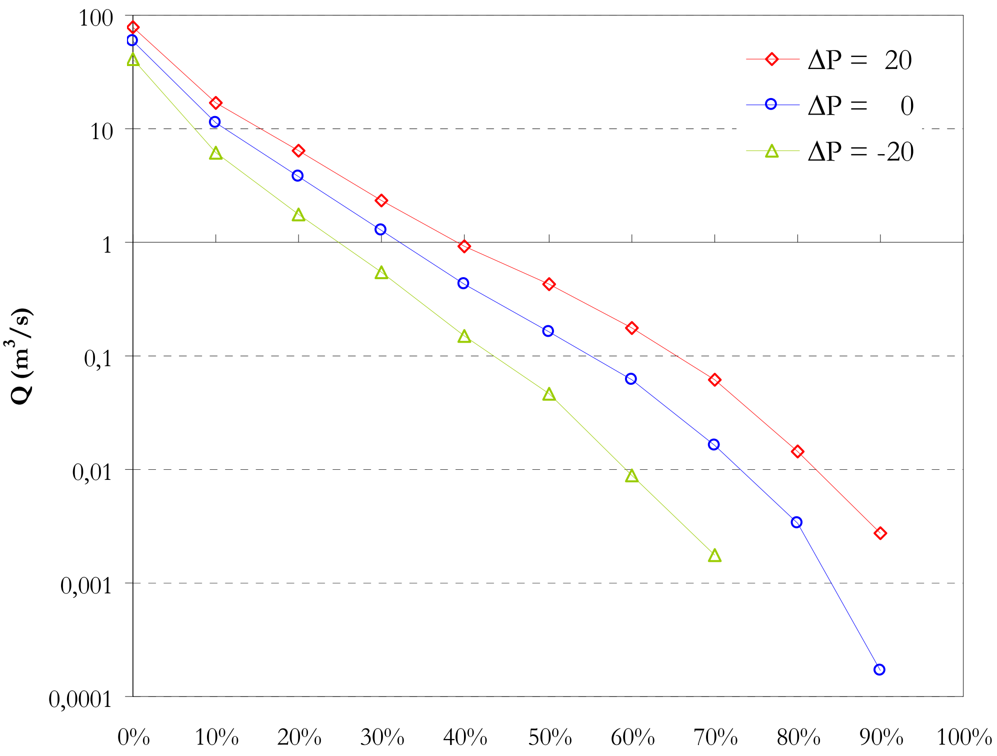


Figure 35. Permanence curves

Evaluation of MODSIM water resource management model

MODSIM was implemented as a generic model of simulation of operations of a system, to support decisions to manage it. It is a simple model and after being implemented in the basin it is easy to use. Therefore it is recommended for the management of the water resources.

It was estimated that five times more water could be used in the basin compared with what it is currently used, but for this it is necessary to store water. Because of this, it is proposed to do a multisite analysis to choose the best locations to build the necessary reservoirs.

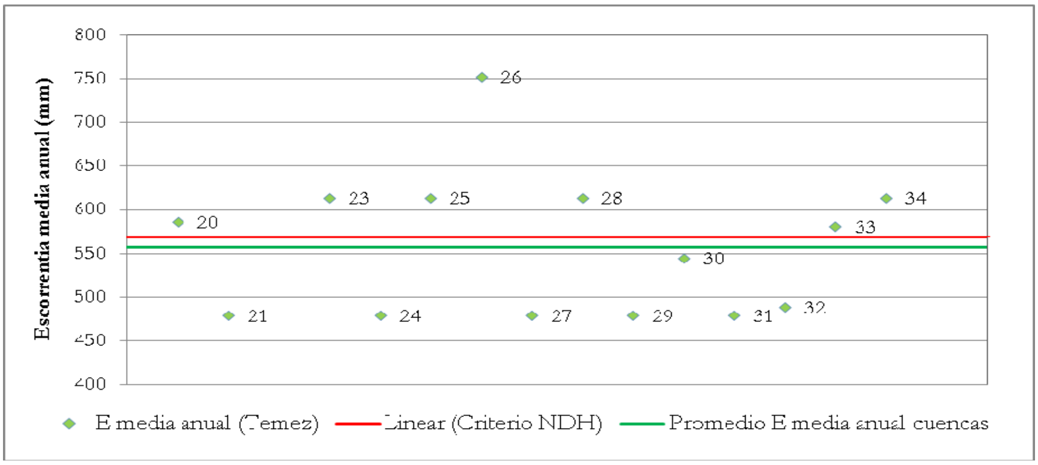


Figure 36. Annual runoff used by DNH vs annual average runoff for the subbasins (Temez). Vertical axis: Annual average runoff (mm). Green dots: Annual average runoff (Temez). Red line: Criterion DNH. Green line: Average annual average runoff.

Table 17. Volume calculated by DNH and frequency of occurrence for the contributing areas to the existing reservoirs

Basin	DNH volume (thousands of m^3)	Frequency
27	7.828	28
34	2.217	53
21	1.933	28
30	10.676	45
33	11.278	51
26	739	81
20	7.401	51
32	3.357	30
28	861	53
24	14.121	28
23	6.043	53
31	3.047	28
29	2.365	28
25	4.738	53

However, to leave upstream of a reservoir a volume of available water equal to the difference between the annual volume determined by DNH and the maximum volume of the reservoir, can have a negative impact. For instance, considering dam 20, based on the results obtained with MOSDIM for the period 1960–2007, the existing reservoir reaches its maximum volume with a frequency of 100% i.e. it fills 100% of years, so de demand is always met. A new reservoir is assumed to be constructed upstream of dam 20 with a volume equal to the available volume based on DNH calculations. Figure 37 shows the basins for both reservoirs and MODSIM scheme. The demand is assumed to be equal to the "useful" volume of the reservoir and is withdrawn in the month of October every year of the simulation. It can be observed that after incorporating the new reservoir, the new one can meet its demands most years while dam 20 does it few years. Therefore, it is recommended to have a more conservative criterion to manage water resources, for example, to consider that the maximum volume to store be reached with a frequency of 80%. Likewise, it is important to say that each basin has its own particular behaviour so it is important to do the approach case by case.

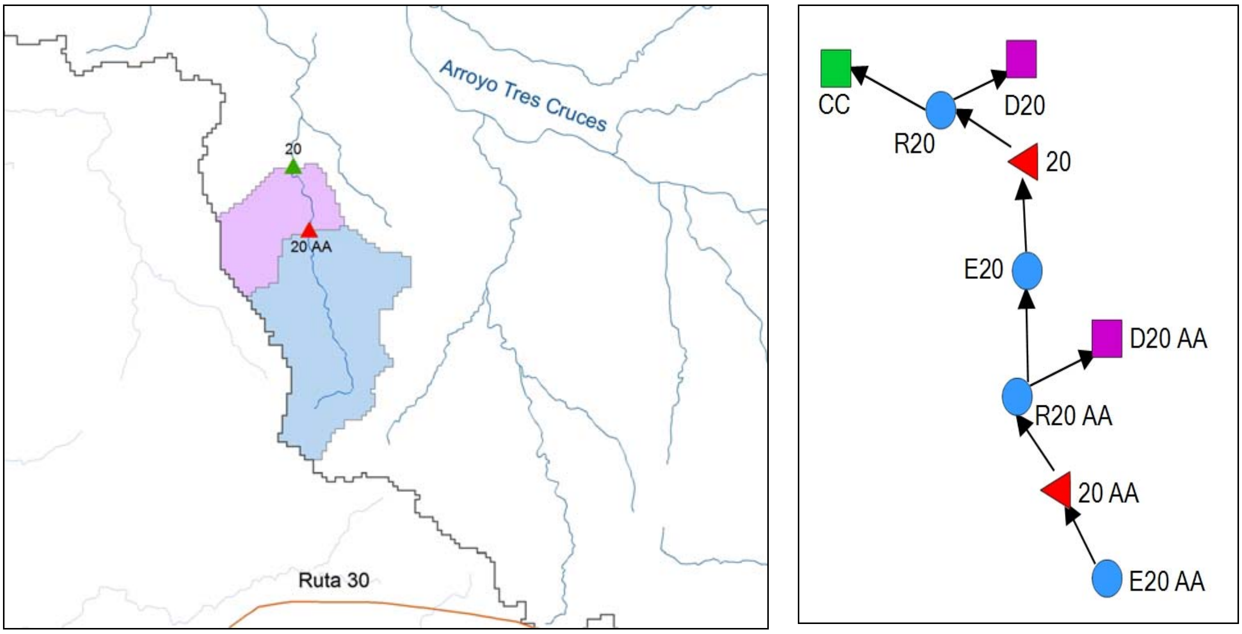


Figure 37. Sub-basins for the two reservoirs and MODSIM scheme

Table 18. Area of the basin/Area of rice for volumes of 80% and 100% frequency

Basin	Área of basin (ha)	Volume 80% (thousands of m^3)	Abasin/ ARice	Volume 100% (thousands of m^3)	Abasin/ ARice
27	1377	4009	4.8	3000	6.4
34	390	1734	3.1	1313	4.2
21	340	990	4.8	741	6.4
30	1878	7095	3.7	5289	5.0
33	1984	8383	3.3	6214	4.5
26	130	752	2.4	487	3.7
20	1302	5574	3.3	4116	4.4
32	590.5	1788	4.6	1348	6.1
28	151.5	674	3.1	511	4.2
24	2484	7233	4.8	5414	6.4
23	1063	4732	3.1	3583	4.2
31	536	1554	4.8	1164	6.4
29	416	1211	4.8	906	6.4
25	833.5	3711	3.1	2810	4.2

Regarding the available water DNH maintains upstream of a certain reservoir, that same criterion could be used for the whole basin. In other words, if the existing reservoir has a maximum volume smaller than the annual volume that the basin produces with a frequency of 80%, there will remain upstream a volume equal to the difference of the latter and the maximum volume of the reservoir met.

Summary and recommendations SWAT daily hydrological model

Based on the advantages and disadvantages presented before about the SWAT model, it is recommended to use it as a tool to validate daily data of precipitation and flow, and to model erosion and water quality in a basin with diffuse source pollution.

To assess the amount of water there is in the basin it is recommended to use the monthly-step Temez model (with 4 parameters against the 27 in SWAT).

MODSIM water resource management model

MODSIM was implemented as a generic model of simulation of operations of a system, to support decisions to manage it. It is a simple model and after being implemented in the basin it is easy to use. Therefore it is recommended for the management of the water resources.

COCIBOLCA LAKE

Little previous work exists on water balance modelling for the Lake Cocibolca Basin. One major (series of) study(ies) corresponds to the PROCUENCA San Juan Project, a Costa Rican – Nicaraguan cooperation project sponsored by UNDP and OAS (OAS, 2007) which focused on the concept of integrated river-basin management (no major attention was given to the basin's water balance). The final aim of this project was to formulate certain general recommendations for a strategic action plan for sustainable management of the water resources in this bi-national basin. However, limited baseline information was available for this purpose. Results from PROCUENCA have been taken into consideration in TWINLATIN (e.g. in WP5). Currently, in the framework of the newly established Nicaraguan Water Law (May 2007), increased interest exists at the Hydrology Direction of the INETER with respect to improving the water balances for the different Nicaraguan River Basins. It is in this context that TWINLATIN aims to provide a distinct contribution through the provision of knowledge and products, obtained from the work conducted under WP3.

The scope of the work to be conducted under WP3 is a function of not only the local stakeholders' interest, but also of the feasibility of the different methodological approaches. In this context, it is important to indicate how the effects of civil war and other destabilising events in Nicaragua can be clearly seen in the lack of and decrease in data quality, especially around 1990. In general, quality control of hydrometeorological time series data (described in more detail in the WP2 report) showed that: firstly, data quality was low for many precipitation stations; and that, secondly, especially discharge time series were highly discontinuous or, in the best cases, contained a lot of data gaps. One of the main objectives of the hydrological modelling work that was developed under WP3 relates to the development and implementation of a methodology which allows for an improved estimation of the basin water balance, and of the uncertainties involved. Transfer of the methodology developed for this case study to the Nicaraguan government institution INETER (which holds the national mandate for the establishment of (sub)basin water balances under the new Water Law) constitutes a big contribution of the project to INETER's role in the future management of the Cocibolca Basin, but also holds the potential for further extension of the developed methodology to other parts of the national territory. National interest in improved water balance modelling is, amongst other reasons, related to the provisions with regard to the extension of water use rights which are contained in this new National Water Law. Considering the long-term potential strategic importance of the Cocibolca Lake, certain interest also exists in the assessment of impacts of plausible climate change scenarios on the basin water balance.

In order to achieve the former goals, a simpler, long-term water balance estimation method was compared to the results of a monthly water balance model applied with uncertainty estimation.

The feasibility of hydrological modelling with a daily time step was assessed in a sub-basin (Mayales River) where sufficient coincident meteorological and hydrological data were available. The modelling study, therefore, also serves as an evaluation of the coherence and quality of the hydro-meteorological data. Within the Nicaraguan part of the Lake Cocibolca basin, the Mayales sub-basin was the only sub-basin for which data availability approached the minimum conditions for which meaningful results from such a modelling approach could be anticipated. Theoretically, the particular type of model that will be applied here should under ideal conditions allow for an assessment of impacts from land use and climate change; however, the feasibility of this will be highly conditioned by the availability and quality of input and calibration/evaluation datasets.

Model development

The main model development for the Lake Cocibolca Basin concerns: geo-statistical interpolation, distributed hydrological modelling, and uncertainty estimation.

Geo-statistical interpolation routines have been set up for the interpolation of time series of climate data in the basin using the freeware Gstat (Pebezma & Wesseling, 1998). The distributed hydrological model used for the modelling of the Mayales sub-basin was developed in the PCRaster software, which is a GIS integrated with a dynamic programming module. The adjustment of the model to Nicaraguan conditions has been done. The PCRaster model has also been embedded in an uncertainty estimation framework as the quality issues with the precipitation data and the large expected uncertainties in discharge data make uncertainty estimation a central issue in this study.

The discharge data series contained many gaps and the uncertainty in the data were judged to be high due to the difficulties to measure discharge in these types of rivers with unstable cross-sections (due to substantial erosion and sedimentation taking place in the river channel).

Water balance modelling: Filling of shorter gaps in the time series

A cross-validation was performed to evaluate the performance of the two methods for gap-filling in precipitation data at all stations with daily data during the periods 1970-1995 and 1996-2005.

Water balance modelling: Simple water balance model

MODIS evapotranspiration data were available for the period 2000-2005, but unfortunately there were no precipitation data in the southern (Costa Rican) part of the basin then, which did not make it possible to estimate the water balance of the complete basin. Mean annual available water resources were calculated as precipitation minus evapotranspiration. The results cannot be considered valid in the Costa Rican part of the basin due to the lack of precipitation data, and it can be seen that the available water resources follow the north-west to south-east gradient in precipitation.

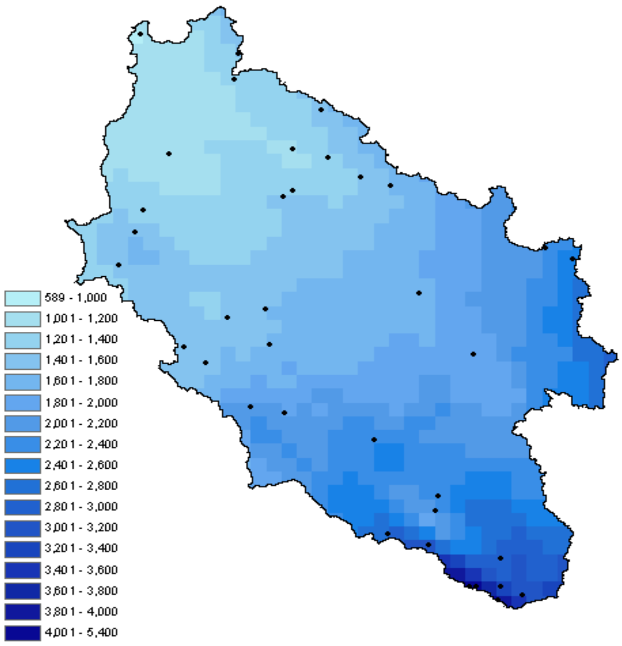


Figure 38. *Precipitation interpolated with Universal Kriging for the period 1975-1994, stations having more than 30% complete yearly data in that period were used for the interpolation and those stations located within the watershed boundary are shown as black dots. The precipitation is considerably higher in the Costa Rican part of the basin.*

Evaluation of hydrological modelling

Gap-filling and interpolation of precipitation

The CCWM method for gap-filling is a relatively simple method that gave better results compared to the IDW method. For the purposes of spatial interpolation of precipitation it is recommended to only fill gaps shorter than a month in the time series and let the longer gaps be handled by the spatial interpolation. The method is more accurate when filled values are aggregated to a monthly time scale compared to the filled daily values.

The availability of precipitation data in the Costa Rican part of the basin is important for the description of the precipitation regime in the basin as the spatial variability in this area is different from the rest of the basin. Universal kriging with anisotropic semi-variogram estimation can be recommended for interpolation of mean annual precipitation in the basin and IDW for automated interpolation of time series data. Station density varies in the basin and over time and so also the accuracy of the interpolated field. Complex topography, rain shadow effects, lack of measurements over the lake and data availability problems all complicate the estimation of the precipitation regime. Estimated precipitation over the actual lake is highly uncertain because of the few stations and large surface area of the lake. Also, such a large lake can influence the climate over the lake itself. The program with the CCWM method for filling gaps and the interpolation tools in ArcGIS Geostatistical Analyst were demonstrated at a workshop in Managua in 2008, and can in the future be used at INETER.

The mean monthly precipitation regime clearly showed the effects of the location of the watershed across the climatic divide between the precipitation regimes of the Caribbean and Pacific coast, and additionally the mountain climate in the Costa Rican part of the basin. The climatic divide is most apparent during July-August when there is a rainfall maxima on the Caribbean coast (the south-eastern part of the basin) and a relative minimum of precipitation, the midsummer drought, on the Pacific coast (the north-western part of the basin).

Calculation of actual evapotranspiration

The advantage of using MODIS data for water balance modelling is that they reflects the actual evapotranspiration and that the spatial coverage, which will be approximately 1x1 km in the final product, is fine enough to make them useful for water balance modelling also at small scales. The limitation is that the temporal resolution is eight days (many small-scale hydrological models use a time-step of one day or less). Another limitation is that the MODIS data do not extend back to before 2000 when the first instrument became operational. The advantage of using Penman-Monteith is that it is a robust formulation and that it is readily applicable everywhere to calculate potential evapotranspiration as long as the necessary input data are available. Taking the MODIS data as a reference, the Full Penman-Monteith formulation performs better than the FAO56 version, in accordance with other studies.

Simple water balance method

The spatial pattern of calculated mean annual runoff shows a clear relation with the precipitation distribution; there are higher values in the south-east part of the catchment compared to the north-west. In the future it would be important to assess the water balance at sub-annual (e.g. mean seasonal) scales too, but some idea can be given by the interpolated mean monthly precipitation. Water resources are especially scarce in the north-western part of the basin during the dry season (Dec–April). There were no complete years of discharge records during the period 2000-2005 for evaluation of the simple water balance method but a cross-comparison to modelled discharge in the Mayales catchment is made. The MODIS project data will be made globally available in the near future and can then be used for water balance calculations in other parts of Nicaragua by INETER.

Monthly water balance modelling in the Mayales sub-basin

The low values of the evaluation criteria for the monthly water balance modelling indicate that there are high uncertainties in the input and/or validation data. The WASMOD model has few parameters and has been shown to give good results in catchments in similar climate conditions where observed data have been of good quality, for example in Honduras and Costa Rica. The model parameters are usually well identified i.e. the best results are found in a small parameter interval and model performance decrease rapidly outside this interval. In this case the evaporation and fast-flow parameters were well identified but the slow-flow parameter was not clearly identifiable. The slow-flow parameter is however less important in catchments such as this one with a fast response to rainfall. The percentage of observed data outside the uncertainty bounds was relatively high in both validation periods. It might be that changing of rating curves in combination with few high flow measurements (which could alter the form of the rating curve a lot) could make it appear as if the rainfall-runoff relationship changes abruptly from year to year even if change is occurring more frequently at high flow events throughout the rainy season. In combination with precipitation data uncertainty this could be a reason for the difficulty in identifying parameter sets providing good simulations for the entire period.

It can be concluded that errors in data are large (there were months with higher discharge than precipitation) and that a limits-of-acceptability approach could be a good way to account for uncertainties in discharge data. In hindsight the limits of acceptability should have been wider as the errors in the modelling process were greater than the estimated limits of acceptability allowed for. It could also be estimated how much the limits need to be expanded to achieve an acceptable percentage of simulated results at the data points that are inside the limits (e.g. 95%). There are only complete yearly discharge data for low flow years. The limits-of-acceptability criterion as defined in this application will however tend to over condition on the most frequently occurring type of flow in the observed records, in this case low and medium flows. To achieve better results for higher flows a weighting of the limits-of-acceptability performance by the flow could be used. Given the better prediction results for low flow years, the limits-of-acceptability criterion could be useful for assessing water scarcity scenarios. On a yearly time scale the observed discharges were inside the prediction bounds for all years (sometimes by a small margin) for the limits-of-acceptability criterion. For the R_{eff} criterion, which is more focused on high-flow accuracy, predicted discharge was overestimated during low flow years

Distributed daily modelling in the Mayales sub-basin

Data limitations and high spatio-temporal variability make daily-scale hydrologic modelling problematic. The model gave higher discharge during recession periods than measured data in the calibration period; this could suggest that evapotranspiration was underestimated or that there is seepage from the groundwater directly to the lake, a process that was not included in the model. It is problematic that complete discharge data are only available for low flow years in the Mayales basin as this makes it hard to evaluate the hydrological characteristics of the basin. In the validation period there were some periods where the observed discharges seemed erroneous in comparison to observed precipitation and modelled discharge, but this could also be the result of precipitation data errors. When potential evapotranspiration is given as input, the dependence on land use lies only in the interception parameter; interception was not used in this application because of lack of suitable land use data covering the modelling period. However, the inclusion of interception would not have greatly affected the results as rains are most often heavy. More important could be the calculation of potential evapotranspiration which might be underestimated, especially in areas with bushy vegetation, with the FAO56 Penman-Monteith method. In future applications the model could be developed to include the calculation of evapotranspiration with the Full Penman-Monteith equation with the meteorological parameters as input, and the land use parameters (such as surface roughness) derived from land use data. Given the large uncertainties in the simulations, modelling of ungauged catchments and scenario modelling on a daily time scale do not appear feasible. Modelling results from daily-scale modelling could be a useful tool for quality control of discharge data as the modelling application also serves as an evaluation of the coherence and quality of the hydrometeorological data.

Cross-comparison of water balance modelling and uncertainties

Mean annual runoff from the simple water balance modelling in the Mayales sub-basin was around 700 mm in 2000-2005. The results from the monthly-scale water balance model gave uncertainty bounds roughly around 150-400 mm which was considerably lower. Possible explanations could be that there is deep seepage from the groundwater directly to the lake in the Mayales sub-basin (the modelled is calibrated on the river discharge) or that the MODIS evapotranspiration is underestimated. It could also be that the monthly water balance model gives too-low results for high flow years as it is predominantly calibrated with low and medium size flows.

Summary and recommendations

Daily scale hydrometeorological analysis using interpolated precipitation is not recommended (if the density of precipitation stations is not very high); given the spatiotemporal correlation structure a 4–5 day timescale would be the shortest possible for meaningful interpolation of precipitation. Larger data availability on a monthly time scale favours monthly or yearly analysis; also on a monthly or yearly scale variability is lower and data more representative. A thorough revision of discharge data should be carried out to remove outliers, and rating curve data should be analysed to assess the uncertainties in the discharge data. In this process it would be important to establish the highest measured discharges included in the rating curve to know which discharge data are based on the extrapolated parts of the rating curves. Such an analysis can be used to set better limits of acceptability in future modelling efforts. If possible, more high flow measurements should be made to reduce uncertainty in peak flows. Frequent rating measurements can also make it possible to change rating curves more often and improve the calculation of discharge from gauge height. Scenario modelling of land use change effects could not be recommended with the present data quality problems. Land use change effects can be expected to be seen in the dynamics of the peak flows; given the high climate variability and the high uncertainty in peak discharges such effects would be hard to detect in the data. It is highly recommended to use uncertainty estimation in future modelling studies in the basin.

Used in a hydrological model, with surface resistance formulations with constraints on soil water supply, vapour pressure deficit and temperature, the Full Penman-Monteith can be applied to calculate actual evapotranspiration in any region. The limitation is the availability of meteorological input data which might not reflect local conditions if the nearest meteorological station is located far away. This can to some extent be solved by utilising downscaling techniques for meteorological variables, or if fields of re-analysis data are used as input to the Penman-Monteith. Another approach to study climate variability impacts on the water balance at the regional or local scale is to use a Regional Climate Model (RCM). A RCM is typically run with boundary condition from a GCM but the resolution is much higher, around 40-50 km. The high resolution local climate scenarios can be used in impact, vulnerability and adaptation studies. In the future use of MODIS project evapotranspiration data in Nicaragua, possible underestimation as compared to modelled discharges should be kept in mind. Further comparisons with modelled and/or measured discharges should also be made to analyse this.

CATAMAYO-CHIRA

The Catamayo-Chira is a basin that has been strongly operated upon. As a result there is high pressure on natural resources, especially water. Natural land cover also has been altered considerably due to agricultural and livestock producing activities conducted by local inhabitants along the river basin, and a high deforestation degree.

This problem is heavier in the higher and middle part of the basin, due to increasing superficial runoff, washing away of nutrients, water erosion and sediment transportation along the river flows into the Poechos reservoir and lower land river beds (e.g. Chira), increasing infrastructure vulnerability in the valley during the rainy season, due to inundation and loss of agricultural soil and changing the hydrological regime of the basin.

The objective for a hydrological model in the Catamayo-Chira river basin is determined in the first place by the need to gain a better knowledge about the hydrological behaviour of the basin, due to limited availability of flow measurements, except in a few strategic zones in the basin. With this tool, specific areas at micro-basin level that are the main water production entities can be detected, as well as erosion processes quantified and the main sediment production zones determined.

The basin's response to different coverages and land uses can be evaluated which allows analysing the influence of the land use change dynamics on erosion and the impact on water production. In this way the model will provide a tool for planning and evaluating land and water use in the basin.

Model selection

One of the objectives of the TWINLATIN project was applying a hydrological and erosion model in the binational basin, adapted to local characteristics thus allowing solving of problems and designing of proposals for better basin management.

The SWAT model was chosen because it had already been applied to big and complex Andean basins, comparable to the Catamayo-Chira basin, offering acceptable results. It is true that the available data show a lack of information e.g. soil cover data, but at the same time this provides an opportunity to conduct further necessary investigations.

Also the climatic and hydrological data availability could be a limitation for model application, due to time and space scale reasons. The model needs a representative scale that describes adequately the special variability over the basin during a certain (long) period. This was controlled by working closely with local institutions administrating these data, collecting available (digital) data, and digitising paper data in order to get a representative measurement station density.

SWAT is also a relatively efficient model that can be run easily on a PC. It is shareware, working on the ArcView-Gis 3.2 platform, a software in which the project personnel had experience. In addition, SWAT offers the possibility to extend the hydrological model by sub-models to analyse sediments, and allows evaluation of different land uses and their impact.

However, being a complex model, it was impossible to analyse the whole extent of the Catamayo-Chira basin, because data needs are enormous. This is why the following criteria were used to prioritise the modelling area:

- Availability of information: amount
- Assessment of collected data: quality and spatial range
- Zones suffering erosion problems and water production zones
- Zones without relevant data for the model

Study area

As a study area for the hydrological and erosion analysis the whole basin area was originally considered, being 17,199.19 km^2. However, this exercise was limited to only a 68% of the total basin area, being 11,790.33 km^2. This was decided based upon the following criteria:

- Data availability and evaluation, as SWAT has highly demanding data requirements. Quantity, quality and spatial resolution of available information were assessed in order to permit a good model application, and subsequent calibration and validation.
- Prioritisation of zones presenting erosion problems and water production zones. This explains the attention paid to middle and higher parts of the basin. One important aspect concerning the lower part is its dryness. Precipitation is very scarce, except for the ENSO phenomenon, and in consequence water erosion is about zero.
- Zones that do not contribute, with relevant data for the model. In the lower part of the basin two huge reservoirs are located. Downstream from these reservoirs, the rivers practically disappear. Most of the release water flows through channels that cannot be modelled because they do follow contour lines, and are also regulated (opened and closed) in a (for the model) irregular way.

One of the reservoirs, San Lorenzo, used to irrigate the San Lorenzo settlement, is 90% located in the neighbouring Piura basin, and releases most of its water to this basin. There is no information available about what percentage of drainage water returns to the Chira basin, and what percentage is evacuated through the Piura basin. There is a minimum flow entering the river Chira by the Chipillico sub-basin, normally just reservoir overflow in heavy precipitation periods. All this would cause a significant distortion in the results.

Based upon these considerations, it was determined that the SWAT model could be implemented in the middle and higher parts of the basin, and for this reason the study area does not include the territories downstream from the reservoirs Poechos and San Lorenzo (Figure 39).

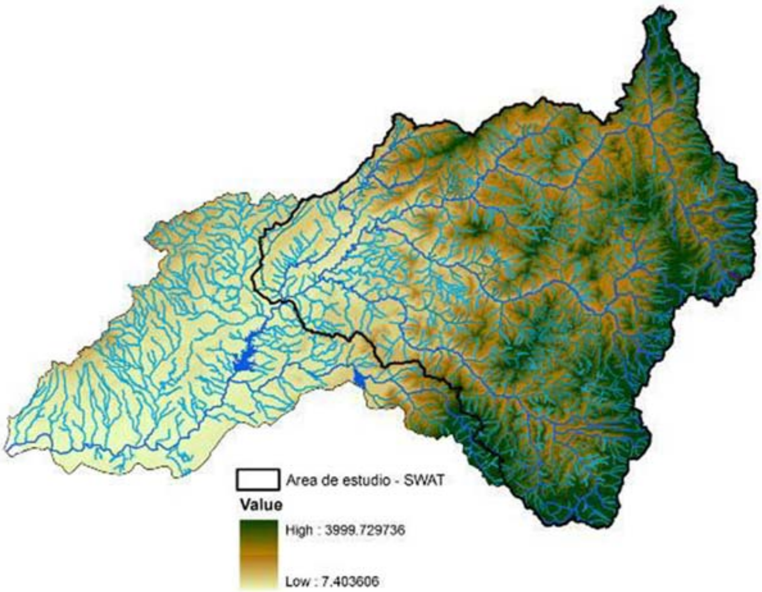


Figure 39. DEM, river network and study area for SWAT in the Catamayo-Chira basin

Model configuration

The model was calibrated for the four sub-basins located in the middle and higher part of the basin (measurement stations Catamayo, Alamor Saucillo, Puente Internacional and Paraje Grande), and at the measurement station Ardilla, located at the Poechos reservoir's inlet, which includes the contribution of these four sub-basins as well as other important contributions. In order to get results in the simulation that reflects data from measured streamflows at these measurement stations, the model was calibrated. This calibration consisted in adjusting parameters that describe hydrological conditions used by the model.

Figure 40. Location of the five measurement stations of used streamflows in the calibration of SWAT.

CAUCA

Several studies have been performed in the Upper Cauca River Basin, considering the implementation of a mathematical model in order to have a better understanding of the hydrology, hydrodynamics, sediments, morphology and water quality processes.

In order to maximise Salvajina dam's operations, in 1987, CVC selected and implemented the hydrological mathematical model HBV/IHMS (Hydrologiska Byråns Vattenvalansavdelning) of the Swedish Meteorology and Hydrology Institute (SMHI), for the forecast of flows (SMHI, 2005). It has also implemented it as a support tool for studies and projects related to water resources management in the Upper Cauca River basin.

HBV/IHMS model

CVC purchased and implemented the HBV/IHMS (Hydrologiska Byråns Vattenbalansavdelning - Hydrological Bureau Water balance) model for the application of the hydrology model in the Upper Cauca River Basin.

The first version of the HBV/IHMS model was purchased and implemented in 1987, to optimise Salvajina Dam's operations. The license was renewed in 1998, and the corresponding training course and license were received. In 2005, the new Windows version was purchased, and the model's calibration was reviewed.

HBV/IHMS is a rainfall-runoff model applied to simulate water flow and hydrological forecast. The main entry in rainfall-runoff models is precipitation data, which together with other physical and climatic variables and with the quantification of hydrology processes using mathematical models, permanently explain basin water storage and continuously simulate the water flows.

Model development

The implementation of the HBV model in the Upper Cauca River Basin was analysed for the development in three work areas:

- Salvajina Dam operation: The objective is generating short, medium and long-term forecast series for the Cauca River flow into Salvajina Dam and the hydrometric Cauca River stations.
- Hydrology studies: Hydroclimatic information provides a tool for the hydrological characterisation of all model scheme basins.
- Determination of water flow duration curves: Necessary records for basins lacking water flow information can be generated for projects related to surface water distribution in basins under CVC's jurisdiction.

For the implementation of the model, information is required from 107 pluviometric (rainfall) stations, three evaporation stations and 57 water flow stations.

Based on available cartography, it was possible to map water divisions for main flows going to existing limnigraphic stations (sub-basins). This also identified points of interest for water flow generation. Average elevation, coverage and sewage areas for each sub-basin were also determined.

Rainfall data are the most important variable for model application. Therefore, a more comprehensive analysis on existing information was performed. Missing rainfall data were determined in search for a common period for stations. Statistical tools were used to complete missing rainfall data. On the other hand, in stations where it was not possible to determine rainfall series, information was obtained using existing correlation with nearby and similar stations in order to establish substitute stations. Once the entry series for each of the stations was determined, their corresponding weight was assessed for the different configurations.

For the execution of the HBV/IHMS model as a support tool in the development of WP8 on global changes, the hydrological modelling is used to obtain the basin's water resource variation data, according to climate planning results provided by climate change models. Calibration and validation were revised at the pilot basin of the Tulúa River located in the middle zone of the Upper Cauca River Basin.

The model was calibrated for the pilot project for integrated water resources management in the Tulúa River Basin (Figure 41).

The multiannual monthly hydrographic behaviour was calculated (in red) and recorded (in green) for the calibration period of the HBV/IHMS model between 1974 and 1995, as shown in Figure 42.

General similarity in trends (shape) and volumes estimated by the model have been observed.

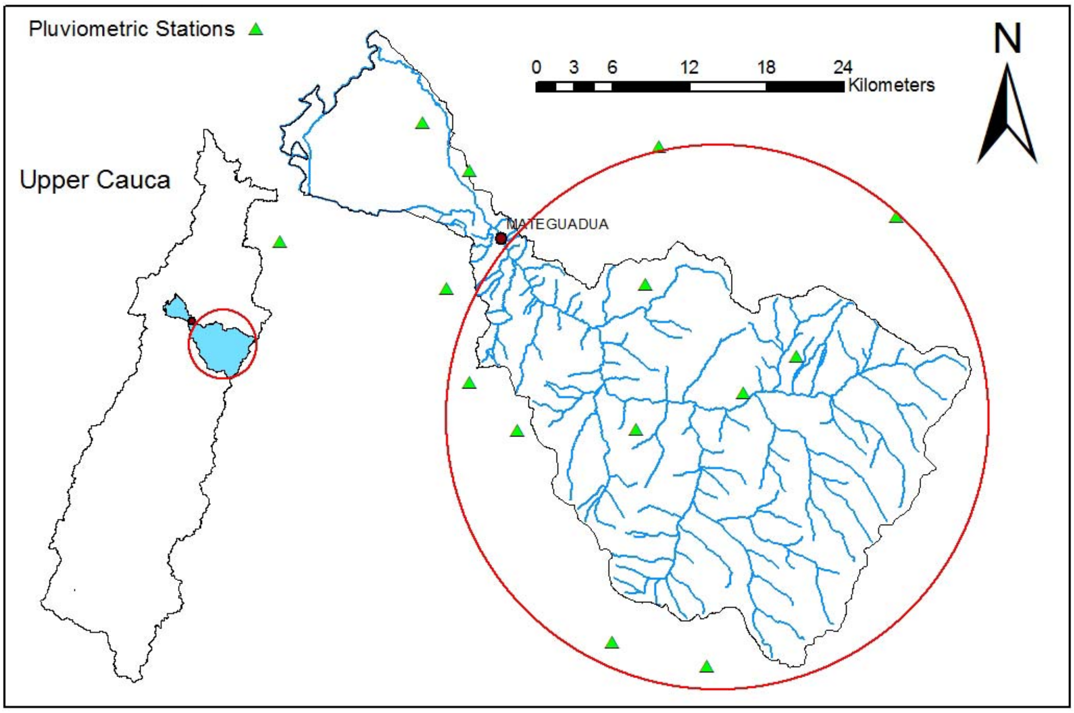


Figure 41. Location of the Tulúa River Basin in the Upper Cauca River Basin

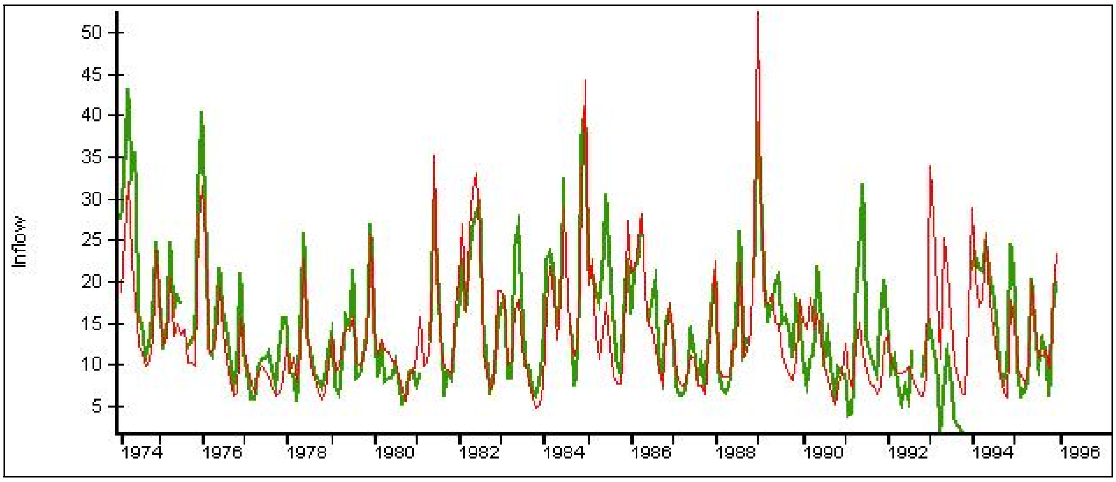


Figure 42. Multiannual monthly comparison of estimated (red) and recorded (green) hydrography for the period 1974–1995 for Mateguadua station in the Tulúa River Basin

Model results were validated for the period between 1996 and 2004. The statistical results calculated included the accumulated difference between the observed and modelled flows of -570 mm and the R^2 Goodness of fit of 0.46. The accumulated difference value is considered high for the validation period, and shows that the model tends to underestimate the flows. The Goodness of fit is considered low for the validation period.

Summary and recommendations

Complete information on the basin's pluviometer series is necessary to overcome the need to use substitute stations, which adds a degree of uncertainty to the model's forecast results.

Revision of existing correlations between the pluviometer stations in the Upper Cauca River Basin are necessary given the fact that the model requires having substitute stations for those where it may not be possible to collect full data.

It is necessary to analyse space distribution and coverage of pluviometer stations currently located in the zone and review pluviometric data during dry seasons since data may be directly influenced by climate phenomena such as El Niño.

Revision of calibration curves of the Mateguadua station on the Tulúa River is necessary, as well as water flow records quality control. Constant updating of inflow information is key in order to have more precise rating curves, uncertainty reduction and updated field record information.

3.4 WP4 Public participation

To ensure the effective implementation and achievement of the objectives of water management, the EU WFD encourage active involvement and consultation with stakeholders. Access to background information and consultation are the lowest levels and is a core requirement of public participation. Based on that, the WP objectives were:

- To develop a consistent and efficient structure for stakeholder involvement, consultation and public access to information, taking into account the prevailing cultural, socio-economic, democratic and administrative traditions, addressing poverty and gender issues, for the Latin-American basins.
- To develop process guidelines for identification of users and stakeholder water requirements that are transferable to other river basins in the regions of the case studies.
- To evaluate the applied methods during the process and in final evaluation report.

During January 2006, IVL was involved in the promotion and expanding the TWINLATIN concept and the involvement of stakeholders in the Baker basin: A number of meetings were performed in order to promote the TWINLATIN activities and concept at the regional and national level. IVL visited the area and had several meeting with the main stakeholders. These meetings were also important in order to understand the different points of view about the problems in the basin. The information obtained during these meetings served as an input to the future research and monitoring activities and for the final communication plan for the Basin. A workshop was organised in Coyhaique where the main public authorities and organisations participated. The Baker basin is currently under national attention due to the short-term plans for hydropower development in the basin.

IVL has been an important catalyser in the activities and strategies followed by CIEMA under the project. A number of meetings and discussions took place with INETER, CIEMA and IVL. Ida Westerberg met INETER personnel during the second and third year of the project and participated in training activities at CIEMA (participants from INETER also attended this event).

IVL attended a stakeholder meeting in Artigas, Uruguay, 4 October 2007, in connection with a project review meeting. National and local authorities and stakeholders participated in this event. This activity was followed by the "Fish Collection Day", a public awareness raising effort, where the researchers captured fish using different techniques in the river in front of the city of Artigas, and the fish were classified by the school children and the adults, with the help of the researchers.

IVL also participated in the organisation of an international public participation and stakeholder involvement international workshop, held in Piura-Peru, May 2008. 150 people attended the workshop "Public participation and gender in water Management". The meeting was covered by the media from both the Peruvian and the Ecuadorian sides of the river basin. Participants from the TWINLATIN partners presented their experiences. Presentations given by invited international guests focussed on gender and water.

Finally, the final project meeting in Rio de Janeiro, 10-13 November 2008, was held back to back with an international South American water manager's meeting and LANBO. IVL coordinated presentations to the wider audience of river basin managers, as well as a lunch and afternoon meeting providing more detailed presentations of TWINLATIN results, as well as giving water managers an opportunity to comment and discuss future developments. The Latin American Network of Basin Organizations – LANBO (www.ana.gov.br/relob), created in 1998 in Bogota/Colombia, is the regional chapter of the International Network of Basin Organization – INBO (www.riob.fr). LANBO has the following objectives: i) strengthen the relationship among its regional members; ii) promote joint INBO activities in the region; iii) facilitate IWRM regional initiatives. During its General Assembly, realized in Debrecen/Hungary in June 2007, INBO decided, with the support of the Latin-American representatives, for the LANBO´s restructuring, asking the National Water Agency – ANA – of Brazil to assume, on a temporary basis, the role of Technical Secretariat. It is in this context that the Temporary Technical Secretariat and the National Forum of River Basin Committees invited TWINLATIN project to take part in LANBO´s General Assembly (LANBO-GA).

BAKER

The area of study of the Project is constituted by the Baker basin, which was described in the Work Pack (WP01) *"History, current status and structure of actors"*. This document was used as a base to design the public participation plan and the communications plan for the basin. In this sense, a summary of the WP01content is delivered as follows.

A little less than 6.000 km2 (22%) of the basin territory is located in the province of Santa Cruz, Argentina, while the remainder is located in the XI region of Aysén. In the basin, Lake General Carrera is located, the main hydrographic characteristic in the basin, which takes the name of Lake Buenos Aires in Argentine territory. The lake has an area of 1.848 Km2, and it is considered the biggest one in Chile and the second biggest in South America.

PLAN OF PUBLIC PARTICIPATION

General objective:

Sensitize the local communities on the hydrological resources management and make them participate in the Baker basin through scientific research and the involvement of relevant actors.

Specific objectives:

- Improve decision making, assuring that such decisions are deeply based on shared knowledge, experiences and scientific evidence,
- The decision must be influenced by the vision and experience of the ones affected by them,
- Consider creative and innovative options, and
- New agreements must be viable and acceptable by the public.
- Make the communities understand and have access to the scientific information generated within the TWINLATIN framework and the activities of the institutions related to the project.

Methodology

The methodology to be used intends to ease a citizen participation process, with an inclusive approach, from the basis and recognizing prior knowledge and capacities of local actors in order to promote their progressive involvement in the course of the process, generating this way, the basis for local participation sustainability in natural resource management. Thus, this process intends to constitute itself into a dynamic and interactive one, designed to communicate the knowledge generated by the project to the community and in turn, receive its contributions to complement and, to a certain extent and within possible, orient current or future scientific work.

Table 19. Structure of the public participation process carried out by the TWINLATIN project in the baker river basin

Stages	Activities	Techniques used to deliver and produce knowledge	Main results (subjects)
Stage 1: Project presentation (July 2006-January 2007)	-Planning of the Communication Plan. - Site visit to the basin	-Project Presentation. -Meetings and interviews with informers and officials from 4 municipalities. -Notes of the meetings.	-Register of stakeholders in the basin. -Cooperation commitments for future workshops.
Stage 2: First round of Participatory Workshops (December 2007)	-Coordination and preparation of the workshops (EULA-CIEP-DGA) -Implementation of the workshops with authorities and stakeholders from Tortel, Cochrane, Chile Chico, and Río Ibáñez.	- Participant Observation. -Presentation of socio-environmental information of the basin. -Consultation for the construction of visions (Discussion groups) -Photographs. - Transcription/codification of the discussion groups. -Content analysis.	-Water rights. -HidroAysén Project.
Stage 3: Second round of Participatory Workshops (October 2008)	-Coordination and planning of workshops (EULA-CIEP-DGA) - Implementation of the workshops with local stakeholders from Tortel, Cochrane, Chile Chico, and Río Ibáñez.	- Participant Observation. -Presentation of information related to global/local climate change. -Survey on vulnerability perception. -Consultation for the construction of visions (Discussion groups) - Photographs, audio/visual recording. - Survey processing. - Transcription/codification of the discussion groups. -Audio/visual editing. -Content analysis.	- Perception about social vulnerability to climate change, changes in the land use, and extreme hydrometeorological events. -Water rights. -HidroAysén Project.
Stage 4: Seminar to present the results (December 2008) Process evaluation (December 2008-January 2009)	-Coordination and planning of the Seminar (EULA-CIEP-DGA). -Preparation of dissemination materials. -Implementation of the Seminar with regional stakeholders in Coyhaique.	-Presentation of the TWINLATIN Project results to the Seminar attendants. - Seminar-like consultation on the people's perception about the issue and the project. - Photographs, audio/visual recording. - Audio/visual recording analysis -SWOT analysis of the process.	-Utility of the TWINLATIN Project results for decision-making and the National Basin Strategy. -Real influence of the partipants on decision-making.

Outcomes of workshops carried out so far

- The communities of Aysén and the river Baker basin have integrated to the globalization processes in a quick manner.
- Such integration is determined by the construction and fitting out of Austral Highway (its construction was initiated in 1974, not finished yet).
- Integration ways: tourism, dams…
- The Chilean law of water has created a market of water: the State (DGA) manages and sells water rights.

- Local communities find it difficult to compete against big multinational companies for the rights purchase (inequality to access water).
- The owners of water rights use water for their private projects.
- In the river Baker basin, the main owner of water is ENDESA, a multinational company, which has a project to build dams to generate hydroelectric energy.
- There are no guarantees for future water access in Baker basin communities.
- Support and opposition from local communities concerning the dams.
- These results are conclusions about participation process activities, but they are not conclusions about citizen participation in Baker basin.

GENERAL CONCLUSION.

The participatory process conducted by the WP04 created spaces for dialogue and reflection among stakeholders and groups of interest of the basin, as well as between researchers and government officials. The main lesson taught by the process is that collaborative and coordinated work is the main way to address the complexity of the IWRM. The work was not free of obstacles, especially when there are 1,500 kilometers of distance between Concepción and Coyhaique, and another 500 kilometers of mostly gravel road from Coyhaique to Caleta Tortel. To this we have to add the disciplinary boundaries of science, and the different interests and objectives of science and public institutions. However, during the work, which lasted over two years, the trusts were established and the necessary adjustments were made in order to integrate the visions and achieve the basic goal of generating relevant information, simplifying it, and presenting it to stakeholders to collect their opinions and identify the most relevant issues affecting them in relation to water resources. As reflected in this report, the relevant or critical issues (water rights, the HidroAysén Project) are the result and the expression of structural changes that Chile has experienced since the 1980s, when the current Water Code (1981) was issued and ENDESA was privatized (1989). As a matter of fact, the HidroAysén Project has brought to light the concentration of water rights in big companies, which has generated a public and parliamentary discussion in the country, that has resulted in a campaign of political and social sectors to "nationalize" Chilean waters. This campaign is led by senators from the center-left coalition and social organizations such as the "Vicariato de Aysén". It began to materialize in September 2008 with the introduction of a constitutional amendment project in the Senate to *nationalize water*, which has generated discussion from different social sectors.

In this context, we can conclude that the main contribution of the WP04 was to produce information in an area where it was scarce, and also to generate a participatory model in conjunction with the CIEP, the DGA, and the communities. This model enabled the development of professionally structured social conversations which were useful to know life experiences of the basin's people, their vision of development, and their perception about complex issues such as climate change and hydroelectric mega-projects in the basin. Collecting these experiences, working with them, systematizing them, and presenting them to stakeholders in the form of didactic material (maps, graphs) was one of the major achievements of the team. The permanent feedback between professionals of the WP04 was crucial to systematize these experiences, which are the basis of the participatory model presented in this report.

However, the most important conclusion is beyond the control of the WP04 and the TWINLATIN Project; this refers to the possibility that the opinions of stakeholders participating in the process -many of which represent the collective interest of the basin's "comunas" (Mayors, Councillors)- will be considered in the decision-making. With regard to water rights, the opinions of stakeholders have reached the offices of the DGA-Aysén, whose Director and officials are working -within the limits permitted by the current law- to respond to the community demands. This does not happen with respect to the HidroAysén Project, which involves the highest levels of the decision-making process of the country: the Executive Power and the Chilean Parliament.

The results of the participatory process carried out by the TWINLATIN Project are a reference material for all the authorities, civil society actors, business organizations, and any citizen who is interested in knowing some of the socio-economic reality and the opinions of stakeholders of the Baker River Basin in relation to water resources. IWRM does not exist by itself, it is necessary to promote it, build it with the help and coordination of the different water users of the basin. The participatory process conducted by the TWINLATIN Project is a knowledge and information input in this great challenge of building an IWRM.

Promoting the sustainable and equitable use of water resources, this IWRM should aim at reducing conflicts and coordinating the actions of water users, as well as providing scientific information for the current public and parliamentary discussions on water resources.

COCIBOLCA LAKE

The biggest lakes in Nicaragua are Cocibolca and Xolotlán. Lake Nicaragua or Lake Cocibolca is the most important hydrological resource and the highest priority for the country. It was recently declared as water supply natural reserve. CIEMA selected Lake Nicaragua basin as research area within the framework of TWINLATIN Project.

Lake Cocibolca basin is of great importance as it possesses in its territory, the biggest water mirror in the country and in Central America, which has enabled in recent years the civil society and private entrepreneurs to understand how important this resource is, and it has provoked national concern and the need to sensitize municipal and local actors. Currently, the introduction of tilapia cultivation in the farms at the interior of the lake has called the attention and concern of Nicaraguans, and has also generated a national debate.

MANAGEMENT OF THE BASIN

Currently, there are serious management issues in Nicaragua and in the selected basin. One of the elements affecting the different decisions is the absence of a Territorial Zoning Law nationwide, which has an effect on the chaotic growth of the cities, producing a negative impact in the basin.

The main problems related to this aspect can be summarized as follows: lack of liaison between planning and public investment, weak bonds between territorial zoning and the reduction of social vulnerability and poverty, absence of urban planning, lack of definition and coordination of normative and institutional framework for urban development, and institutional management weaknesses at national level.

In spite of the aforementioned difficulties, all the municipal institutions have designed their environmental management plans of their territory, which include work components that contribute to mitigate the environmental impacts in the basin; however, these efforts are carried out virtually without budget, and some town councils define small amounts that do not represent a solution to the problems.

It is important to mention that most of the environmental actions are being developed by the Municipal Environment Committees at local level (CAM for its Spanish acronym) where all local institutions are represented; however, it is the NGO's which perform important activities on this subject.

MECHANISMS OF PARTICIPATION

Numerous governmental institutions and civil-society organizations perform actions in the basin. There are different participation structures, mechanism that is regulated by the Law of Citizen Participation and that allows to define the participation levels at national and local levels.

Participation develops in different levels, several groups of actors or networks of actors linked to water management in micro basins, amongst them: local actors, presented at individual level, family level and sector of peasants, actors in communities and municipalities, actors at national level represented by the governmental sector, we also have international actors, from the civil society, such as NGO's, and private institutions. All of them play a role of equal importance in the network; none of them is better or worse than the other one.

Local actors are necessary; however, they hardly get involved in the processes and they are given little importance, and there are difficulties of communication mainly with the municipal councils.

BACKGROUND OF PUBLIC PARTICIPATION AND COMMUNICATION

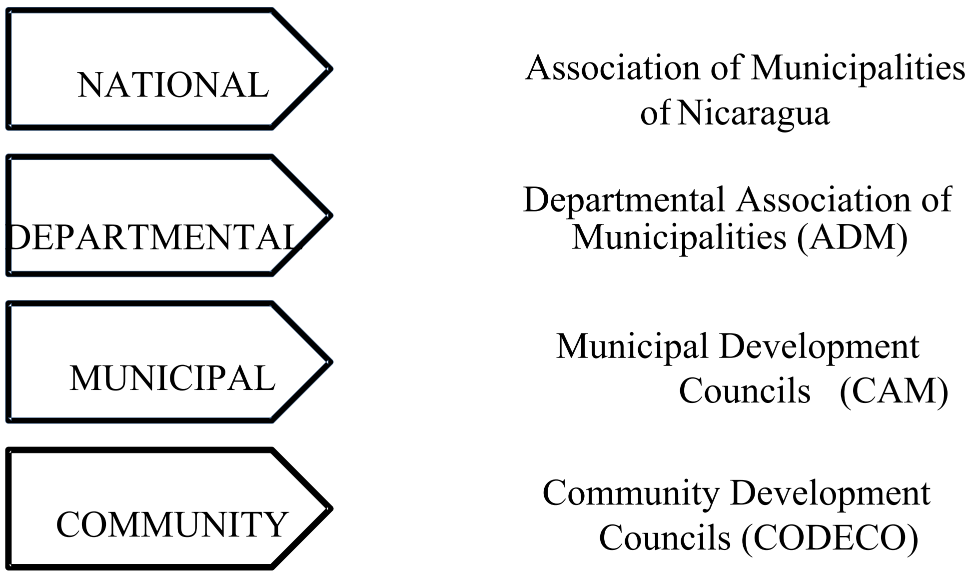
After a period without institutional and political interest in water care, in the last three years the cross-border Project called Pro Cuenca has been finished, which laid the foundations for action continuity to promote research studies in the basin. One of its results is the creation of the Association of Municipalities of River San Juan Basin (AMUCRISANJ for its Spanish acronym), an association that alerts about the deterioration levels of the basin and the lake, and sensitizes on the importance of protecting the resource.

Under these circumstances, the mass media have prioritized the information of hydrological resources and a very special place is occupied by Lake Cocibolca.

The TWINLATIN Project, in order to trigger the citizen participation process, made a diagnosis about the participation processes in the basin, which identified the actions carried out by the different competent institutions:

- The Council and participant institutions at CAM promote people's participation by means of sensitization campaigns, getting help from the radio and local television channels, workshops, fairs and contests. In a coordinated manner, the institutions members of CAM participate in these activities in most municipalities, as well as community leaders and educational institutions involving teachers and students.
- The institutions participate by contributing their own resources and donations to reach the objectives of the activities programmed in environmental plans.

Structure of levels of citizen participation at municipal level



The existence of initiatives at National and Municipal levels emerges from the effort to achieve organizational benefits to communities.

The Basin Committee. In some sub-basins these committees are organized, however, they should comply with the new features defined on the recently approved Water Law. The committees should encourage citizen participation in the management of water resources; they will be forums of consultation, coordination and cooperation among the organizations of the Basin. These committees will be composed of:

a) Representatives of users of water from the different uses in the basin.

b) Representatives of the Board of the Basin Organization.

c) Representatives of the Autonomous Regional Councils, where appropriate.

d) Representatives of Accredited Non – Governmental Organizations.

It can be said that the Basin Committees will be the place where the civil society organization should play an important role to avoid deterioration of water resources.

In connection with the legislation, the participation of residents and cities located in the basin of Lake Cocibolca takes an important role. The existing legal framework allows their involvement and active participation. A concrete example of it are the different levels of participation at the municipal level, which are supported by the legal framework related to the Law of Citizen Participation and take up Article 3 of the Law.

The Municipal Environmental Commissions (CAM), have a background and work experience accumulated over several years, allowing them to participate in the formulation and development of environmental management plans in municipalities and *departamentos.*

In some sub basins from the Great Basin of Lake Cocibolca, there are other examples that concretize other participatory mechanisms and key players involved in the appeal and performing of various mechanisms of communication and dissemination, such as: The Coalition of Organizations for the Right to Water, Club of Youth Environmentalists, Consumers League (Great importance of the participation of water users), Humboldt Center, GPAE, others.

For TWINLATIN Project, a mechanism for coordination and support has been the Association of Municipalities, Departmental Associations of Municipalities (ADM) and the Municipal Environmental Units (UAM). This is the case of the Association of Municipalities of Boaco (AMUB), and UAM – Nandaime, where they have performed activities in specific sub-basins.

TWINLATIN Project has coordinated activities with the National Information System and the Institute of Territorial Studies.

Identified Conflicts in the Municipalities of the Basin

1. The water of the Ñocarime Lagoon is shared by the municipalities of Potosí and Buenos Aires. The lagoon was declared as a forest natural reserve by the municipality of Potosí, without considering the municipality of Buenos Aires. The latter states that there are vested interests in this objective. The Sugar Refinery Compañía Azucarera del Sur (CASUR) wants to use the water from this lagoon.
2. According to recent information from a national television station, local fishermen are concerned about the current diversion of water by the Compañía Azucarera del Sur (CASUR), because of the importance that it has as a source of income for their families. In the interview, MARENA believes that the effect of it is local, and not national, for that reason the lagoon cannot be declared as a protected zone. MARENA advises that involved municipalities should analyze the situation; that probably there are other answers to the problem; it proposes to use another legal figure, such as ecological park, etc.
3. In Belen, Rivas, the banana cultivation is causing water levels to drop from the wells that supply water to the families.
4. One of the problems in Santa Lucia is that INAFOR does not participate in the CAM and it is considered as the cause of deforestation in the area. It gives permission to cutters, even after being found *red-handed,* violating the law and cutting without permits.

After the results of this diagnosis, it was observed that there are different initiatives at all levels. However, not all *departamentos* and municipalities have a clear mission in the protection of the Basin. Most municipalities have environmental plans, but do not have a real budget to ensure the success of the various environmental activities.

In the Municipal Environmental Units (UAM) we can indicate that 90% of the activities are geared toward awareness and environmental education, but there are no studies or complete projects of investigative source under implementation, documenting the current state of the sub-basin.

It is necessary to highlight the results of the Binational PROCUENCA San Juan Project, the most important in the basin, which began in 2001 ending in 2005. Lake Cocibolca shares the riverside of Río San Juan with the neighboring country of Costa Rica.

On aspects of civic participation, this project, since its inception, carried out a “Building Capacity Process in Citizen Participation”. Through the implementation of this exercise, it was obtained significant achievements such as:

- Generation of knowledge and information on economical, social and environmental matters.
- Organizational Strengthening. Alliances and agreements between public and non-public, as well as, educational priorities at formal and informal levels of education.
- Institutional strengthening. Facilitated coordination, outreach, and job sharing. Greater impact is observed in the municipalities of Nicaragua.

- Efforts to incorporate a gender perspective in the process of public participation. It was limited to a study on gender relations of women and men in the basin. This item introduced restrictions at the level of local actors.

Target Shares of Citizen Participation in the Basin.

The methodology of work developed in TWINLATIN Project Nicaragua in the component of Citizen Participation, is based in the Research – Participation – Action Method, along with the component of Dissemination and Information.

To do so, it was taken as a reference existing organizational aspects and results of research conducted in the basin. This program began in late 2006; the first work results were obtained at the end of the same year, when the project was initiated.

The first phase was to explore and evaluate existing initiatives in the basin.

The techniques of participation and involvement of actors that were carried out were based on the conceptual framework outlined at its beginning, and are the following:

- Diagnosis of municipal organization in the basin.
- Coordinating with members of the Associations of Municipalities of each departmento population settled in the basin.
- Design of interview guidelines and informal conversations.
- Preparation of educational lessons.
- Editing specific notebooks by sub-basin.
- Coordination and identification of actors at the national level.
- Analysis and identification of actors in the municipal level.
- Identify the level of actors and map elaboration.
- Specific workshops for environmental education and participation.
- To strengthen and support organizational activities at the community level.
- Technical work meetings.
- Briefings
- Technical tours and talks with local actors.
- Preparation of informative materials on water resources in the sub-basin, subject to the activities.
- Participation in local and national forums executed according to the basin.
- Develop and coordinate technical workshops.
- Develop press and radio articles.

After the diagnosis, it started with the first phase of the implementation of different workshops of citizen participation, selecting priority sub-basins to approach. It succeeded in engaging the various levels of national actors, institutional, departmental, and locals, representatives or technical delegates from the municipal Environmental Units, institutional technicians from governmental agencies, associations and civil society organizations, including producers, owners of private protected reserves, of community level, and so on. In the first stage, it is worthwhile to underline the presence of mayors and local authorities in the workshop conducted in relation to the sub-basins of the Mayales, Acoyapa, and Oyate Rivers.

Content and workshop programs were emphasized on Management of Water Resources, exchanges between actors on the current state of the basin, and on the application of the SWOT technique, to identify existing problems in terms of resource management. As a result of this process, it was possible to obtained different matrixes developed in conjunction with the actors (See sample at end of document).

In the second and third stage of work, emphasis was given to let people know the obtained results from the different components of the work developed. This process was carried out through the implementation of workshops at departmental level, with presence of actors from governmental source and civil society organizations. In total, six workshops were conducted, the last, or closing, with high-level actors or decision-making.

PLAN OF PUBLIC PARTICIPATION

With the Plan of Public Participation, capacity building is sought through the participation of actors at different levels, for the resolution of problems originated by environmental pressures in the hydrological resource of Lake Nicaragua basin.

Specific objectives

- Make a diagnosis through supervised interviews (conversations), municipal organization initiatives in the basin.
- Contribute through the TWINLATIN project to other research efforts that intend to study the basin, giving priority to mapping and/or actor identification aspects, as well as levels of participation and address of the Hydrological Resource.
- Report with research products generated by the TWINLATIN Project to different actors settled in the basin.
- Coordinate actions with the Municipal Environment Committees in technical and specialized aspects generated by the project.
- Develop specific information and consultation workshops on pollution and legislation aspects.
- Create a technical consultation committee of the Project to succeed in TWINLATIN actions.
- Involve different actors to analyze and revise the strategic plan for the management and conservation generated by the project.

Methodology

The work methodology developed by the TWINLATIN Nicaragua project in the framework of the citizen participation component is based on the research – participation – action method.

The work component is developed at the same time as the spread and information component.

To that end, we took as reference already existent organizational aspects and the results of the research carried out in the basin. This program was commenced at the end of the year 2006; the first outcomes were obtained at the end of the same year, with the project already commenced. The first phase consisted on exploring and diagnosing the initiatives existent in the basin.

In short, the participation and involvement techniques of actors at project level have been made based on the conceptual framework defined to carry out this work.

Performed Activities

Activity	Execution Date	Basin/ Subbasin/	Headquarter	Comments
Phase One Implementation of Workshops				
Design, Planning and Implementation. Workshop on Civic Participation.	April-2007	Sub-basin of River Malacatoya	Municipality of Boaco	Coordinated with the Boaco Association of Municipalities (AMUB)
Design, Planning and	May	Sub-basin of River	Municipality	Coordinated with

Activity	Execution Date	Basin/ Subbasin/	Headquarter	Comments
Implementation. Workshop on Civic Participation.		Ochomogo	of Nandaime	the Environmental Unit of Nandaime Town Hall
Training course to technicians from local institutions on Solid Waste Management	June	Sub-basin of River Ochomogo	Municipality of Nandaime	Coordinated with the Environmental Unit of Nandaime Town Hall and given by a teacher from CIEMA
Design, Planning and Implementation. Workshop on Civic Participation.	Sept. 2007	Sub-basin of River Oyate	Municipality of Santo Tomás. Chontales	Coordinated with Chontales Association of Municipalities (ASOCHOM)
Training for professionals and specialists from the National Institute of Water Resources on Management georeferenced data using the Archydro software.	August 2007	INETER Facilities	INETER Facilities	Provided by members of the technical team of the TWINLATIN Project.
Workshop on Integrated Water Resources Management	April-2007	Sub-basin of River Malacatoya	Municipality of Boaco	In coordination with the Central American Network of Engineers

Second Stage Implementation Workshops				
Activities of Dissemination of Information and Materials Design				
Editing Educative Lesson on Water Resources – Malacatoya Sub Basin	March	Sub-basin of River Malacatoya	Managua	Integrated into the notebook given to the actors in the workshops.
Editing Educative Lesson on Water Resources - Ochomogo River Sub basin	April	Sub-basin of River Ochomogo	Managua	
Editing Educative Lesson on Water Resources - Oyate River Sub Basin	August	Sub-basin of River Oyate	Managua	
Editing and layout of 2000 notebooks for primary level (to write)	March-2007	Sub basin of River Malacatoya		It was donated to the Environmental Units of each municipality and the Executive Secretariat of the

				Boaco Association of Municipalities (AMUB)
Editing and layout of 2000 notebooks for primary level (to write)	May	Sub basin of River Ochomogo		It was donated to the Environmental Unit of the Town Hall of the Municipality of Nandaime.
Editing and layout of 2000 notebooks for primary level (to write)	August	Sub basin of River Oyate.		It was donated to the Environmental Unit of the Town Hall of the Municipality of Chontales and the Association of Municipalities (ASOCHOM).

Activities of Education and Awareness				
Participation in National Forum on Lake Cocibolca	March 2007	Basin of Lake Nicaragua	Municipality of Granada	Participating with the aim of addressing the basin, and its protection
Participation in Local Water Forum	April 2007	Sub-basin of River Malacatoya	Nandaime	In order to know the problems of the Resource, at the Basin level.
Exhibition Stand at the Local Fair on Lake Cocibolca	October 2007	Basin of Lake Cocibolca	Municipality of Granada	Initiative of the Cocibolca Navy and ESTESA TV network.
Participation in courses on the model of software HEC.	March, 2008	Participation of four members of TWINLATIN Project, who work in the basin of Lake Cocibolca	Managua,	

Third and fourth Work Stages				
Workshop on "Citizen Participation: Dissemination of Results and Compilation of Views from actors in the Basin of Lake of Nicaragua"	Nov.2008	All the departamento of Granada	Colonial City of Granada (Shores of the Lake)	There was a great participation of actors

Workshop on "Citizen Participation: Dissemination of Results and Compilation of Views from actors in the Basin of Lake of Nicaragua”	Nov. 2008	All the Departamento of Rivas	Municipality of Rivas	There was the presence of local industry actors
Exchange and dialogue with actors in the area of the archipelago of Solentiname and Wetlands	Nov.2008	Wetlands, Islands	San Miguelito, Islands, Wetlands	Dialogue, conversation and technical visit with various actors
Implementation of National Workshop*	February, 2009	All national actors	Municipality of Rivas	With the presence of actors in the decision making level

* In the process of defining

Results

Results from the various actions of each of the affected sub-basins are the following:

- Editing articles in: The UNI’s Journal “Revista Nexo”; twice in UNI’s Newsletter, and addressing the activities of the TWINLATIN Project in La Prensa and El Nuevo Diario newspapers, the electronic newspaper La Verdad de Granada, Radios, and Local TV stations.
- Report of each citizen participation workshop carried out in each municipality: Details of the program, list of participants, SWOT matrix, pictures, event guide, program, etc.
- SWOT matrixes of the sub-basins affected by the Project’s activities.
- As a result of the different presentations, the involved actors handle the concept of Integrated Management of Water Resources (IMWR) and the impact of their activities on Lake Nicaragua.
- About 300 actors were involved in municipal workshops.
- An agreement was signed with the Direction of the National Environmental Information (SINIA), based in MARENA.
- An agreement was signed with INETER.
- Survey data on Climate Change.

Three planned phases of the conceptual framework and activities from the formulated plan were accomplished. However, the main impacts to this component were caused by the late entries of the budget. The activities of citizen participation are activities with direct action that require previous planning and economic resources, if this does not happen, there is a risk of facing action at the local level with little credibility. I is best not to do so. When dealing with topics and activities in the municipalities, expectations are created and the institutional prestige in charge of the project is lost.

As a result of the lack of credibility of the municipal elections that just past, at the request of the Executive Secretariat, the workshop was not implemented in the *Departamentos* of Boaco and Chontales.

Conclusions

The Town Hall and the institutions participating in the CAM, promote people's participation through the planning of awareness campaigns, assisted by radio and local television stations, workshops, fairs, and competitions. In a coordinated manner, in most of the municipalities, institution members of the CAM participate in these activities, as well as community leaders and educational institutions, involving teachers and students.

The institutions participate by providing their own resources and donations to achieve the objectives of the programmed activities set in the environmental plans.

Participation actions are important, but sensitive on how to approach them. That is why they should start from the beginning of the project and have the time needed for planning, having a team, and the resources needed, so that the actions turn to be positive and, at the same time, to get basic information to achieve the objectives of the projects.

The vision of identifying barriers for the protection of water resources is essential for the country, especially, for projects of this nature. Thus, disrupting activities leaves a negative taste to local actors, who create expectations when institutions are not able to effectively complete the planned actions.

There is a high level of organization at the basin level, many of actions undertaken, in great percentage, are directed to other non-environmental actions and the resource of the basin of Lake Cocibolca is at risk of further deterioration that started many years ago. The Basin of Lake Cocibolca, in practice, requires investing to investigate it, needing that the participation of universities keep on going, as well as governmental institutions and the people organized to achieve the goal defined by the National Water Law.

The institutions must direct their actions towards the decontamination of solid and liquid wastes; to prevent water erosion; control of livestock, the direct discharge of sewage from the population and trade; improper use of agro-chemicals; to promote the construction of sewage systems; to guide actions of awareness and environmental education; to improve the quality of life of the inhabitants of the basin; to strengthen the existing organizational structures, at different levels, and institutional presence, and provide them with the necessary resources to carry out environmental monitoring.

Consequently, of the little impact so far achieved in some sub-basin, there is little presence of the actors in the actions planned and executed related to citizen participation. This allows that projects which formally start activities, continue doing so to achieve the credibility that is required and the goal of protecting the watershed becomes a reality, like making immediate action, in function of Lake Nicaragua (Cocibolca).

The actions developed by the Project, allowed that local actors know the objectives of the TWINLATIN Project and the information of the current state of the basin, including proposals for protection.

CAUCA BASIN

According to provisions in Decree 48 dated January 15, 2001, which modifies Article 7 of Decree 1768 of 1994 and the Articles 1 and 2 of Decree 1865 of 1994, the Regional Autonomous Corporations have three planning instruments: the Triennial Action Plan, the Annual Investments Operation Plan, and the Regional Environmental Plan. The latter, with a 10 year duration, must be collectively proposed, with the participation of the different social regional stakeholders, and from there, set the environmental commitments and responsibilities for each stakeholder.

Considering Colombia's position as the leader of the region in the regulation of legal participative instruments, the process for the 2002-2012 Regional Environmental Plan was developed respecting the legal terms of the different mechanisms of citizen participation in effect in Colombia: Law134 of 1994; Law 70 of 1993 and Regulatory Decree 1745 of 1995.

Environmental management scenarios allowed participation, action and coordination by the different institutional, entrepreneurial, and community stakeholders. Some of these scenarios originate from the standards, while others are created by the stakeholders within the environmental management consolidation process in the Department of Valle del Cauca, and their goal is to facilitate the achievement of development sustainability.

For this reason, the 2002-2012 Regional Environmental Plan "Committed Participation" follows the basic principles of participation in environmental management described in the "Guidelines for a Policy for Citizen Participation in Environmental Management".

The institutional actors in the basin are presented in the following figure:

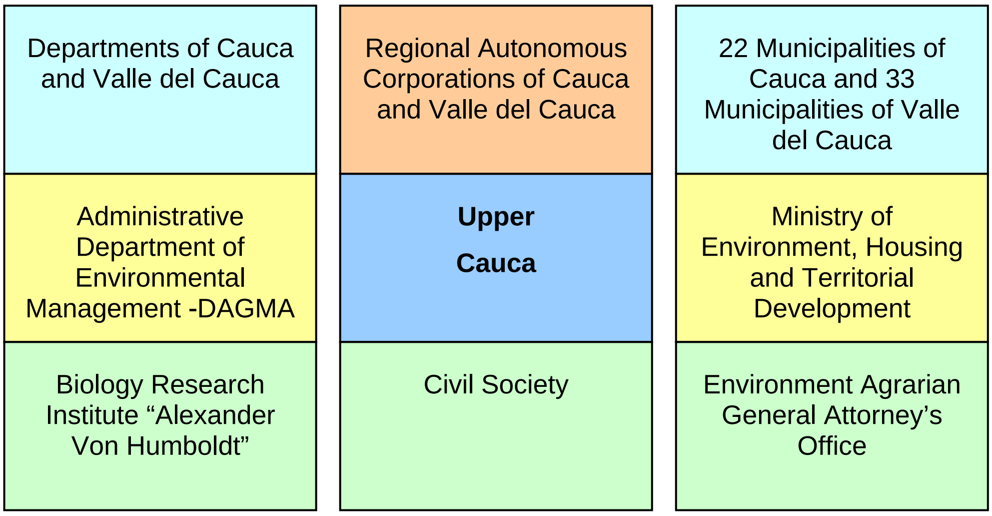


Figure 43. Actors of the environmental management in the Upper Cauca

The present document synthesizes actions developed in the sub-basin of the Bolo River, a tributary of the Cauca River, as a pilot basin for public participation through the formulation, design and implementation of a strategy for the empowerment of social stakeholders related to water management plan in such territory.

Objectives

The general objective of the Public Participation Plan was to involve the inter-institutional and social stakeholders in the TWINLATIN Project activities that are developed within the framework of the Strategic Management Plan of the Upper Cauca River Basin, which was the target applied to the pilot zone in the Bolo River sub-basin.

Specific objectives

- Develop an efficient structure for participation.
- Develop process guidelines for the identification of water requirements.
- Evaluate applied methods.

The methodological process for the plan proposal uses prospective, strategic and participative planning concepts, includes nine phases, out of which, the first five include such methodology: Preliminary Phase, Environmental Appraisal, Environmental Prospective, Objectives and Strategies, Follow-up and Evaluation. The other four phases, as part of the complementary process for its legalization, administration and dissemination, are: Consolidation and Edition, Plan Approval, Instrumentation and Dissemination.

For the Environmental Planning of the Bolo River Basin

The Water Basin Development and Management Plans (POMCH), are framed within Decree 1729/02, which has the objective of negotiating and, at the same time, involving the social stakeholders in a way that allows maintaining or reestablishing an adequate balance between the economic management of such resources and the conservation of the physical-biotic structure of the basin, and especially, its natural resources through territorial planning and citizen participation via training workshops and the implementation of conservation, protection, efficient use of water programs and projects.

The construction of the Bolo River Basin Management and Development Plan– POMCH – considered the active and participative involvement of social stakeholders as a fundamental aspect, through the implementation of methodological strategies that allowed the development of organization, community participation, and environmental education processes, for the recovery, protection and conservation of the basin, with the purpose of having a collective proposal created by the social stakeholders and CVC that responds to the community needs, problems and demands in search of a balance in the relationship between mankind and the environment.

Methodological Process

The Bolo River Basin Management and its Development Plan is based on the active and direct participation of social stakeholders in all the phases of the process, not only as direct sources of information, but as participating stakeholders in the Plan proposal phase. This includes the development of an education process that provides the necessary information and tools for the organized participation, in which these groups become responsible for the construction and execution, evaluation and follow-up of the POMCH, promoting real participation scenarios and encouraging the communities, as well as other stakeholders, to manage their own development in harmony with others that respects the natural resources.

The methodological process proposed for this Plan emerged from the knowledge of each of its social stakeholders, their characteristics, their customs, their day to day activities in the river basin, looking for the implementation of techniques that are participative and that allow collecting the relevant information from each stakeholder, contributing to the analysis, not only from a technical perspective, but from a social and cultural point of view. This will make the Plan a result of the collective construction between the social stakeholders and CVC, which will also respond to the real needs of the people, settled in the Basin.

Wanted Participation Levels in each Group of Actors

- **At level of transfer of information**: attached to activity socialization and results.
- **At level of consultation**: They were made and they will continue with actors who have contractual links with CVC and/or CRC in subjects related to TWINLATIN, such as Universidad del Valle, CIAT and its affiliated organizations, IDEAM, The Ministry of Environment, Housing and Territorial Development.
- **At level of active implication:** the neighboring Regional Autonomous Corporations belong to this group, amongst which, the most involved one is the Regional Autonomous Corporation of Cauca CRC. Also belong to this category the Governments of Cauca and Valle del Cauca in any of the Secretariats, the Municipalities, the Ministry of Environment, Housing and Territorial Development and the Research Institutes, with IDEAM as the most involved one.

PILOT PROJECT FOR THE BOLO RIVER SUB-BASIN

The Bolo river basin is located on the western side of the Central Mountain Range, in the jurisdiction of the municipalities of Pradera, Palmira and Candelaria, Department of Valle del Cauca. The northern limit of the Bolo River is the Nima River basin. On the east, it borders the Department of Tolima, on the West, the geographical valley of the Cauca River and on the south, the Frayle River basin.

The river basin area from its head to the mouth of the river is approximately 379.14 km^2, out of which 70.7% is located in the municipality of Pradera, 25.8% in Palmira, 3.4% in Candelaria and l 0.1% in Florida (See Figure 44).

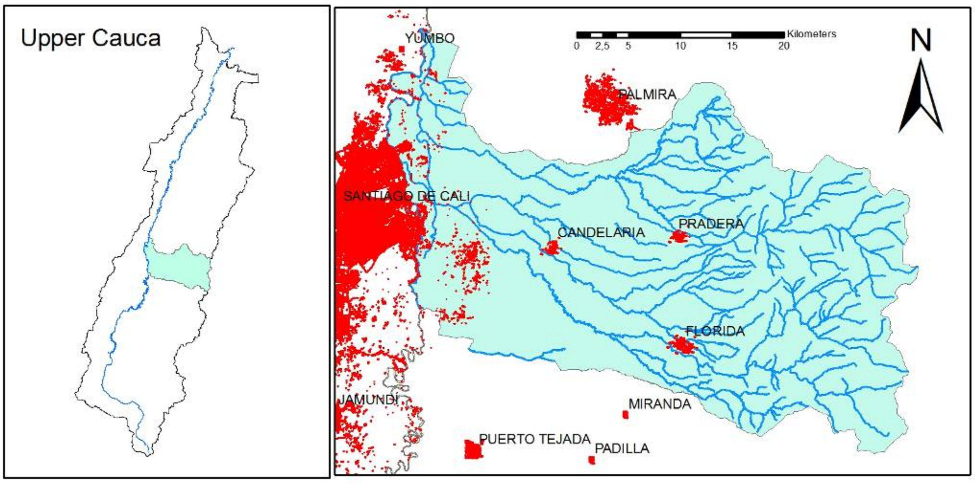


Figure 44. General location of the study zone.

The Bolo River source is located at Las Hermosas Moor (3,800 meters above sea level), with a total length of 64.22 kms. and has an average water flow of 3.9 m3/second. (Upstream of the Bolo River Station at an altitude of 970 meters above sea level). The confluence of the Bolo and Brayle Rivers originate the Guachal River. Its main affluents are the Aguaclara River, and the Bolo Blanco, El Silencio, El Danubio, La Esperanza, Los Negros, El Nogal, El Muerto, Tamboral, El Tablón and La Leona Streams.

In terms of strategic ecosystems, 50.4% of its territory is located in the Andean jungle, 17.8% in the sub-Andean jungle, 14.5% in the moor and 17.3% in dry jungle. The basin shows a rectangular form with a narrowing towards its mid zone *(Synthesis of the Water Resources Information in the Valle del Cauca -. CVC –Water Resources Group. 2000).*

There are two rainy seasons and two dry seasons in Valle del Cauca every year. During the summer time, (July, August, September) the river flow decreases significantly, generating conflict in the use of water among the diverse uses and beneficiaries. This situation has to be taken care of by the environmental authority through the implementation of mitigation measures such as irrigation shifts. However, this and other water management strategies will not be sustainable in time without the direct and committed participation of the community. Due to this, and to the increasing water demand in the Bolo River basin, users of the zone participated with CVC in a project for the optimization of water usage in the Bolo River.

General project activities

The project, which has been supported by the economic and technical contribution of the TWINLATIN Project, has developed participative activities to approach the legal, social and technical issues of water management, with the users settled in the middle-upper and flat zones of the Bolo River, in order to define and implement the mechanisms for efficient water resource management. A general plan was built with short, medium and long term actions that will result in the creation of one or several organizations that efficiently manage the water, which would be the ones in charge of performing self-management for the improvement of the conditions to have access to water.

Finally, it is expected to consolidate an organizational structure around water supply for the different uses in the Bolo River sub-basin that allows the effective participation of the user sectors in charge of the basin's development and the decision-making in the management of its territory, having water as the articulating element.

In order to reach such purpose, the following specific objectives were set with the participation of water users' representatives, both for the mid-upper zone and the flat area of the sub-basin:

- Detailed water demand-supply report.
- Inventory of users of the Bolo River water.
- Inventory of the hydraulic infrastructure in the Bolo River water consumer area.
- Social characterization of the water users and determination of the resource use.

- Localized identification of the water deficit in the zone and action plan to mitigate the deficit.
- Prepare a proposal for the administrative water structure agreed upon by the community users.

The application of guidelines for the development of public participation has been framed by considerations that are essential for the stakeholders participation, in a collective construction process. This work scheme is shown in the following figure, which shows the core of the process formed by the institution, the operative or facilitating process team, and the representatives of the different user sectors located in the influence zone of the Bolo River.

Participation of social actors in the Bolo Basin

The objective was also to facilitate the awareness process, the discussion, training and negotiation with the middle and lower Bolo River basins, to generate appropriation of the water resources, commitment and collective work attitudes in the definition of an adequate water management structure, with the support and consultancy of CVC.

A series of activities made with the project work team allowed reaching the proposed objective at the social and community level. Figure 45 shows the meetings and workshops held by the middle and lower zone and the CVC professionals.

Figure 45. Workshop held with the Lomitas users (community house)

A water user's characterization and their relashionship with other social organisations and institutions were also done in order to have a solid base for future organissative structure proposal for the basin managenment. This assessment was done at the La Floresta Community, Lomitas Community and at the flat zone of the basin.

The description and information analysis was done under the following aspects:

Users Characterization

- Who they are, what they do, their level of development and actual status.
- Conditions of the community's participation and organization. What brings them together, what sets them apart, type of leadership, organization forms and plans for change.
- Water resource perception: Their opinion about the water, collective creativity about water use, which is its relation with the environment, what actions are used for water conservation, water future, etc.
- How is the relationship with the other communities and institutions. The identification of the community-institution relationship was made using the Venn diagram technique that allows visualizing the institutions existing in the location and their level of vicinity or distance.

Organizational Activities
Based on this statement and users opinions obtained during the different workshops, the following organization alternatives were proposed:

Alternative 1. Just One Organization for the Entire Basin

This scenario will consider the design, construction and operation of only one organization in charge of its users interests, their level of development directly linked to their desire, and the participation of users, not only in the participative identification of problems and later proposal of solutions in aspects such as the design, planning and construction of works, but in the active participation in the training sessions and technology transfer, which are the fundamental bases for adequate water management awareness.(See Figure 46)

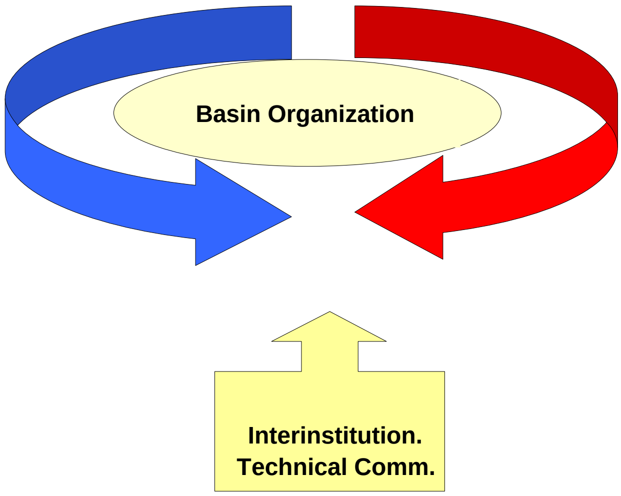


Figure 46. Alternative 1, Organizational Scheme

The upper basin or production zone, where most natural resource conservation work is required, especially for water, and the flat land or consumption zone, where water is intensely exploited, will be included in this project. It is convenient to clarify that the conservation work must be constantly monitored directly by the organization and the government institutions dealing with natural resource sustainable use.

Those users in charge of the efficient use of water planning according to regulatory guidelines in effect will be located in the middle and lower zones (consumption areas). This attitude will allow them to be backed by environmental entities.

Attention fronts defined in the Action Plan have to be approached with the implementation of this structure. In order to provide guidelines for tasks to be developed by the organization, the following vision and mission of the organization was built jointly with the users.

Following is a brief description of each of the organization components:

- Users General Assembly: This assembly will be formed by all the existing users in the organization's jurisdiction, who must be duly registered in it. The periodicity of the meetings will be defined in the by-laws.
- Board of Directors: This group will be formed by user representatives appointed in the General Assembly Meeting, allowing the participation to users settled in different basin locations (derivations).
- Advising Committee. This group will include a representative of the Valle del Cauca Regional Autonomous Corporation – CVC, who will look after the enforcement of corporate guidelines and standards with respect to sustainable water use, a representative of the municipal government, who

will verify that guidelines provided by the organization do not interfere with the municipal land management plans and representatives of the other entities present in the zone, to coordinate forms of participation for knowledge and technology transfer.

- Training and Resource Management Area: The Board of Directors will select the members from a threesome presented by the General Users Assembly.
- Operative Area: This will be chosen by the Board of Directors, form a threesome presented by the General Users Assembly.

Advantages:

- The advantage of this option is to consider the basin as a sole territory, having to face several fronts simultaneously, in order to reach the desired goal. From the financial point of view, this alternative may represent a more economic operation by only one organization.
- It is easier for the Corporation (CVC) to take care and maintain constant communication with just one organization.
- Being able to have access to national and international resources through the presentation of an organization covering a broader work area.

Disadvantages:

- Directing all efforts and economic resources towards those sectors having users with the greater economic and political capabilities.
- Flat zone users in certain occasions may have a greater management power than those in the upper basin.

Alternative 2. One Organization for Each Derivation

As in the previous option, the organizational structure would be the same, adjusted to a smaller area (See Figure 47). Goals and activities required to handle, distribute and efficiently manage the water will be the same.

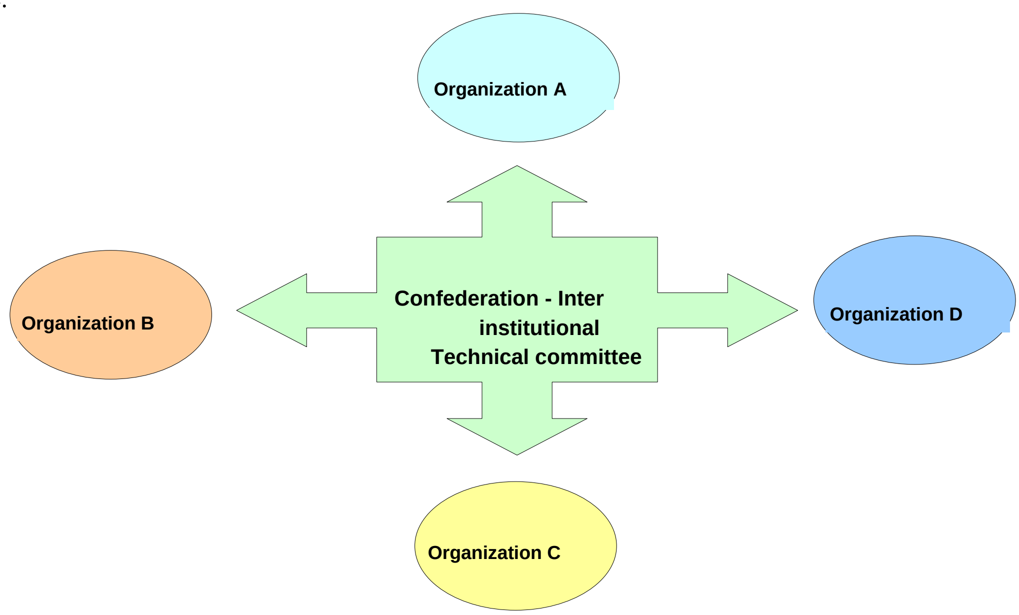


Figure 47. Alternative 2, Organizational Scheme

Work to be done would be located in a smaller territory, without dismissing relevant activities towards water sources and adequate water demand management.

Advantages:

One of the great advantages of this option is the individual knowledge of users shared among them because generally, in some of the derivations sectors covered, the users have been there for many years, in some cases being considered as territory colonizers. This degree of familiarity will allow working in a more committed way to reach the proposed goals and, at the same time, select individuals within the derivation that will be leaders in the Organization's management and operation.

Disadvantages:

- Lack of sufficiently committed persons that lead the process and have the required management capacity to reach the proposed goals, and in some cases, with the required economic and political level to make the necessary investments for the proper usage of water.
- The participation processes of institutions within the organizations may occur at a slower pace due to the amount of requirements and commitments to comply with.

To be able to work in a uniform way, it is recommended to have an organized group duly incorporated to debate the investment plan and other activities that may affect the work and operations made by the Organization. This Organization shall allow the participation of institutions present in the zone as facilitators of the process, contributing with technical, economic, legal, training, management and dissemination support, among others.

Alternative 3: An Organization for the Middle Area and Another One for the Flat Area
Given the existing differences among the users in their territory identified in the "Stakeholders Characterization" and the difficult Access to technological advances with respect to training and costs, there is a third option consisting of two organizations, which would have the same objectives as those considered in the two previously described alternatives.
User participation through the Organization must be based on their management capacity. The lower area must have an Organization that takes care of the actions and plans of the Organization geographically located above them because the proper management implemented in the middle area will be reflected in greater availability to comply with the lower zone demands.

This Organization form creates some kind of Independence between them, represented by the fact that the lower zone may, as long as the Organization allows it, contribute economically or with training in some aspects for the Middle Zone Organization. At the same time, the Middle Zone Organization will respond with efficient water management to guarantee acceptable water flow levels to cover the water needs of the communities of the zone. At the same time, this will enable both organizations to carry out work in the upper basin to promote the adequate recovery, conservation and regulation of the water flow produced there.

Whichever alternative is implemented in the work zone, it must be clearly established that the purpose of any water users Organization is to obtain the active and permanent participation of its members in the development, conservation and rational use of soil and water resources, in accordance with dispositions issued by the responsible environmental authority, following the water standards, regulations and realities for each region.

CVC´s knowledge communicational plan

One of the conclusions of the water users and stakeholders analysis done at the Floresta, Lomitas Communities and at the flat zone of the Bolo basin was the low perception and trust agianst the local water institutions, an specifically to CVC. For this reason CVC developed a communicational plan in order to disseminate the water resources activities and knowledge in-house.

The Communication Plan designed for the dissemination of the knowledge acquired by the Corporation on water resource management considers two fundamental aspects: the edition and publication of the book "The Cauca River in its Upper Valley – A Contribution to the Knowledge of One of the Most Important Colombian Rivers" and the Dissemination and Transfer of Water Resource Management.

The main purpose of the book is to allow the Valle del Cauca and Colombian leaders, planners and all stakeholders interested in technically knowing the Cauca River, to have a study and analysis tool for its main characteristics, which shall be considered for its structured use planning.

The Water Resource Management Dissemination and Transfer Plan is proposed in order to strengthen water management in the region through the empowerment of its stakeholders, transferring the knowledge acquired by the Corporation in its day to day technical and social activities.

The first stage formula of the Dissemination and Transfer Plan includes the dissemination and transfer within the Corporation, and to the Regional Autonomous Corporations and the Bolo and Tuluá River Basins.

The general schemes to establish a knowledge transfer culture within the Corporation and with other stakeholders related to water management at regional and national level are defined during this first stage. A pilot plan with a general scheme that may be adapted to the rest of the territory's basins is proposed for the Bolo and Tuluá River basins.

Specific objectives

1. Dissemination and transfer of knowledge acquired by the Corporation in terms of water resource management.
2. Strengthen corporate water resource management.
3. Establish management of CVC Regional Environmental Directions in each of the territories in its jurisdiction in terms of water resource topics.
4. Sensitize, inform, make aware and train the public and private stakeholders on efficient and integrated water resource management.
5. Strengthen stakeholders settled in the territory by providing community participation, leadership and auto-management.
6. Facilitate the availability and use of information given to different users.
7. Promote alliances among the different water resource users.
8. Facilitate reaching the goals established in the 2007 – 2009 Triennial Action Plan.

Target Public

The target public are CVC officials, Regional Autonomous Corporations - *CAR's, and* Stakeholders participating in water resource management in the Bolo and Tuluá River basins (Cities' management, Umatas, JAL, JAC, education centers, etc.)

Plan Duration

The Water Resource Management Dissemination and Transfer Plan in the jurisdiction zone of CVC is initially proposed for a five year term starting from its proposal until the implementation of the two proposed stages.
This Dissemination and Transfer Plan shall be permanent and transversal in the actions taken for water resource management in the Corporation jurisdiction zone. Therefore, the Plan is susceptible to adjustments made during its implementation and development. Likewise, the Plan for the following period shall be proposed and/or updated, adjusted to the Corporation's Triennial Action Plan.
This first stage is designed for implementation in 2009, simultaneously making the adjustments required in advance to the II stage that covers the rest of the jurisdiction.

CUAREIM - QUARAI (Uruguayan side)

Concerning public participation for water administration, this is mainly given by the integration of Irrigation Meetings of River Cuareim, which has an advisory nature that represents both users and non-users. A place for discussion and exchange of ideas is generated there concerning irrigation projects approval requests and/or water use rights requests with the different purposes they were destined. To this end, they hold periodic open meetings so that citizens are able to participate and give their opinions.

Another citizen participation mechanism is Public Audiences, which make publicly known the request made to the State to get public water use rights to the general population and in particular to the ones directly affected in their rights.

PLAN OF PUBLIC PARTICIPATION

The National Direction of Hydrography of Uruguay (DNH for its Spanish acronym) has permanent relation with other public actors, namely, the Ministry of Cattle-Raising, Agriculture and Fishing (MGAP for its Spanish acronym), National Direction of Meteorology (DNM), Public Administration of Sanitary Works (OSE for its Spanish acronym), Municipal Council of Artigas (IMA for its Spanish acronym).

There is a permanent relation with the farmers in the basin with irrigation rights by means of Irrigation Advisor Regional Committees who work as advisors and collaborators for the Ministry of Transport and Public Works (MTOP for its Spanish acronym) concerning the administration of hydrological resources allocated to irrigation. These Irrigation Advisor Regional Committees are made up of a representative from DNH, a representative from MGAP, at least two representatives of the farmers with irrigation rights and the same number of owners in the zone elected in the ballots in accordance with established procedure and with 3-year validity. They have the following competences: coordinate with users on equitable water redistribution in shortage periods; give opinions on water use requests; give advisory on works to adopt for better use, collaborate with MTOP to keep the official register of hydraulic works updated; supervise the use of works and report infringement of norms; mediate and procure conflict conciliation; report the activities made by public and private institutions; plan and develop spreading activities.

Since this is a cross-border basin, a Uruguayan – Brazilian Committee was constituted for the Development of Cuareim river and this in turn, constituted the Local Coordination Committee (CCL for its Spanish acronym), which is made up of: in the Uruguayan side: Artigas Shopping Center; IMA; OSE, DNH; the Association of Rice Producers of Artigas; and in the Brazilian side: the Association of Rice Producers of Uruguayaza; Rural Union of Barra do Quaraí; Prefecture of Uruguayaza; EMATER Quaraí; CORSAN Quaraí; IRGA Quaraí; Municipal Prefecture Quaraí; Aquapan.

In this case, we present the activities performed in the Uruguayan side:

In terms of citizen participation and communication in the basin in general aspects, the creation of the Local Coordination Committee (CCL) marks a before and after, since, though the years the Uruguayan party of such committee has achieved increasing integration with the citizens thanks to the slow, at the beginning, but growing and solid support received from the Uruguayan Delegation of the River Cuareim Committee. In addition to its directors, CCL integration is totally open and in general, a huge number of institutions participate as well as service entities, development agencies, individual neighbors, etc.

Objectives

Ease access to information by creating mass media so that the population can participate in the various projects undertaken in the basin.

The objective of this WP was:

- to increase, promote, and support stakeholder involvement in the management of the basin
- to empower stakeholders through communication of information, training, and educational activities

Public participation is the mechanism to follow in every democratic system which enables, amongst other factors, to reach a consensus in order to make decisions, it eases the search for solutions for detected problems; it helps to achieve project and decision transparency; and it clarifies the responsibilities of the parties.

Methodology and activities

All the activities carried out within the public participation plan made for the River Cuareim basin are based in accordance with the definitions of the Frame Directive on Water of the European Union.

Many activities (sensitization conferences, workshops, presence in the media, edition of spreading and sensitization materials, etc.) and interventions of CCL delegates are oriented to children and students. The outcomes of these activities with the support of the TWINLATIN Project are analyzed by CCL members searching for communication mechanisms in order to spread them to the population and mainly to teachers to reach this way, the students.

Moreover, this work pack, understood as the cross axis has been included in the other work packs; therefore, some activities have been concerning the water care for quality and quantity (WP2), models (WP3), management sustainable strategies, pressure of pollution and analysis of impacts, changes and vulnerability (WP08), optimum solutions and their social-economical impacts (WP09). These activities are described in detail in the Final Report, see attachments.

Some of the most important activities carried out have focused on how the project´s achievements can be sustainable and continued after the TWINLATIN project. In this aspects some highlighted activities are :

a) Regarding water quality of the Cuareim river, the general public believes and feels that it is very degraded, a condition that worries many neighbours. To this, in the framework of TWINLATIN, DNH (National Directorate of Hydrography, Uruguay) and IPH (Hydraulic Research Institute, Brazil), and the National Directorate of the Environment (DINAMA), CCL and Artigas Municipality (IMA), all from Uruguay, devised and launched a water quantity and water quality monitoring program. This program involved teachers and students from the basin schools. For the first time the monitoring was performed by Uruguayan and Brazilians as well. Practically in every monitoring campaign, the media interviewed the technical personnel to inform the population of the work in progress.

b) On October 7th, 2008, CCL Artigas receive a letter from the National Directorate of the Environment (Uruguay) requesting it to promote a meeting with the ANA (National Water Authority) of Brazil to continue with the water quality monitoring, even after the TWINLATIN project is over.

c) On June 16, 2008 in the computers of CECOED in the City of Artigas was installed the preliminary early alert system for Floods program, so that trials could be done. In that meeting representative from CECOED, CCL, the Meteorological Station of Artigas, Artigas Police and DNH participated and the procedure to run the model was explained. This activity relates WP3 (Modeling) with WP4 (Public Participation).

d) In the framework of TWINLATIN it was done an assessment of the current administration of the water resources in the basin that is currently carried out by DNH, DGRNR (General Directorate of Renewable Natural Resources of the Ministry of Agriculture and Fishing with the active participation of the Irrigation Board and a simpler paperwork process is proposed and with more autonomy to the regional offices of both ministries and more public participation in the making decision process. The proposal was presented to the Authorities and to the population in the TWINLATIN Final Meeting. This activity relates WP5 (Sustainable Management Strategies) with WP4 (Public Participation) and is classified as a proposal for the future to strengthen the current active participation (Ai) in the decision-making process.

e) Environmental awareness of the population, through the field days: “Our river asks for help, let’s clean its borders” . This is an activity that CCL had been doing prior to the TWINLATIN project and that continued doing it during TWINLATIN. In 2006, TWINLATIN supported the organization done by CCL. The activity was declared of Departmental interest by the Departmental Board and of Education interest by CODICEN at the national level, what permitted a greater participation of the education centers. More than 1400 neighbors participated in the event (all registered), with an important increase in children and young people.

f) In the framework of TWINLATIN and in relation to Work Package 9 (Economic Package) it was organized a binational workshop of public participation with the objective of envisioning possible future development scenarios for the basin. The ideal number of participants for the workshop was decided to be 30, 15 Uruguayans and 15 Brazilians. These scenarios would be then communicated to local and national authorities. The workshop took place June 17 and 18, 2008, at Barra do Quarai.

g) In September 2008, TWINLATIN supported the visit of the National Director of DINASA (National Directorate of Waters and Sanitary) of Uruguay and two technical personnel to visit the ANA (National Agency of Waters) of Brazil to address the management of transboundary basins, including the Cuareim-Quarai River Basin. This was a very important instance when results and findings of the TWINLATIN project were addressed binationally at the highest possible level.

h) TWINLATIN FINAL PUBLIC PARTICIPATION MEETING IN THE BASIN. On December 18th, 2008 took place in Artigas at the PAOF center, the binational TWINLATIN meeting to present the results of the project obtained by IPH and DNH. Both TIWNLATIN coordinators presented the project with its goals, and the different technical personnel that led each working package presented the results to the attendants. The media was present.

As a result, it was signed by Brazilians and Uruguayans the "**Letter of Artigas**", in which CCL is asked to create binational working groups to develop a binational monitoring plan of water quantity and water quality for the Cuareim River, and to assess the goodness of the hydrological model developed in the framework of TWINLATIN by IPH to be used as a tool by both countries to manage the water resources of the basin.

CONCLUSIONS

Different activities were programmed to reach these objectives for all the Working Packages to have a public participation component (Table 20). Different approaches were used: Active Involvement, Listening, Learning, Informing and Consulting.

Among the 14 activities enumerated in Table 20 there are some worth to stress.

As the Cuareim River basin is transboundary, shared by Brazil and Uruguay, the effort required to promote integrated management of the basin and stakeholder involvement is remarkable. Nevertheless, TWINLATIN achieved to organize in the framework of WP9 a two-day binational workshop with a balance participation of representatives of both countries, where locals worked together to envision a master plan for the basin.

For the first time a binational monitoring took place and high-school teachers and Municipality personnel were invited to join in the work. They received training and participated in the field work. In the same way for water quantity monitoring, the project received the support of the Association of Rice Growers, and in particular of one of its members to install gages and construct the necessary structures to measure the balance of water in his irrigated rice field. These two examples show that there are ample opportunities to involve local people in activities that are assumed to be responsibility of the government and that could enrich or be beneficial to both parties.

The environmental public activities which took place in the basin, like cleaning the river or collecting and classifying the fish were very welcomed by the population, showing that there is a big interest and concern about environmental issues. This enthusiasm should be fostered by new activities.

Table 20. List of Public Participation activities carried out in the basin during the TWINLATIN project

	Active Involvement	Listening	Learning	Informing	Consulting	Activity	WP	Binational or National
1		X		X	X	TWINLATIN kick-off	All	Binational
2	X		X			Water quality-quantity monitoring	WP2	Binational
3	X					Water quantity monitoring	WP2	Uruguay
4	X		X			Implementing Preliminary Flood Alert System	WP3	Uruguay
5	The implementation of the proposal would promote Active Involvement					Sustainable Management proposal	WP5	Uruguay
6		X	X	X		Fishing Day Activity Educational Activities	WP6	Uruguay
7			X			River's Day Activity	WP6	Uruguay
8		X		X		Presentation Work in progress	All	Binational
9					X	Request to local entities of needs and concerns	All	National

10		X				WP Twining Activity	All	All TWINLATIN partners
11	X	X		X		2-day Workshop-ZOPP methodology	WP9	Binational
12						Meeting of Authorities	All	Binational
13	X	X		X		Workshop	WP9	Binational
14		X		X	X	Final Project Presentation	All	Binational

CUAREIM - QUARAI (Brazilian side)

The delineated strategy for the TWINLATIN Project to encourage the public participation in water management of the Quarai/Cuareim river basin was based on the existing institutional framework in Brazil and the RS. The main identified stakeholders were:

- the Water Resources Department, by its Planning Division;
- the State Water Resources Board;
- the National Water Resources Board, by its Technical Workgroup on Management of Transboundary Water Resources;
- and the local NGOs.

Regarding the potential conflicts for the water use in the Quarai/Cuareim river basin, some actions were listed to be undertaken in the scope of the TWINLATIN Project:

- *Discussion forum on water use efficiency in rice irrigation:* events with purpose to instruct the irrigators in the basin on the agreements and norms in act about water resources use and to discuss the needs, conflicts and efficiency in the water use by irrigated rice;
- *Presentation on an overview of the Brazilian Water Resources:* event that must presents to community the current status of the water resources in the country, in terms of overview, framework and instruments of management and planning (National Water Resources Plan).
- *Workshops to presents the WUG implementation in RS*: events with purpose to present the current status of implantation of the State Water Resources Management Framework, the Plan of Water Resources in RS, the implementation of the WUG in the State and the importance of its role in the Quarai river basin and discuss the implantation of the PWU;
- *Technical workshops:* events destined to the discussion of specific subjects, aiming to promote the technician debate and to consolidate the population knowledge:
    - Subject 1: how to work the water cycle and a hydraulic basin;
    - Subject 2: extensive timber cultivation impacts on basin water cycle.

The above related actions must be integrated to the project time table, based on the timing foreseen for the execution of WPs 5, 6, 7 and 9, as detached in the item 4.

Antecedents of public participation and communication on the river basin

The strategy to implementing the Water Resources Framework in RS has been differentiated of the rest of the country in some aspects. Might be expected the civil society to organize itself intending to solve an existing conflict in relation to the use of a water source. However, in basins of little economic expression and low population density, for example, where it does not have forward reports of water use conflicts, a natural process of society organization to compose a basin committee does not occur.

The Water Basin Committees formation process in the RS has been occurred for induced demand, while in other States the formation of the basin committees has occurred only for motivation or pressure from the organized society. It is observed in Figure 48 that, from 25 existing basins in RS, 18 ones have implemented basin committees, covering a large part of the State. However, most of the population and the GIP (Gross Internal Product) of the RS is located in the metropolitan region of Porto Alegre and some few urban conglomerates in the hydrological region of the Guaíba lake. It is further noticed the only basins that do not have a committee or an instituted provisory commission are the transboundary basins of the Quarai river, Negro river and Jaguarão river (all of them sharing waters with Uruguay).

Lately the State of the RS, through its Water Resources Department (WRD) and its Water Resources Fund (WRF), encouraged and promoted the formation of basin committees, even in regions that did not report of important conflicts for water use. It's the case of some tributaries of the Uruguay river.

The river Uruguay, in the boundary between the States of Santa Catarina and Rio Grande do Sul, has waters of Federal domain. In this way, the constitution of a committee of the Uruguay River would involve a joint effort between two States and the Federal Government, coordinated by the National Water Agency (ANA). Aiming to provide the arrangement of the water resources framework into State level, it had been constituted in the RS the basin committees of the right-margin tributaries of Uruguay river, with exception of the Quarai river. Thus, the formation of the committees, the approval of its internal regulations and its establishment had been carried out in State level. The institution of Basin Committees in rivers of the Union's domain must be accomplished by act of the President of the Republic (FL 9433/97, Art. 37, only Paragraph).

In the case of rivers in domain of the Union and transboundary (Quaraí), it is still necessary to coordinate the process of management with the country that shares the waters of the basin. The 2nd paragraph of Art. 39 of the FL 9433/97 defines that in the case of basins located in the country bord and/or transboundary rivers with shared management, the representation of the Union in the committee must include one representative of the Federal Foreign Office.

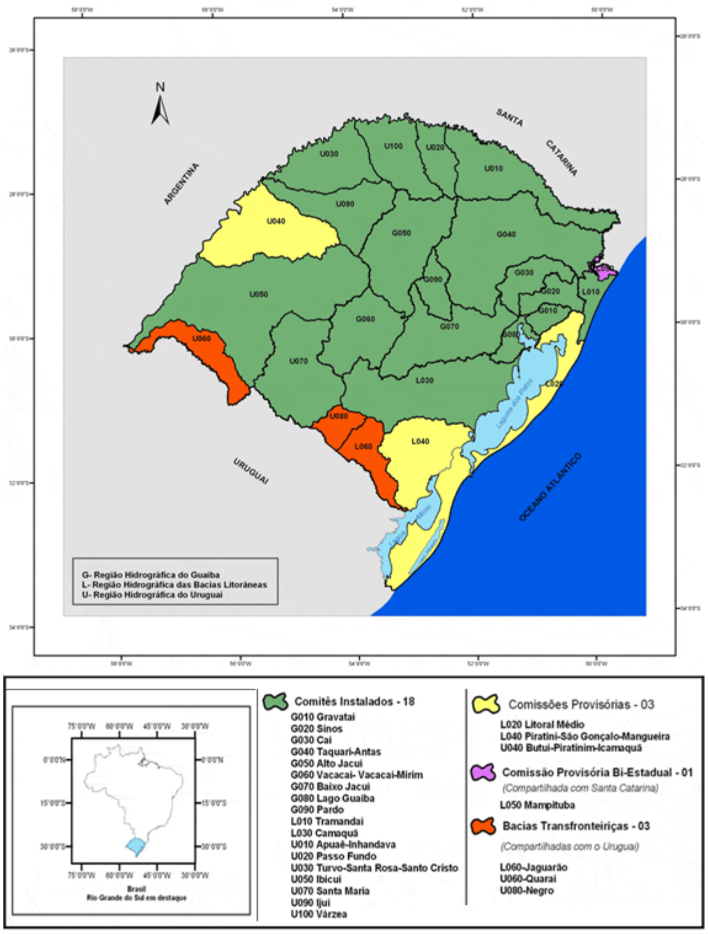


Figure 48. Current status of Basin Committees implantation in the RS. (Source: WRD-RS)

The first experience of public participation in the basin occurred during the preparation of a diagnosis on the conditions of supply and demand of water, in 1996. At that time, there was a workshop on planning for the possible actions for water management. One result of this initiative was the amendment to the agreement of 1991 and the effective implementation of the Coordination Committee Place, with Brazilian and Uruguayan representatives.

Public Participation Interface in TWINLATIN

Classification of Water Bodies (CWB) and River Basin Management Plans (RBMP) are instruments foreseen in the EU WFD and for consequence; they are objects of study in the TWINLATIN Project. Besides some conceptual differences, both instruments are foreseen in the Brazilian water legislation.

In Brazil, the Classification of Water Bodies establishment according to preponderant water uses is a legal instrument foreseen in FL 9433/97 and aims to ensure the water quality compatibility with the basin's higher exigency level use and to reduce the costs to combat water pollution, by means of preventive and continuous actions.

The Classification of Water Bodies must be approved by the respective Basin Committee and, therefore, with a wide public participation. In the Classification of Water Bodies process the population in the basin defines which is the uses intended for the water bodies in the future, based on economic, social and environmental studies previously carried out.

To reach the approved Classification of Water Bodies goals they are stipulated targets to be accomplished in a given time. To each target they are associates action to be undertaken in the basin. The set of described goals, targets and actions composes the core of the water resources planning in Brazil and originates the RBMP, which must also be approved by the Basin Committee.
In such case, it is understood the public participation activities in TWINLATIN Project must be centered in the work packages 6, 7 and 9, following the timetable defined for these activities. It is pointed out, however, that the start running of a public participation process hardly is carried out without a complete involvement of the society. In the Quarai river basin, due to the absence of a Basin Committee and for the lack of articulation between the different stakeholders, the process of public participation in the water resources management is a process that still must be induced. Thus, a consistent institutional support is necessary, with continuous financial and technical contributions, modifying the intermittent character of the actions undertaken in this intention in the basin so far. It is worth pointing that even with 18 formed Basin Committees in the RS, only 8 ones have initiated an effective process of water planning, exactly in regions where there are water conflicts and strong anthropic pressures.

OBJECTIVES OF THE WP IN THE BASIN

The main objectives of this WP in the Quaraí/Cuareim basin were:

- the conception of a management plane for the basin, and
- the implementation of the Basin Committee in Brazilian side.

METHODOLOGY

Public participation is promoted in three different levels: federal government (National Water Agency – ANA), state government (Environmental Agency – FEPAM, the Water Resources Department – DRH and the State Institute for Rice Cultivation – IRGA) and local community and institutions.

Several meetings and workshops were held between the IPH and ANA to introduce the project and define lines of action (September 2006 to June 2007):

- Assisting and presenting the TWINLATIN Project in the 35th meeting at the "Technical Board on Transboundary Water Resources" of the National Water Resources Council (27/09/2006);
- Preparing a paper on an overview of the TWINLATINg 1st year of activities and its submitting to the Strategic Water Management Workshop (Cap-Net Brasil, GWP Brasil, ABRH);
- Meeting at Agência Nacional de Águas – ANA to present the TWINLATIN Project and assessing a likely partnership whit IPH in the scope of TWINLATIN activities (26/10/2006);
- Participating in Strategic Water Management Workshop, held in Brasília, and presenting the paper "The TWINLATIN Project and the assessment of the Quaraí river basin: overview of the 1st year of activities" (04-06/12/2006);
- Meeting at ANA, dealing the establishment of a Technical Cooperation Agreement between the Agency and IPH, in the scope of the activities performed in TWINLATIN Project (05/12/2006);

- Preparing and submitting to ANA a technical statement on the situation and needs for carrying on monitoring and modeling activities in Quarai river;

- Meeting in IPH with Eng. André R. Pante/ANA, for definition of simulation scenarios of hydrological modeling, considering different restrictions on water use for rice irrigation. The evaluation of these scenarios helped ANA in the definition of water rights on the basin (10/01/2007, 22/08/2007).

- There were contacts about to occur directly between ANA and DNH/Uruguay to treat about transboundary relations at Quarai river basin that can be credit to TWINLATIN efforts.

As a result, an agreement was signed between the ANA and the HPI, technical cooperation between the parties in March 2007: "Framework of technical cooperation between the National Water Agency and Federal University of Rio Grande do Sul - UFRGS, by Institute of Hydraulic Research, aimed at combining efforts to develop Technical Studies related to water resources in basin areas" (in Annex B).

The action of IPH in the basin continued with a participation in a meeting for discussed the implementation of the Basin Committee in Quarai city, called for the DRH. In this event, the WP1, WP2 and WP3 were presented to the stakeholders. In Consequence, IPH was invited to explain these WPs in other similar events in Uruguaiana, Barra do Quaraí e Santana do Livramento. The participation of the TWINLATIN team was defined as essential for this goal.

In July'2007, the legal base for the implementation of the basin Committee was complete. The act of the foundation of the Committee is signed for the governor of Rio Grande do Sul, in the octobre'2007. For different reasons, the Committee was really created in December '2008 and the IPH is one of his members. With great institutional advance, IPH staff tried to define the bases of a management plan for the basin. For such, they chose applying the ZOPP methodology– Planning projects under certain objectives – developed by a German Agency for Technical Cooperation – GTZ.

A workshop named ZOPP was proposed to DRH, which accepted to support a meeting with people from Uruguay and Brazil in order to discuss the management of the basin and establish evolution and planning scenarios. The meeting should bring together the same number of Uruguayans and Brazilians representing different sectors of the society of the basin.

The outlines of the workshop (dates, place, number of participants and represented entities) were set, involving representatives from DNH, CCL and the provisional commission of Quarai Committee. Totally, 32 people had been invited, 16 of each country.

For the methodology characteristics, participants assemble a problem tree with problems they understand as the main ones, in which the lack of an independent management structure was defined as the main one. Concerning that, cause and effect problems had been defined, indicating which actions must be accomplished for solving the problems of the basin. These actions were then detailed, being deadlines, costs, responsibilities and inherent or estimated risks to each intended product identified. These contributions were put at a Logical Framework that allowed programming the tasks. All actions were distributed among the local stakeholders.

Figure 49. Images of ZOPP workshop, 17-18 June 2008, Barra do Quaraí, RS.

ACTIVITIES

Due to a delay in the budget from the TWINLATIN project, financing was then an option. However, budgetary problems did not enable DRH to fulfill its initial proposition, postponing the accomplishment of the workshop for after the rice harvest (in April and May). The financing source was then substituted, being responsibility of the farmers from the basin, defined together with DRH. It is extremely important for a shared management because the event became responsibility of the people from the basin and no longer from external sources. All lodging and feeding expenditures were supported by stakeholders of the basin: Barra do Quarai Farming Union and Uruguaiana Rice Farmers Association. The workshop was held in Barra do Quarai, in June 17 – 18, 2008.

The first approach of the plan was used for the economic analysis in WP9.

The figure below show the meetings in 2007 for discussion the creation of the Basin Committee of the Brazilian side of the Quaraí river basin. Information about meetings can be found on http://www.barradoquarai.net/Ambiente/comite.htm .

Figure 50. Meeting for discussion about the creation of the Basin Committee of the Brazilian side of the Quaraí river basin: Barra do Quaraí, 11/06/2007.

RESULTS

A preliminary assessment shows that the population of the basin is touched by the problem and they can assume the management of their natural resources. The technical base was generated by the TWINLATIN project, taking the discussion to a very qualified level of decision, enough to decide on its use, launching of effluents or the implementation of reservoirs or agricultural projects modifying the current local productive matrix. Now, the capacity of using these information and models might be developed, so local decision may also be straightened.

A clear inclination to carry out a shared management in the basin can be observed in the Logical Framework, with the discussion of limiting techniques and policies in both countries, such as inadequate environmental laws, management of water resources, taxes for using the water and education. It is also known that an independent management is not enough for it depends on some modifications in the law and in the Binational Agreement itself, within the scope of the Foreign Affairs Department of these countries. So, an informal management was designed, delimiting common tasks to subsidize the elaboration of an initial plan for managing the water resources in this basin. Thus, for the first time a shared management plan will be elaborated, identifying conflicting points in institutional and legal arrangements and considering solutions for that.

An interesting aspect of the workshop was that the participants realized they would not know how to organize the management process. The IPH staff suggested the adoption of the Global Water Partnership ToolBox – GPW, as a base document to determining this structure. Fundamental reference for study and analysis was given to the participants of the workshop.

NEXT STEPS

The process of citizen participation, developed from May 2007, made possible the formation of an arrangement of shared management, whose tasks are programmed up to December 2008, defined in a Logical Framework.

From the Brazilian side, Quarai Committee will be the place for discussions, not having the power of deliberating of executing by now. These roles must only be set after defining the composition of a binational Committee, with necessary repositioning state water committees.

From the Uruguayan side, there is no institutional committee for management of Basins, which is partially fulfilled by *Junta de Riego*. In the planning workshop such distinction between Brazilian and Uruguayan management models and how important it is to discuss management outlines in the basin was clear.

A first management planning draft is being elaborated. The first draft of the final configuration was finished in October 2008, in order to enable the formulation of economic studies and definition of viability and effectiveness indicators. TWINLATIN staff will follow up the discussion on this first configuration and they will carry out an earlier assessment together with the committee in charge of that.

The propositions approved by this Committee will be applied in the hydrologic model, assessing the resulting quality and quantitative alterations after implementing it. This second assessment will be taken to the committee and, after some adjustments, it will be presented to a bigger group, for example the ZOPP workshop or any other the committee understands as suitable. After approving this plan, the economic assessment can be done, ending up the TWINLATIN Project in the basin.

The participation of IPH will continue up to 2010, when the mandate will be finished. During this period, TWINLATIN resulting measures will be monitored.

CONCLUSIONS

The goal reached by IPH exceeded initial expectations: it was created the Basin Committee of the Quaraí river and defined the first draft of the basin management plan.

The process of discussion and creation of the Committee was the fastest into the legal framework, because was possible use the results of the others WPs. The quality of these materials and the knowledge about the environmental of the basin created a powerful base for development of the new component of the National Water Management Framework (NWMF).

CATAMAYO-CHIRA

The main problem is the social-economical poverty and the environment of the basin, added to the inequalities in gender which have an effect on poverty issues. Besides, in the basin, there are precarious economical activities for survival, the water supply is limited due to deficient management of hydrological resources and demeaned ecosystems. On the other hand, there is lack of inter-institutional articulation to manage the basin in a comprehensive manner, the actors do not know the reality of the basin, there is lack of social actors in the management of resources and there are not any mechanisms of participation and representation.

Table 21. Type of organisations per subbasin, Catamayo Chira basin

Institutions and organisations	Subbasins						Total	%
	Catamayo	Alamor	Macará	Quiroz	Chipillico	Chira		
1.- Social organisations	1295	530	1007	1209	742	1819	6602	53,6

2.- Productive organistions	340	70	205	94	47	74	830	6,7
3.- Govermental agencies	795	361	1069	901	409	1063	4598	37,4
4.- Non-govermental agencies	60	20	30	32	4	67	213	1,7
5.- Institutional networks	11	11	12	6	4	22	66	0,6
TOTAL	2501	992	2323	2242	1206	3045	12309	100,0

Source: Diagnóstico Socioeconómico de la Cuenca Binacional Catamayo-Chira. Consorcio "Los Ceibos", Oct 2005

MANAGEMENT OF THE BASIN.

The management of the hydrological resources at the Catamayo - Chira cross-border basin faces a problem which does not greatly differ from the current international panorama characterized by lack of quality information, the absence of tools to manage such information, the limited technical and technological capacities of competent institutions and lack of clarity about their competences, as well as the existence of a population that is barely sensitized, barely informed and barely participative of the management processes.

MECHANISMS OF PARTICIPATION

The participation of the population in the management process of the territory is characterized by its instability and the lack of representation of both the civil society and organizations. There is lack of leadership, weak managerial capacity in social, productive and women organizations, as well as NGOs, and local governments. These are characterized for their organizational precariousness, functional instability and weak managerial capacities.

OBJECTIVES

According to these guidelines, and taking into account the aforementioned problems, as well as the background and possibilities of the Catamayo - Chira basin, there are three general objectives defined:

1. Spread to the population of Catamayo - Chira basin the main actions performed by the TWINLATIN Project (spread). In this case, we had the experience and outcomes obtained from the Catamayo - Chira cross-border Project; thus, from the moment TWINLATIN starts working, the communication unit of UNIGECC spreads its main activities, in local media of both Loja and Piura. The Project's web page is also used, www.catamayochira.org, to spread the news of TWINLATIN, as well as electronic bulletins. In terms of radio broadcast, the already existent agreements with UNIGECC are used, and panels about the main packs are made with different actors of the basin. The WATER QUALITY subject is prioritized, since in the Peruvian side it is an issue that causes great interest in both the mass media and the population that suffers from the consequences. Besides, there are interventions in a television program called "Cultivating" (Cultivando). As of 2006, there is one person in TWINLATIN's communication unit. On the web page, an independent space is created to place all TWINLATIN news, the press and radio broadcast continues; they make materials, a video on water quality in the Basin, a 2008 calendar about the monitoring and bio-monitoring program of water quality, gigantography.

2. Sensitize the population on the hydrological resource comprehensive management, (social communication and sensitization). The radio was the main media to reach the population with messages about good environmental practices. Existent agreements were used to have an effect on priority subjects: basin, water care and quality, reforestation, garbage, cutting of trees, etc. A radio broadcast strategy was defined in two stages: broadcast of spots and broadcast of social dramas that collected the voices, knowledge and main practices of the population.

Other sensitization activities were the participation on fairs, lively music played in streets by bands: "Event with youngsters from the basin due to the international day of water", cross-border event "Women and youngsters for water", participation in other events on gender, political women organizations, the promoting groups of Local Development (GIDELES for its Spanish acronym) in the basin and other initiatives such as IRAGER in order to spread and sensitize on the GIRH subject.

It is important to stress the work carried out with the journalists (especially on the Peruvian side). Some training and sensitization workshops on environmental subjects have been carried out. In the last year, they participated in three internships in the basin to be aware of the problem and of the work carried out by the Project and to talk to the population. A cross-border network of journalists was constituted, and we can say that they have higher commitment to publish environmental news.

Furthermore, some workshops and training courses have been carried out, and some information has been collected with the participation of several key actors of the Basin, the cross-border Platform of Women, with GIDELES, with user committees, with technicians from municipalities, with associations.

3. Promote and assure the participation of competent institutions and social actors in the research developed from the Project (Public participation)

PLAN OF PUBLIC PARTICIPATION

Methodology and activities

In the course of the Catamayo - Chira cross-border Project, an identification of the actors was carried out, as well as of the various target groups, their profile, level of participation, habits of communication, existing social networks, most respected leaders, etc. This information was collected in the TWINLATIN Work Plan report 1 (WP1).

Based on such mapping of actors and in collaboration with the Productive Development area, the Zoning area, the Communication and Gender units of the Catamayo - Chira cross-border Project, the TWINLATIN project designed the proposal of the Public Participation Plan (PPP) for the formulation of the Zoning Plan and for TWINLATIN’s core activities. Such plan was adapted to the objectives and activities of each group.

In the TWINLATIN project, four levels of participation were identified where the different actors in the basin were located (i) technical level of institutions in each one of the national spheres (Peru and Ecuador), (ii) technical level of local institutions with direct competences, (iii) organized groups – social and productive and (iv) the general population. For each level, different information needs were defined, as well as forms of participation and strategies.

Table 22. Stakeholder groups and institutions involved at different participation levels

GROUP OF ACTORS	INSTITUTIONS INVOLVED
Consultive Committees Institutions with legal competences	**Perú:** Gobierno Regional Piura, Autoridad Autónoma Chira Piura, Proyecto Especial Chira Piura, Unidad de gestión Proyecto Binacional Catamayo Chira **Ecuador**: Consejo Provincial de Loja, PREDESUR, Unidad de gestión Proyecto Binacional Catamayo Chira.
Binational Technical groups Technical representatives from institutions with direct competences	**Perú:** Gobierno Regional Piura, Autoridad Autónoma Chira Piura, Proyecto Especial Chira Piura, , Dirección de Salud Sullana, Universidades, PETT, SUNASS, SENASA, EPS Grau, OSINERG, IMARPE, PROFODUA, Unidad de gestión Proyecto Binacional Catamayo Chira, ATDRs, ONGs y Cooperaciones Internacionales **Ecuador**: Consejo Provincial de Loja, PREDESUR, CNRH, Direcciones provinciales MINAG, MIDUVI, UMAPAL, Unidad de gestión Proyecto Binacional Catamayo Chira, Universidades, ONGs y Cooperaciones Internacionales.
Identified social and productive groups Water users, Productive groups, GIDELES, women associations, mancomumities	Municipios, Mancomunidades, Juntas Parroquiales, Grupos Impulsores Organizaciones Productivas, Organizaciones de mujeres, Organizaciones sociales Juntas de Usuarios de riego, Comisiones de regantes, Juntas de agua potable Comunidades Campesinas, Redes Educativas
General population	Population in general, educational community, universities, etc.

Concerning the **first level**, informative activities were carried out with the responsible ones of the participant institutions in the cross-border Technical Groups to report about the outcomes of the work carried out by the technicians in the groups and to achieve their political commitment in the development of the processes. Periodic local and cross-border meetings were carried out to get approval for the suggested and elaborated proposals and the continuity of the process with institutional commitments. To that end, financing proposals were made at the end of the project for the sustainability of the participation developed by local institutions.

The Cross-border Technical Groups have been an excellent participative work tool and methodology (see WP02 and WP03 report), for the achievement of the objectives of that work pack and for the sustainability of the initiated processes, once the project is finished. These groups participate receiving the information generated by the TWINLATIN Project, and getting assistance and the required specialized technical training (SWAT/ WATEM SEDEM models, ARCH HYDRO database, water quality monitoring program). Furthermore, it has been complemented with visits to the field and internships for on-site validation of the results that were being generated. These internships are a way to sensitize the technicians and their institutions on the importance of teamwork, exchanging experiences, with a basin approach and in a cross-border manner.

Concerning the **Social and productive organized groups**, there was a social base already identified and strengthened, thanks to the work of Catamayo - Chira Cross-border Project. A sensitized and motivated base; that is why, in several occasions, the training need or technical advisory need arose from them, covered by TWINLATIN. Other times, already-opened spaces were used by Catamayo – Chira Project (training workshops, participation, and sensitization) where TWINLATIN technicians participated to cover gaps in certain issues (especially water quality and erosion). And lastly, specific needs were identified, the groups were summoned and we worked with them.

As far as possible, the TWINLATIN team has accompanied these social groups whenever they have requested this. It is essential to generate a space with them if effective participation and exchange of information and knowledge is sought. That is why, the field visits are important, to be on site, in their reality, in their meetings, in their decision spaces, knowing their dynamics.

Two training courses were carried out (Peru, Ecuador) which lasted two days about water quality with technicians from municipalities and parish councils.

Cross-border workshops were carried out with the Cross-border Platform of Women on water quality and social control, erosion, hydrological resource management, and sometimes they were accompanied in the activities that take place in their organizations and communities.

Concerning the general population, the carried-out activities were already explained in the spread and sensitization items.

Obtained Outcomes

Different from the rest of work packs, the participation and social communication component is difficult to quantify or measure. Since it is considered as cross axis, the other works are the ones with tangible outcomes as a consequence of applying participation or communication strategies.

- The TWINLATIN project has **spread and transferred all the information** generated in its research (in all work packs) to the institutions and actors involved in the Basin.
- All the generated information is in the Project's web page and in a multimedia CD.
- The involved institutions and actors in the basin know about the project and its activities, they know how to access the information. TWINLATIN is a reference for many of them.
- There is an identified **structure and map of actors** to work with.
- The identified social actors in the basin are committed to, trained in and sensitized on the process. **Sustainability** guarantee (institutions, social organizations, the mass media, general population)
- The **cross-border technical groups** on water quality and erosion and hydrology are the two greatest results; they are constituted, sensitized and trained. They have spread and shared their information with the rest of institutions.
- The rest of work packs have specific participation outcomes.
- Most of the population is sensitized on the comprehensive management of hydrological resources, especially concerning water quality (communication activities, presence in the media)

- The **Public Participation Plan** is designed and implemented.
- Assessment of public participation activities. Amongst other objectives, **The International Meeting of Citizen Participation and gender on water management** was a manner to assess the work carried out in that sense. Amongst the experiences presented, the TWINLATIN experienced was shared**.**

The International Workshop "Public participation and Gender in the water management", organised in Piura, Peru (with TWINLATIN partners' participation), served as an excellent platform for reviewing the public participation objectives in TWINLATIN as well as a source of experiences, theoretical and practical examples and lessons learnt. This workshop was organised by UNIGECC in coordination with IVL and in association with the Gender and Water Alliance (GWA), the German technical aid service (GTZ), PREDESUR, PROHIDRICO and Nature and Culture International (NCI). More than 100 people (mainly from Latin-American and European countries), attended this workshop and extents media coverage took place. The workshop was carried out the 20th and 21st of May 2008 in Piura, Peru.

The main objective of the workshop was:

- Tools developments and challenges in Public participation and gender in water Management as one of the key elements in the development project proposals towards sustainability

Specific objectives:

- To sensibilise private and public actors about the importance of an active public participation and gender approach in the water management

- To create a platform for discussion, debate, compromises between experts, researchers, technicians and social organizations

- To collect and systematize successful experiences and knowledge presented in the workshop. Presentations, discussions and conclusions are available in the following link "http://www.catamayochira.org/LIBRO%20SISTEMAT%20AGUA.pdf".

- Systematization and publication of the experience.
- **Twinning activities**, assessment meeting in Piura, after the meeting, with the representative partners of WP04, to present their progress.

CONCLUSIONS

The basin management has demonstrated to be one of the bases to guarantee water management in a strategic manner and in the long term. However, this management must lay the foundations for social construction processes, with mechanisms and participative processes, capable of achieving the necessary institutional character and being coherent with principles of governance. This participation, when performed with adequate representation in an organized, trained and responsible manner, is fundamental to achieve sustainable and effective basin management.

The basin management participation presents a special complexity due to the numerous existent actors; that is why, in each concrete case, the required institutional formula and the mechanisms to develop will be different.

Nevertheless; we will always need clear and agreed objectives, legal acknowledgment of the participation structure that is formed and social backing or legitimacy of the structure to have a successful participation. To achieve adequate representation, all sectors must be included, with actors and actresses of the high, medium and low parts of the basin. Another aspect of special interest is the involvement of women; we know that men and women make a differentiated use of the natural resources due to their roles; therefore, their needs and interests must be incorporated in the course of the process.

It is necessary to continue spreading the TWINLATIN Project results, the importance of the applied research must be acknowledged as well as its benefits, so that each time more actors get involved.

Sensitization in natural resource management is crucial to change habits and to improve the environmental practices of the inhabitants in the Catamayo – Chira basin.

The existing relation with the communication offices of the institutions with competences in the basin management is important because it has made possible to collaborate in communication activities, getting better results and larger coverage and scope in the basin territory. We recommend continuing with these interrelations in order to join technical and financial efforts.

3.5 WP5 Sustainable Management Strategies

The objectives of this WP were:

- To identify possible weaknesses in the current institutional structure of administrative organisations with responsibilities related to river basin management.
- To develop a sustainable institutional structure for river basin water management with effective decision routines. This is to be achieved by close collaboration and communication between relevant administrative organisations. The proposed management strategy is to be presented at political level at the end of the project

IVL has supported the Latin American partners in the work tasks on identification of weaknesses and strengths in current management structures. The countries prepared national reports on this subject and the results of this work was presented and discussed in a WP 5 workshop held in Montevideo 27-28 June 2008. The conclusions from the workshop and the recommendations for future improvement strategies for the different countries are an important part of the WP 5 results, and constitute a unique strategy document since it has been elaborated by a large number of water authority representatives on national as well as regional level, and by researchers. IVL assisted the WP leader, DNH, in the compilation of the work package report

CEH-W

A presentation of water management activities in the Thames basin and progress with WFD implementation was made at the sixth project meeting in Wallingford in June 2008.

The advanced state of river basin management and the abundance of management plans in the Thames basin, has enabled it to demonstrate and contribute examples of good practice to the other TWINLATIN basins in order to encourage improved management approaches. A field visit during the Wallingford meeting took project partners to see the Jubilee River flood alleviation scheme for Maidenhead, a wetland system for wastewater management at Sheepdrove Organic Farm, and instrumentation at the Boxford monitoring site.

LA Basins

The work done in this Work Package by the Latin American Partners is summarized in the following paragraphs.

CATAMAYO-CHIRA

UNIGECC concentrated the effort on supporting the management of the cross-border territory of Peru-Ecuador (Catamayo-Chira basin) through the creation of a Binational Technical Secretariat with a shared vision by both countries. This Secretariat will articulate the management organizations in both Perú and Ecuador (the Regional Council of Basins in Piura, Peru, and the Catamayo Basin Organization in Ecuador). The outcome of this Work Package is the result of a public participatory process, including the participation of institutions with competences from both countries.

Proposal of the binational coordination mechanism

In Peru, the Regional Council of Basins in Piura is proposed to be created, and in Ecuador, the Catamayo Basin Organization. Both entities, based on their own national juridical dynamics, will look after integrated management in the Catamayo – Chira cross-border basin through a coordination mechanism called the Binational Management Organization (OGB for its Spanish acronym), under the protection of present and future agreements between the two states. Therefore, a structure proposal is needed where the vision and objectives of the Basin concur through a Binational Technical Secretariat.

The following diagram shows the **national, regional and binational articulation.** That is, the processes generated by the Binational Technical Secretariat of the Catamayo – Chira basin (space of participation of the basin actors) must be tied to the legal framework and the guidelines in each country. To that end, the Technical Secretariat will keep a close relation with the Regional Council of Basins Piura and the Catamayo Basin Organization. They depend in a direct manner on the National Council on Water – Peru and the General Secretariat of the National Council of Hydrological Resources – Ecuador SG-CNRH as they are national normative institutions that govern mainly the Integrated Management of Hydrological Resources in Ecuador and water management in Peru, where the main policies and decisions are generated to be later transferred to the sub-national levels for their application.

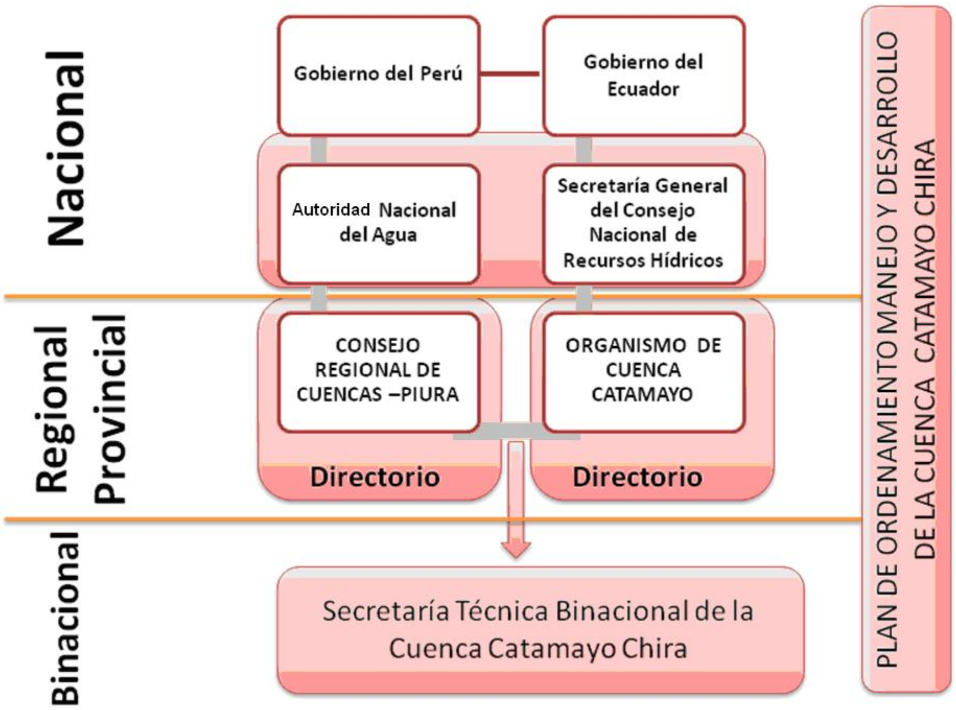


Figure 51. National, regional and binational articulation diagram

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Nacional = National; Gobierno del Perú = Government of Peru; Gobierno del Ecuador = Government of Ecuador; Autoridad Nacional del Agua = National Authority on Water; Secretaría General del Consejo Nacional de Recursos Hídricos = General Secretariat of the National Council of Hydrological Resources

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Región Provincial = Provincial Region; CONSEJO REGIONAL DE CUENCAS – PIURA = REGIONAL COUNCIL OF BASINS – PIURA ; ORGANISMO DE CUENCA CATAMAYO = CATAMAYO BASIN ORGANIZATION; Directorio = Board

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Binacional = Binational; Secretaría Técnica Binacional de la Cuenca Catamayo Chira = Binational Technical Secretariat of the Catamayo – Chira basin;

PLAN DE ORDENAMIENTO, MANEJO Y DESARROLLO DE LA CUENCA CATAMAYO CHIRA = ORDINANCE, MANAGEMENT AND DEVELOPMENT PLAN OF THE CATAMAYO – CHIRA BASIN

The Binational Technical Secretariat will be integrated by a technical delegate of each institution from the Boards of the National Organizations, including the institution that exercises the presidency, who will integrate a binational team led by an executive secretary, who will be hired through a selection process in accordance with the required profile. The executive secretary will coordinate the technical secretariat team and will be the link with the respective national / local instances.

BAKER

EULA's work was based on the current Chilean's legislative framework and the National Strategy for Integrated River Basin Management that seeks to protect water resources (quality and quantity) for human consumption and ecosystem considerations. This National Strategy is being implemented through three pilot programs. The Baker River Basin was selected as one of them. TWINLATIN has considerably contributed to the initiation of this pilot project, which has three stages: the basin's institutional development, the basin's management plan, and the implementation and follow up of that plan.

Work on the integrated management of the Baker river basin can be situated in the context of the National River Basin Strategy ENGICH, which seeks to protect the water resources, in terms of quality and quantity, in order to guarantee human consumption and to grant objectives of ecosystems preservation with sustainable exploitation of hydro resources. The main objectives of this Strategy are as follows:

Principles:
- Complementarity & Gradualness
- Decentralization
- Appreciation of the country's diversity
- Sustainable development
- Prevention
- Participation of Civil Society and Productive Sectors
- Information access

Objetives:
- To develop and institutional apparatus that will enable a gradual change to an integrated basin's management focus.
- To reduce pressure from productive areas on the quality and quantity of water resources in critical zones.
- To strengthen the roles of basin users, through conditions that will allow to better channelize demands.
- To move forward in the consideration of environmental issues in the management of water resources, establishing a basis for minimal ecological flows and other biological key factors to resolve with regard to water quality, among others.
- To upgrade the data bases of information and knowledge regarding the management of the water resources, and the knowledge of relationships and dynamics among ecosystems.
- To gradually implement the strategy through pilot program initiatives.

These principles and objects are oriented towards a strengthening and upgrading of the decision making process in the management of the environmental and water resources of the country's basins through the implementation and development of public tools of private management. To achieve that, the Strategy suggests the establishment of an appropriate institutional framework at both national and local levels.

At national level, a Basin's Secretaries Quorum will be constituted, formed by seven department secretaries: (1) National Defense, (2) Economy, and Treasury (3) Public Works, (4) Health, (5) House and Urban Development, (6) Agriculture and (7) the president of the Directive Board of the National Council for the Environment. This quorum will be in charge of advising the President of the Republic and supervising the general implementation of the integrated river basin management strategy. Furthermore, there will be Technical Department that will perform as an operative body of the quorum; it will be formed by the General Water Directorate (DGA) and the National Environmental Commission (CONAMA).

At the local level, Basins Offices will be established, whose objective will be to manage the water resources to satisfy the demands upon them, looking to conciliate the interests of all the public and private parties involved. Likewise, there will be Technical Regional Departments, formed by the regional representations of the General Water Directorate and the National Environmental Commission, in an analogue way as at central level.

In the Baker river basin, these two last institutions have already come to an agreement in six lines of action, each one of them has one or more associated objectives for the local implementation of the National River Basin Strategy, accordingly to the situation of the zone and the specific requirements of it. These objectives are in a preliminary stage and must be valued and prioritize through the corresponding Basin Department.

Table 23. Lines of action and local objectives for the implementation of the ENGICH in the Baker river basin, Aysen Región.

Lines of Action	Local Objectives
Hydric resource exploitation	1. To Develop Mechanisms that help solve the requirements for basin water exploitation rights.
	2. To move forward in the determination of the market for water in the basin, identifying the main transactions and the implicit value of such a resource within different parts of the basin.
Management and Water users	3. To identify, create and strengthen users' organizations, so as to publish the demands for water resources and the conflicts associated therewith.
Variability and Climate change	4. To identify the extensions of the climate change variations in the reserves of freshwater in the basin and in the acceleration of geomorphologic processes that may represent a threat to the nearby communities.
	5. To evaluate the vulnerability of the basin's population to climate change and to specific threats associated to it.
Knowledge of resources and water ecosystems.	6. To establish studies that would enable the determination of an acceptable minimum ecological discharge rates in the main elements of the hydrographic network in the basin.
	7. To move forward in the upgrading of the DGA's hydrometric network in the basin.
	8. To conduct research on the development of an optimum plan for monitoring the General Carrera Lake.
	9. To maintain and power up the monitoring programs for water quality that the DGA keeps on the Baker river basin's rivers.
	10. To move forward in the research of key biotic indicators, so as to establish a set of rules for further revision of the Baker NSCA.
Hydric ecosystems Protection	11. To reach a level of protection for shoals or banks of the basin identified as Priority Sites for Biodiversity Conservation, specifically in areas such as Jara Bay - Jeinimeni Steppe y Entrada Baker - Valle Chacabuco, and to move in the development of corresponding managing plans.
Water and Society	12. To identify the best valued ecosystem services by the community, analyzing their protection level under the current normative tools and the possible modifications in the short term.
	13. To move forward in the development of a payment system for environmental services.
	14. To power up an education program oriented to establish common sense around water and its importance; promoting its efficient use.
	15. To educate, at city council and tourism associated organizations levels, about the meaning of the Law 20.256 regarding recreational fishing, and to generate information for further definition of priority areas for the development of such activity in the basin.

COCIBOLCA LAKE

CIEMA proposed the creation of the Regional Corporation for the Sustainable Development of Lake Cocibolca with an Integrated Water Resources Management approach. It formulated a 3-year transitional plan for state institutions and municipalities to adopt the General Water Act. This implies the establishment of a common methodology on environmental planning, land use management, and watershed approach to unify their administrative procedures. Enphasis was also put in the need of monitoring, collection, and preparation of basic data and information necessary to manage the basin.

Activities summary

1) An analysis of the legal framework was done, including the changes promoted by the recently approved General Law of National Waters (Law 620) that affect the way the institutions will coordinate activities and duties on water resources management.
2) During the development of the Project each meeting and workshop organized by the component Citizen Participation (WP04) was useful to conduct an analysis of strength, opportunity, weakness and threat (SOWT) with the stakeholders of the different municipalities attending that meetings and workshops. The workshops of this last period of the Project were developed at Granada city, on November 18th 2008, and at Rivas city, on November 19th. In both workshops was done an intensive exchange of ideas with the stakeholders about the best way of management of the Lake Cocibolca basin. On the previous period a SOWT analysis was done during Juigalpa and Boaco workshop.
3) An identification of the main problems and disagreements on implementations of actions and politics by the institutions also was done.
4) Meetings with Environmental Ministry (MARENA) and Territorial Studies Institute (INETER) were accomplished. Also it was a meeting with personnel of the Environmental System Information (SINIA-MARENA) in order to plan SINIA activities.
5) Based on collected data (interviews, legal framework, SWOT analysis) a General Strategy of Lake Cocibolca Basin Integrated Management was elaborated. This proposal is focused on the ecosystems integrated management and includes the following strategic axis:

    a. Organization Strategy for Development of Lake Cocibolca Basin
    b. Institutional Strengthening Strategy (Previous Strategic Actions)
    c. Lake Cocibolca Natural Resources Conservancy and Management Strategy
    d. Sustainable Production Business Strategy
    e. Communication and Education Strategy
    f. Commercial and Sporting Navigation on Lake Cocibolca Strategy
    g. Financial Strategy

    The proposal includes the description of the organizational structure of the so called "Sustainable Development of Lake Cocibolca Basin Corporation" as well the solutions to restrictions existing in the current legal and institutional framework for the integrated basin management.

6. From November 2th to 5th, 2008, the southeast zone of the Lake Cocibolca was visited, with others TWINLATIN team members, to know, within WP05 objectives, applied productive schemes and its effects on the environment on that zone specially onto the wetlands as indicative ecosystems, as well to know, from the farmers own viewpoint, the main basin problems of the zone. The wetlands visited were "Los Guatuzos", San Miguelito, Solentiname and Punta Mayales.
7. Attendance to the final TWINLATIN meeting at Rio de Janeiro, Brasil, in which a summary of the WP05 Lake Cocibolca Basin conclusions was exposed. After this meeting the International Forum on Basin Management, developed in that city in that days was attended.
8. Final Report elaboration to be submitted to national authorities.

CAUCA

At Cauca basin the greatest challenge faced by the region in terms of water management is the start up and implementation of the Water Resources Integrated Management Model. Law 99 of 1993 started a stage of changes in responsibilities that affects the Surface Waters Management Program and generates an adjustment period during which lessons are learned from experience in order to define the model to be used.

The application of a sustainable management model is consolidated to optimize the water resource distribution in the area of influence of a water flow, integrating the vision of technical, social and economical aspects, and empowering the civil society in order to improve living conditions. The analysis is based on the actual legal framework, the specific characteristics of the region, the existing problems, and the different environments present. It also collects CVC's experience on water resources management.

General Objectives and Principles for Water Resources Integrated Management

Objective
Establishment of guidelines to promote the knowledge, conservation and sustainable use of water resources, coordinating the Basin Use and Territorial Plans in search of an equal resource distribution to obtain social, economic and environmental benefits.

General Principles of Water Resources Integrated Management

- Water is a natural resource inheritance of all, having a strategic value for the actual and future development of the Department of Valle del Cauca.
- It is necessary to find equilibrium among water resource interests and the interests of water-depending stakeholders.
- Water is not an unlimited asset.
- Adequate availability of water in terms of quantity and quality cannot be taken for granted.
- Water resource management must consider real costs, as well as the possible economic and social benefits of its use.
- Water resource conservation and sustainable usage require an inter-sectorial approach and must be regionally focused with ample participation by all levels of the Government and the civil society.
- Warning principles will be adopted for the use and protection of water resources, especially in cases that may potentially represent a risk for its sustainability and are not scientifically documented for the Valle del Cauca conditions.

CVC identified two fundamental strategies for the Integrated Management of the Water Resources that are the adoption of a hydrographic basin as a management unit, orienting all actions according to the basin's planning and regulations plus the participation of all stakeholders in the management of the water resources. To implement them, CVC choose two 6-year pilot projects: the Bolo River pilot project and the Tuluá River pilot project. The latter is the one that CVC focused on in the framework of TWINLATIN.

CUAREIM - QUARAI (Uruguayan side)

In general terms, the management process in the basin of the Cuareim River, has been accompanying the general process of the management of the water resources in the rest of the country. The notorious increase in irrigation in the basin goes hand in hand with the need to prioritize the issues related to integrated management of the basin, principally the natural resources water and soil.

The institutional management proposal is for the Cuareim River basin in Uruguayan territory.

The basic objective is to have a decentralized institutional management model so to have a more efficient technical-administrative-environmental management by the two Ministries with competence in the subject, to the benefit of the water users, producers, and inhabitants of the basin.

A specific objective is to serve as a pilot experience to extend the management model, with its eventually modifications, to other basins in the country. In particular it will be to the whole basin of the Cuareim River, towards a joint binational management of the basin.

The main principles used for the formulation of the proposal are:

- Horizontal coordination between the Regional Chiefs, with residence and office in the same basin
- The joint and integrated evaluation of the Irrigation Projects, that includes the evaluation of the hydraulic works, the land use plan, and the environmental issues
- Include as a relevant and innovative aspect, the joint approval with joint resolution
- Look for management based on the current legal framework and the corresponding regulations, to avoid generating or proposing new laws or regulations that without their approval would make not feasible the proposal

- Increase the institutional presence and its participation in the water resources management in the basin
- Greater relationship and contact with the users and social actors
- Logistic and support management structure based in the local offices
- Decision-making process in the basin for most cases, leaving out exceptions established in legal or administrative norms
- Publicity and dissemination of actions and resolutions
- Audits and controls at different stages in the process

Based on the strengths and weaknesses of the binational Cuareim-Quarai River Basin's current management system **DNH** has prepared a proposal that looks for its improvement, orienting it towards a sustainable, coordinated, participative, and shared management. The implementation is conceived in four phases. Phase A are actions to be achieved by Uruguay that include the institutional strengthening of the current Irrigation Board, assigning to it new roles and competences and also the creation of the Broaden Irrigation Board, with participation of other institutions related to the water in its different components and not just the irrigation sector. The three other phases include steps to be followed by both Brazil and Uruguay to move towards a shared management of the whole basin.

CUAREIM -QUARAI (Brazilian side)

The new Brazilian legal framework created the need of implementing new institutional actors. **IPH** in the framework of TWINLATIN actively participated in the formation of a State Water Management Committee for the Quarai River Basin for state waters. The creation of this Committee fulfills an institutional gap. TWINLATIN has contributed with fundamental data and a hydrologic model for the basin that has become a great asset for the preparation of a basin plan. IPH presents in its proposal what could be the next steps to be followed to make possible the creation of an autonomous management structure for the basin. IPH has been invited to be part of the State Water Management Committee for the period 2008-2010.

Strength, Weaknesses and Proposals – Prepared at the International Workshop on Sustainable Management Strategies, June 2008 - Montevideo, Uruguay

The current river basin management in the five basins differs, due to the diversity and complexity of the institutional and legal frameworks of the different countries. There are also important differences in their evolution and historical antecedents. Basin management in transboundary basins is clearly even more complex. Therefore, it is difficult if possible at all to draw overall conclusions. Nevertheless, after team-work of the delegates of the TWINLATIN partners to the International Workshop on Sustainable Management Strategies held in Montevideo, it was possible to create a matrix with the vision of the participants on the strengths and weaknesses each basin has regarding their current management, including proposals and recommendations for improvement. This matrix provides a general and summarized vision of the current management situation in the basins and helps to assimilate, compare, and analize issues common to all.

The following TWINLATIN partners participated in the workshop: IVL, UNIGECC, CVC, IPH, and DNH and delegates from national organizations: the National Directorate of the Environment (Uruguay), the National Directorate of Renewable Resources (Uruguay), the National Directorate of Waters and Sanitary (Uruguay), the National Water Agency (Brazil), and the Regional Water Authority (Peru). EULA and CIEMA were unable to participate nevertheless their analysis was later on incorporated into the matrix. During the workshop, IVL presented the "Water Framework Directive" and "The Swedish Example". Speakers from each American basin explained the antecedents, historical evolution, and current situation of their respective basin's management, as well as several proposals for the development of a sustainable management of the water resources and the associated natural resources in their basins, with direct participation of stakeholders.

In the strengths and weaknesses columns of the matrix, those inherent to each territory are stated. Now, it will be just pointed out those that are common to most of them. As a common strength it stands out that generally there exist mechanisms of permit and concession of use of water or environmental authorizations. The level of development of those systems is different in all cases. The legal framework is generally adequate for water abstraction issues while the picture is more diversified for water quality. Consideration of ecological effects of pollution or over-abstraction when decisions on permits are taken is rare in Latin American countries. Legal framework, competence, and methods for management of water quality and use of ecological status in water management need to be developed. Knowledge on the effects of poor water quality needs to be disseminated and the benefits of good water quality risen.

In some countries water management is still based on administrative borders rather than natural river basin borders, which causes unnecessary complications in management.

There are participative mechanisms in an organized way of the users and the civil society interested in the water management and associated natural resources of their basins, in greater or lower degree. Nevertheless, it is observed in general terms, difficulties in the management and access to information, discouraging and stopping active and permanent participation of stakeholders.

Resources and staff at Water Authority Organizations is an acute problem in most countries. The effect is weak control and enforcement and lack of scientifically-based data.

There are difficulties in the coordination of involved institutions in the management of the basins, superposition or not clear definition of competences.

There are legal and institutional tools, but in many cases they are not enough, or not fully implemented, and/or not oriented towards integrated management. In the case of the transboundary basins participating in the project, bi-national agreements are still lacking or are insufficient and/or not oriented towards shared management between the countries.

The proposed management systems include various components of development or improvement towards an integrated management of the water resources. In the concept of integrated management, the different uses of water are interdependent and have to be considered in a joint manner. In the same way, problems in different areas have to be analized in a planned way and the projects that are undertaken have to take into account the hydrological, biological, chemical, physical, and socio-economic consequences.

The countries will advance in the management and shared management of basins if they take as much as possible advantage of the strengths they have and they confront their weaknesses. The process is a long-term one, in which the effort has to be put into modifying those aspects of the water management that are inadequate, preferably in stages, to do it in a reasonable period of time. As has been shown in some of the TWINLATIN river basins, an important first step for transboundary rivers is to share collection and use of data, so that a jointly accepted information-base is built.

Table 24. Strength, Weaknesses and Proposals for Catamayo-Chira River Basin – Prepared at Workshop

BASIN	STRENGTHS	WEAKNESSES	PROPOSALS
CATAMAYO - CHIRA RIVER BASIN **PERU - ECUADOR**	Specific agreements between Ecuador and Perú	Diplomatic processes for implementation are slow	Generate sustainability of the processes already initiated, for example land use planning, database, as management tool
	Systematic information of the basin for both Perú and Ecuador	Institutional and legal frameworks are in the process of revision, proposals need to be adapted to changes	Analyze possible alternatives of financing by both countries
	Awareness of the civil society of the need to participate in the management of the shared basin	Dependency on the funds of the International Technical Cooperation	
	Management tools developed: studies, models, database	Both countries have different motivations for the shared management of the basin	
	The area has been prioritized by the International Technical Cooperation		
	Increasing expectation on the development of alternative economic activities		

Table 25. Strength, Weaknesses and Proposals for Upper Cauca River Basin – Prepared at Workshop

BASIN	STRENGTHS	WEAKNESSES	PROPOSALS
UPPER CAUCA RIVER BASIN	Legal framework for integrated management of basins	Implementation of norms, follow-up, and control	Increase dissemination to inform the population
COLOMBIA	Knowledge of the state of the natural resources, and especially of the water resources. More than 40 years of water quantity and quality data, surface and groundwater.	Low interinstitutional coordination, overlap of competences	Integrate the civil society
	Clear and articulated planning tools, problems of the basin have been identified	Deficiency in management control, lack of logistic, lack of infrastructure to comply with the norms	Strengthen user's associations so that they can comply with all the competences of the administration of the resource
	Participation: Environmental NGOs (planning) and water-user associations	Infrastructure of exploitation is deteriorated or does not exist	

Table 26. Strength, Weaknesses and Proposals for Cuareim-Quarai River Basin (Uruguay) – Prepared at Workshop

BASIN	STRENGTHS	WEAKNESSES	PROPOSALS
CUAREIM-QUARAÍ RIVER BASIN - URUGUAY (UY)	Institutionality: Structures working in the basin, a base for binational management (decentralization and participation)	Binational Management: institutional disparity between Uruguay and Brazil. Brazil does not have management organisms in the Basin	Optimize the current binational structure in the basin (CRC)
	Irrigation Board: many years of experience, new roles could be added to them for a binational management	Lack of definition of crops' water demands	Broaden the competences of Irrigation Boards to include other sectors
	Both Brazil and Uruguay: there is a juridical and institutional base in an International Treaty (CRC-Commission of the Cuareim River)	Processes of granting water rights are slow, and do not meet the time-schedule of users	Change the frequency of water quality-quantity monitoring
	Good relationship between inhabitants of both sides of the river (Brazilians and Uruguayans)	Permit system strongly oriented to irrigation sector, not taking into account an integral approach	Delegate authority to local authorities and the Board
	Process of water allocation: publicity, participation, public inventory of hydraulic works and of lands	Just beginning with the collection of water quality data in the river	
		Final decision is still centralized, out of the basin	

Table 27. Strength, Weaknesses and Proposals for Cuareim-Quarai River Basin (Brazil) – Prepared at Workshop

BASIN	STRENGTHS	WEAKNESSES	PROPOSALS
CUAREIM-QUARAÍ RIVER BASIN **BRAZIL - BR**	Mobilization-capacity of users allowed the formation of a Basin Committee	Incomplete implementation of the State's management system in the basin	Strategic Plan for the Basin
	Users trust the technical representatives of institutions for the management of the basin	Few economic development options in the basin	Promote technical debate over parameters to be monitored
	Composition of the basin committee, broader vision of management of the basin	Historical stagnant economy in the basin	Protocol of communication between Brazil and Uruguay
	Presence of Federal Authority (National Water Agency (ANA)) in the basin	Low investment capacity	ANA could delegate management to the basin
	Robust hydrologic model for the basin	Environmental legislation dissimilar in Brazil and Uruguay	Agree on a shared hydrologic model for granting water rights
	Users are aware that water can be charged for	N° of stations and monitoring campaigns are not enough	
	At state and federal level they are aware of the complexity of the system to manage the basin	Disparity between Brazil and Uruguay regarding availability of data on line	
	Legislation in Brazil and Uruguay have common management principles		
	Both Brazil and Uruguay have juridical, institutional and water-policies stability		

Table 28. Strength, Weaknesses and Proposals for Lake Cocibolca Basin

BASIN	STRENGTHS	WEAKNESSES	PROPOSALS
LAKE COCIBOLCA BASIN	Community organization in all municipalities of the basin. The municipalities have updated environmental plans, environmental units and committees.	State institutions have not taken ownership for the Water Act and are not ready for its implementation	Formulate a 3-year transition plan for state institutions and municipalities to appropriate the General Water Act.
	The National Water Act is focused on watersheds and on IMWR	There is no Land Management Law. nor Land Use plans at any level. Little political will.	Organize the Regional Corporation for the Sustainable Development of Lake Cocibolca, an autonomous body, mixed (public-private)
	Existence of an institutional framework with competences and hierarchical functions to manage watersheds: National Council of WR, National W Authority, Basin Organizations, Basin Committees	There is lack of a water resources inventory, of the water balance, and other basic studies, such as erosion	Give priority to the formulation of a medium and a long-term economic development plan and land use plan for Lake Cocibolca with a IMWR approach
	Lake Cocibolca has been declared of natural interest as a natural reserve for drinking water	Weak monitoring system of hydro-climate variables. No monitoring at Lake Cocibolca.	Promote the adoption of the Land Management Law and Coastal Law
	Existence of a permanent forum on Lake Cocibolca as a coordination entity among municipalities, government and civil society	Municipal governments have not yet appropriated the defined competences under the Law in relation to protection and control of natural resources and environment.	Do the inventory of the water resources and soils, forests, biodiversity. Do the water balance, erosion study and update land use information.
	Existence of research institutions specialized in territorial studies	Insufficient budgets and skilled human resources to implement legal framework	Regional training program and strengthening of the technical and financial resources of the municipalities
		Extremely weak inter-institutional coordination.	Establish a hydrometeorological and Environmental Monitoring program, particularly on the Ometepe island and the lake itself.
		Short term vision	Improve Law Enforcement

Table 29. Strength, Weaknesses and Proposals for Baker River Basin

BASIN	STRENGTHS	WEAKNESSES	PROPOSALS
BAKER RIVER BASIN	**National Level (NL):** There is total independency of the Environmental and Water Resources Management Regulatory Bodies from the state organizations that have to deal with likewise matters and environmental issues	**National Level (NL):** Institutional dispersion in the management of water resources and lack of inter-sector coordination, with the exception of the Environmental Impact Assessment	Develop an institutional apparatus that will enable a gradual change to an integrated-basin management focus
	(NL): There is legislation regarding the protection of the water resources, ecosystems, biodiversity	**(NL):** The current system does not protect ecosystem conservation as it promotes consumptive uses	To reduce pressure of productive areas on the quality and quantity of the water resources in critical zones
	(NL): There is a binational treaty Argentina-Chile to protect shared water resources and associated life	**(NL):** There is no regulative framework to preserve the glaciers (an important reserve of fresh water)	To strengthen the roles of users in the basin to better channel their demands
	Local Level (LL): surface water quality standard to protect surface waters at Baker River Basin is at its early stage of implementation	**(NL):** There is a great number of water rights granted to few uses (In the case of Baker River Basin, to hydroelectric companies)	To move forward into the consideration of environmental issues in the management of the water resources by establishing minimal ecological flows and other biological key factors
	(LL): There are planning tools at regional level that are a good base to generate integral management tools for Baker River Basin	**Local Level (LL):** Small water users have little or no knowledge about the mechanism for obtaining water rights	To upgrade the database and the knowledge of relationships and dynamics among ecosystems
	(LL): There is explicit interest of irrigation users at Baker River Basin to implement irrigation technologies for more efficient water use	**(LL):** Lack of water user's associations in the basin. Low local management and capacity negotiation	To gradually implement the strategy through pilot program initiatives
	(LL): The low level of human intervention in Baker River Basin is a favorable context for the development of an innovative management framework	**(LL):** Lack of interest in participating in water management	

3.6 WP6 Pollution pressure and impact analysis

WP6 Objectives:

- To further develop and transfer modelling of transport and source apportionment for pollutants, as a required part of pollution pressure assessment in river basins
- To assess the pollution pressure and its impact on water conditions in the Latin American river basins

Erosion and sediment delivery to water bodies is considered to be the maximum exponent of non-point source pollution within the Basins. Together with sediments, nutrients and pesticides can also reach the river system. From this perspective, the spatially and temporally explicit modelling of erosion and sediment delivery is a good starting point for addressing non-point source pollution.

A number of twinning efforts under TWINLATIN focused on both aspects mentioned above and it has been one of the important achievements of the project. KULeuven was continuously giving support to the Latin American partners in the implementation of the WaTEM /SEDEM model (Verstraeten et al., 2002). Quality of input maps was improved for UNIGECC and CVC. In particular effort was put in the improvement of the digital elevation models of both areas: since WaTEM/SEDEM is a topographically based erosion model, model results are strongly affected by the quality of the DEM. Soil erodibility (K) maps and rainfall erosivity (R) maps were prepared, in case of UNIGECC in cooperation with EULA. For UNIGECC a calibration and validation methodology and procedure was discussed and defined. The calibration and validation procedure was finalized for UNIGECC, and efforts were put in the final report of WP6 for this partner. Strategies for the spatial analysis of pollution sources distribution were defined. In a twinning activity in Stockholm, Carolien Tote used WaTEM/SEDEM to model sediment delivery in the Mälaren catchment. Main purpose of this exercise was to use the modelling results for cross-validation of the SWAT modelling results. A report of this twinning activity was written. KULeuven has also recently started to give support to DNH for WaTEM/SEDEM application.

As an overview conclusion from the work conducted under TWINLATIN, it is important to highly recommend the **systematic generation of metadata in all future efforts** on the LA Basins. For the storage of the information generated under TWINLATIN a Georeferenced Information System was proposed from the beginning of the project. For structuring and implementing this database, the **ArcHydro** data model was used as a reference in most of the LA basin (Cocibolca, Baker, Cuareim/Quarai, Catamayo/Chira).

BAKER

The pressures and impacts associated to these projects were not studied under TWINLATIN, as this activity is part of the Environmental Impact Assessment that the company had to produce. Activities under TWINLATIN have been focused on aspects that would not be addressed by other means (e.g., development of georeferenced environmental database, procedure for the future systematic generation of metadata, use of the ArcHydro data model, hydrological modeling and climate change impact assessment, etc.).

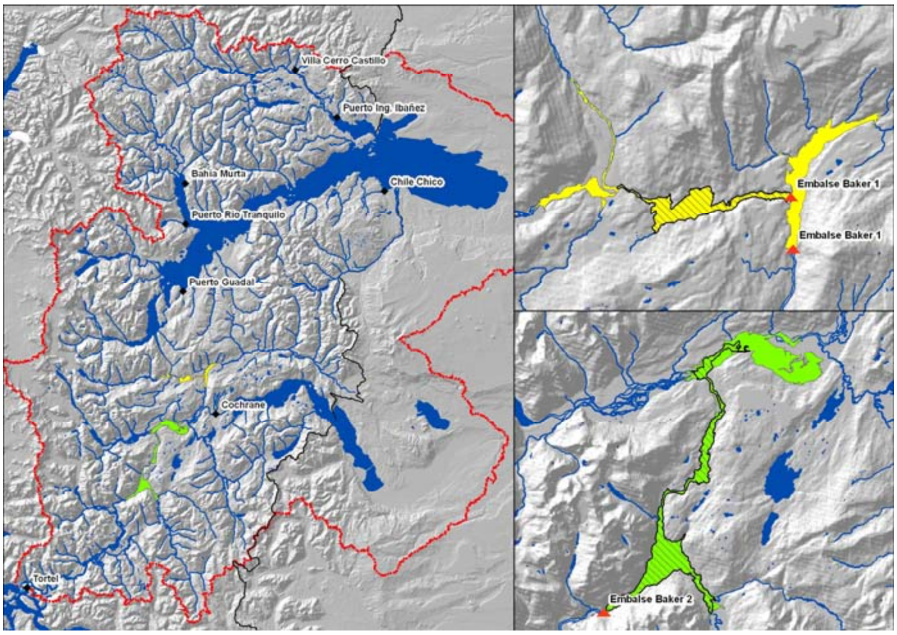


Figure 52. Projected hydropower reservoir flooded areas (the sketched area presents the predicted flooding area presented in the EIA)

The following table 30 then provides a résumé of those natural factors and anthropic activities that exercise pressure and may come to modify and produce an impact on the morphology of the Baker Basin's hydrographic network.

Table 30. Natural and anthropic factors that influence on the morphology (and potentially also water quality) of the Baker river basin

Source	Volcanism	Mining	livestock	Agriculture	Forestry	Industry	Human settlements	Aquiculture
Ibáñez river	X		X	X	X		X	X
Manso river	X		X	X				
Murta river	X		X		X		X	X
Engaño river			X		X			X
Tranquilo river		X		X	X		X	
Leones river				X				
Dunas river			X					
Los Maitenes river			X	X				
Las Horquetas river			X		X			
Aviles river		X	X					
El Baño stream		X	X					
Jeinimeni river			X	X			X	
Nef river			X					
Chacabuco river		X	X	X	X			
Cochrane river			X	X		X	X	X
Del Salto river			X					
Ñadis river			X		X			
Jaramillo river			X					
Baker river			X				X	

Under TWINLATIN, for the Baker River Basin itself no specific pollution pressure modeling work was conducted. This is the result of a priority setting and feasibility analysis in which it was concluded that, for the Baker Basin: ***(i)*** due to the lack of basic/baseline information layers at the onset of the TWINLATIN project for this Basin, attention during TWINLATIN mostly needed to be focused on conducting an inventory of drivers and pressures in the Basin, and on their incorporation in the Basin knowledge base; ***(ii)*** these information sets were then further complemented by means of intensive field monitoring on the river network of the Baker Basin; a description of this work and its results is included in the Work Package 2 and 7 reports; ***(iii)*** due to the interest at the General Water Directorate DGA Aysen in hydrological modeling and the establishment of basin water balances, a lot of effort was put into the development of a hydrological modeling application for a snowmelt-fed river basin –outside of the Baker Basin, but for which sufficient datasets allowing such an approach were available; extrapolation of results and lessons learnt from this approach can now be made for the Baker Basin (see the Work Package 3 report); climate change scenario impact assessment was conducted for this hydrological modeling application, and again extrapolation of possible consequences for the Baker Basin was made (see the Work Package 8 report); ***(iv)*** modeling of erosion and sediment transport could not be conducted for the Baker Basin, but through twinning with other partners important new know-how for conducting such modeling work in Chilean basins has now been acquired.

CAUCA

Identification of gradation and degradation zones

The morphologic model of the Bugalagrande River allowed an understanding of the river's morphologic behavior, identifying the areas susceptible to erosion or gradation.

The integrated analysis of results obtained through the mathematical model of the three different hydrological conditions analyzed allows the identification of the river basin zones or sectors that, due to hydraulic or morphological conditions, are prone to gradation or degradation processes. The intensity and occurrence of these processes will depend, among other factors, on the contribution and availability of river material. The anthropic river interventions, mainly waterbed material exploitation, will affect these processes, causing significant impact on the basin morphology. The establishment of these zones is extremely significant in the definition of general material extraction management in the Bugalagrande River. Sectors showing a systematic trend towards gradation processes are defined as the areas of potential exploitation.

In general terms, it can be said that the section downstream from El Placer Station, in an extension of approximately 6 km., does not show significant bottom level changes. Therefore, this section is not subject to gradation or degradation processes. After that section and up to El Voladero Dam (approximately 3 km.) and where PISA S.A. operates in material extraction, deposits are formed depending of the hydrologic regime of the river. The higher the water flow, the higher these deposits will be.

A degradation process is observed in a section about 4 km long located immediately downstream from the dam, with an intensity depending of the circulating river flow. The lower these flows are, the lower the bottom level degradation will be.

At La Isla, all of the different scenarios of the mathematical model show a 2 km. long gradation sector. Therefore, the sector is considered potentially exploitable, but the intensity and magnitude of the volumes to be exploited in the sector will depend on the sediment transport rates and the basin status at the site, as well as upstream and downstream.

The final part of the modeled section shows a relatively important erosion process during the high water flow year. These values decrease in significance in the average hydrology year and are even lower in the year with low water flow levels.

Figure 53 shows the basin sections where gradation and degradation processes were identified and those without significant bottom level changes.

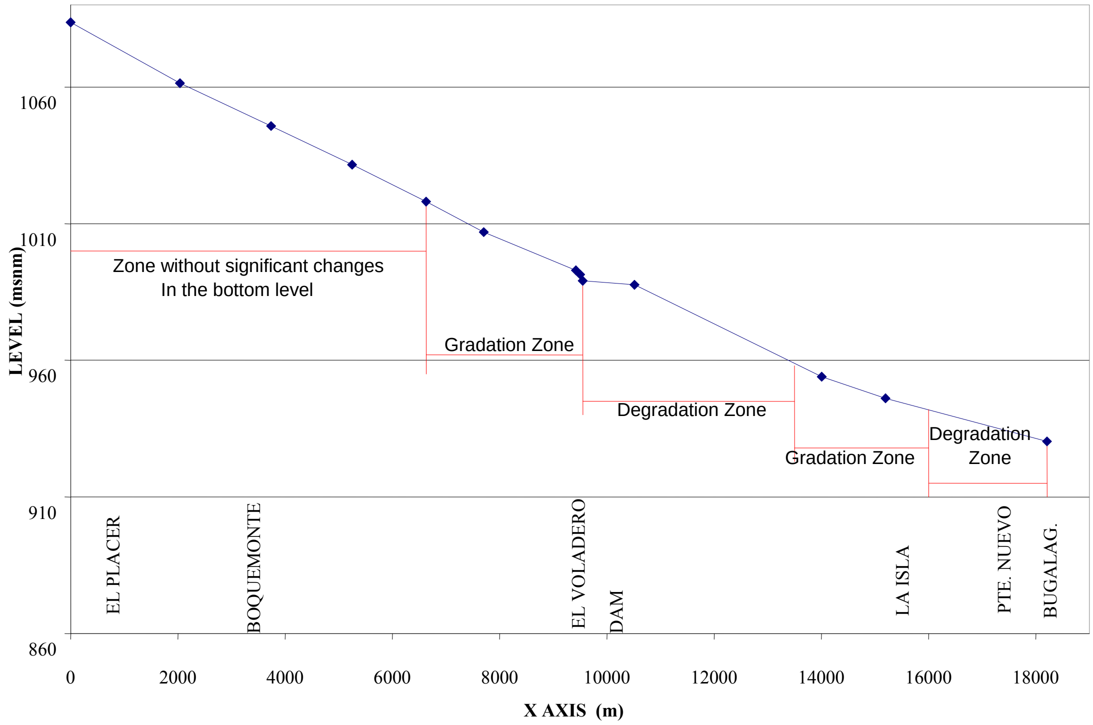


Figure 53. *Gradation and Degradation Zones in the Bugalagrande River*

CUAREIM-QUARAI (Uruguayan side)

The main land uses in the Cuareim River basin are farming, cattle raising, mining, and urban areas; being the first one of biggest importance in relation to water consumption, mostly for the production of rice. To meet these needs, there are many dams and direct intakes in the Cuareim River and its tributaries.

Diffuse source pollution modelling results

Taking into account that WaTEM-SEDEM was run to evaluate the sediments that are exported to the water bodies and that the pressure on the water bodies is caused by those sediments produced by human impact activities, it was decided to run the model for two different scenarios: “Current” (March 2008 land use) and “Hypothetical” (land use with no human intervention, all land that is currently under farming is changed to grassland).

The results that are presented below **are not quantitavely valid**, because the model could not be calibrated due to the lack of monitoring, and therefore those values can only be used in a relative not absolute way. As a first approximation, the model shows lower river export values in the case of the Hypothetical scenario (all grassland) than in the current scenario (table 31)

Table 31 Relative difference of sediment production, deposition and export (as the model has not been calibrated) for the Current and Hypothetical scenarios

WaTEM-SEDEM results	Scenarios	
	Current	Hypothetical
Total Sediment Production	4,925,867	3,718,190
Total Sediment Deposition	2,892,925	2,097,204
Total Sediment Export	2,032,943	1,620,985
Total River Export	2,032,397	1,619,804

Among the outputs that the model generates, the "Project River Sediment" file was analyzed. This file shows per segment of the river the amount of sediment that inputs it from upstream, what is input from the segment-specific area, and what outputs the segment.

With this information per river segment, two analyses were done. First the amount of soil exported from the segment-specific area per hectare; above what would be exported if it were under the hypothetical scenario was calculated and is presented in Figure 54.

Secondly, the degree of accumulated exported sediment that reaches the segment (Figure 55).

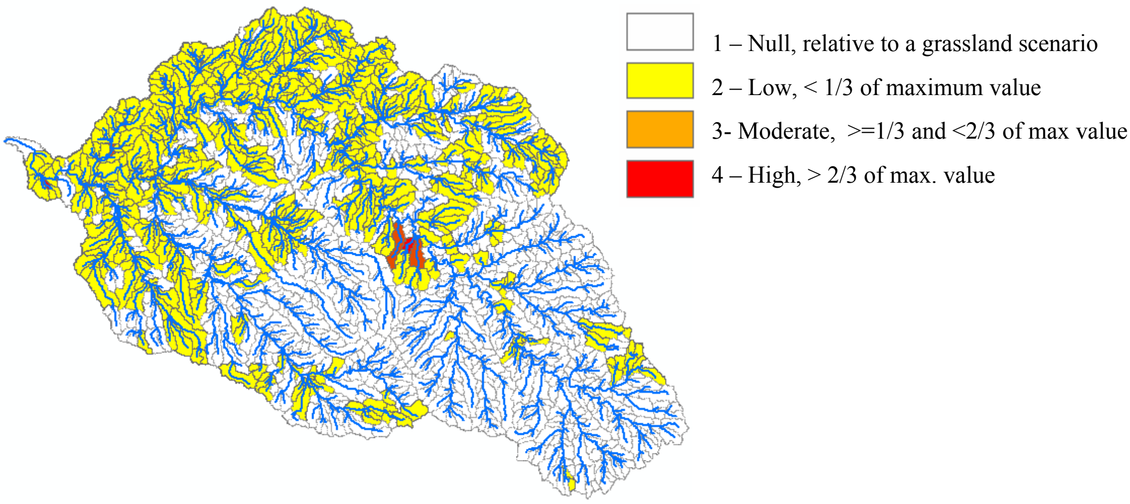


Figure 54 Total amount of soil exported from the segment-specific area per ha

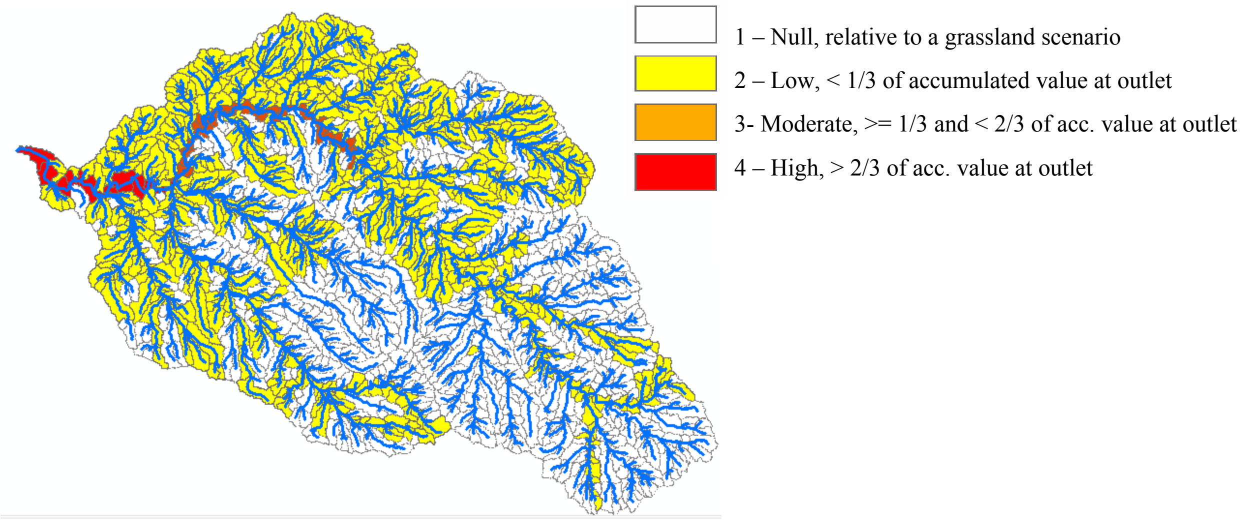


Figure 55 *Degree of accumulated exported sediment that reaches the segment*

Flow Regime Modifications and Aquatic Habitat Modeling

To analize the effect of dams on fish communities, subbasins were chosen (6 in August 2006, 5 in March, 2007), spread in the Cuareim River Basin, with streams with and without dams. In each subbasin, a sample of the fish community was taken and water quality parameters were measured upstream the dam, downstream the dam, and at a control point in a stream without a dam in the same subbasin (or as closest as possible to it). To be able to compare results among points and subbasins, all were 3rd order streams.

In this study, 9817 individuals were collected, corresponding to 62 taxa.

The cluster analysis done among sites and the two samplings considering presence and absence of species shows a great similarity in the species found.

Although differences or trends can be observed in the variables of the community as well as in the water quality parameters, the analysis performed to determine the possible differences among the sites (downstream, upstream and control) were not significant in any case.

The results indicate that in this first approach, there exist a high heterogeneity among subbasins and treatments (aa, ab, c). This heterogeneity was seen in the absence of significant differences among sites and treatments, and so it can be stated that the dams did not affected in a similar way the fish communities in the analyzed systems. The effects are site dependent, that is, depending on the characteristics of the creek with the dam (altitude, surface of the lake, age, activity in the basin, etc), different effects are observed. In some subbasins the best "quality" parameters, were observed upstream the dam, in others downstream, and at least in one, in a control site. In general terms, although in not a significant way, it was observed that between the two sampling, the control sites were those with less variation in the fish community.

The big variability found at the sites upstream and downstream the dams can be attributed to a direct effect of the new environment generated by the dam, where some species can be more favored than others, and then the community of fish upstream the dam will be subsidized by species present in the lake. The movement of fish from the lake to the creek upstream can provoke a greater variability within the fish community. On the other hand, at times of high flows, when the reservoirs overflow through the spillways, it can occur a movement of a big quantity of individuals of few or of many species to downstream the dam, adding a new source of variability to these sites comparing with the control sites, where the variability will be attributed to the natural movement of the different species.

In terms of species, it was not observed any that inhabited exclusively in the control sites that is in sites with no influence of dams. This suggests that of the collected species none would be strongly affected by the dams.

In this study, expected effects were observed, like the high variability of the sites affected by the dams. Nevertheless, other effects like the absence of migratory species of the upstream sites or the presence of own species of the reservoirs could not be detected. The migratory species (dorado, sábalo), were not found in any of the sites, what could mean that those species may not use bodies of such low order in their biologic cycle; therefore the isolation effect on species of higher mobility should be studied in reservoirs on streams of higher order.

CUAREIM - QUARAI (Brazilian side)

Considering the poor available information to Cuareim/Quaraí river basin was not possible to apply a sophisticated model to assess the impact of different sources of pollution.
Therefore, an estimation of consumption and total loads from point sources and diffuses sources of pollution was performed. These values must be reviewed in future studies when available results from water quality monitoring data.

This item presents the main results related to pollutant loads estimated for the Cuareim/Quaraí river basin as previously shown.

The main pollutant loads in the Cuareim/Qauraí river basin related to diffuse sources of pollution such as livestock and rice irrigation. Total annual pollutant load were estimated for the whole basin from the reference values obtained in the literature for different soil uses. It is highlighted that for these classes of soil use, more detailed estimates for the livestock and rice irrigation activities were presented in the tables above.

Table 32. Estimated Annual pollutant load generated within the Cuareim/Quaraí river basin (Kg) due to soil use

Place	Soil use	BOD[1]	Total Nitrogen[1]	T. Phosphorus[1]	Fecal coliforms[1,2]
Brazilian side	Forestry	223.797,81	200.075,24	11.189,89	-
	Pasture	5.350.506,81	1.791.256,63	325.683,02	1,22E+15
	Urban	31.874,13	4.667,48	814,87	8,31E+5
	Agriculture	2.083.264,65	596.045,16	65.970,05	2,91E+12
	Total	**7.689.443,40**	**2.592.044,52**	**403.657,83**	**1,23E+15**
Uruguayan side	Forestry	262.297,14	234.493,64	13.114,86	-
	Pasture	8.116.510,58	2.717.266,58	494.048,47	1,86E+15
	Urban	66.254,22	9.701,92	1.693,80	1,73E+6
	Agriculture	948.510,27	271.379,33	30.036,16	1,33E+12
	Total	**9.393.572,20**	**3.232.841,47**	**538.893,29**	**1,86E+15**
Total in whole basin		**17.083.015,61**	**5.824.885,99**	**942.551,12**	**3.08 E+15**

Flow regime modeling results

The conclusions about the scenario analysis related to water resources development in the basin is that the use of water already has a large impact on the river Cuareim/Quaraí. The very low base flows of the main river and its tributaries very early motivated the local farmers to build reservoirs for individual use. The impact of the use of the water of these reservoirs seems to be relatively small, however the impact of the presence of the reservoirs is not negligible.

The most important impacts related to water resources use in the Cuareim/Quaraí river basin are the direct withdrawals of the rivers, which are drying the river out sometimes. The modeling results confirm the presence of conflicts among different water users (farmers and public supply) and between the users of the two involved countries.

Results of the water resources development scenario confirm outcomes of a prior analysis, which suggested that water is the most important limiting factor to rice growing activity in the basin.

Preliminary Analysis of Potential Impact Zones in Function of Spatial Distribution of Pressures

The analysis conducted to estimate the pollutant loads due to impacting activities developed in the Cuareim/Quaraí river basin did not allow the confection of a map of potentially affected areas as a function of different pressures. However, point sources of pollution are particularly related to urban settlements, specially the cities of Quaraí and Artigas. The Figure 56 shows a map created during the development of WP7, showing reaches of the rivers which would be affected by issues related to human consumption of water (indirectly sewage).

The diffuse sources of pollution due to rice culture are widely distributed in the basin, however more severe effects are felt in areas with greater concentration of rice fields. The spatial impact can be indirectly observed looking for the water demands for rice irrigation. Similarly, the impact on the hydrologic regime, caused by the construction of a large number of agriculture reservoirs can also be observed in the main river and tributaries.

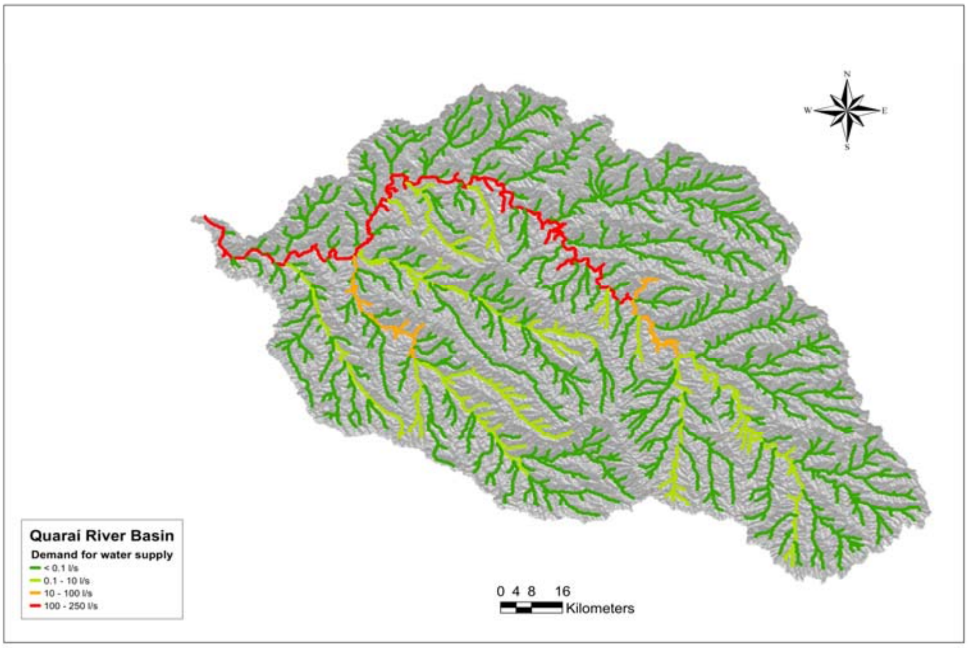


Figure 56. Demand for water supply in the total upstream drainage area

The spatial occurrence of diffuse sources of pollution or the identification of most affected areas is hampered due to lack of information. There are no data for assessing the regions where the largest cattle and sheep herds occur. However, it is known that the cattle and sheep are freely raised on pasture areas. The mapping areas used for the development of extensive livestock farming should be developed in future researches.

COCIBOLCA

Lake Cocibolca is not nearly as heavily polluted as Lake Managua, which receives the waste waters from the Nicaraguan capital. However, the Cocibolca Lake regularly hits the national media with alarming messages over a progressive deterioration of its environmental and ecological status. It is indeed generally acknowledged among the Nicaraguan public opinion that the quality of the waters of the Cocibolca Lake has deteriorated significantly over the past decades. Several theories that try to explain this deterioration are on hands, one of the main ones being the progressive deforestation and land-use conversions in the terrestrial part of the basin. This deforestation would have led to an increase in erosion and thus sediment, pesticide and nutrient loads towards the rivers and lake. However, data-based analyses that provide clear, structured and in-depth views on the real status of the lake are scarce, or difficult to obtain.

Water shortage problems in the area are frequent and may increase in the future, e.g. under several plausible scenarios of climate change (*see also the Work Package 8 report*). It is highly probable that under such circumstances the lake will become an important source for the provision of freshwater in this region, as it is the only large superficial freshwater supply in this highly populated and semi-arid part of Central America. It becomes clear how a further deterioration of water quality in the Cocibolca Lake may jeopardize these development plans.

Preliminary analysis of zones of major potential impact as a function of the spatial distribution of pressures

The use of a Georeferenced Environmental Database for the Cocibolca Basin (SIGACC) based on the ArcHydro data model has facilitated the application of a methodology for spatial impact assessment and source allocation through the definition of individual river reaches as water bodies of the river category, and through the automated delineation of their corresponding *reach-specific* and *total-upstream* drainage areas (see also the Work Package 7 report). The definition of these reaches and their corresponding drainage areas by means of the ArcHydro Toolbox has been based on a detailed hydrography map for the Cocibolca Lake Basin which has been prepared under TWINLATIN.

Two different perspectives can be used when identifying impact zones and/or defining mitigation/prevention measures: (i) the mapping exercise can be based on the subdivision of the territory in natural drainage units and their corresponding river reaches; or (ii) the political-administrative (sub)units can be used.

The first option originates from a subdivision of space as a function of the spatial context at which the processes that lead to the non-point source pollution occur, whereas the second subdivision takes as a base the spatial units at which decisions (and actions) are (under)taken. In what follows, an example application is given for sediment delivery to the lake using the individual river reach/corresponding drainage area as the mapping unit. In a similar way, the process can be applied for mapping cumulative or mean potential impacts for each administrative unit.

Sediment transport and delivery

The description of results given under this point consists of a spatial mapping of the water bodies which (through the activities and/or land cover in their associated drainage areas) probably cause a major impact in terms of sediment delivery (Figure 57). In future work and for the implementation of management strategies, this same information can also be assembled at the level of the political-administrative (sub-)unit (e.g. municipalities), as was indicated before.

Figure 57. Cummulative mean annual sediment transport contributions of individual river reaches in the Cocibolca Basin hydrogrpahic network (qualitative representation – the thicker the brown line, the more sediments the river reach contributes (example preliminary results only))

The map shows how different rivers contribute different amounts of sediments to the Cocibolca Lake, as modeled by WATEM-SEDEM tool (limitations described throughout the report need to be taken into account, e.g. lack of input data for the Costa Rican part of the basin - map only representative for the Nicaraguan part).

Pesticide pollution risk

As with most of the products obtained under Work Package 6, the currently obtained results from the mapping exercise on potential pesticide pollution source areas (Figure 58) are provided as a first reference. For the time being, Figure 65 can be used to get a preliminary idea of where potential contamination with the depicted pesticide types may be expected.

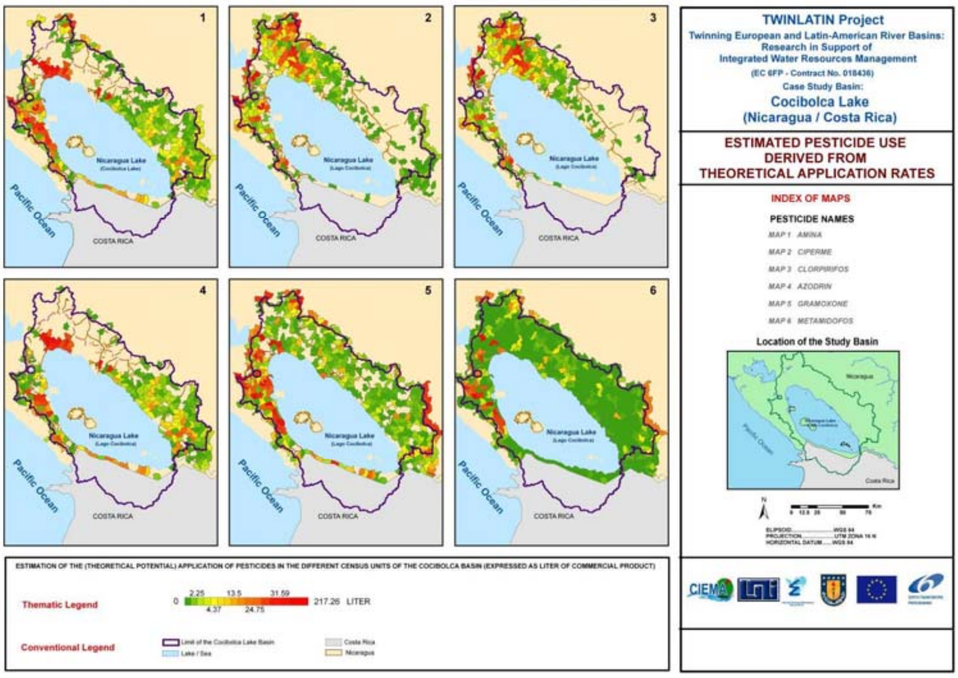


Figure 58. Pesticide use in the Cocibolca Lake Basin (Nicaraguan part): theoretical approximation based on typical application rates for different land use types

CATAMAYO-CHIRA

The main sources of water pollution in the Catamayo-Chira river basin are outlets of waste waters that mostly are spilled into channels without any previous treatment. This leads to obvious contamination in some parts of the river, as around the city of Sullana. Only 15% of total urban wastewaters in the river basin is treated in some way. Furthermore, only 25% of the existing water treatment plants operate properly. The urban wastewater discharges are thought to be the main source of water contamination in the Catamayo-Chira River basin.

The lower part of the Chira system has the most important focus of pollution due to urban waste water discharges because this area has the highest level of development and the highest population density of the basin. The most important wastewater discharge points are located around and in the main cities.

Industrial wastewater discharges

The main economic activity in the Catamayo-Chira River Basin is agriculture. Only 8.1% of the active population works in the secondary sector. But even if nowadays the industry is not very significant in the river basin economy, it represents an important point source of water pollution because in most cases, industrial plants discharge their waste waters to the channels without any previous treatment. Often these effluents are mixed with urban wastewaters.

In the Catamayo Subbasin, the Malacatos - Catamayo area is an important region of industrial pollution. Alcohol, brick and tile industries emit their industrial and sanitary wastewaters to the urban sewage system or directly to the channels or river. This zone as well has the largest agro industrial plant (sugar production, "Ingenio Azucarero Monterrey") that discharges its sanitary and industrial waste waters directly to the river. The plant also has an area of 2,000 ha. of sugar cane production, where pesticides and chemical fertilizers is being applied intensively. In addition, in this area the distilling industry ("*industria de la destilación de aguardiente*") produces a residue (called "*mosto*") that is spilled into the channels and water courses. This waste has a high temperature, a low pH and high contents of alcohol residues. These polluting discharges are frequent because ten different plants produce "*mosto*".

The industrial activity in the Peruvian area is located mostly in the lower part of the basin. This zone presents a medium level of industrialization and is located between the Poechos reservoir and the estuary of the Catamayo-Chira.

The main diffuse sources of water pollution in the basin are urban, industrial, mining and agricultural wastes. Another important diffuse source of water contamination is the sedimentation, which constitutes probably the most important contamination problem in the river basin. The simulation of processes of erosion and sedimentation is therefore in the focus of this report.

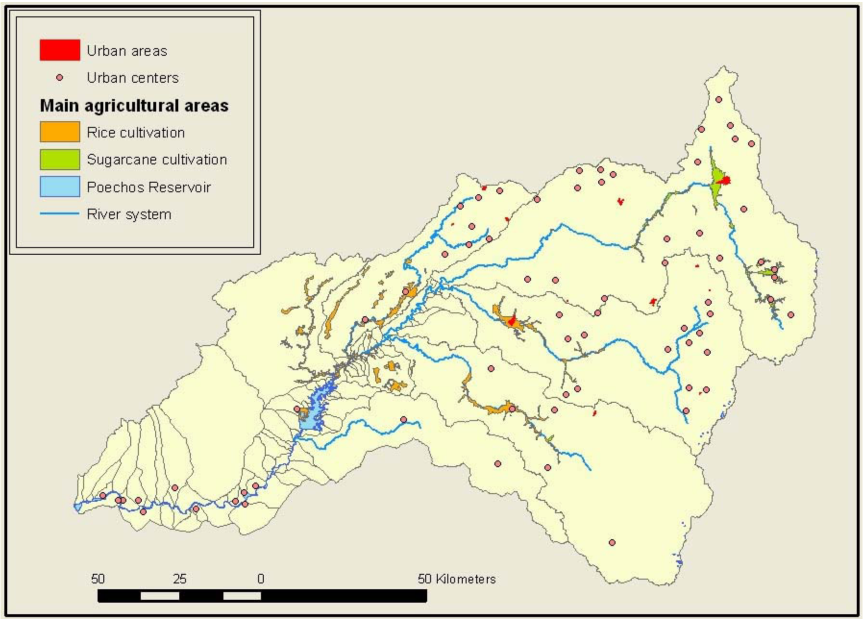


Figure 59. Distribution of the main agricultural areas with high grade of chemical input

Combining annual soil erosion and sediment delivery rates, it is possible to identify the critical areas delivering most of the sediment to the river system. Soil conservation measures will show the largest effects if concentrated in these areas.

The spatial distribution of micro basins with highest sediment export values is shown below. Amongst the 25 micro basins with highest sediment export values, 18 appear throughout the three rainfall conditions, and 5 micro basins are listed in at least two periods. 20 of these basins were identified as micro basins with highest annual soil erosion rates.

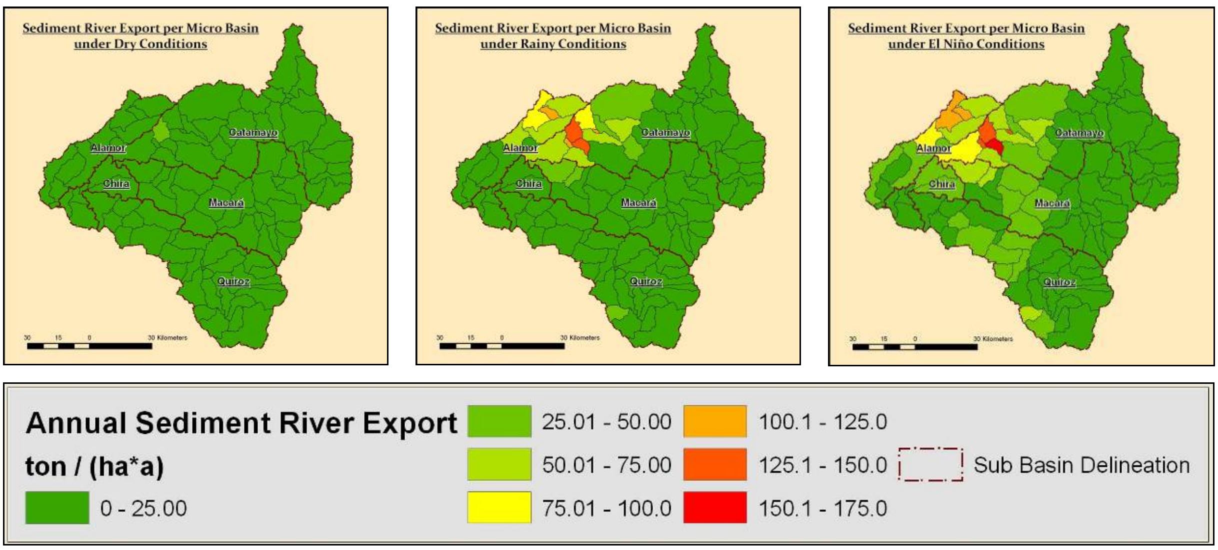


Figure 60. Sediment export per micro basin (in fractions) under dry, rainy and El Niño conditions

The 23 micro basins that were identified to be the ones with the highest sediment export rates – that are therefore the main sources of diffuse pollution of the river systems by sediment load and causes sedimentation of the Poechos reservoir – can be observed in Figure 61. Twelve of them are located in the Catamayo sub basin. Other micro basins are located in the Alamor, Macará and Quiroz subbasin.

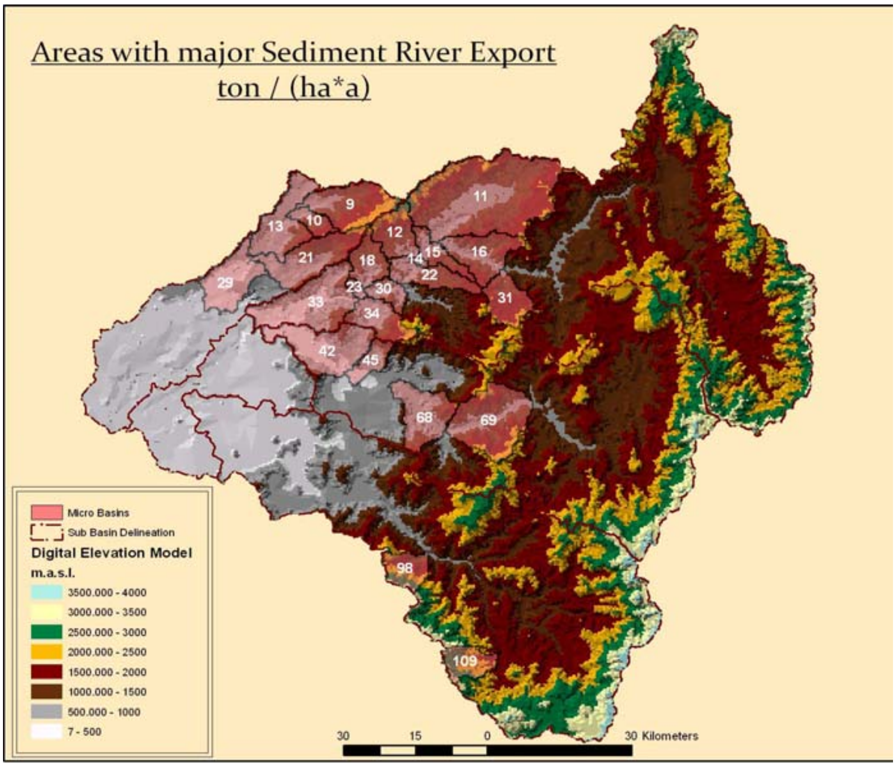


Figure 61. Micro basins with highest sediment export values throughout the different climatic series

As described above, the main **impact** of diffuse pollution in the Catamayo-Chira basin is the sedimentation of the Poechos reservoir. This phenomenon however can only observed at the reservoir – that means only at one specific point situated at the outlet of the study area. This implies that, no matter what the spatial distribution of pollution pressures is, the impact is always the same.

As far as it concerns soil loss and river pollution, a differentiation of impact however is already realized in deliverable 6.1 – Pressure Modeling Results. There, the most affected areas / micro basins in terms of sediment production and following river export are identified.

NORRSTRÖM

Norrström river basin is one of the most studied areas in Sweden, much because of its location in a densely populated area with its outlet to the Baltic Sea in Stockholm. The basin is commonly divided into 12 tributaries, all with outlets in Lake Mälaren. Administratively, the Norrström basin belongs to 31 municipalities, and is a part of six different counties. The closest area around Lake Mälaren covers 4900 km^2 and is dominated by forest.

Nutrient loadings for Lake Mälaren.

TAble 33 shows the SWAT simulated average value for agricultural land and forest for the period 1996-2001. In a comparison with the values in both and, the simulated values are satisfying and show on a good match with earlier studies.

Table 33. ***Average modelled nutrient loading values for forest and agricultural land use for the subbasin Lake Mälaren from the SWAT model runs for the calibration and validation period***

		Average nutrient loading kg/ha	
Subbasin	**Land use**	**Nitrogen**	**Phosphorus**
Lake Mälaren			
	Agriculture	12	0,26
	Forest	1	0,07

Table 34. ***Areal specific losses for Nitrogen and Phosphorus (kg/ha) In the Norrström area before retention.*** *(Brandt et al., 2002).*

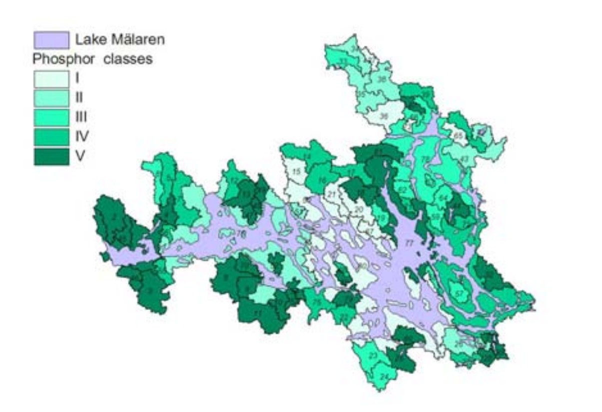
Nitrogen kg/ha		**Phosphorus kg/ha**	
Arable land	Forest	Arable land	Forest
5.0-10.0	0-1.0	< 0.3	< 0.03
	1.0-1.5		

To improve the pressure modelling, two flow proportional measurement stations have been set up in the Lake Mälaren area. This will lead to better understanding of the dynamics of phosphorus (and nitrogen) losses from agricultural land and better quantification of the total load. The catchments were chosen to match with the national sub-basin division system and to have at least 50 % of the land use as agricultural land and no major known point source discharges to the streams (i.e. waste water treatment plants).

The result from the flow proportional nutrient measurements showed that the earlier model settings gave a good nutrient dynamic and that the model responded well to increase in water flow. The settings needed however some calibration to better correlate to the flow proportional values.
The values received from the flow proportional measurements proved an important factor in the work to further improve the model settings. With flow proportional measurements the understanding and possibilities increased drastically.

To provide maximum benefit of the work in WP6 to the end-users, the resources were concentrated on the tasks relating to improvement of modelling of nutrient transport to Lake Mälaren, which has been described above. The nutrient loads that the TWINLATIN project resulted in shows that the nutrient loads from the area nearby Lake Mälaren has a significant impact, and should not be forgotten when assessing the eutrophication problem of Lake Mälaren.The need for further measurements are however great and focus should be on flow proportional measurements.

The impact of the high nutrient pressure on biological parameters such as benthic fauna average score/diversity or habitat survey, is however not negative in the river itself. Tjernell and Axner (2005) showed by surveys of benthic fauna and fish habitats that the biological status of that specific tributary is high. This follows expectations, in that the biological statuses of river segments are not degraded by high nutrient transport. The effect is instead on downstream lakes, such as Lake Mälaren, where algae blooms and increased primary production causes oxygen deficit as well as changed ecology in terms of changed habitat suitability for benthic flora (due to e.g. lower sight depth) and fish. These problems also hamper use of the water for drinking water production. When the impact of nutrient pressure is assessed it is thus crucial to consider the effect on downstream lakes and the sea. The classification of chemical impact to be developed by the water authority will build on the existing assessment guidelines of the Swedish Environmental Protection agency, in which the class boundaries for nutrient discharge are given (very high, high, moderate, low, very low). As an example, classifying the tributaries modelling results achieved in the project according to this nomenclature gives the result presented in Figure 62 and Figure 63. It should be noted though this nomenclature is under revision by the water authority and the Swedish EPA jointly.



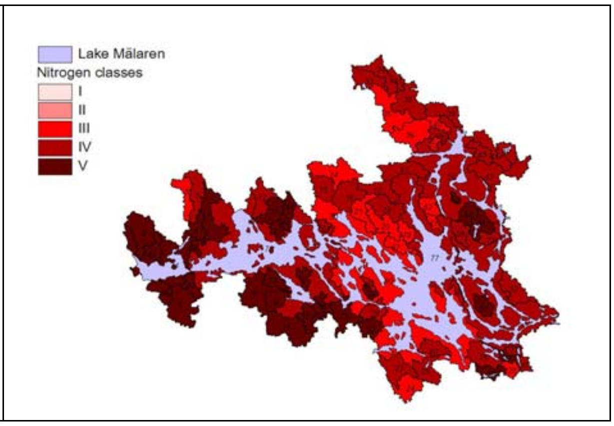


Figure 62. Area specific losses of Phosphorus kg/ha

Figure 63. Area specific losses of Nitrogen.

SUPPORTING THE EROSION ASSESSMENT AT THE LA BASINS (KULeuven)

The efforts of KULeuven in WP6 were concentrated on the support of Latin American partners in the application of WaTEM/SEDEM. WaTEM/SEDEM is a spatially distributed soil erosion and sediment delivery model that was developed at the Physical and Regional Geography Research Group (KULeuven, Belgium). WaTEM/SEDEM was specifically developed to simulate the impact of soil conservation and sediment control measures as well as land use changes on local soil loss and sediment delivery to rivers, in the framework of IWRM. The model aims at providing useful information for land managers to select the most effective catchment management scenario.

In the framework of TWINLATIN, WaTEM/SEDEM was applied in four Latin American basins (Catamayo-Chira, Cauca, Lago de Nicaragua and Cuareim), and in one European basin, the Norrström basin (Sweden). In case of the Latin American basins, KULeuven provided support to the Latin American partners concerning data inputs, data quality, GIS support (data conversions etc.), methodology, test runs, calibration and validation procedures, spatial analyses and final reporting. Two meetings were held at KULeuven (Belgium) with the objective to exchange experiences and build capacity: 05/09/2007 (with Bart Delvaux, UNIGECC) and 17/06/2008 (with Patrick Debels, EULA/CIEMA). In Europe, a WaTEM/SEDEM modelling exercise was done in the Norrström basin (Sweden) with the objective to cross-validate SWAT erosion modelling results. Therefore, IVL and KULeuven organised a twinning activity at IVL in Stockholm (1-3/09/2008).

WaTEM/SEDEM was successfully applied in 4 out of 5 Latin American basins (Catamayo-Chira, a subbasin of the Cauca basin, Lago de Nicaragua basin and Cuareim basin) and in one European basin (Norrström). Many experiences were exchanged in between partners.

The most important problems encountered were problems of data quality and data quantity. In particular problems with quality of Digital Elevation Models were significant, since a high-quality, high-resolution DEM is crucial for determining accurate erosion and transport capacity rates and for routing sediment through the landscape. Also the lack of good erosion measurements to calibrate and validate the model caused important problems. In certain cases (Cuareim, Norrström, Lago de Nicaragua), the model could not be calibrated due to lack of information, and only qualitative analyses were achievable. In two cases, the model was run including a tool to incorporate the effects of ponds or reservoirs in sediment trapping (Cuareim, Lago de Nicaragua).

In the case of Catamayo-Chira, WaTEM/SEDEM was used to evaluate the impact of land use change scenarios (WP8).

Other work in WP6 was concentrated on erosion problems in the Catamayo-Chira basin. MSc thesis student Stijn Van Kerckhoven of the KULeuven collected, digitized and analysed sedimentological and bathymetric data of the Poechos reservoir in Peru. Sediment yields and the effects of ENSO on sediment production were analysed. Some important findings of this investigation were presented at the European

Geosciences Union General Assembly in Vienna (April, 2008). A scientific paper about this research is in preparation.

Finally, KULeuven worked on the modelling of sediment fluxes at the scale of South America. Understanding the spatial and temporal controls on sediment fluxes is important as sediment fluxes provide important information on geomorphic activity in a basin and are related to important biogeochemical cycles such as C and P. The Area Relief Temperature (ART) and Discharge Relief Temperature (QRT) models were developed based on a large global dataset, with the aim of prediction of long-term sediment flux from river basins to the coastal oceans using a small number of basin parameters (drainage basing, discharge, basin relief and climate). In this research, the applicability of these models on the South American continent was tested, using not only sediment data near river mouths, but also information from intra-continental, smaller river basins. The database consists of observed sediment load, average discharge, drainage basin area, minimum and maximum elevation, basin averaged temperature and number of years of sediment measurements for 294 stations in Argentina, Bolivia, Brazil, Colombia and Ecuador. The ART and QRT models with original coefficients performed badly, resulting in very large underestimations of intra-continental sediment fluxes. However, when applied to basins comparable in size to those used by Syvitsky et al. ($> 120 \cdot 10^3$ km²) a good agreement was obtained, indicating the importance of scale. In order to assess intra-continental sediment fluxes more accurately, new coefficients were determined for the ART and QRT models using multiple linear regression. This resulted in R^2 values of 0.73 and 0.76 for ART and QRT respectively. Almost 50% of the predicted values were within a factor 2 of the observations. Still, the modified models strongly underestimated sediment fluxes in the Andes region. We attribute this to the fact that ART en QRT-type models do not allow to account for the effects of tectonic uplift. The introduction of a binary factor to discriminate the Andes drainage basins from the rest of the dataset led to a considerable improvement with R^2 values: 0.78 (ART) and 0.83 (QRT). We were not able to detect any additional significant impact of land use/cover. Despite considerable uncertainties about data quality, the modified ART and QRT models have a high predictive power across 4 orders of magnitude of catchment size, provided that basins located in the tectonically active Andes region are separately accounted for. Some important findings of this investigation were presented at the European Geosciences Union General Assembly in Vienna (April, 2008). A scientific paper about this research is in preparation.

3.7 WP7 Classification of Water Bodies

WP7 Objectives:

- To document protected areas.
- To categorise water bodies concerning ecological status using a relative scale and examples of class boundaries identified in co-operation with stakeholders and authorities from the river basin countries.

Water bodies as analytical units

The EC WFD gives indications on how to identify individual water bodies, how to organize them according to category, and how to establish a typology for each category of water bodies. For the establishment of a water body typology for a TWINLATIN case study basin, both the regional natural conditions as well as the national legal and institutional framework need to be taken into consideration. The establishment of water body typologies for the TWINLATIN basins is documented in what follows, and is based on local adaptations of the methodology proposed in the framework of the EC WFD and the experience of the methodology used in applying this framework in the Biobío river basin under TWINBAS (EC 6FP).

Where relevant and/or applicable, the former is taken as a reference for the activities related to this work package in the TWINLATIN river basins.

BAKER

Reference conditions for Rivers
For the establishment of the desired levels of ecosystem health, "*reference conditions*" typically have to be determined for each representative water body type, based on the natural conditions that can be observed in the field (or deduced from expert knowledge).
Consequently, in order to proceed, the individual analysis units, called "water bodies", first have to be defined in space. Then, a typology has to be established, which allows for a spatial differentiation between water bodies, based on their physical and ecological characteristics as well as those of their surrounding environment.
A set of representative elements from each water body type can then be selected, for which it can be reasonably assumed that "natural" or "reference" conditions (still) occur at these sites. These water bodies can then be analyzed in the field, in order to set reference conditions which will further allow evaluating the current status at other sites that belong to the same river body type. The term "reference conditions" covers both physical & chemical, biological, morphological as well as hydrological characteristics of a given water body type.

In the light of the limited baseline information available for the basin, an evaluation has been made of the location of those sites that currently present a high potential (probability) of (still) presenting (close to-) reference conditions.

For this evaluation, the following parameters were considered due to their potential influence on aquatic ecosystem health (many additional parameters could be included; however it is thought that many of these are correlated to the more general parameters described below; also, currently information for these additional parameters will most often not be available for the Baker Basin):

- Density of road network in the reach-specific drainage area.
- Area of vegetation in the total upstream drainage area of a water body which presents indications that it probably has been burned during the historical forest fires in the zone.
- Presence of a priority area for mining activities.

A quantitative indicator (index) was assigned to each one of the above specified criteria, reflecting the level of human intervention within the area of influence of each water body. Through an analytical combination of the estimated impacts of human activities represented by these distinct GIS layers, a first approximation could be obtained of the degree of "*accumulative intervention*" for each individual water body in the basin. This new information layer can now be used for the identification of probable reference sites, as well as for a preliminary analysis of those sites that are currently or potentially under risk of being severely impacted by human activities. This basic application under TWINLATIN is highly flexible, and is especially interesting as a showcase on how to further extend and improve the applied approach in the future, which is highly useful in the context of an adaptive management approach (*management is adapted and improved as new information becomes available over time*).

The information source for the road network used corresponds to the Office of Highway Administration, of the Ministry of Public Works, and considers in addition to the currently existing routes also future investment projects which aim to improve current conditions, or the construction of new routes. In addition, different categories of routes have been given differential weights, considering that, for example, a path not suitable for heavy vehicles has a different effect on an adjacent river reach, in comparison with a network designed with a higher standard.

In this way, by pondering the different land routes and quantifying their density with respect to the length of each river segment considered as an individual water body of the river class, a derived indicator has been constructed. Carrying out an arrangement of these results, and considering the probable effects of development of this human activity in the reaches, Figure 64 has been constructed. In this Figure, the reaches are assigned a color which allows differentiating for the different pressure degrees.

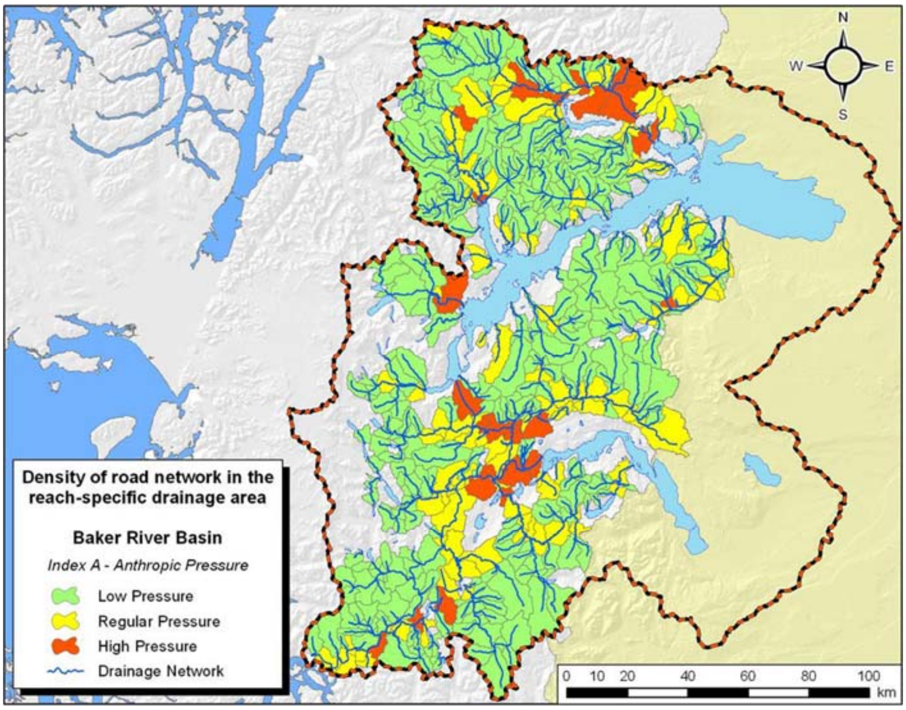


Figure 64. Index of Antrophic Pressure due to the "density of the road network" proxy.

As a second factor, a map was incorporated that identifies the different areas of the basin that were affected by the different historic forest (and grassland) fires associated with the colonization of the basin. Although it has not been possible to verify the source of this map, according to the information requests made to the different Services and Public Departments of the Region, it is probable that its origin is from a study carried out by the Center for Information on Natural Resources (CIREN-CORFO) in the year 1979.

Figure 65 shows the distribution of the results of the calculations for areas in the basin more affected by the burning of native vegetation for the different reaches used in the classification exercise. Just as in the previous case, the specific drainage areas of the different segments have been used to represent the magnitude of this factor on the map, and its distribution in a spatial context.

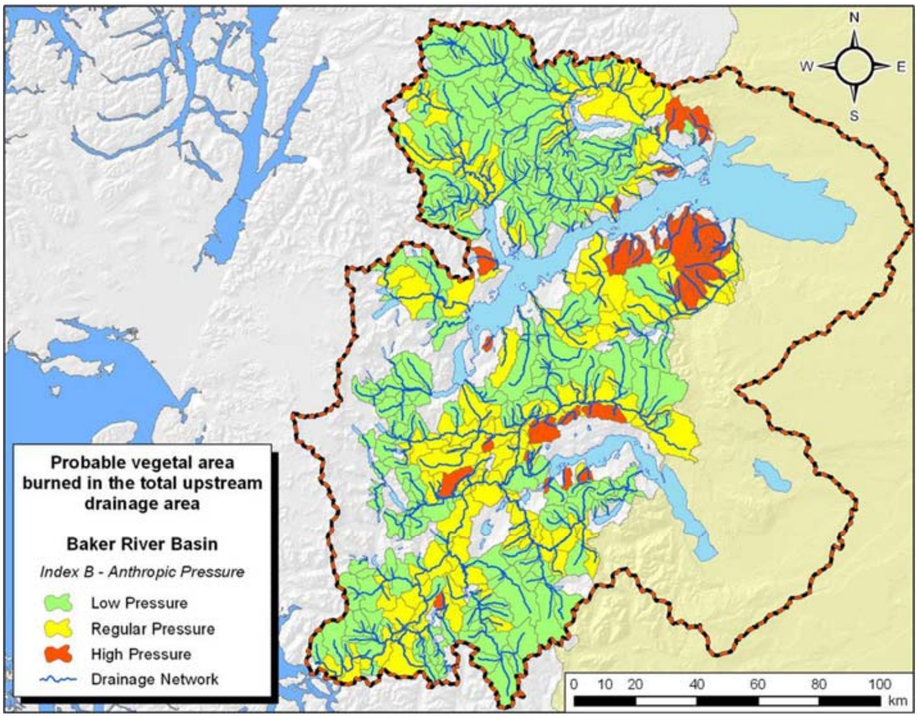


Figure 65. *Index of Antrophic Pressure by probable vegetal area burned (historically).*

As a last factor, the areas prioritized for mining activity in the Baker River basin were used. Although these areas are much more spatially focused than the two previously considered factors, in the authors' opinion, they represent poles of development of anthropic activities directly but also indirectly associated to mining activities.

The information source corresponds to the results of the Work Package on Pressures and Impacts in the basin, and for its consideration regarding the distribution in the basin, the ratio between the priority areas and the size of the specific drainage basins was determined.

River water bodies potentially under reference conditions

Using the principles of multi-criteria analysis, the previously generated GIS layers were mathematically combined by assigning a weight factor to each layer and then summing all individual contributions. The result of this operation is a quantitative index, which reflects the potential deviation of local river water status from reference conditions. The index can thus be interpreted as reflecting the "*degree of naturality*" of the water body and its surrounding environment. In order to allow for a more qualitative interpretation, class limits can be established in order to identify the probability for a given reach to be "*under reference conditions*" as "*high*", "*regular*" or "*low*".

The results of this analysis are presented in Figure 66, in which it is observed how the greater pressures – both historic and present – are concentrated in the valley zones, near the bigger lake water bodies. It is indeed in these areas where the settlements and productive activities concentrate. It is important to observe that the pressure on the water environment in the sector of Chile Chico and in the surrounding areas of Cochrane and Puerto Ingeniero Ibáñez is not very different. Opposite this is the situation of reaches which probably present a status closer to a "*natural status*" than others.

In the next step, it needs to be evaluated under what status the different elements (water bodies) belonging to the different typologies (generated at the beginning of the classification exercise) are found. For each considered water body type, what is the quantity of reaches or segments (individual water bodies) that fall under the different categories that represent the degree of natural status.

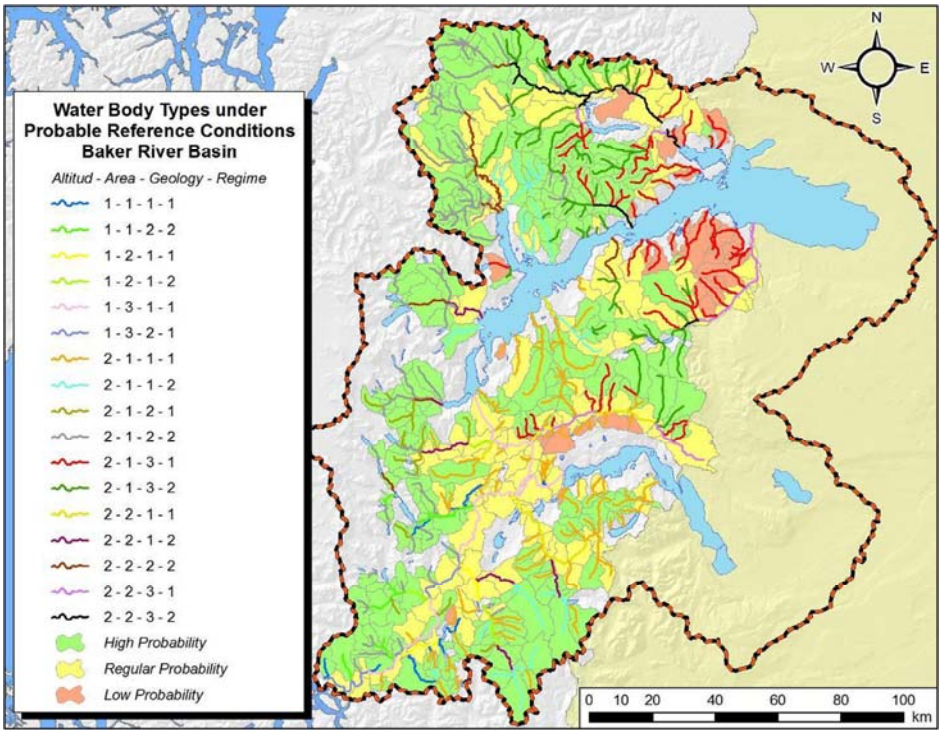


Figure 66. Rivers water body types probably under reference conditions

From the given and tabulated results, it can be observed how most of the river types defined for the Baker River Basin probably possess good conditions or moderately good conditions. This corresponds to a particularly interesting situation which enables the establishment of reference conditions based on field monitoring, a possibility which today is increasingly difficult to find in many river basins in the world. The most critical cases in the Baker Basin with regard to river water body types without or with very Little elements in probably natural conditions correspond to the types 1-2-1-1 (*Lower Altitude + Main tributaries + Metamorphic and Sedimentary + Rainfall Regime*) and 1-3-2-1 (*Lower Altitude + Baker river + Plutonic + Rainfall Regime*); for these cases it would be recommendable to conduct more intensive monitoring in the future, and combine this information with expert judgment, this in order to validate the established typology, or in order to eventually correct the results.

From this perspective, the use of the selected typology and the analysis of reaches under reference conditions will allow focalizing resources and efforts, such as for example the planning of monitoring campaigns or the development of management and planning tools for the water quality of the aquatic resources in the Basin.

Reference condition monitoring in the Baker River Basin

With the aim of *(i)* establishing a data base with information about the current physical-chemical and biological characteristics of the water bodies in the Baker River Basin, and at the same time *(ii)* providing a data base that can serve as testimony of reference for the evaluation of future conditions in the rivers, and finally, *(iii)* as a form of carrying out an initial validation of the results obtained from the classification exercise, next and as a first approximation, we show the results of the two campaigns of intensive monitoring (in this case focused principally on the biological characteristics) carried out in the Baker River basin, which were partially sponsored by the TWINLATIN project.

Both campaigns, for motives of logistics and land accessibility, were carried out during the summer season of the years 2006 and 2007, covering a total of 50 sample that were distributed throughout the basin, at different spatial scales, for example from first order reaches until the area of the Baker River mouth.

Most of the sites monitored during the two intensive campaigns correspond to reaches with a regular probability of presenting reference conditions. Although this situation is not ideal for effects of the definition of ecological reference conditions for each water body type, it should be considered that the former is a direct consequence of the low development of access ways (roads) in the basin, and from the consideration of the presences of the road network as one of the influencing factors in the evaluation of the probability of presenting reference conditions of the different reaches: given the logistical conditions typical of the basin, the sample sites had to be concentrated in the sectors that were accessible by land. Therefore, it can logically be expected that the sample sites will be located in areas of human intervention, and, as such, results from monitoring may therefore be affected by these human activities.

In spite of the former, when looking at the sampling distribution over the 17 defined water body types, it can be observed how only for two members of the typology it was not possible to include representative elements. Knowing this, and in case it would be really desired, special emphasis can be put as to also include these two types in future monitors. Alternatively, possible patterns of similarity with other similar typologies that have been monitored may be established.

With respect to the monitored parameters, it can be indicated that both campaigns focused on biological variables, reason for which in each site macro invertebrate samples were taken and analyzed. In addition, a monitoring of the main physical-chemical properties in the water column was also carried out. These results were tabulated, in which the ID and type of monitored river reach in each campaign were also given, as well as the specific species richness. The database that was constructed and obtained in this way thus constitutes a very valuable contribution that will enhance the possibility to evaluate future evolutions in the quality and characteristics of the rivers in the Baker Basin.

In addition to the species richness per sample site, order or class abundance was also estimated for each monitoring season.

To date, clear patterns that relate the characteristics or magnitudes of these biological indicators with the different types of water bodies could not be clearly identified. On one hand, there is the possibility that the number of classes generated in the typology may be high for the variability patterns of biological and physical-chemical characteristics in the basin (in this context, it should be considered that we are dealing with a zone with a climate that does not favor the development of high biodiversity). On the other hand, it is also possible that the variations in detected characteristics at the different monitoring sites respond to the effects of very specific conditions of the monitored microhabitats, an aspect that cannot be taken in consideration when applying the GIS typology exercise to the level of the entire basin (at least not with the cartographic scale at which the input data sets were available). Even so, the database constitutes a very interesting source of information for future evaluations and detections of change in the basin.

In a similar way, in the case that the monitoring efforts can be further extended in the future, the background information obtained in such a way can then again be taken into consideration in future revisions and eventual modifications of the Secondary Surface Water Quality Standard for the Baker River Basin, which is currently in development (currently in a state of "draft-project", having been approved under this stage by the national Environment Committee through Exempt Resolution # 1,879 from June 16th 2008; an important amount of information generated under the TWINLATIN project has been used in the preparation process of this "draft-proposal", through the collaboration between EULA and DGA Aysén under TWINLATIN). (The state of "draft-project" means that currently, citizen observations to the normative process are no longer accepted, and the currently available background information is under revision).

The results of the abundance analysis according to class or order for all stations sampled during the campaigns of 2006 and 2007 were also tabulated.

Secondary Water Quality Standard Project for Baker River

As was already indicated under the previous point, currently the environmental authority is developing a project of law that seeks to establish physical-chemical quality objectives for the main reaches of the Baker River. This project is known as the "draft-project" of the Secondary Water Quality Standard for the Baker River basin. Currently, the "draft-project" as such, considers for the definition of quality objectives only the river reaches indicated in Figure 67 in function of the objectives of the "draft-project", the only reaches currently considered correspond to the main rivers. This is because for these river monitoring information (upon which to base the standardization process) is currently available, and, at the same time, it is more urgent to establish quality criteria for these reaches, due to the risk of deterioration that these systems represent. The exercise carried out under TWINLATIN for additional reaches comes to complement this information (the rivers not considered in the Standard make up a "knowledge gap", for which the information generated under TWINLATIN can be of great relevance in the future, in case of greater and accelerated development in zones which currently present little investment – such accelerated development may e.g. be triggered by the hydropower development in the Basin and the associated extension of the transportation networks.

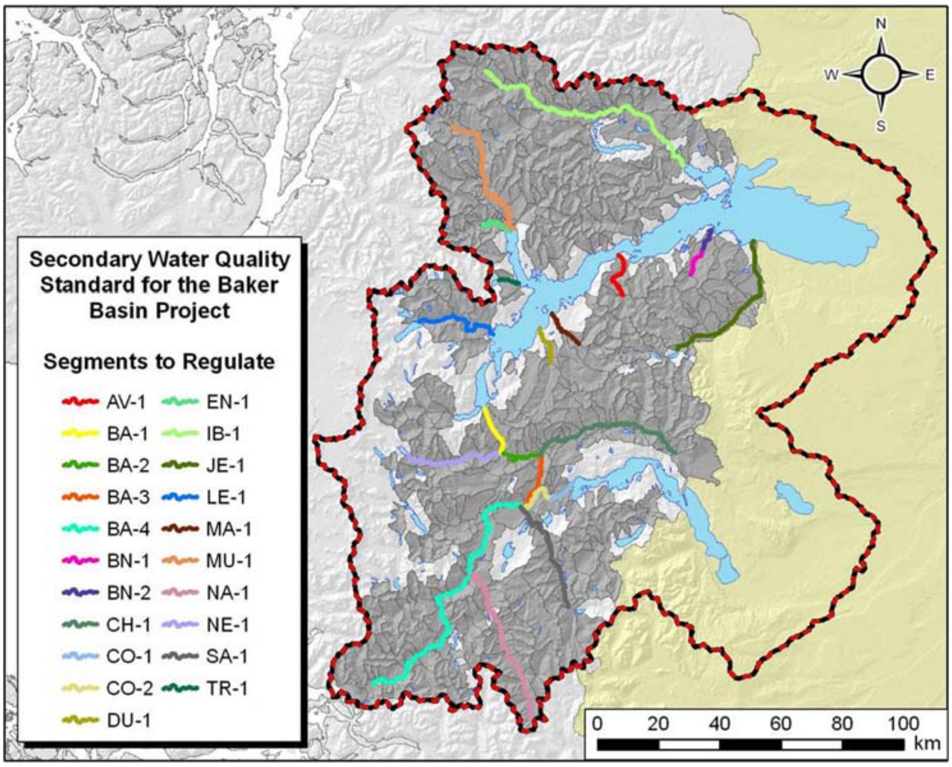


Figure 67. Segments defined by the Secondary Water Quality Standard Project

In order to offer a comparison between the reaches currently included in the "draft-project" (a very reduced zone of the entire basin has currently been included due to priority function) with the preliminary results of the definition of river typologies and reference conditions for the drainage network of the Baker River (much more complete coverage of the basin). This summary indicates for each one of the segments to regulate, the different segments of water bodies of the river type (ID WB) that are represented within this segment, as well as the corresponding typology code, and the probability for finding reference conditions in each element.

It is observed that the majority of the reaches incorporated in the water quality standard are represented by the occurrence of more than one typology along their extension. In addition, it can also be observed how these mostly classify as having "moderate probability for reference conditions", due to their vicinity to areas of anthropic development in the basin.

Summary

According to the classification exercise, a total of 17 river typologies considered as representative for the Baker River basin were established, of which -after an estimation in function of a pressure analysis- the conclusion was reached that the majority of the different typologies have segments under a probable reference condition status. The exception to this case would be two river typologies, which, due to the reduced number of segments that make them up, and due to their proximity to centers of human activity, it is probable that they do not have good reference conditions in any of their elements. The previous indicates that currently, the Baker Basin still presents exceptional conditions (in comparison with many other basins in the world) which allow for the experimental definition of reference conditions. Such exceptional conditions were taken advantage of through important monitoring which was conducted under TWINLATIN, and which offers us a very valuable source of information for future activities of basin management. Those sites where samples still could not be taken, can – in the case of being considered relevant – receive preferential attention in future monitoring efforts, or it can be tried to associated them to the typologies that were sampled, eventually making use for such purpose of local expert judgment.

The project for the definition of a Secondary Water Quality Standard for the Baker River basin is currently in the process of development. The efforts in that project have been focused on those sectors of the basin where there is the greatest presumption of the existence of impacts (current or potential future). As part of a process orientated towards the implementation of the concept of an adaptive management (in function of the available knowledge to date, and taking in consideration the evolutions that will take place in the future), such rules will be subject to a periodic revision. The efforts carried out under TWINLATIN, in combination with the ongoing completion of the data base on characteristics of the elements of the hydrographic network in the basin, initiated under TWINLATIN, already provides, and will keep providing extremely valuable information for such an adaptive management approach in the Baker River Basin.

CUAREIM-QUARAI (Uruguayan side)

The **objective** of the present work was to advance in the knowledge of the **ecological status** of the water bodies in the Cuareim River basin and to contribute with information towards the **definition of a Monitoring Plan**.

The methodology used was inspired by the one proposed by the EU Water Framework Directive, with the necessary adaptations to the characteristics of the basin.

The study includes the analysis of the main pressures detected on water bodies (rivers), followed by a preliminary risk classification of their current ecological status and an explanation on how this information could be used for the selection of sites for reference stations.

Combining three layers of information for the Uruguayan territory: altitude, contributing area and geology, 17 classes were obtained and therefore the river reaches were grouped by expected similar natural characteristics. For each class one reference station should be established. Some of these classes are quite small in area so they should be further analyzed to justify the need of a reference site.

Based on Farming, Volume-Regulation, and Export-Sediment pressures, 15% of the river reaches in Uruguayan territory, including the main channel, would be at risk of not attaining the desired ecological status. If other pressures were added: urban areas, direct intakes, industry discharges, and highways, that 15% would increase, but more research is needed to quantify that value.

All typology zones presented relatively high values of environmental quality in reference to fish communities. Up to now, the total number of registered species for the basin is 110, what represents 50% of the total number of species for the country. To be able to relate the results from the collection of fish and the classification of rivers at risk by the pressure analysis, it would be necessary to differentiate per typology the exact location of the collections to be able to see if there is any relationship with the pressures.

The number of arboreal and arbustive species with restricted distribution is high in the Cuareim River basin. As for this analysis it was used a historic record, an updating of field effort is recommended to have a more accurate idea of species present in the area. This basin is the distribution limit of many arboreal species, such as *Patagonula americana* (guayubira), a very singular species that is only found there.

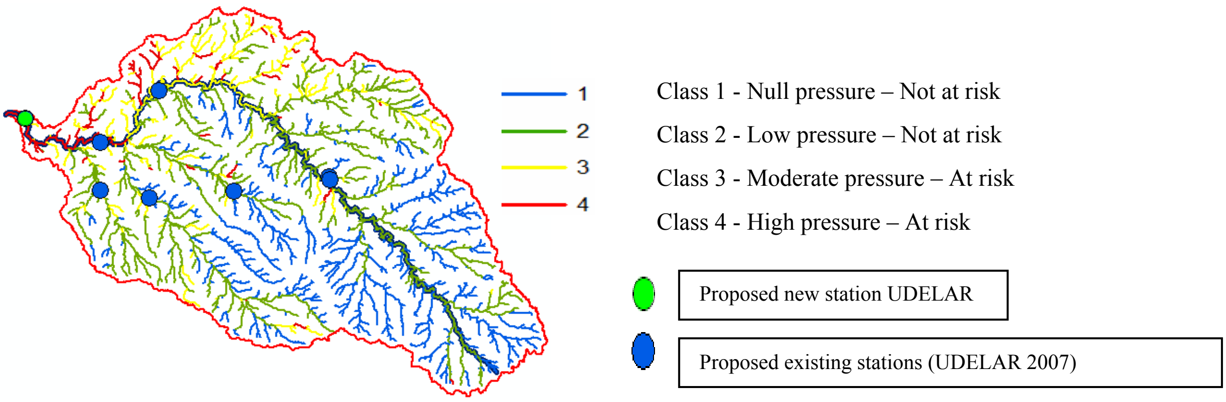


Figure 68. Classification of rivers based on farming, volume-regulation, and export-sediment pressures for the Uruguayan territory

Effort should be put to extend research about fish species and arboreal species to the Brazilian territory, to complete the comparison for the whole basin.

Finally, from TWINLATIN Working Package 2, the water quality-quantity monitoring was done in 4 locations, 3 on the main channel and one on Brazilian territory. As the results are backed by a low number of observations, these conclusions are not definitive:

- The quality of the Cuareim river in general is good
- Some variables show an increase in the relative concentrations closer to the mouth of the river
- Some variables show an important association with the flows or volumes of water at the moment of the sampling

The water quality-quantity monitoring has to be continued and there is a need to assess again the location of the stations with an integrated basin approach.

CUAREIM - QUARAI (Brazilian side)

The present report had as main objective to describe activities related with Classification of Water Bodies in the Cuareim-Quaraí River Basin, within the scope of Work package 7 of the TWINBAS project (Brazil).

To achieve the desired classification the Water Framework Directive from European Union was adapted and applied. It was unable to implement the WFD in its entirety because unavailability of consistent biological and physical-chemical data. Therefore, the classification was restricted to the inclusion of hydromorphological parameters.

The water body typology in the Cuareim-Quaraí River Basin was established using the System A classification scheme with some adaptation due to particularities in the basin. Rivers were grouped in 20 typology regions in the basin through 4 hydromorphological parameters.

Type-specific reference conditions for each water body type were established using the best available data. Two classifications of water bodies were performed based on the combined analysis of a series of layers representing different types of human pressures. For this purpose in the Classification I and Classification II were used five and six layers respectively. Geoprocessing tools were widely used in these processes.

These two Classifications schemes clearly show that the main economic activity developed in the basin, supported primarily on the rice production, is the principal human press over the ecological status of water bodies. The rice irrigation practice leads either the change of land cover and the available water quality and quantity. Mainly in the Brazilian side of the basin this impact on water bodies is more sensitive.

Aspects related to water quantity and quality also have relevant importance for a great number of people that need drinking water, mainly those established near the major urban settlements as Artigas and Quaraí. So these potential risks need to be considered in the decision-making process of Cuareim-Quaraí River Basin, in order to safeguard water quality and health of the human population.

The researchers involved in this process hold that these preliminary results and conclusions within the Work Package 7-TWINBAS can be further improved, once the field gathering biological and physic-chemical data is implemented in the whole basin.

The Classification of Water Bodies in the Cuareim-Quaraí River Basin restricts to hydromorphological parameters has limitations inherent to the used approach, so this consideration should be taken into account when using the classification for practical decision-making

COCIBOLCA

Currently, almost no field data is available which would allow for a characterization of the different water body ecosystem types in the Cocibolca Lake Basin. A characterization of water body types and their physical-chemical, biological and hydrometeorological baseline conditions based on field data would however also here provide an interesting means for improved water resources management, especially with the aim of protecting important aquatic ecosystems. Unfortunately, under the current Nicaraguan socio-economic context even when the former is seen as important by water stakeholders, it does not constitute a top priority; for this and several other reasons, the data gathering that would be required for such a purpose cannot be achieved in the current context, and definitely not under the TWINLATIN Project.

Even so, we believed that the generation of a theoretically deduced river water body typology may provide a very interesting first view on where major differences in river ecosystem types can be expected. By this means, the work conducted under WP07 provides a basic reference map which can prove very useful whenever resources would become available which would allow to gradually advance in the establishment of the above mentioned reference conditions. In such cases, further validation (and/or correction) based on field data of the Cocibolca Lake water body typology would of course also be required.

One of the problems that are generally believed to have a major influence on the environmental quality of the Cocibolca Lake Basin and its water resources is the erosion and sediment transport phenomenon. It is in this context that under Work Package 6 work was conducted on the construction and implementation of the WATEM-SEDEM erosion and sediment delivery model for the Cocibolca Basin. The application of this spatially distributed model allows quantifying sediment contributions to the lake generated from the different micro- and sub-basins in the watershed. If it can be assumed that the model provides a realistic representation of these spatial patterns in the Basin, then the model can be used to identify those areas which are delivering the most sediments (and associated contaminants) to the lake ecosystem. However, due to the high spatial variability in the Basin of natural terrain and climatic conditions (such as slope, soil type, precipitation), also without human intervention different sediment contributions can be expected from different sectors of the Basin. For this reason, under the present work package a first approximation for the “reference land cover conditions” was used to establish “reference” spatial erosion patterns and magnitudes under natural land cover (forest) in the Basin. These “natural” micro-basin or river reach contributions can then deducted from the results obtained from the “current land use” erosion & sediment maps, in order to obtain a view of where human-induced sediment delivery is high(est). This would then indicate the areas where mitigation/prevention actions may be most effective, and therefore their inclusion in a priority list for action can be considered. In such a way, a classification of water body status (with respect to sediment contributions) can be produced.

The results obtained from the work under TWINLATIN -in particular the methodological development- prove very useful for practical basin management for the Cocibolca Lake area. For this purpose however, an updating and further improvement, in collaboration with the local water sector stakeholders, of the used land use and soils map would be highly recommendable.

The methodology applied to the Cocibolca Basin proves very useful and can easily be implemented in other Latin-American basins where similar problems need to be addressed.

CATAMAYO-CHIRA

Establishment of reference conditions

In the Catamayo–Chira basin, due to the limitation of available resources and lack of base information for the basin, the River Quiroz sub-basin was prioritized as a pilot zone to assess the water bodies that present high potential to be considered referential. In addition, local organizations develop research work in this zone and they gave us support to perform this assessment.

The protection of hydrological resources is a high priority. This reality gives priority to the research on macro-invertebrates, benthonic diatomaceous in sites of reference in order to increase the knowledge of natural dynamics in these rivers and to be able to use this information in the future to establish the ecological status of the rest of the basin and to restore the zones that are degraded, taking into account the conventional parameters which help us understand the behaviour of these organisms.

The ecological quality of the water bodies in the River Quiroz sub-basin was assessed in 15 points that correspond to 9 tributaries of the River Quiroz. Concerning the water quality assessment, it is very important to know beforehand if the point to assess can be of reference or not. To establish reference conditions, some parameters were taken into account:

Biology parameters: based on the study of macro-invertebrates benthonic and epilitic diatomaceous, organisms that are usually used in the studies related to river pollution due to the excellent signals about the quality of the water supplied. When used in the monitoring process, its status can be clearly understood.

Physical – Chemical parameters: physical and chemical characteristics were studied such as the temperature that can help to predict and/or confirm other water conditions such as its direct influence in other factors of water quality such as dissolved oxygen, the survival of some aquatic species, the electric conductivity related to the presence of salts in water. Dissolved oxygen that is essential for life, can be an indicator of how polluted water is and how good this water can provide support to vegetal and animal life; pH measures the relative water acidity.

Nutrient parameters: nitrate and phosphate concentrations were measured. The nitrates can come from fertilizers, sewage water and industrial waste that can cause eutrofization. The phosphates are present in fertilizers and detergent and can reach water with the agricultural runoff, industrial waste and sewage water discharges; and, similar to the nitrates, they are nutrients for plants. When there is too much phosphate in water, it favors its growth.

Visualization of the esthetic quality: A series of basin characteristics were measured; river-section and river-bed that can be the origin of aquatic community degradation, as well as the conservation status of the river bank forest based on the vegetation coverage of the river bank, structure or maturity degree, complexity and naturalness of the system, and the fluvial channel alteration degree.

Work developed

The River Quiroz pilot sub-basin was chosen because it was the most representative one in the Catamayo–Chira basin. It presents a great heterogeneity and the largest number of life zones, which makes this sub-basin a zone with high ecological potential.

In the office, 15 sampling points were tentatively established worked in GIS taking some considerations such as scarcely-altered or greatly-altered by men, easy access; those points were later validated in the field. The sampling stations adjusted seven out of the 14 water body types established for this sub-basin.

The physical – chemical, biological parameters were measured as well as direct application rates in the field to determine the ecological status of the water bodies in the River Quiroz sub-basin.

Seven inhabitants from different sectors of a Peasants Community called Yanta were trained on bio-indicators. These people were chosen by their leaders in communal assembly.

There was an exchange of knowledge between the technical team of the Catamayo Chira – TWINLATIN project and the community team, which was a success because was combined scientific knowledge with traditional knowledge, explaining for example that the insect they use as bait in their old fishing style is an indicator of the health status of their rivers.

In the lab, the macro-invertebrate benthonic and epilitic diatomaceous taxa were determined, each group was counted and metrics were applied such as the Family Biotic Index for macro-invertebrates and the General Diatomaceous Index.

With the information obtained from the bio-indicators and the biotic indexes, an assessment was made concerning the ecological classification of water bodies in the River Quiroz sub-basin.

Ecological classification of water bodies

The index to identify stations of reference considers that values over 100 are necessary to consider one point as "reference" (Prat *et al.* 2007); therefore, the results obtained in all campaigns indicate us that 5 of them can be considered "of reference".

The quality index of the riverbank forest of Munné *et al.* 1998, indicates that stations *SQ 10, SQ 1, SQ 3, SQ 9, SQ 12, SQ 13 and SQ 14* have very good and good quality, as shown in Figure 69.

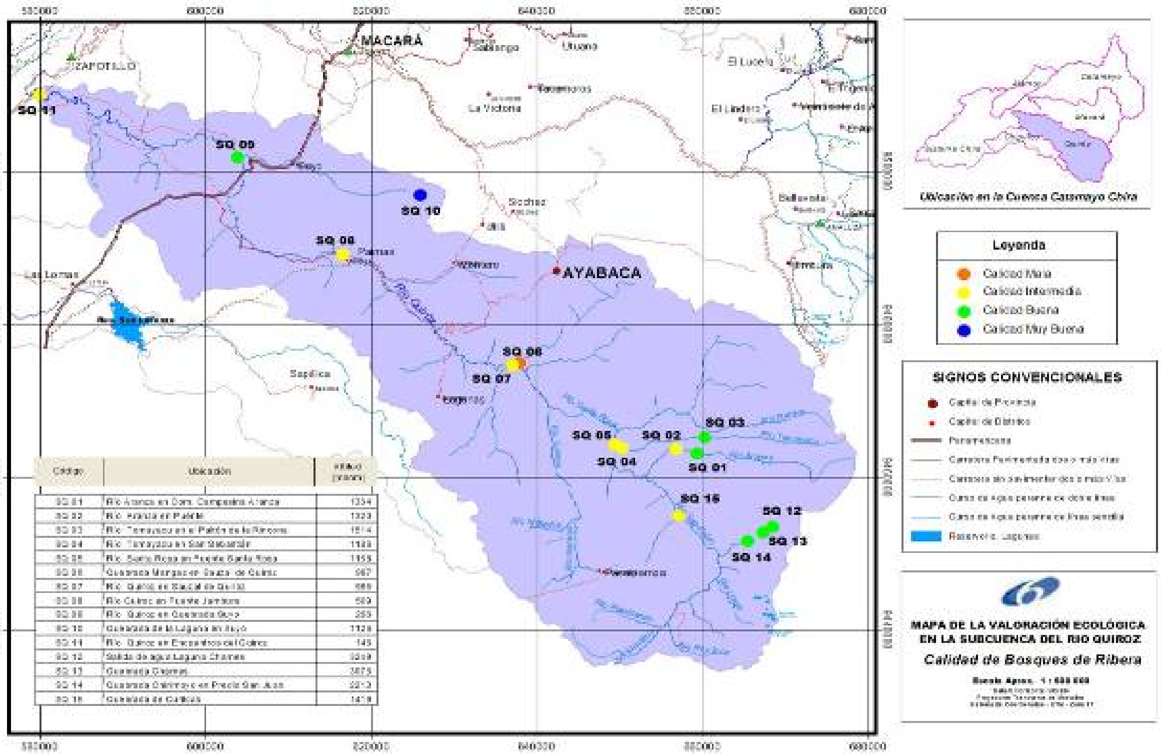


Figure 69. Ecological valuation of the water bodies in the River Quiroz sub-basin according to the quality of riverbank forest

The indexes applied to the macro-invertebrate group indicate that in general, the water bodies present acceptable quality, but as the elevation decreases, there is anthropic alteration. Figure 70 illustrates the assessment according to the Water Framework Directive classification.

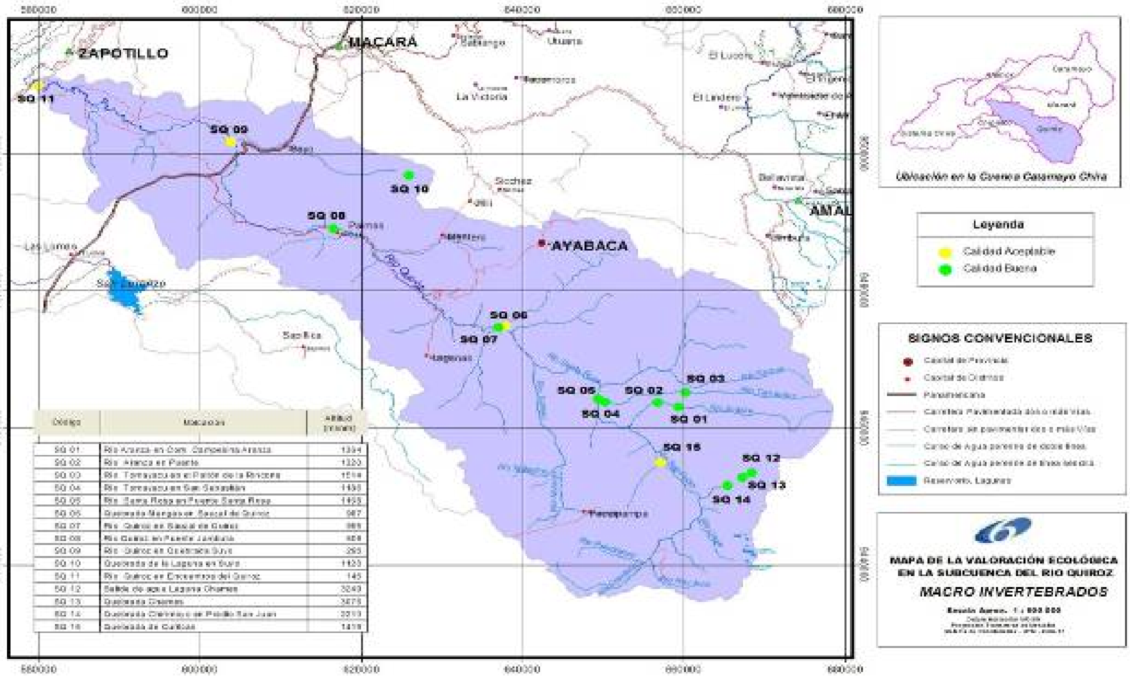


Figure 70. Ecological valuation of the water bodies in the River Quiroz sub-basin according to rates applied to the Macro-invertebrate group

The results of applying the General Diatomaceous Index indicate that in general, the water bodies present acceptable quality as shown in Figure 71.

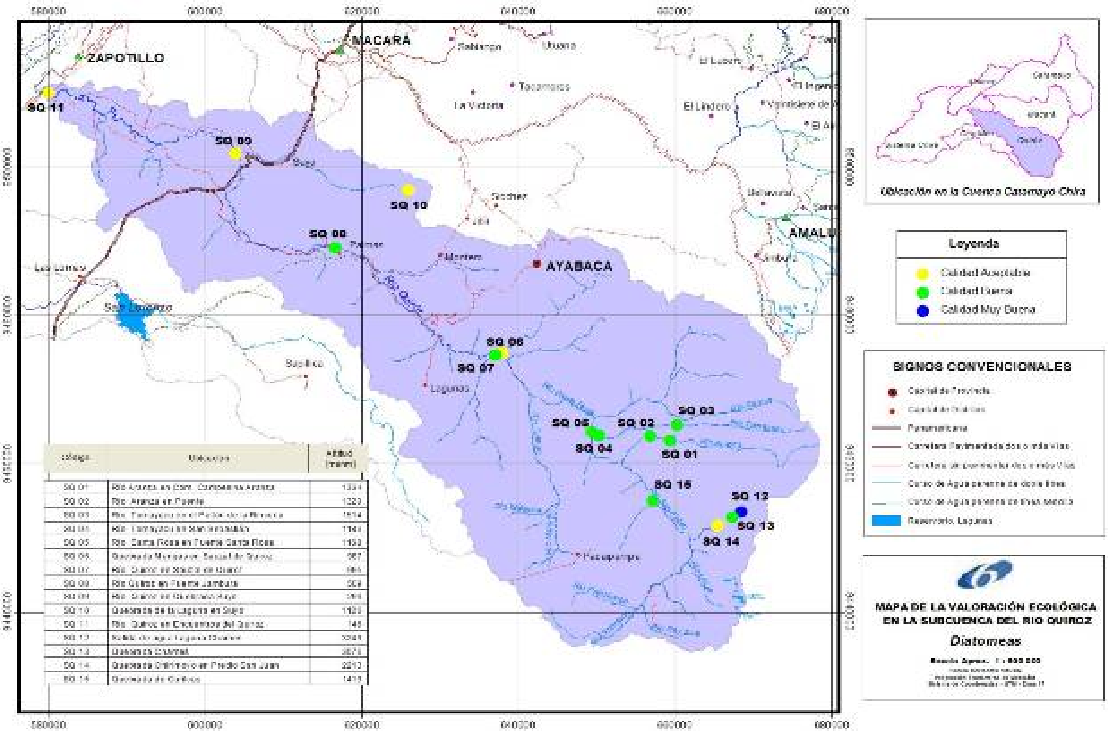


Figure 71. Ecological valuation of the water bodies in the River Quiroz sub-basin according to rates applied to the Diatomaceous group.

Water bodies at risk

In the River Quiroz sub-basin, some pollutant pressures have been determined, which are mainly distributed on sewage water discharged directly to the river without any type of previous treatment, these discharges are located in Ayabaca, Pacaipampa and Suyo. There is domestic waste discharge produced by the cities, and as they lack discharge treatment, the sewage goes to streams, rivers or water mirrors. Only 15% of urban zones have previous treatment, and only 25% of them, work properly.
The pollution produced in rural towns whose resources are agriculture and cattle-raising at small scale, is given by the lifestyle of the population; for example, the inhabitants raise their animals inside and outside their homes, the excrement and waste produced pollute the soil, generating bad smells and the risk of disease transmission.

Many towns located in rural areas lack domestic sewage water elimination systems or they are not working. Therefore, the same towns are being polluted as sewage water is discharged to the same town soils, polluting the subsoil and also underground water by filtration.

CAUCA

The classification of water bodies according to reference or anthropological pressure conditions is made by crossing the criteria considered to set the threat categories in the protected areas, the soil use (degree of natural environment, percentage of forest coverage soil use), degree of erosion and population density. Table 35 shows the categories according to the threat represented by the pressure for each of the variable categories or ranges.

Table 35. Threat categorization according to the anthropic pressure variables

Variable	Category	Degree of Pressure
Protected Areas	Under protection	Low
	Without protection	None
Degree of Natural Environment	Less than 25%	High
	25 to 50%	Moderate
	Greater than 50%	Low
Degree of Erosion	Low	Low
	High	High
	Very high	High
Population Density	Less than 0.9 inhab./Ha	Low
	0.9 to 74 inhab./Ha	Moderate
	Greater than 74 inhab./Ha	High

Figure 72 shows the map with the Water Body Classifications resulting from the crossing of the different reference condition variables. It can be seen that the low zone of the basin presents a very high threat, while the middle zone shows a moderate condition and the upper zone and the middle zone strip show low pressure in most of its protected areas with forest coverage.

The number of water bodies that cover most of the basin are rivers or creeks having low pressure is the 42% and the zone showing moderate pressure represents the strip of water bodies with a pressure increasing trend and the water bodies with having high pressure and a contamination threat from pollution, represent the majority of water bodies rivers in the basin, at the end of the day, represent most of the water bodies in the entire basin (58%). Table 36 shows the river length percentage values by water body classification.

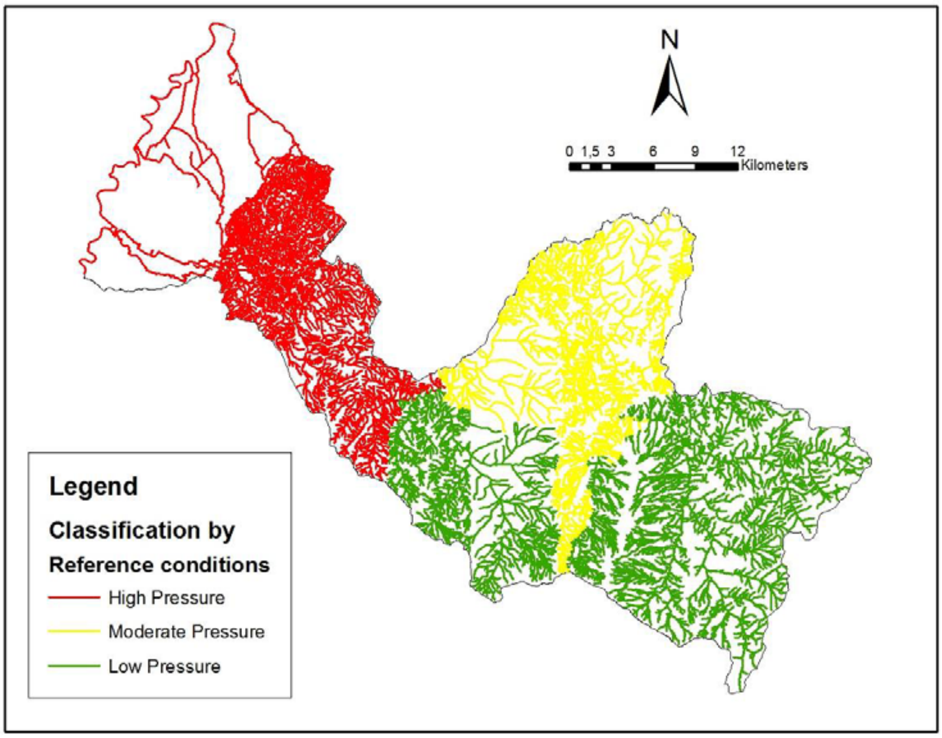


Figure 72. Water bodies classification according to reference conditions

Table 36. Percentage of river lengths in the basin according to pressure degree

Classification	**Length (Km)**	**Length Percentage**
High Pressure	1082.7	34.6%
Moderate Pressure	733.7	23.4%
Low Pressure	1316.3	42.0%

The above classification represent just the first water body classification effort, since it is still necessary to include a set of the most representative elements of each type of water body, which reasonably match the "natural" or "reference" existing conditions. (The term "reference conditions" refers to the physical, chemical, biological, and morphological characteristics of a water body. These conditions have to be validated in the field).

The study includes the results of previous analyses made in the WP06 contamination pressure work package, whose results were relevant to determine the classification of anthropological pressure coverage due to soil use impact. The degree of erosion resulting from rainfall effects was determined, providing diffuse source information.

According to the quality and contamination index results assessed by CVC, which include the physical-chemical and bacteriological results (2007), it is observed that such indices do not vary drastically throughout the Bugalagrande River profile. Therefore, these were not included as a determining variable of the reference condition in the classification. It is recommended to include them in the classification of other river basins showing variations in the quality indices.

In order to evaluate quality indices in the different tributaries of the Bugalagrande River basin, it is recommended to gauge and take samples of the physical-chemical and bacteriological quality, and include the variables in the classification map according to water quality conditions.

Since currently there are environmental impact assessment studies being done at the small hydroelectric plants, it is necessary to make hydro-biological analyses that allow the description of ecological impacts that may appear due to these works construction.

It is recommended to prepare strategic methodologies in order to evaluate impacts generated in the work influence zone, as eco-systems impacted by water flows, such as forests and wetlands.

Twenty-three (23) types of water bodies were establish through cross reference of the included variables according to the first classification made. By overlapping the reference variables or degrees of pressure, the results show that 58% of the water bodies in the pilot Bugalagrande basin show contamination. This is a situation, that in general terms, represents the status of the entire Upper Cauca Basin, where agricultural activities and population settlements generate the greatest pressure on water bodies.

THAMES

In the Thames River Basin, the water body classification work largely been completed by the Environment Agency and the Department for the Environment, Food and Rural Affairs (Defra) (see Defra, 2005a[2]; Defra, 2005b[3]). In the basin, 449 river water bodies, 46 lake water bodies, 7 transitional and 3 coastal water bodies, several heavily modified and artificial water bodies and 45 groundwater water bodies were identified. In addition, a register of 101 drinking water protected areas, various areas for the protection of economically-significant species, 17 recreational waters, 10 nutrient sensitive areas and 23 areas for the protection of habitat and species was also established. Diffuse pollution pressures account for the majority of the water bodies at risk of not achieving good ecological status, though point source, abstraction and morphological pressures are also significant in some instances.

Reference conditions for the water bodies were based on the Environment Agency's biology GQA (General Quality Assessment) classification system which uses macro-invertebrates which are found in virtually all UK rivers, do not move far and respond to water pollutants as well as to physical damage to their habitat. The biology GQA is the closest measure of status currently available for the biological quality element of the WFD's ecological status classification scheme, but results from the LOCAR programme suggest that this conventional biological assessment is inadequate and a new ecosystem-based approach is needed. Thus, the water body classification requirements of the WFD will allow the Environment Agency and stakeholders in the Thames River Basin to take a more holistic and integrated approach to water management and the improvement of aquatic environments in the future.

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[2] Defra. 2005a. Summary report of the characterisation, impacts and economic analyses required by Article 5: Thames River Basin District. Crown copyright 2005. (http://www.defra.gov.uk/environment/water/wfd/pdf/thamestext.pdf)

[3] Defra. 2005b. Maps to support the Summary report of the characterisation, impacts and economic analyses required by Article 5: Thames River Basin District. Crown copyright 2005. (http://www.defra.gov.uk/environment/water/wfd/pdf/thamesmaps.pdf)

3.8 WP8 Change effects and Vulnerability Assessment

WP 8 Objectives:

- To assess the effect of climate change scenarios regarding frequency and magnitude of flooding events, water availability and water quality using scenario modelling for the Latin American river basins, and to analyse the ecological, societal and economical consequences.

- To identify planned or foreseen rural and urban development, to model future pollution pressure and changed water abstraction, and to estimate the hydrological, chemical and biological/ecological effects of these changed conditions using GIS and physically-based scenario modelling

- To assess water body vulnerability based on the modelled changes caused by climate and human development.

Work Package 8 "Change effects and Vulnerability assessment" was formulated to estimate water body's vulnerability to pressure, based on monitoring data and model calculations. Main interests are the effects of future climate change, land use change and water resources developments on the hydrological regime, on water availability and water quality, and its ecological, societal and economical consequences. The hydrological, chemical and biological/ecological effects of changed conditions are estimated using GIS and physically-based models.

In the first phase, future scenarios were created. The scenarios concern climate change, land use change and water resources development (rural and urban development, hydropower projects, etc.). After change scenarios were created, the impact of these scenarios was estimated using calibrated and validated models. For that reason, input from Work Packages 3 ("Hydrological modelling, flooding, erosion, water scarcity and water abstraction") and 6 ("Pollution pressure and impact analysis") was needed. In a third phase, vulnerability of water bodies was assessed based on the modelled impacts of future scenarios.

Table 37. GCMs for which the global ΔT simulations from MAGICC were used to produce regionalized change patterns for the TWINLATIN study sites

GCM	CCCMa	CCSR/NIES	CSIRO	ECHAM4.5	GFDL	HADCM2	HADCM3	NCAR/PCM	CSM
SCENGEN name	CCC199	CCSR96	CSI296	ECH498	GFDL90	HAD295	HAD300	PCM	CSM98
Country	Canada	Japan	Australia	Germany	USA	UK	UK	USA	USA

The following table summarizes which **climate change scenarios** were developed, the methods used to create the scenarios and what methods were used to assess the impact of future climate change scenarios).

Table 38. Future climate change scenarios in TWINLATIN basins

Basin	Climate change scenarios	Method of scenario creation	Method of impact assessment
Baker	Perturbations of time series with change signals for temperature and precipitation	MAGICC/SCENGEN Regional Climate Model	SWAT
Catamayo-Chira	2 climate change scenarios based on A1 and B2 and 4 Global Climate Models	MAGICC/SCENGEN	SWAT
Cauca	Perturbations of time series with change signals for temperature and precipitation	MAGICC/SCENGEN	HBV
Lake Nicaragua	Perturbations of time series with change signals for temperature and precipitation	MAGICC/SCENGEN Regional Climate Model	Analysis of change values, expert judgement
Quaraí/ Cuareim	Hypothetical changes in annual mean precipitation and temperature for sensitivity analysis (precipitation: -20%, -10%, -5%, -1%, +1%, +5%, +10%, +20%; temperature: from -3 °C to +3 °C in steps of 1 °C)	Expert judgement	MGB-IPH
	Monthly changes in temperature and precipitation	MAGICC/SCENGEN	
	Extrapolation of frequency of ENSO events an non-lineal tendency	Analysis time series 1931-2002	Assessment of irrigated/harvested area and net returns
South America	8 Global Climate Models with one SRES scenario A1B, and HADCM3 with three SRES scenarios A1B, A2 and B1, for time horizons 2020, 2050 and 2080.	IPCC website www.ipcc-ddc.org	GWAVA

The following table summarizes which **land use change scenarios** were developed, the methods used to create the scenarios, and what methods were used to assess the impact of future land use change scenarios.

Table 39. Future land use change scenarios in TWINLATIN basins

Basin	Land use change scenarios	Method of scenario creation	Method of impact assessment
Baker	none		
Catamayo-Chira	1. Development based on actual trends	Expert judgement	SWAT and WaTEM/SEDEM
	2. Sustainable development scenario	Expert judgement based on ecologic/economic landscape study	
Cauca	Changes of cropland area	Modelling of change patterns and maximum areas	HBV
	De/afforestation (25 – 35 – 40 % of the basin covered by forest)	Expert judgement	
Lake Nicaragua	none		
Quaraí	10% of the land covered with pasture changes into forest plantations (Eucalyptus) 1. without contact to groundwater 2. with moderate access to groundwater 3. with facilitated access to groundwater	Expert judgement	MGB-IPH
Cuareim	Soils suitable for summer crops will change from pasture into rice	Expert judgement	Assessment of irrigated/harvested area and net returns
South America	none		

The following table summarizes which **water resources development scenarios** were developed, the methods used to create the scenarios, and what methods were used to assess the impact of future water resources development scenarios.

Table 40. Future water resources development and changes in water demand scenarios in TWINLATIN basins

Basin	Water resources development and changes in water demand scenarios	Method of scenario creation	Method of impact assessment
Baker	Hydropower development		Refer to WP 9
Catamayo-Chira	none		
Cauca	Changes in water demand related to population growth, bovine industry, agriculture and industry	Population growth projection Expert judgement	HBV
Lake Nicaragua	none		
Quaraí	Five scenarios related to the presence or absence of water resources structures related to irrigation: 1. Actual situation: widespread use of water for irrigation and large number of small reservoirs 2. No reservoirs, no water abstractions (baseline for comparison) 3. Reservoirs, but no water abstractions (analyse the effect of reservoirs on main river stream flow) 4. Reservoirs and water abstractions only from reservoirs 5. Reservoirs and water abstraction from rivers and reservoirs, but no return flow from the irrigated rice fields	Expert judgement	MGB-IPH
Cuareim	Changes in water demand related to the conversion from pasture into rice, and because of irrigation of grasslands Two large reservoirs in the upper basin	Expert judgement	Assessment of irrigated/harvested area and net returns
South America	Changes in water demand related to population growth for time horizons 2020 and 2050	Population growth projection Expert judgement	GWAVA

BAKER

Due to its particular climatic and geomorphological characteristics, and its resulting difficult accessibility, disclosure of the basin for human development and tourism has been very slow. As a consequence of this, also the development of environmental or hydrometeorological monitoring networks has been very limited (*see also the Work Package 2 report*). Therefore, considering the very limited amount of observed hydrometeorological time series data for the Baker River Basin (and especially, considering the nearly-complete absence of measurements from the higher parts of the Basin where it is assumed that most of the input into the basin water balance takes place), for the analysis of the potential impacts of change scenarios on the water resources in the Basin the following indirect approach was proposed and used under TWINLATIN:

- Under a previous twinning project TWINBAS (EC 6FP Contract Nº 505287) hydrological modeling using the **SWAT** tool was conducted for a selected sub-basin (**Vergara**) of the Biobío Basin, which itself is located in Central Chile. The selected sub-basin is located in the Chilean Central Valley between the Andean and Coastal Mountain ranges and it therefore presents a hydrological regime which is mainly rain-fed. The Vergara Basin represented a first, relatively simple case study for testing the applicability and usefulness of the hydrological component of SWAT in Chile, under the conditions of limited data availability which typically exist in many parts of the country (but which, even so, are much better than those for the Baker river basin).
- Building further upon the experiences acquired under TWINBAS, in TWINLATIN a more complex SWAT model application was attempted in the **Lonquimay** sub-basin, another sub-basin of Biobío which is located in the Andean Mountain Range and in which **snowmelt** contributions are important (see also the Work Package 3 report). Minimum data availability exists for this sub-basin, and it was considered that an attempt to model this sub-basin may provide highly useful information that throws a light on the possibilities and additional monitoring needs which would enable future similar efforts on the Baker River Basin.
- Change scenarios for the impact modeling exercise on the Lonquimay sub-basin were obtained from 2 important sources: *(i)* the **MAGICC/SCENGEN** tool (Hulme et al., 2000; Wigley, 2003a; Wigley, 2003b; Wigley et al., 2000); and *(ii)* the results from a **Regional Climate Model (RCM)** run for Chile recently conducted for the Chilean Environmental Administration CONAMA by the Department of Geophysics of the University of Chile (CONAMA-DGF, 2006). These scenarios were used to drive the change analysis of the hydrology of the Lonquimay Basin. For this purpose, a step-by-step manual (*in Spanish*) on the use of the MAGICC/SCENGEN tool v4.1 for the generation of change signals was developed at EULA (Chile) and CIEMA (Nicaragua), applied to the Biobío (and also Cocibolca) Basin, and made available as a "twinning contribution" to the other Latin-American project partners.
- In addition to the former, the same approach based on MAGICC/SCENGEN and the RCM runs was also used to generate change scenarios for the Baker River Basin itself. Even without conducting the hydrological modeling for the Baker Basin, this change signal information already provides very useful information which allows making a first estimation of the potential local and regional impacts of climate change.
- The information obtained from the RCM run for the Baker River Basin was incorporated in the Georeferenced Environmental Database for the Baker Basin **SIGACB** using for this purpose the ArcHydro data model, and is available for future reference.
- The topic of **Glacial Lake Outburst Flows (GLOFs)** – which had been registered in the past in the Baker River Basin during the decade of the 1950s, and which have now occurred again on several occasions during 2008 – is briefly touched, as this may be relevant from the perspective of (hydropower) development versus climate change impacts.
- A basic **vulnerability** assessment exercise was conducted with the stakeholders during the twinning workshops which were held in the Basin.
- An index for the evaluation of **adaptation** practices was proposed too.

Scenario simulation and analysis under TWINLATIN

In order to evaluate the sensitivity of the hydrology of the two sub-basins of Biobío to climate change, the impacts of the different plausible future climatic scenarios developed and described were simulated. First, the meteorological series for the Basin for the 1961-1990 reference period generated by means of the RCM model (CONAMA-DGF, 2006) was used to establish a "simulated" baseline (in future efforts, the real observed baseline can also be used for studying change impacts, in combination with change factors). The RCM reference period also corresponds to the baseline period modeled by the MAGICC/SCENGEN tool, so this allows for an easy first comparison of the hydrological results obtained by perturbing the "baseline" input time series for the SWAT model with the change signals obtained from both the GCMs (MAGICC/SCENGEN) as well as those from the finer-scale RCM runs. As such, the used methodology allows for both an evaluation of the impacts of uncertainty associated with the existence of different GCMs and emission scenarios, as well as of the effects of scale on change signals and their associated impacts.

As a first approximation to the analysis of the hydrological sensitivity of the Lonquimay system to climate change, and in order to allow for a more direct comparison of change factors obtained from MAGICC/SCENGEN and the RCM, the perturbations of the control time series in both cases were assumed to be uniform in space and time; as such only the magnitude of the variables temperature and precipitation was affected and not their spatial and temporal distribution. The results obtained for the Vergara sub-basin are also given here, as they allow for an evaluation of the differential impacts of climate change in a rainfall-fed versus a mixed snow/rain-fed river basin.

The vast majority of the 42+2 climate change scenarios (2071-2100 versus 1961-1990) developed for each sub-basin under TWINLATIN from the Regional and Global Circulation Models indicate a reduction in annual precipitation rates for the Biobío Basin (values range from + 7 % to – 60 %). This change in precipitation rates is accompanied by a rise in the mean annual temperature (all scenarios, without exeption), which varies between + 1 ºC and + 3.5 ºC . Whereas due to scale, the MAGICC/SCENGEN tool only provides a single change value for both Biobío sub-basins, with the RCM application a more sub-basin specific change factor could be obtained. From these RCM results, it can be seen how the increase in temperature tends to be higher in the Andean sub-basin; however the decrease in precipitation tends to be less drastic.

From the modeling of the hydrological response in the Vergara and Lonquimay basins to the 42+2 climate change scenarios – which was conducted using the previously calibrated and validated SWAT model tool- a wide range of variations in possible future mean annual and monthly discharge rates was obtained (Figure 84 and Figure 85). Even when differences in the results can be observed depending on the modeled scenario, it is possible to conclude that in both basins the hydrology –according to the results of SWAT – appears to be highly sensitive to changes in the modeled climatic variables.

In the case of the Vergara Basin, the percentage reduction in discharge rates is considerably higher than the corresponding percent change in annual precipitation (Figure 85). This indicates a major impact from climate change in the basin hydrology than what might be initially expected by just considering the value of the change in annual precipitation. Even so, a clear linear relationship between both changes can be observed from Figure 73, which would allow for making a first assessment of potential impacts in water resources for this and other nearby basins directly from change signals for annual precipitation.

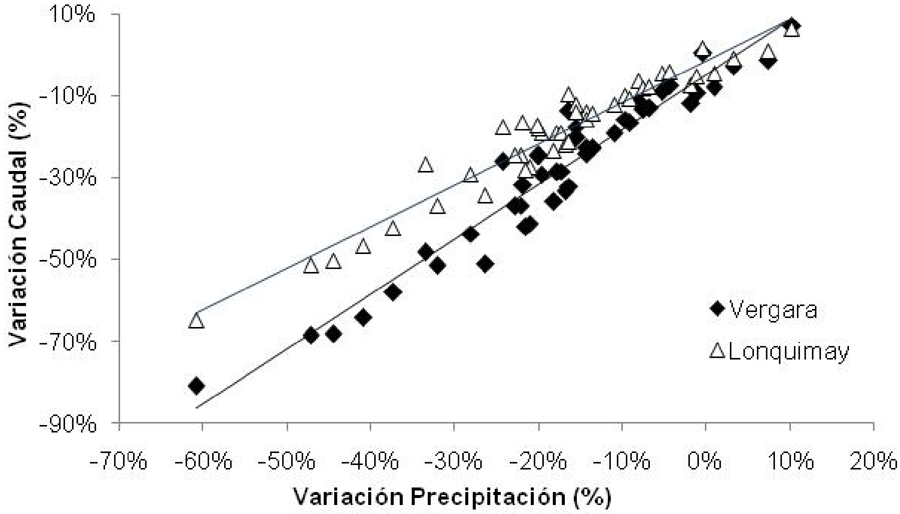


Figure 73. Relation between % changes in mean annual precipitation (X-axis) and mean annual discharge rates (Y-axis) for the rainfall-fed Vergara and mixed-regime Lonquimay sub-basins (Biobío Basin, Chile)

A similar phenomenon can be observed in the case of the Lonquimay Basin. It should be mentioned, however, that for this sub-basin the proportional increase in the changes in discharge (with regard to changes in precipitation) is much less pronounced. On the other hand, in the case of this sub-basin of mixed (rainfall-snowmelt) hydrological regime, the combined effect of changes in precipitation and temperatures leads to significant modifications in the form of the annual hydrograph. The simulations clearly illustrate what has been expressed by Gleick (1986), Chalecki and Gleick (1999) and Lopez-Moreno and Nogues-Bravo (2005), i.e. a rise in the rate of rainfall versus snowfall during the winter months, a shorter snow season, and an earlier snowmelt discharge maximum due to global warming.

Even if only 2 sub-basins of Biobío have been modeled (approximately 20% of the total Biobío Basin area), the results already allow for a first qualitative, or even semi-quantitative interpretation of what may occur in the Biobío Basin – and other similar basins – as a consequence of climate change. The results of this work clearly indicate how climate change can and most probably will constitute an additional stress factor to ecosystems and human society in many river basins, clearly indicating the importance and usefulness of anticipated mitigation and adaptation actions, such as a major awareness building among stakeholders on the needs for rational water use, and a further promotion of the concepts of integrated and adaptive water resources management practicing.

For the Baker River Basin that different GCMs produce different change signals for precipitation, whereas all GCMs produce a rise in temperate. The HADCM3 produces a slight decrease in precipitation (2050), the results from the RCM runs – which have been driven by the HADCM3 – indeed also show a decrease in precipitation for the time window centered on 2085. however in certain sectors of the basin the simulated decrease is considerably higher than the mean value obtained for 2050 from MAGICC/SCENGEN. In the Baker Basin, the divergence in the results obtained for mean annual precipitation from MAGICC/SCENGEN for the different GCMs thus complicates an unambiguous evaluation of the potential impacts of climate change on water resources; however increased snowmelt and associated hydrological changes due to increased temperatures (all models) can certainly be foreseen. In addition to this, we remember the relative good representation of the baseline in the Basin by means of the HADCM3-driven RCM model run.

Public participation in the Baker Basin and the perception of vulnerability

During the public participation workshops held in the second half of 2008 in the different municipalities of the Baker River Basin, a small exercise was conducted as to evaluate the existing perception of vulnerability towards the effects of climate change among stakeholders in the basin. For this purpose, through a questionnaire, stakeholders were allowed to express their perceptions with regard to the factors that in their opinion most influence their vulnerability towards the (water resources-related) effects of climate change (Figure 74). Previous to the application of the enquiry, a powerpoint presentation was given in which the concepts of vulnerability, exposure, sensitivity and adaptive capacity were explained in simplified terms. The enquiry was applied twice, once before and once after results from the work on the exposure component in TWINLATIN (described in previous chapters of this report) were shown (also in a simplified manner). The aim here was to see if the provision of information from site- or region-specific research influenced the stakeholder's perception of vulnerability.

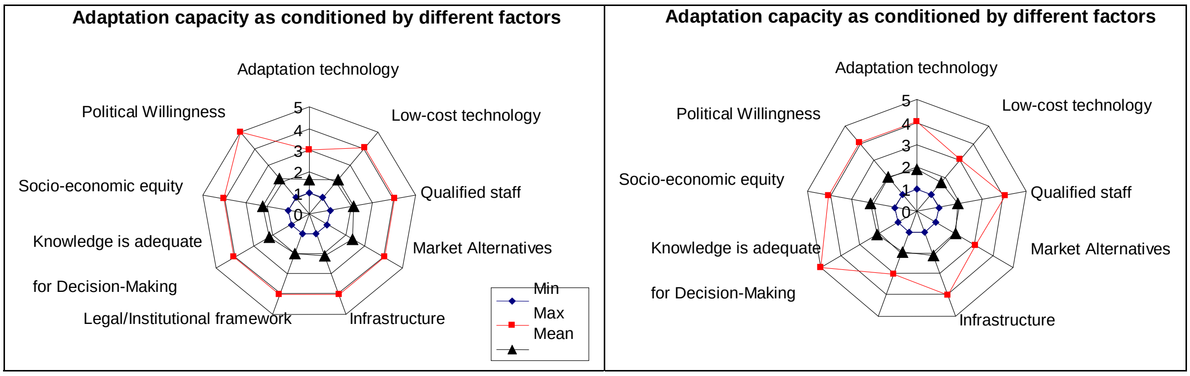


Figure 74. Stakeholder perception with regard to vulnerability - factors that condition adaptive capacity to climate change perception before (left) and after (right) the results from TWINLATIN research

Figure 74 shows outcome from this public participation process. Each axis in the graph represents a factor which is considered to influence the adaptive capacity of stakeholders. Participants were asked to assign a high value to those factors whose current conditions in the Basin or country positively contribute to their adaptive capacity, whereas a low score needed to be assigned to those factors whose current condition is seen as a cause of low adaptive capacity, and which thus contribute to higher vulnerability.

Factors were: *(i)* the existence of technology which would enable adaptation; *(ii)* the availability of this technology at accessible costs; *(iii)* the existence of qualified personnel to make use of such technology; (*iv*) the existence of market alternatives (*this could be eg. good market prices for more drought-resistant crop alternatives in case of predictions of a drier climate*); (*v*) the availability of adequate public infrastructure (*this could be eg. flood protection dams; early warning systems, etc.*); *(vi)* and adequate legal/institutional framework; *(vii)* adequate knowledge for decision-making (*eg. results from research on climate change impacts; adequate monitoring networks*); *(viii)* socio-economic equity *(inequity is a negative factor as the poor tend to have less adaptive capacity)*; (*ix*) political willingness to act.

From the results (minimum versus maximum scores) it can be seen how different stakeholders had different opinions with regard to the impact of the different factors; however, mostly a low adaptive capacity was indicated in the results. After information from the TWINLATIN assessments on the potential impacts of climate change was presented to the stakeholders, only for 2 factors a higher maximum score was obtained (one of them being the availability of knowledge for decision-making). For several other factors, a lower maximum score was obtained. It is important to indicate here that the current results are based on a small amount of questionnaires only (participation of stakeholders in public events in the Baker Basin was typically very low). For this reason, we do not conduct a more in-depth analysis of the obtained results here. We do believe however that larger-scale applications of the conducted approach can provide highly valuable information on the fields/those aspects from society where efforts need to be focused, if vulnerability levels are to be lowered.

Summary

Different steps were undertaken in order to address the topic of climate change impacts and associated social vulnerability: ***(i)*** a hydrological modelling application was built for 2 sub-basins of Biobío, with different hydrological regime; the Lonquimay sub-basin which is located in the Andes and which receives important snowmelt contributions is considered to represent an interesting case study for what may also happen under climate change in the Baker River Basin (which is located further south, but for which current hydrometeorological data availability does not allow conducting detailed modelling work); ***(ii)*** climate changes scenarios were generated and discussed for both the Biobío and Baker basins, based on output from both RCM and GCMs; ***(iii)*** for the Biobío sub-basins, the hydrological impacts of these change scenarios were modelled by means of the SWAT tool; ***(iv)*** an interpretation of the model results was made, and a basic assessment of what may also happen in Baker –based on the obtained change signals- was conducted; ***(v)*** the role of scenario modelling for the quantification of the exposure component of the vulnerability equation was indicated, and additional information was provided on the occurrence of GLOFs in the Baker Basin during 2008; ***(vi)*** information from the work under TWINLATIN was shared with stakeholders in the Basin, and an exercise was conducted in which the perception of the adaptive capacity among stakeholders was evaluated; ***(vii)*** an index was developed which may help identify optimum adaptation options in future work.

The wide range of values for the change signals that can be obtained in an impact assessment study such as the one presented for the Biobío and Baker Basins is a direct consequence of the uncertainties that persist with respect to the intensity and even direction in which change in climatic variables will manifest itself at the local and regional level, under global warming: information based on different GCMs provides different regional change patterns for a single change value in mean global temperature (MAGICC/SCENGEN). For a given study site, change results obtained from a finer-scale modelling exercise (RCM runs) may also differ considerably from what is obtained from the GCMs (although in this case, only the magnitude and not the direction of change was affected). In addition to this, the hydrological model itself (through its conceptualization, parameterization, calibration,…) also influences in the final range of values of the changes in mean annual or monthly discharges. The modeling that was conducted in this case with the SWAT tool is deterministic, in the sense that one input delivers a single output, so the uncertainty that is inherent to the model approach is not even reflected in the final results.

Even so, important conclusions can already be made from the conducted work, which may be useful for defining adaptation measures in the field of water management: different sensitivity to climate change could be observed in the snow-fed (or mixed) versus the rainfall-fed sub-basins, and proportionality factors between changes in annual precipitation and discharge (~elasticity) could be obtained. These may be helpful for making quick assessments of what may happen in similar basins in other parts of the country. The quantification –through modeling- of the potential hydrological effects also proves useful in awareness building and in a stakeholder evaluation of exposure, sensitivity, adaptive capacity and the resulting vulnerability. Specifically for the Baker Basin, it can be assumed that an increase in temperature may lead to a significant change in the annual distribution of discharge, as a consequence of reduced snowfall and earlier and increased snow and glacier melt; the frequency (and magnitude?) of phenomena such as GLOF may be increased, posing a threat on human communities living downstream. For this reason, a complete inventory of peri-glacial lakes in the Basin which may be subject to GLOFs becomes highly desirable.

CATAMAYO-CHIRA

In the frame of TWINLATIN, two types of changes are being modelled. First, those related to land use change, measuring the impact that different scenarios of land use would have on the sediment and water production. Second, those related to climate change. Different scenarios of Greenhouse Induced climate change will be evaluated, calculating the impacts of every one of them on the sediment and water production.

The land use change in this study are absolute changes between defined land use classes and do not imply land use modifications, like intensification of agriculture or forest degradation. The modelled climate changes are absolute changes in temperature and relative changes in precipitation, including data that can be generated from this change like the changes in intensity of rainfall.

The effects that those changes have on the study area are assessed by the analysis of production and deposition of sediments as well as the production of water. As described above in 'special issues' those phenomena are one of the gravest problems in the basin.

Limitation of the study area

The area that is covered by the Hydrologic Modelling as well as the Impact Assessment and Modelling of Change effects is limited to certain parts of the Catamayo Chira basin.

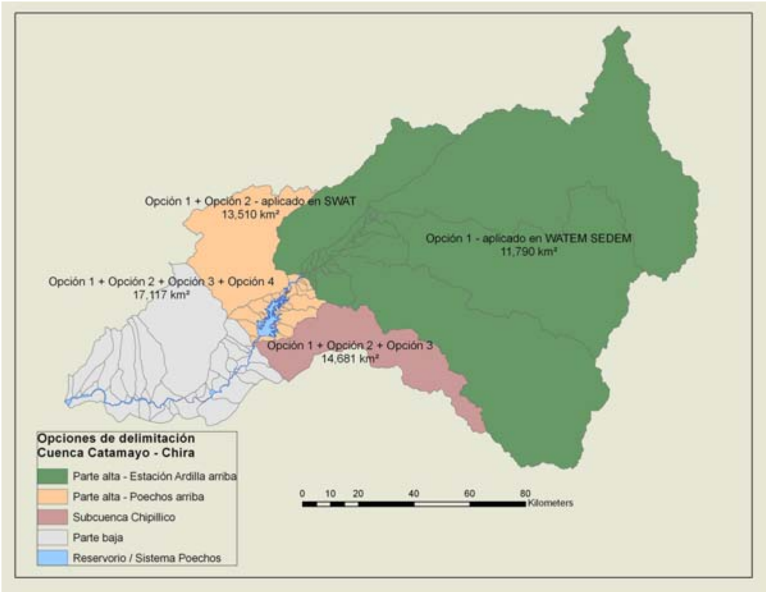


Figure 75. Study areas for Impact Assessment, Hydrologic Modelling and Change Effects

As described in the respective reports (see WP 03, WP 06) the modelling of the whole basin is made impossible by the presence of reservoirs that feed irrigation systems outside of the basin and irrigation channels that alter the natural course of water. For those activities data availability is insufficient to allow integration in the two models used. In the following map various options for study areas can be observed. The study areas selected for the Hydrologic and Impact Assessment Modelling both reach from the upper limits of the basin to just above the 'Poechos' reservoir at about 125 m altitude. Here the study area is marked by the sediment and flow volume gauging station 'Ardilla'. The total size of the study area is therefore reduced to about 11,790 km².

Models used to analyse the effects of change

As mentioned above the *Soil Water Assessment Tool* (SWAT) and the *Water and Tillage Erosion Model/Sediment Delivery Model* (WaTEM/SEDEM) are the tools that have been chosen to model the effects of changes in the Catamayo Chira basin.

SWAT quantifies the impact of land use management on water production and soil erosion while WaTEM/SEDEM produces maps of sediment production and sedimentation areas. Therefore the model results complement each other showing both how much and where erosion takes place and sediments are produced.

Description of climate change scenarios

With the objective to analyze the performance of the 17 available models in the Catamayo-Chira basin, the variation of temperature and rainfall were modelled for 2025, 2050 and 2080. Graphics of the dispersion of the projected precipitation and temperature, as well as the monthly variation of each parameter, were analyzed. The comparison of the obtained future scenarios with the formerly mentioned tendencies in the historic data, taking into consideration the spatial resolution and climatic sensibility of each model, permitted to select the GCM used in the elaboration of climatic scenarios (Oñate-Valdivieso, 2008). Finally, the following four GCM's were chosen as they adjusted best to the local conditions of the basin Catamayo-Chira:

- CSSR96, ECH498, BMRCD2, HADCM2

Two SRES scenarios were chosen to generate future climate change scenarios for the Catamayo Chira basin: the A1 and the B2 scenario. The A1 scenario is based on very rapid economic growth, global population that peaks in mid-century and declines thereafter, and rapid introduction of new and more efficient technologies. The B2 scenario considers a future world in which the emphasis is on local solutions to economic, social, and environmental sustainability, with continuously increasing population and intermediate economic development.

The MAGICC/SCENGEN outputs for both the A1 and the B2 SRES scenario clearly indicate a further increase of temperature in the study area around the year 2050. In the case of the A1 scenario this temperature increase however shows much larger variation (between 1.4 °C in February 2045 and 2.7 °C in July 2055) (Figure 76). In the B2 scenario, the range of temperature increase is from 1.1 (February 2045) to 2.0 (August 2055). The relatively warmer months such as December to March are the ones that present lower temperature increase while the colder months June to August present the strongest increase.

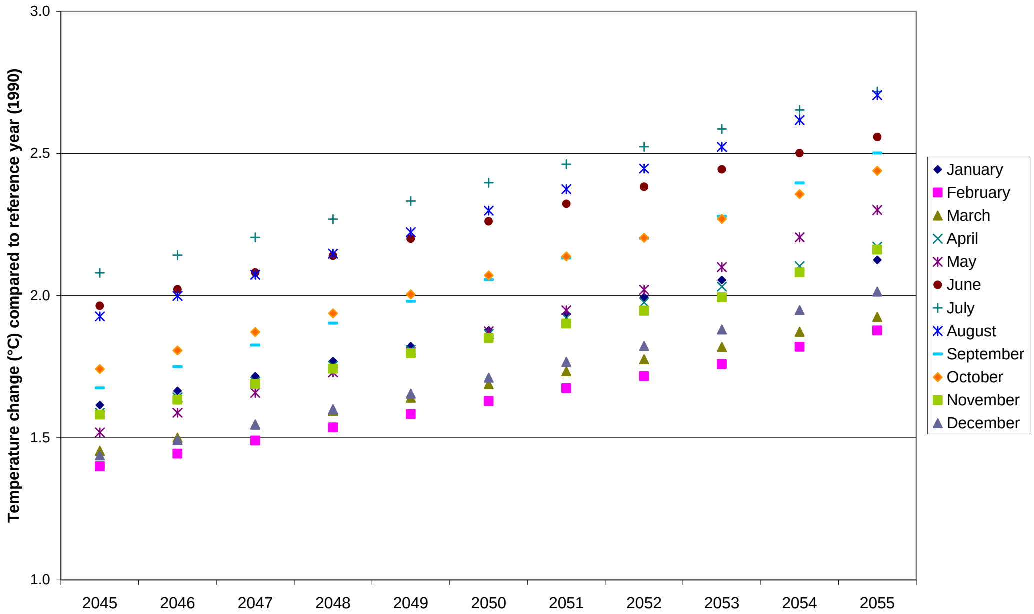


Figure 76. Simulated monthly temperature change for 2045 – 2055 – A1 scenario

The effects of a greenhouse induced climate change on the local rainfall characteristics seem more ambiguous. The model results indicate again more moderate changes in the B2 scenario than in the A1 scenario but in the course of the years contradictory tendencies can be observed.

In the *B2 scenario* the months with a tendency of increasing rainfall and months with a tendency of decreasing rainfall are clearly differentiated. Here only the months of February to March and June to July present positive figures, while for the rest of the months the model indicates decreasing rainfall. The consequence in the local context could be that the rainfall period, that actually presents maximal rainfall amounts from February to April or October to December changes its temporal distribution pattern slightly.

The *A1 scenario* presents the same tendencies although the values for increasing rainfall in June are considerably higher than in the B2 scenario and also the expected decrease of precipitation, for example in November is extremer.

In both cases an overall decrease of rainfall amounts can be expected as 8 of 12 months (B2 scenario) or 7-9 of 12 months (A1 scenario) present negative tendencies for the period 2045 – 2055. The consequences on the basins potential of water provision would therefore be negative in future, while consequences on sediment production are not clear. With diminishing rainfall amounts, the rainfall intensity might also decline but on the other hand, the increasing rainfall intensities during the dry period, when vegetation cover is low, sediment production might as well increase. A tendency that is assumed as 'very likely' by the IPCC is, that heavy precipitation events become more frequent in the 21st century (IPCC, 2007). As a consequence, independently of a greenhouse gas emissions scenario, an increase in erosion rates might be expected in the future. Unfortunately this hypothesis can not be verified with the data obtained by MAGICC/SCENGEN and was therefore not simulated neither by SWAT nor by WaTEM/SEDEM.

The simulated climate change scenarios refer to climate data of the year 1990 and are applied to the monthly precipitation and temperature data of the meteorological stations in the basin. In the case of the SWAT model this data series can directly be introduced into the model.

For the Catamayo-Chira basin, the effects of two climate change scenarios, and two land use change scenarios were assessed.

To generate future climate change scenarios, two SRES scenarios were selected: the A1 and the B2 scenario (IPCC, 2000). The A1 scenario is based on very rapid economic growth, global population that peaks in mid-century and declines thereafter, and rapid introduction of new and more efficient technologies. The B2 scenario considers a future world in which the emphasis is on local solutions to economic, social, and environmental sustainability, with continuously increasing population and intermediate economic development. Both scenarios, created using MAGICC/SCENGEN, consist of a raise in temperature, and an overall decrease in precipitation, with shorter but more intense rainy seasons.

Also, two land use change scenarios were created. The first scenario is based on the actual land use tendencies, mainly the deforestation of dry, natural and humid forests and their conversion to pasture areas and cropland. The second scenario was based on an economic and ecologic landscape value study, which represents a "Sustainable Development" since both economic and ecologic developments of the basin are considered.

The SWAT model was used to assess the effects of land use change and climate change on water discharges. In both land use change scenarios, an overall increase in water discharge is expected. However, the first scenario would result in a decrease of the base flow and an increase of discharge during the rainy season. This could raise the risks of flooding. The second scenario shows a more equilibrated increase of water discharge, both during the rainy season and during the dry season. The reduction of drought during the dry months would be a very positive development. Basically the same microbasins, mainly located in the centre of the basin, remain the ones with highest water yields in both scenarios. In contrast, the effects of both climate change scenarios consist of a decrease of water yield. Decreases are more pronounced in the B2 scenario.

Both the SWAT model and WaTEM/SEDEM were used to assess the effects of changes on soil losses and sediment production. Both models show comparable results. The first land use change scenario would result in a slight increase of sediment yield; while the second (sustainable development) land use change scenario would lead to a decrease of soil losses around 20 %. This reduction of soil losses in the Catamayo-Chira basin would be very important, since the use of the Poechos reservoir will be limited due to siltation. The spatial distribution of microbasins with largest erosion problems remains more or less the same in both scenarios, compared to the baseline situation. For both climate change scenarios, small reductions of soil loss rates were predicted. Nevertheless, these results are not reliable, since the impact of an increase in rainfall intensities could be modelled neither by SWAT nor by WaTEM/SEDEM, while heavy precipitation 'very likely' will become more frequent in the 21st century (IPCC, 2007).

In any case, the results of this scenario impact assessment need to be analysed with caution. Especially the uncertainty of the assessment of the impact of climate change is high. First, the simulations of MAGICC/SCENGEN refer to 1990 as the baseline year. This year was one of the driest of the last 30 years. Second, the same climate change factors for temperature and rainfall were applied for the whole basin, without differentiation between lower and upper part of the basin. Third, we have no estimations on future frequency or intensity of ENSO events. These events cause special concern in the Catamayo-Chira basin, where extremely high soil losses were registered during the last ENSO events.

The application of both SWAT and WaTEM/SEDEM also is a source of uncertainty, since the coarse resolution of baseline data affected the calibration and validation process of both models. In the reports of Work Package 3 (Hydrological Modelling) and Work Package 6 (Pollution Pressure and Impact Assessment) these uncertainties are addressed in more detail.

Future investigation should now be focussed on the areas identified as predominantly affected by soil losses and mostly important in terms of water production. Mitigation and protection measures should be formulated and implemented in these areas.

CAUCA

Analysis of climatic and socio-economic factors to evaluate water supply and demand in the Tuluá River pilot basin are associated with climate change prediction backed up by global scale change models, and with the evolution of land use, agricultural, animal husbandry and industrial activities, as well as population growth in the studied area. These are the important factors having an impact on water resource supply in the zone. The study is developed taking into consideration information available on the different environmental variable forecasts. These are later jointly analyzed through an actual or baseline water demand and supply balance and considering a future plan for 2020 and 2050.

A joint study held between CVC and "Universidad del Valle" (Inter-Administrative Agreement 110 of 2007) for the socio-economic and soil use change variable planning was used in the vulnerability assessment(CVC and Universidad del Valle, 2007).

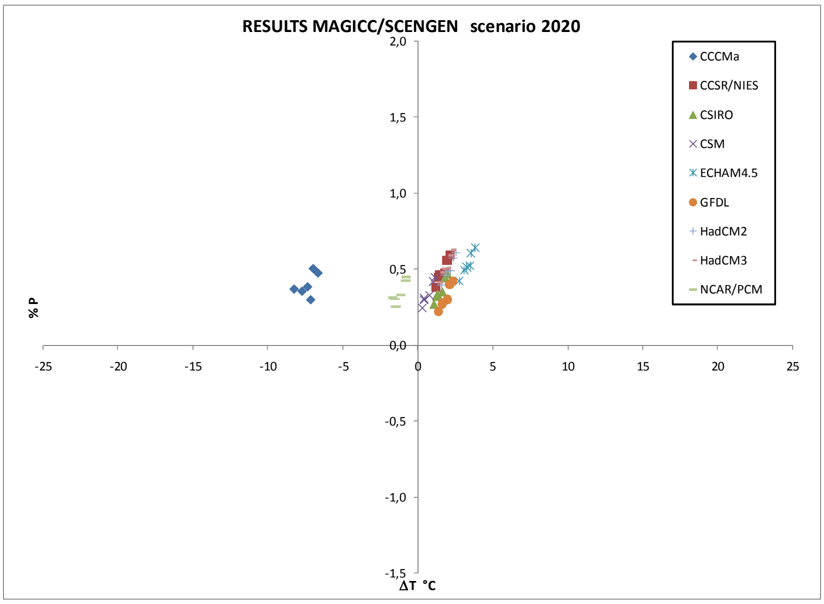
Climate change

Climatic change is reflected in the basin in terms of water resources supply analyzed with the MAGICC/SCENGEN model results and basin observations according to historic rainfall data registered for the last 30 years in the different river basin stations.

Figure 89 shows the results of the MAGICC/SCENGEN v 4.3 model application (see Annex 1). Results of runs made for future scenarios applying MAGICC/SCENGEN used the 1990 global temperature and rainfall data as reference and proposed future climatic scenarios for 2020 and 2050. All cases show a wider range of rainfall increase directly proportional to time. The analyzed grid corresponds to the area located at (0 to 5°) latitude and (-75 to -80°) longitude, where the Upper Cauca River basin is located.

All scenarios present a temperature increase ranging from 0.2 – 0.6 °C and 0.8 – 1.5 °C for 2020 and 2050, respectively. Also, most cases show an increase in rainfall, except for the GCMs CCCMa and NCAR/PCM. When we exclude these GCMs, the basin shows rainfall increases between 0 – 4% and 0 – 10% for years 2020 and 2050, respectively.

a)



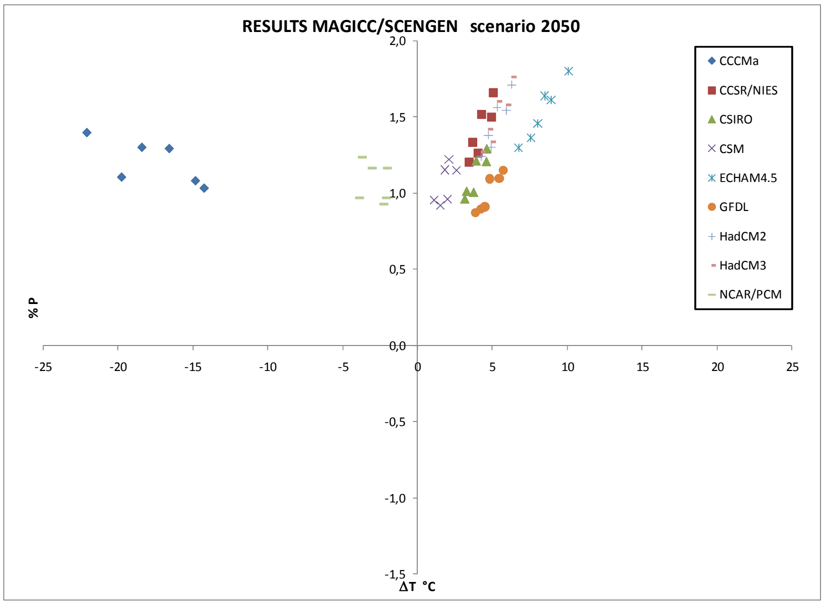
b) 

Figure 77. Results of MAGICC/SCENGEN: (a) 2020 and (b) 2050

Land use change

Changes in the land use are relevant bio-physical and socio-economic factors that determine water resources and soil demand in the river basin. One of the main activities demanding soil resources in the basin is industrial agriculture, such as sugar cane plantations. There are other crops found in a large area of the study zone.

The main crops were identified for this study and forecasts were made for the area covered in the Tuluá River basin. Crops, which represent 98.4% of the agricultural area in 2006 include: sugar cane, potato, corn, sorghum, coffee and soy bean.

Two procedures were used in creating the land use change scenarios: (1) the implementation of a statistical model that allows estimating change patterns in the variable according to recorded historic data, and (2) a model which determines maximum areas per crop, according to environmental conditions such as altitude, temperature, soil type and precipitation. Both models were combined to create a land use change scenario for 2020, the critical condition being the largest area resulting from the two procedures.

A cross-section of the projected areas in the two previous stages was made. When the projected area for a crop, according to census registers was larger than the area estimated by the limiting factors, this was used for the 2020 land use scenario (Table 41).

The year 2006 was used as the baseline situation, since this was the most recently updated cartography available.

Table 41. Use of land for agriculture in 2006 and 2020

Crop	Area 2006 [ha]	Area 2020 [ha]	% change	% of cultivated area (2020)
Sugar cane	8.591	10.352	20,5%	25%
Sorghum	491	296	-39,7%	1%
Soy bean	81	0	-100,0%	0%
Corn (flat land)	745	1227	64,7%	3%
Coffee	977	986	0,9%	2%
Native grass	36.984	26.819	-27,4%	66%
Feeding grass	462	12	-97,5%	0%
Potato	4.159	1.194	-71,2%	3%
Total	*52.491*	*40.886*	*-22,1%*	*100%*

The analysis shows that area designated for agriculture tends to decrease in the future. Sugar cane will be the most important crop in the agricultural area of the basin, representing 25% of the total area. The native grass figure was estimated in order to associate it with extended livestock breeding in the basin and establishing bovine demand for 2020. Therefore, the estimated area is representative, covering 66% of the total projected area. Coffee plantations also show a growing trend towards 2020. This crop is located in the most vulnerable area associated with climate change and variability. This is an important factor to be considered in future studies in order to estimate local impact on coffee production systems. Census registration of potato crops was a projected area of 63 ha, while land use cartography shows an area of 4,159 ha. The average of these areas was used, considering that the census area has a decreasing trend and affected the cartography area in 2006. As a result of this, it is of vital importance to confirm the 2006 data. Figure 78 shows the productive systems and the maximum areas according to environmental limiting factors. Changes are mainly noticed for coffee and potato. Although native grass occupies the largest area in the basin, it is expected to experience no noticeable change.

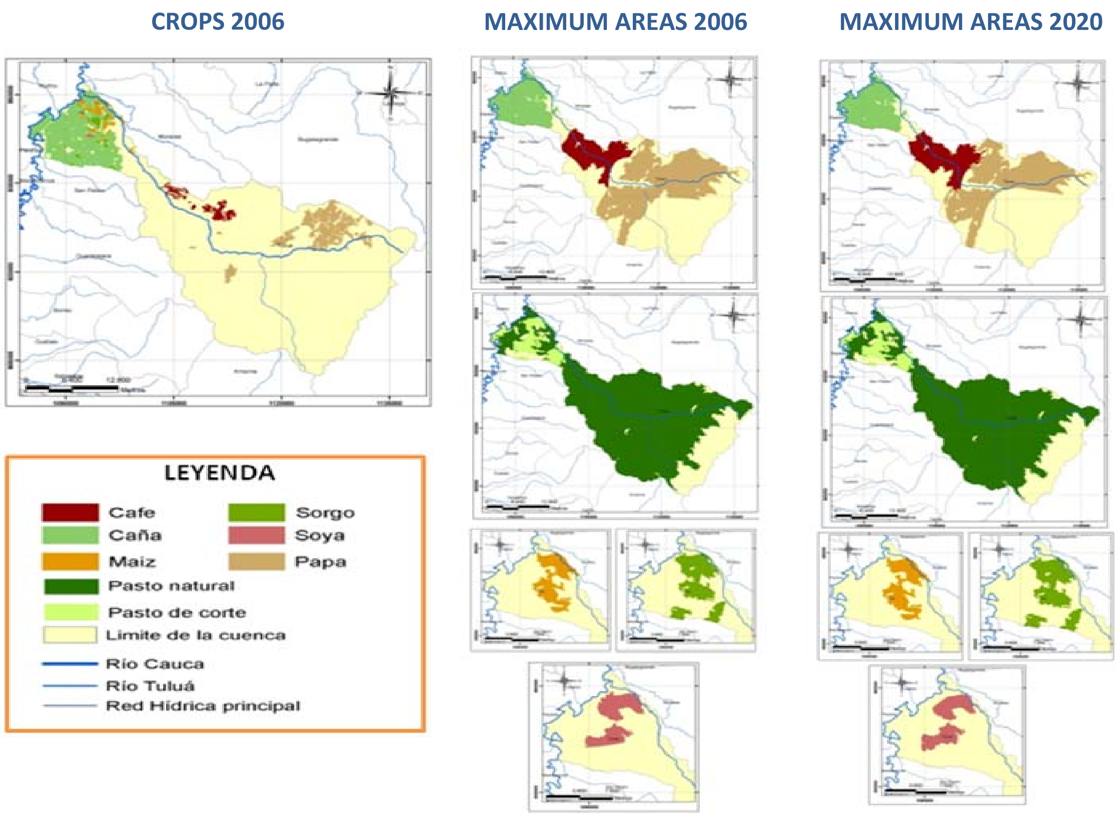


Figure 78. Productive systems and maximum productive areas according to limiting factors (2006 and 2020)

The projected changes in agricultural land were used to predict agricultural water demands. Additionally, the effect of de/afforestation is evaluated. Therefore, scenarios were created through expert judgment. In the baseline situation (scenario 1) 35 % of the basin is covered by forest. A second scenario includes afforestation (40 % forest coverage), and a third scenario considers deforestation (25 % forest coverage).

Changes in water demands

Environmental and socio-economic factors determining water demand in the Tuluá River basin are linked to land use, agricultural, animal husbandry and industrial activities and to population growth. Historical information was collected from the census in order to understand how pressure is generated on the water resource supply in the study zone.

The water demand for each of the socio-economic factors identified (agricultural, industrial, bovine and domestic use) in the Tuluá River Basin was estimated in order to study the combined effects of socio-economic factors. The environmental demand (ecologic floor) was also calculated in order to present a more comprehensive summary of the water resource demand factors and to integrate them into an offer-demand analysis.

Scenario impact assessment

Methods used for impact assessment

Scenario impact assessment was made estimating a water balance for 2020.

The calibrated HBV hydrologic model (see the WP 2 report) was used to evaluate water supply in 2020, using the MAGICC/SCENGEN model output. Input data series of the HBV model were altered and the water flow for the analysis of the water balance in the future scenario was generated.

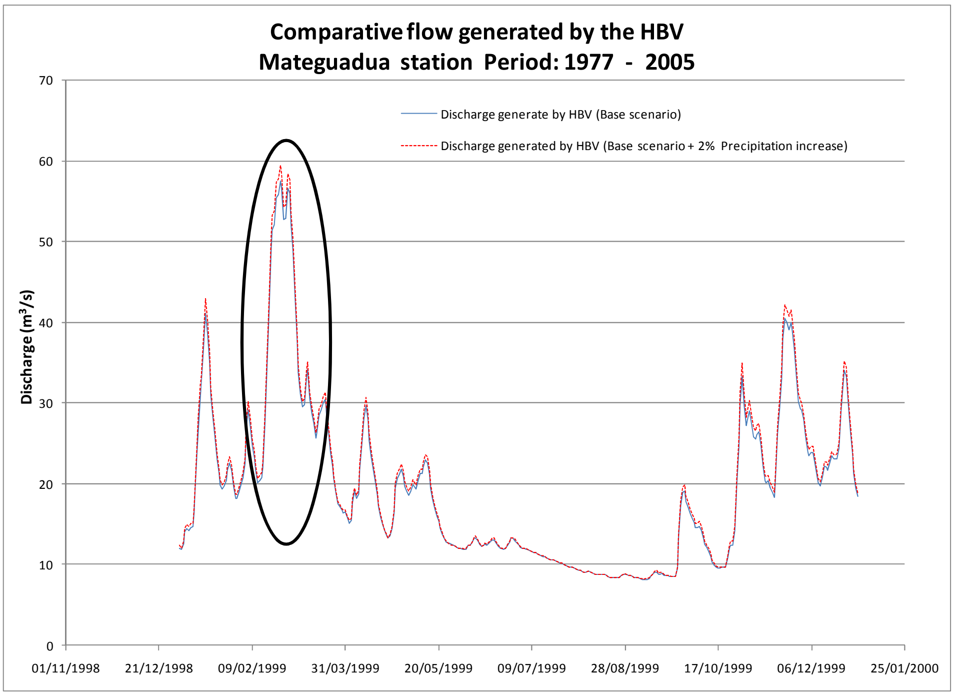
This study did not include an analysis of future diffuse source contamination impact (see erosion modelling in WP 6 with WaTEM/SEDEM), due to lack of information for the Tuluá River basin. However, the results presented in WP 6 in the neighbouring Bugalagrande river pilot basin could be interpreted in the same manner for the Tuluá River basin, considering their similarity in terms of topography, morphology, hydrology, etc. The implementation of this erosion model, complying with all requirements required for good calibration, would have allowed calculation of the direct incidence of soil loss and the effects of change related to agricultural and animal husbandry activities. Evaluation of erosion and the related problems causing soil resource deterioration in the future will allow the identification of sensitivity to change relevant to this aspect within the basin.

Separate effects

Projected changes are analyzed separately in each of the studied components: the change in the water supply characterized in the precipitation and water flow of the basin, as well as the water demand related to land use and population changes.

Climate change

According to the results of the MAGICC/SCENGEN climatic change model, precipitation historic series were modified, and the HBV previously calibrated hydrologic model was used as described in the WP 3 report. The model was run using estimated rainfall changes, and the flow series were obtained. This allowed determining flow changes in the Mateguadua station at the Tuluá basin, according to 2020 estimated climatic changes. Figure 79 shows a 3 % increase in flows, considering a 2 % precipitation increase at the study basin. Impact of increased precipitation is expected to be larger on high flows than on low flows.



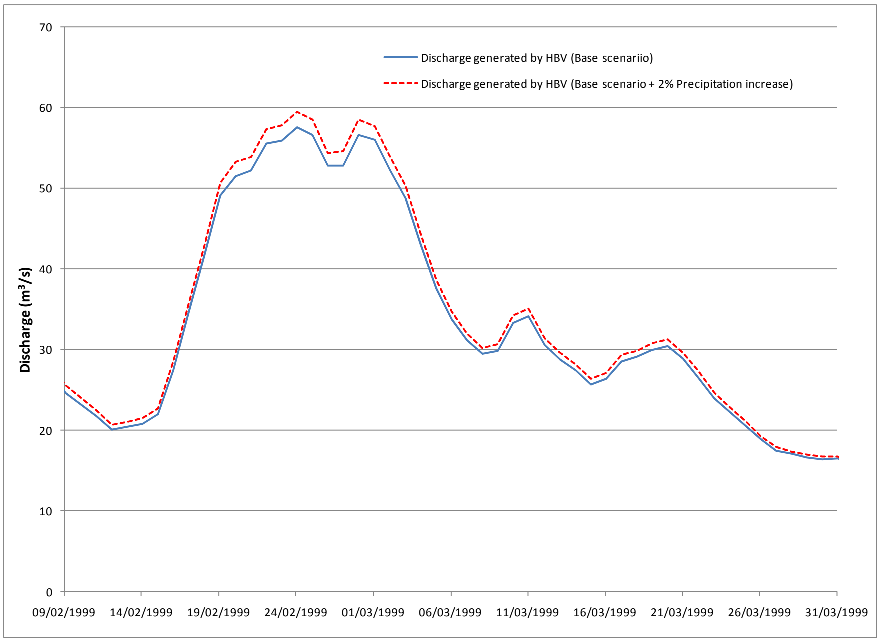


Figure 79. Predicted effects of climate change on discharge

Land use change

A sensitivity analysis of the HBV model was made for the flow generation, modifying land use according to three scenarios, considering changes in forest coverage percentage in the basin (25 % - 35 % and 40 % forest coverage).

Figure 80 shows HBV model runs for the analysis of sensitivity to de/afforestation. Water flow generated at the Mateguadua station does not show sensitivity in the model considering changes in forest coverage.

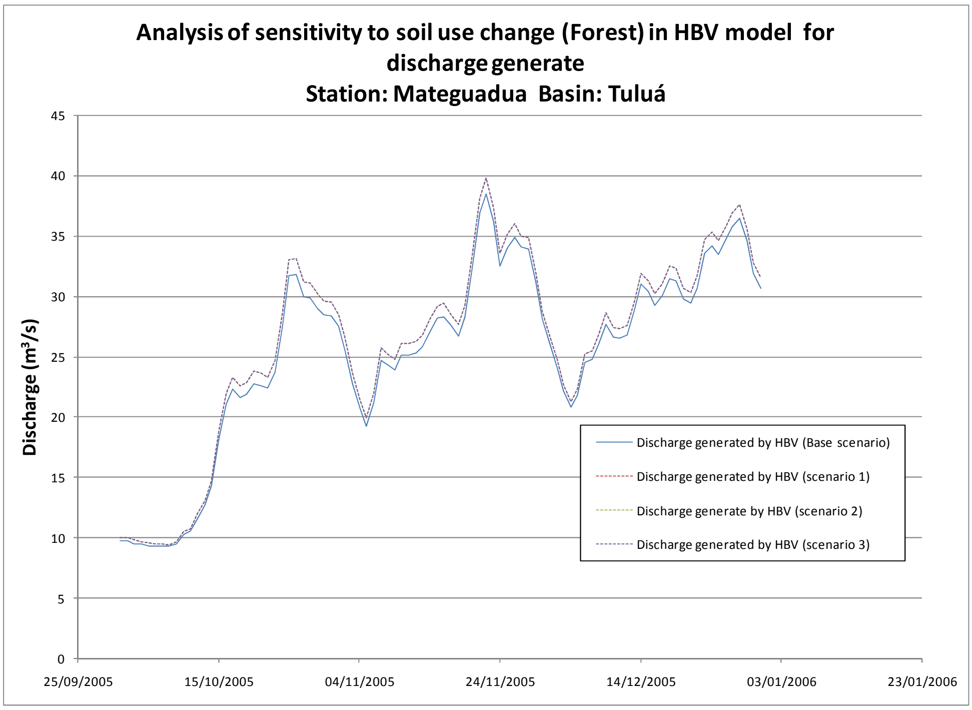


Figure 80. Predicted effects of de/afforestation in the Tuluá river basin

Changes in water demand

Agricultural Demand

Agriculture is one of the main activities having an impact over the basin. Therefore, it is of crucial importance to analyse the effects of changes in the agricultural demand. Average monthly precipitation and the agricultural demand for 2006 and 2020 are shown in Table 42 and figure 81.

Table 42. Water balance in 2006 and 2020 considering agricultural demands in the Tuluá river basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2006													
Consumption zone													
Precipitation	84.0	93.5	141.0	163.9	136.4	76.1	56.4	55.8	108.8	173.6	147.9	97.2	1334.5
Demand	79.3	76.5	82.3	70.9	67.6	64.9	75.4	82.1	78.0	71.1	65.8	69.8	883.7
Balance1	4.7	17.1	58.7	93.0	68.8	11.2	**-19.0**	**-26.3**	30.7	102.5	82.1	27.3	450.8
Production zone													
Precipitation	113.6	112.5	163.7	196.0	155.7	85.7	60.0	64.2	109.7	214.1	201.3	142.0	1618.5
Demand	36.9	32.2	35.5	29.9	30.6	30.8	35.9	37.6	34.3	31.7	28.6	32.8	396.7
Balance1	76.7	80.3	128.2	166.1	125.1	54.9	24.1	26.6	75.3	182.5	172.7	109.2	1221.7
2020													
Consumption zone													
Precipitation	93.9	92.6	142.2	148.0	123.7	81.6	68.7	64.6	115.2	147.2	147.4	96.3	1321.4
Demand	79.5	80.0	91.4	88.0	84.6	70.9	70.8	80.4	88.9	94.7	85.4	76.8	991.3
Balance1	14.4	12.6	50.8	60.0	39.1	10.7	**-2.1**	**-15.8**	26.3	52.5	62.0	19.5	330.0
Production zone													
Precipitation	128.3	119.7	166.3	192.9	151.6	99.1	72.7	72.5	116.1	203.6	201.4	144.8	1668.8
Demand	28.8	26.7	32.6	31.5	28.3	23.6	23.6	25.2	27.9	34.1	31.4	30.1	343.8
Balance1	99.5	93.0	133.7	161.4	123.3	75.5	49.1	47.2	88.2	169.4	170.0	114.7	1325.0

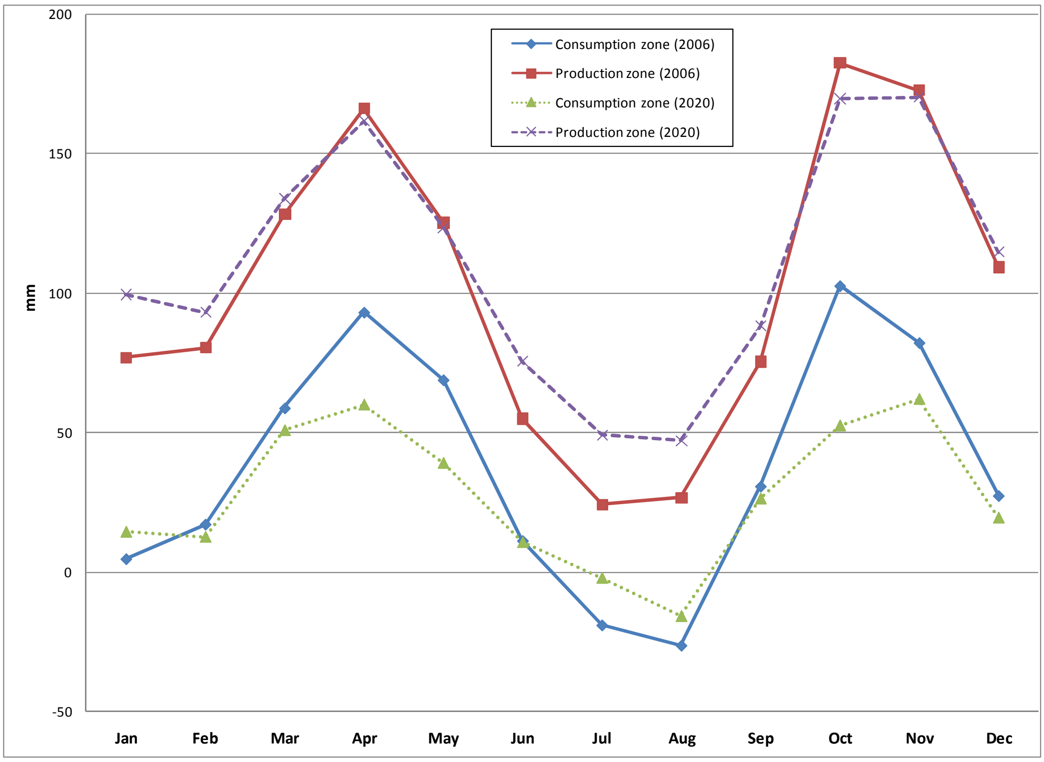


Figure 81. Water balance in 2006 and 2020 considering agricultural demands in the Tuluá river basin

In the production zone, water availability in 2020 will be 8 % higher than in 2006. This is a consequence of the reduction of agricultural demand caused by the reduction of area covered by crops and an increase of precipitation by 3 %. The water balance is especially higher in the dryer months (Jan-Feb and Jun-Sep).

In the consumption zone, on the other hand, water availability is estimated to be reduced by 27 %. The reduction can above all be noticed in the wetter months (Mar-May and Oct-Nov). The dry season (Jul-Aug), in contrast, shows higher water availability. Water availability seems to be better spread out over the year.

Combined effects

According to the precipitation-agricultural demand balance, the net basin water demand is shown in Table 43. The ecological flow is included in the water demand, with an estimated value corresponding to 10% of the multiannual monthly average registered at the Mateguadua station. The agricultural demand was estimated using a 1/0.33 factor resulting from the fact that sugar cane is the crop with the largest extension, and its irrigation is mainly done by gravity. The project efficiency was estimated 33 %, corresponding to a gravity irrigation system, which includes conduction, distribution and application efficiencies. The highest demands occur during the dry season, in July and August, both in 2006 and 2020, showing water deficits.

Table 43. Actual and predicted water demand associated to socio-economic factors

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2006													
Agricultural	0.0	0.0	0.0	0.0	0.0	0.0	57.4	79.6	0.0	0.0	0.0	0.0	137.1
Bovine	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.9
Domestic	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	2.6
Industrial	9.3	8.7	9.4	8.1	7.9	7.7	8.9	9.6	9.0	8.2	7.5	8.2	102.4
Environmental	4.2	3.7	3.9	4.7	4.4	3.4	2.7	2.3	2.1	3.1	5.1	4.6	44.3
Net	*13.7*	*12.7*	*13.6*	*13.1*	*12.5*	*11.4*	*69.4*	*91.8*	*11.4*	*11.6*	*13.0*	*13.1*	*287.3*
2020													
Agricultural	0.0	0.0	0.0	0.0	0.0	0.0	6.4	48.0	0.0	0.0	0.0	0.0	54.4
Bovine	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1.3
Domestic	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	2.9
Industrial	8.7	8.5	9.9	9.6	9.0	7.6	7.6	8.5	9.3	10.3	9.3	8.5	106.8
Environmental	4.3	3.8	4.0	4.9	4.5	3.5	2.8	2.4	2.2	3.2	5.4	4.8	45.7
Net	*13.3*	*12.7*	*14.3*	*14.8*	*13.9*	*11.4*	*17.0*	*59.2*	*11.9*	*13.8*	*15.0*	*13.7*	*211.1*

An estimated net demand of 211 mm is estimated for 2020. August shows the highest water demand (59.2 mm) in the year. Water demand in 2020 is 27 % less than the demand of 2006, mainly due to the decrease in agricultural demand. The highest percentage increases in water demand are expected in the bovine sector (50 %).

At inter-annual level the greatest water demand increases (approximately 20%) are projected for October and November, being mainly affected by greater demand in the industrial sector. In general, the domestic, industrial and environmental demand for 2020 is expected to increase 10 %, 4 % and 3 %, respectively.

Consequently, an offer-demand water balance was analysed (Table 44 and Figure 82).

Table 44 Actual and predicted water balance in the Tuluá river basin

	Jan	Feb	Mar	Abr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2006													
Surface water offer	15	13	14	17	15	12	10	8	7	11	18	16	156
Ground water offer	36	36	36	36	36	36	36	36	36	36	36	36	432
Total Offer	51	49	50	53	51	48	46	44	43	47	54	52	588
Net Demand	14	13	14	13	13	11	69	92	11	12	13	13	288
Net Balance - mm/month	*37*	*36*	*36*	*40*	*39*	*37*	***-24***	***-48***	*32*	*35*	*41*	*39*	*301*
2020													
Surface water offer	15	13	14	17	16	12	10	8	8	11	19	17	160
Ground water offer	36	36	36	36	36	36	36	36	36	36	36	36	432
Total Offer	51	49	50	53	52	48	46	44	44	47	55	53	592
Net Demand	13	13	14	15	14	11	17	59	12	14	15	14	211
Net Balance - mm/month	*38*	*36*	*36*	*38*	*38*	*37*	*29*	***-15***	*32*	*33*	*40*	*39*	*381*

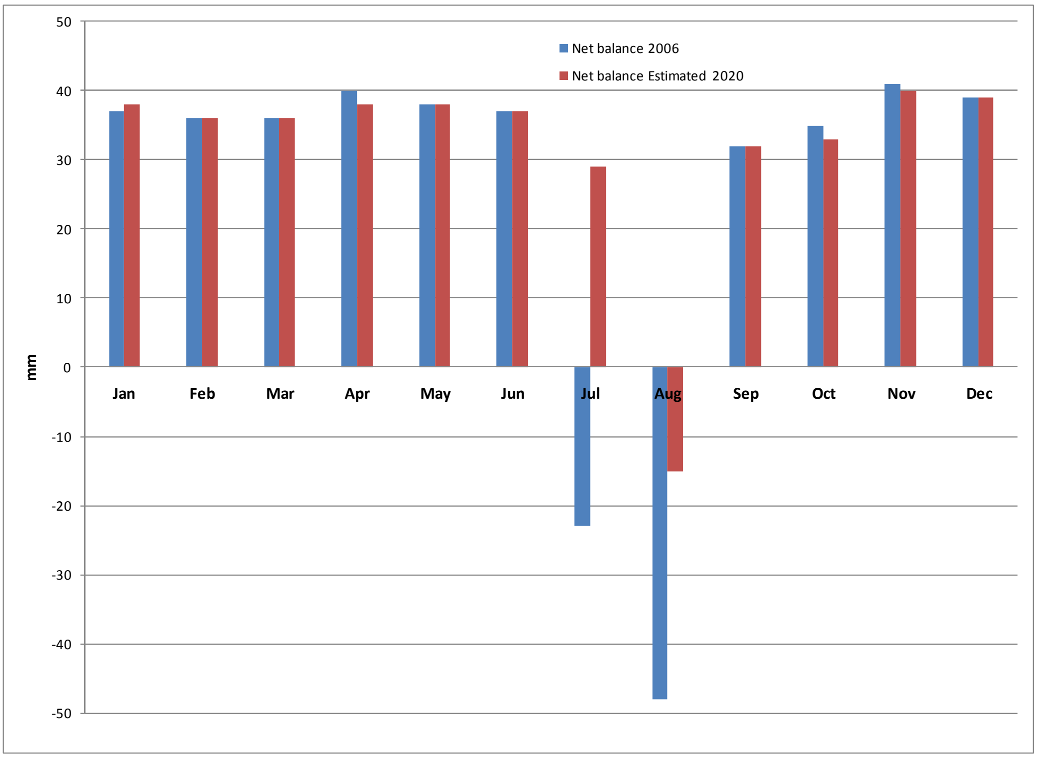


Figure 82. Actual and predicted water balance in the Tuluá river basin

Results of the predicted water balance in the Tuluá river basin show an increase of the net yearly availability to 382 mm in 2020, compared to an actual availability of 301 mm. The month of August is the only month with a -15 mm deficit. In the actual situation, two months show an important negative balance (July and August). Compared to 2006, net water availability is expected to increase with 27 %, mainly as a result of the reduction of agricultural practices and an expected increase of rainfall. However, a small reduction in water resources is expected during the months of January, February and June.

Vulnerability assessment

According to the results shown in the scenario impact assessment, the Tuluá river basin is not expected to experience important damages from future climate change, land use change and changes in water demand. From these results we might therefore conclude the basin is not very vulnerable to change, considering the future scenarios evaluated in this study. The Tuluá basin is representative of the Upper Cauca Basin study area. The analysis seems to demonstrate that different water dependent stakeholders will not suffer larger deficits in the future compared to the actual situation.

One of the main stakeholders having an impact on land use due to the demand of raw material production for the manufacturing of bio-diesel is the sugar cane producing sector. This sector is presently adapting new technologies to reduce the use of irrigation water, using more efficient irrigation systems such as aspersion irrigation, precision agriculture systems and irrigation by windows.

In general terms, the productive sector activities create a basin not very sensitive to change. However, it would be interesting to study other factors experiencing change, such as the ecological factors, that also depend on the water supply and demand in the basin, and that may be much more sensitive to – for example – climate change. More specific research is required on the impact of climate change on forest and moorland vegetation, which may have a significant impact on the still unknown water resources conservation and the biodiversity of the basin.

Summary

Climate change results for the pilot basin are expected to cause higher discharges that can be replicated in the Upper Cauca River Basin and in general, in the entire south-western zone of Colombia, according to global scale models. Climate change impact assessment resulted in larger water availability at the Mateguadua station in the Tuluá pilot basin, as was shown by data obtained using the model calibrated in the context of Work Package 3. However, these results should be interpreted with certain care, since the input of the hydrologic model was created by using the future climate change scenarios of the MAGICC/SCENGEN model.

According to climate variable data and compared to the demand-offer balance of the land use and socio-economic variables, the most sensitive crops to climate changes (precipitation and temperature) in the Tuluá River basin are coffee and potato. The environmental limiting factors of the future climate change scenario in 2020 forecast an increase in coffee production and a decrease in potato crops. In general terms, food products are more sensitive and vulnerable to changes in the river basin.

Results shown by the WaTEM/SEDEM erosion model in the Bugalagrande pilot basin (see WP 6 report) corresponds to a basin that progressively loses soil and may turn into a critical scenario in terms of land use due to the increase in agriculture for food and agro-industrial purposes, as well as grass feeding areas. The final result is production decreases and therefore, a slower economic development in the region.

According to demand-offer water balances for the present conditions and the 2020 scenario, the Tuluá River pilot basin does not evidence severe vulnerability to global change. No significant impacts are to be found in terms of the environmental and socio-economic variables of the basin. However, the estimates of the analyzed variables represent certain degree of uncertainty and therefore, require complementary studies in order to reduce the uncertainty and obtain better future scenarios.

It is acknowledged that climate change is represented through future climate prediction in terms of precipitation and air temperature patterns that has a high degree of uncertainty. That is what is shown by the results of global circulation models in the Andean Region. Large climate variations are present in our region, making it very hard to estimate the magnitude of the expected changes. Although the TWINLATIN project shows a base analysis for the possible changes in precipitation and temperature, it is important to make progress in the reduction of uncertainty levels, as well as the inclusion of variations associated to extreme hydro-climatic phenomena such as droughts, floods, events associated to ENSO. This would help to improve the reliability of the analysis of water supply, which is an important tool for the environmental and territorial management.

For the analysis of socioeconomic variables involved in the demand-offer balance, some factors were assumed; such is the case of the industrial demand which according to previous studies have been adopted as demand values. It is important to update or have more accurate data in order to have a more accurate model and change impact.

Additionally, it is important to consider the impact of change on productive systems in the basin. One should consider the economic value of possible changes associated with crop yield and production. This is an important process that must be considered for the different environmental and technological present and future activities. Different management scenario should be considered through the creation of a panel of experts in order to reach an agreement on socio-economic and environmental variables and to analyse the impact of water resources availability related to the actual local situation, reducing uncertainty in results. The so-called POMCH, a plan of integrated basin management for the region (Planes de Ordenamiento de las Cuencas Hidrográficas) is currently under construction.

COCIBOLCA

In the present study – in order to incorporate in our evaluation the impact of uncertainty associated with the conceptualization/simplification of the global and regional climatological processes in the different models, as well as with the existence of different scenarios for the future emissions of greenhouse gases – we analyzed the change signals obtained from MAGICC-SCENGEN for 9 different GCMs. We further considered the combined effects of greenhouse gases and aerosols, and for each GCM we simulated change for the 6 SRES "marker" emission scenarios: A1FI, A1T, A1B, A2, B2, B1 (IPCC, 2001). As such, a total of 54 scenarios were obtained from the tool. Changes for precipitation and temperature were simulated for a future time window of 30 years centered on 2050; the mean annual results are shown in Figure 83and Figure 84.

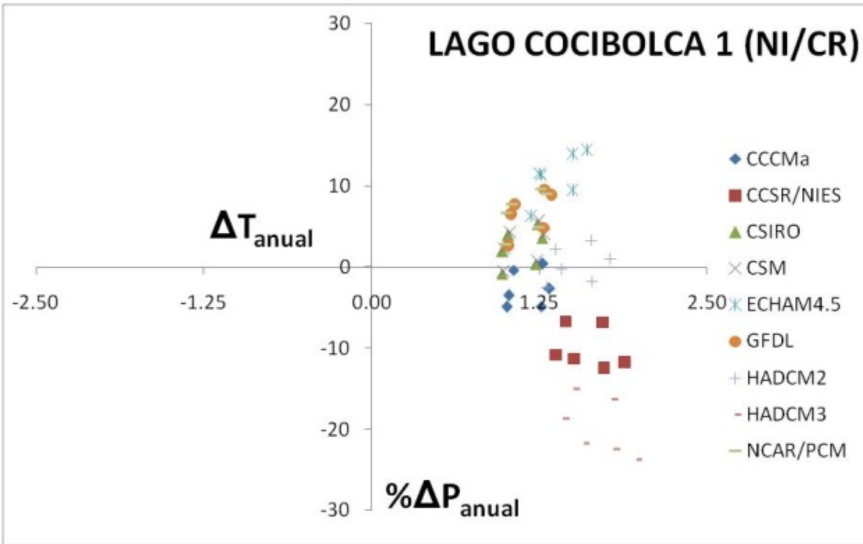


Figure 83. Results from MAGICC/SCENGEN for 6 SRES marker scenarios and 9 different GCMs changes in mean annual precipitation [%] and temperature [ºC] between a 30-year time window centered on 2050 and the simulated 1961-1990 reference climate (Pacific side, 90° - 85ºW | 10° - 15ºN)

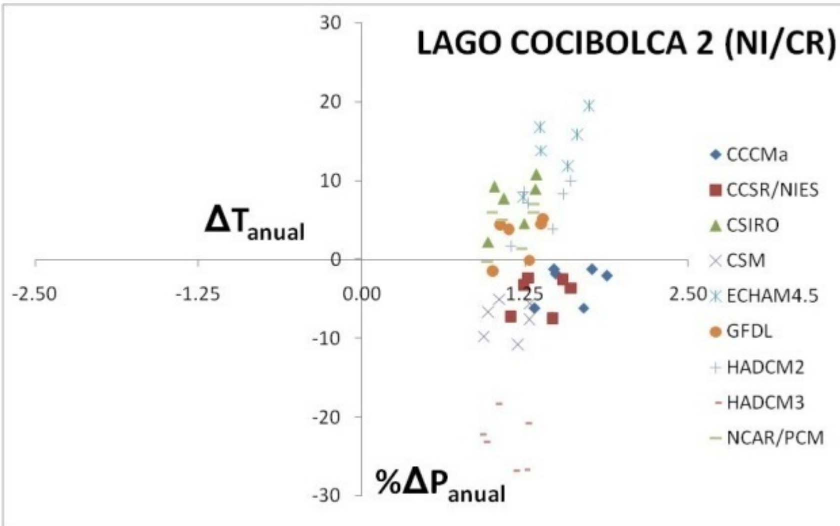


Figure 84. Results from MAGICC/SCENGEN for 6 SRES marker scenarios and 9 different GCMs changes in mean annual precipitation [%] and temperature [ºC] between a 30-year time window centered on 2050 and the simulated 1961-1990 reference climate (Atlantic side, 85° - 80ºW | 10° - 15ºN)

Creation of regional scenarios based on the output from an RCM

Two large-scale GCM models (HadCM3 and ECHAM) were used to force the regional-scale simulations conducted by means of the PRECIS tool at the Cuban Meteorological Institute[4]. Under TWINLATIN, daily time series from these runs for the output variable "precipitation" could be obtained from the Cuban Meteorological Institute for the emission scenarios A2 and B2, for a rectangular set of grid points which contains the Cocibolca Lake Basin (both Nicaraguan as Costa Rican part).

At each point of the grid, 6 daily time series could be obtained: the first two series correspond to the simulated reference or control climate ("*current*" climate) for the 1961-1989 and 1961-1990 time windows, for the RCM runs driven by the HADCM3 and ECHAM boundary conditions, respectively. The "future climatic conditions" time series obtained from the RCM/Hadley runs are available for the period 2071-2099, for both the A2 and B2 emission scenarios. For the RCM/Echam run, the corresponding time series are available for the 1991-2099 time period. The full time series have been

[4] http://precis.insmet.cu/Precis-Caribe.htm

incorporated in the ArcHydro-based Environmental Database for the Basin, and have been handed over to INETER for future research activities.

From the ArcHydro database, spatial and thematic queries were conducted as to construct data layers that represent the spatial patterns of mean annual precipitation over the Cocibolca Basin obtained from the PRECIS/HADLEY and PRECIS/ECHAM model runs, for the common reference period (1961-1989) and for the common future time window 2071-2099. From these data layers, percentage change factors were calculated.

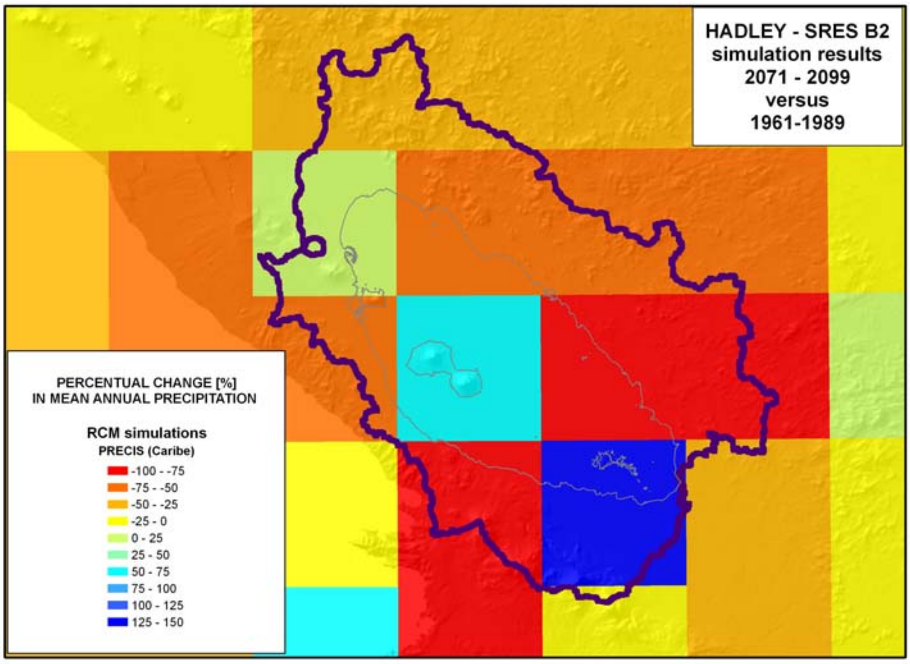


Figure 85. PRECIS/Hadley SRES B2 emission scenario. Change [%] in simulated mean annual precipitation patterns over the Cocibolca Basin between the future time windows 2071-2099 and the reference time window 1961-1989

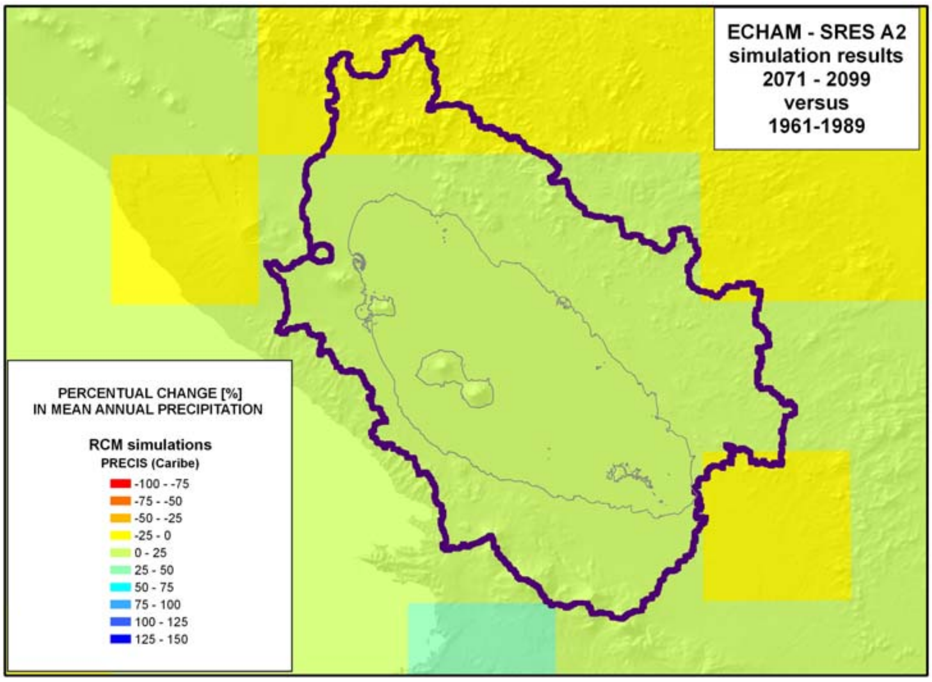


Figure 86. PRECIS/Echam SRES A2 emission scenarioChange [%] in simulated mean annual precipitation patterns over the Cocibolca Basin between the future time windows 2071-2099 and the reference time window 1961-1989

Land use change

Due to the variable spatial coverage of the existing historical and current land use maps for the Cocibolca Basin area, the highly heterogeneous interpretation techniques and classification schemes that have been used in the preparation of these maps, and the lack of validation data or quality assessments (see also the Work Package 6 report), no land use change modelling was conducted for the Cocibolca Lake Basin under TWINLATIN. Instead, the recommendation is formulated here for the use of a bi-national, well-established and agreed-upon protocol, and a uniform classification scheme in all future work.

Scenario impact assessment

Separate effects

Climate change

For the Cocibolca Lake Basin, it can be seen from Figure 85 and Figure 86 how for both 5º x 5º cells different GCMs produce different change signals for precipitation, whereas all GCMs produce a rise in temperature. The MAGICC-SCENGEN output for **HADCM3** produces a considerable decrease in precipitation for the **2050** time window, between approx. **- 15 %** and **- 25 %** for the western cell, and between approx. **- 18 %** and **- 28 %** for the eastern cell. The MAGICC-SCENGEN simulations of the **ECHAM** results, however, project an increase in mean annual precipitation in both cells, with a magnitude between **+ 5 %** and **+ 22 %**.

The results from the RCM runs driven by the **HADCM3** also show a decrease in precipitation over the Cocibolca Basin for the time window centered on **2085**, but by the end of the century these would be of a larger magnitude: values range from **- 30 %** to **- 44 %**. For the same time window, RCM runs driven by **ECHAM** deliver an estimated increase in mean annual Basin precipitation between **+ 14 %** and **+ 20 %**. The spatial patterns over the Basin obtained from the RCM are not clear; therefore no further interpretation of these has been made. Instead, the conclusions that were formulated are based on the mean change values over the Basin (Table 46).

In the Cocibolca Basin, the divergence in results obtained for mean annual precipitation from MAGICC-SCENGEN for the different GCMs complicates an unambiguous evaluation of the potential impacts of climate change on water resources; however increased temperatures and associated changes in the basin hydrology and in the lake physics/chemistry/biology can be foreseen. In addition to this, we can indicate here that the HADCM3-driven RCM runs gave a much more realistic representation of mean annual precipitation over the Cocibolca Basin for the reference period (***Table***). Climate change signals directly or indirectly derived from the HADCM3 indicate a considerable reduction in annual precipitation over the Cocibolca Lake Basin. Under such a scenario, the combination of reduced precipitation and increased temperature can be expected to generate considerable impacts in the basin's water balance and in the physical-chemical and biological characteristics of the lake.

Table 45. Mean annual precipitation over the Cocibolca Lake Basin [mm yr^{-1}] for the reference climate and a simulated change scenario (2071-2099) obtained from the Regional Climate Modeling exercise PRECIS-Caribe (Insmet)

mean anual precipitation Cocibolca Lake Basin [mm yr^{-1}]	REFERENCE CLIMATE		CHANGE SCENARIO (2071-2099)	
	STATION DATA	RCM (simulated)	SRES A2	SRES B2
PRECIS – HADLEY* (RCM)		1323	922	745
PRECIS – ECHAM* (RCM)		454	518	545
TWINLATIN*	1758			
INETER*	1566			

* the reference period is 1961–1989 for the PRECIS data set, 1975–1994 for the TWINLATIN observations data set; data from 1980–2000 were used for the INETER Water Balance calculations

Table 46. Changes in mean annual precipitation over the Cocibolca Lake Basin [%] for the reference climate and a simulated change scenario (2071-2099) obtained from the Regional Climate Modeling exercise PRECIS-Caribe (Insmet)

% change in mean annual precipitation	CHANGE SCENARIO (2071-2099)			
	SRES **A2**		SRES **B2**	
PRECIS – ***HADLEY*** (RCM)	-30.3		-43.7	
PRECIS – ***ECHAM*** (RCM)	+14.3		+20.2	
MAGICC/SCENGEN -***HADLEY***	-45.7 (P*)	-54.5 (A*)	-26.4 (P*)	-32.4 (A*)
MAGICC/SCENGEN - ***ECHAM***	+14.9 (P*)	+18.8 (A*)	+14.9 (P*)	+18.8 (A*)

** output from MAGICC/SCENGEN is for 5º x 5º pixels; P corresponds to output that approx. covers Nicaragua's Pacific side (model pixel 90° - 85º W | 10° - 15ºN); A corresponds to the Atlantic side (pixel 85° – 80°W | 10° - 15ºN)*

The results of this work show how climate change can and most probably will constitute an additional stress factor to ecosystems and human society in the Cocibolca Basin, clearly indicating the importance and usefulness of anticipated mitigation and adaptation actions, such as a major awareness building among stakeholders on the needs for rational land and water use, and a further promotion of the concepts of integrated and adaptive water resources management practicing.

Vulnerability assessment

Exposure of society

Results obtained from the climate change scenario analyses documented in the previous chapter relate to the "exposure" component of vulnerability, in the specific field of global warming impacts on regional climatology (with logical deductions towards impacts on water resources and basin hydrology). The generated regional climate change scenarios for the Cocibolca Lake Basin area show a high probability of a considerable increase in the mean annual temperature, which may result in an exposure of society to considerably different future conditions of availability and quality of water resources in the Cocibolca Lake and its surrounding basin.

Vulnerability of water stakeholder

Without having conducted major, quantitative analyses on the "sensitivity" component of vulnerability, the magnitude of the "*plausible*" impacts obtained from the scenario analyses for the Cocibolca Lake Basin in combination with the high levels of poverty and the probability of associated low adaptive capacity allow us to assume that a considerable vulnerability potential exists for both human society as well as the natural ecosystems in this basin.

It can thus also be assumed that a considerable amount of adaptive capacity would need to exist or to be generated in the basin if vulnerability towards the impacts from climate change on water resources is to be maintained at, or reduced/brought down to levels which are acceptable for society.

Indications of existing and potential future vulnerability of society in the Cocibolca Lake Basin to the water resources-related effects of climate change and variability already exist indeed: fish mortality in the lake has repeatedly been observed, and has been associated to changes in the lake water temperature in the past; hurricane pathways have crossed the lake basin area in the past, causing floods and damage to human infrastructure and productive systems; water scarcity, seasonal and/or periodical droughts have already seriously affected the water provision to households in several of the major cities in the Basin over the past – a solution based on the production of drinking water from the Cocibolca Basin will be influenced by the future quality of water resources in the lake and on costs for pumping water from the lake to the higher-laying cities.

Public participation and the perception of vulnerability

During the public participation workshops held in the Cocibolca Basin in the second half of the year 2008 in the Municipalities of Granada and Rivas, an exercise was conducted as to evaluate the existing perception of vulnerability towards the effects of climate change among the participating basin stakeholders. For this purpose, through a questionnaire, stakeholders were allowed to express their perceptions with regard to the importance of different factors that are known to influence vulnerability towards the (water resources-related) effects of climate change. Previously to the application of the enquiry, a PowerPoint presentation was given in which the concepts of vulnerability, exposure, sensitivity and adaptive capacity were explained in simplified terms. The enquiry then was applied twice, once before and once after results from the work on the exposure component in TWINLATIN (described in previous chapters of this report) were shown (also in a simplified manner). The aim here was to see if the provision of information from site- or region-specific research influenced the stakeholder's perception of vulnerability.

This twinned approach was also applied in other TWINLATIN basins, e.g. the Baker Basin in Chile. Assistance of stakeholders at the public participation workshops in Nicaragua however was considerably higher than in e.g. Baker (historical-political reasons can explain this). For the Granada and Rivas workshop respectively, 36 and 15 opinions could be collected. These numbers are still relatively small, but allow already obtaining a first impression on which factors – according to the opinion of stakeholders – are insufficiently developed in the basin and, as such, contribute to a low adaptive capacity.

Figure 87 up to Figure 90 show the outcome from this public participation process. Each axis in the graph represents a factor which is considered to influence the adaptive capacity of stakeholders. Participants were asked to assign a high value to those factors whose current conditions in the basin or country positively contribute to their adaptive capacity, whereas a low score needed to be assigned to those factors whose current condition is seen as a cause of low adaptive capacity, and which thus contribute to higher vulnerability.

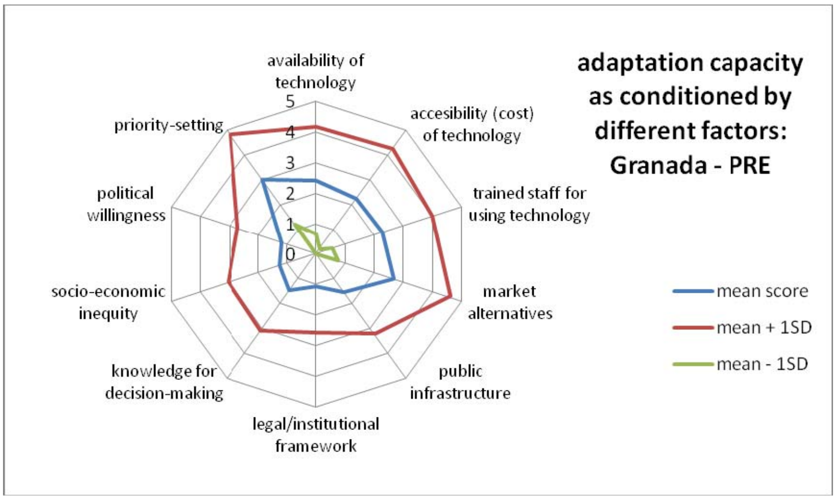


Figure 87. Cocibolca Lake Basin's stakeholder perception with regard to vulnerability - factors that condition adaptive capacity to climate change (Granada workshop, previous to showing results from WP08; n = 36)

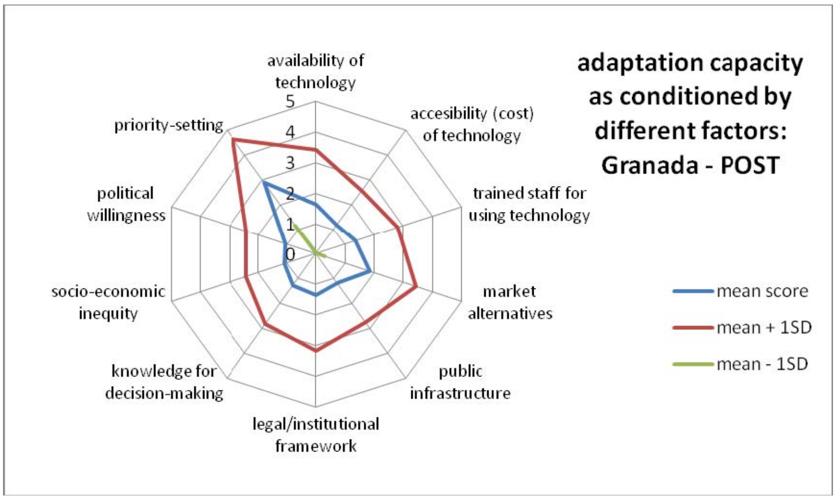


Figure 88. Cocibolca Lake Basin's stakeholder perception with regard to vulnerability - factors that condition adaptive capacity to climate change (Granada workshop, after results from WP08 have been shown; n = 32)

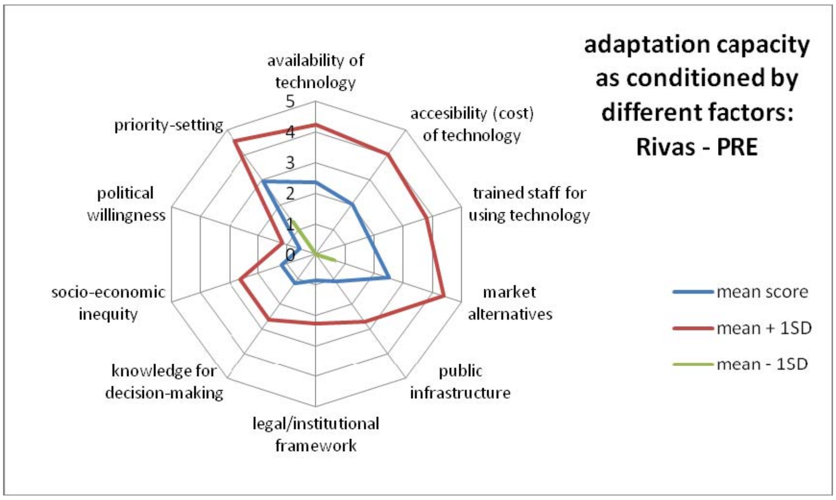


Figure 89. Cocibolca Lake Basin's stakeholder perception with regard to vulnerability - factors that condition adaptive capacity to climate change (Rivas workshop, previous to showing results from WP08; n = 15)

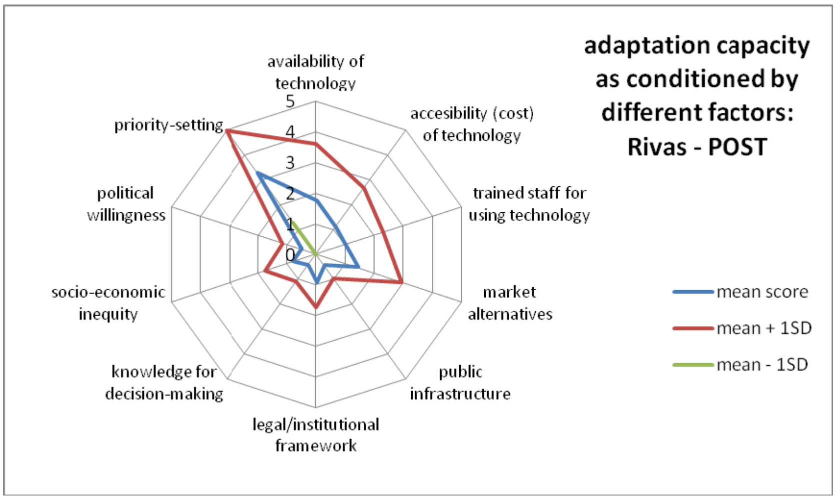


Figure 90. Cocibolca Lake Basin's stakeholder perception with regard to vulnerability - factors that condition adaptive capacity to climate change (Rivas workshop, after results from WP08 have been shown; n = 15)

Factors were: *(i)* the existence of technology which would enable adaptation; *(ii)* the availability of this technology at accessible costs; *(iii)* the existence of qualified personnel to make use of such technology; (*iv*) the existence of market alternatives (e.g. good market prices for more drought-resistant crop alternatives in case of predictions of a drier climate); (*v*) the availability of adequate public infrastructure (e.g. flood protection dams, early warning systems, etc.); *(vi)* and adequate legal/institutional framework; *(vii*) adequate knowledge for decision-making (e.g. results from research on climate change impacts; adequate monitoring networks); *(viii)* socio-economic equity (inequity is a negative factor as the poor tend to have less adaptive capacity); (*ix*) political willingness to act; *(x)* the importance the stakeholders themselves give, or are able to give –due to priority setting- to the topic of climate change.

In all cases and for most factors, rather low mean scores were obtained (nearly almost ≤ 3). A remarkable result is also how for factors in the lower half of the graph (especially from the "political willingness"-"market alternatives" diagonal downwards) typically the lowest scores were given ("market alternatives" itself however, does not get this typical low score). Somewhat surprising is also how the "priority setting" systematically gets the highest score. The evaluation of this factor was conducted to see if stakeholders consider that other worries than climate change (and variability) are much more urgent, with the result that not sufficient attention can be given to this topic. This exercise however seems to indicate that stakeholders in the Basin do consider climate change and variability a high-priority topic.

In many cases, scores obtained after the results from the TWINLATIN research on the exposure component had been shown tend to be lower than during the first application of the enquiry. This seems to indicate that through the awareness building exercise the perception of vulnerability (due to lack of adaptive capacity) is higher than before.

The mean value for the "knowledge for decision-making" was low in all cases, and did not increase after information from the research was provided. This seems to indicate that a high demand exists among the basin stakeholders for additional, probably higher-resolution and more specific information on the topic of regional, local and sectorial impacts of climate change.

It is important to indicate that the current results are based on a small amount of questionnaires; even so the exercise provides interesting preliminary information on what factors of the vulnerability equation future efforts should be focused. As such, it can also assist in defining topics for future research.

Adaptation to reduce vulnerability

In order to reduce vulnerability, a timely adaptation to probable new environmental conditions under climate change becomes imperative. Adaptation in the context of human society can be defined as: 'adjustments in human systems in response to actual or expected climatic stimuli (~*exposures*) or their effects (~*exposures + sensitivity*), in order to moderate harm or exploit beneficial opportunities' (IPCC, 2001). It is an integral part of the implementation of the United Nations Framework Convention on Climate Change (UN, 1992), and 'requires urgent attention and action on the part of all countries' (UNFCCC, 2002).

After the evaluation of vulnerability, a next logical step in the preparation of society for the potential impacts of climate change thus consists of the definition of adaptation practices for stakeholders in the water resources sector. Through the implementation of such adaptation practices, vulnerability can be addressed and reduced.

In this context, at CIEMA-UNI/EULA-Chile under TWINLATIN and through a collaborative research effort with a group of non-TWINLATIN researchers from the Latin-American and Caribbean Region brought together by the Inter-American Institute on Global Change Research **IAI**, starting from a common interest in impacts in the water resources sector a prototype multi-purpose index was developed and proposed for use in the evaluation of practices for adaptation to climate variability and change. The Index of Usefulness of Practices for Adaptation (**IUPA**) allows the user to assign weights and scores to a set of user-defined criteria for evaluating the general usefulness of adaptation practices. Individual criterion scores are then aggregated into a final index value. Both the final value and the individual parameter scores provide useful information for improved decision making in the context of the definition of adaptation measures for climate change. An innovative aspect of this IUPA index is that guidance is given to the user through the inclusion of recommendations on evaluation criteria and criterion-specific weight factors. This guidance is provided by the aforementioned expert panel from the Latin-American and Caribbean Region (LAC). Although the index has not been applied yet in any of the TWINLATIN case study basins (no major adaptation practices are known), its usefulness for both TWINLATIN and other basins in the world was demonstrated through a practical application for an existing adaptation practice well-known to one of the research group members. The proposed index is particularly practical for a quick first assessment or when limited financial resources are available, making the tool especially useful for practitioners in the developing world. The index is flexible both from the perspective of its construction and use, and additional expert opinions can easily be included in future versions of the tool. The excel worksheet used for calculating the index value is shown in Figure 91. The index and its application are described in detail in Debels et al. (2008).

Index for the evaluation of the Usefulness of Practices for Adaptation - IUPA v1.0

Case Study: Improving Disaster Management, Chile

I			II					III					
VARIABLES			SUGGESTIONS OF THE PANEL					EVALUATION BY THE USER					
		NAME OF THE VARIABLE	SUGGESTED WEIGHT (0-10)	SUGGESTED RELEVANCE	n	σ	level of agreement	ASSIGNED WEIGHT	ASSIGNED RELEVANCE	SCORE (design phase)	WEIGHTED SCORE (design)	SCORE (post-implementation)	WEIGHTED SCORE (post-)
A	B	C	D	E	F	G	H	I	J	K	L	M	N
A SUGGESTED "CORE" VARIABLES	1	ACCOMPLISHMENT OF THE OBJECTIVES	8.3	HIGH	8	1.0	M	9	HIGH		-	8	72
	2	REQUIRED IMPLEMENTATION TIME	6.8	MEDIUM	8	0.7	H	7	HIGH		-	8	56
	3	TOTAL COST	6.6	MEDIUM	8	1.3	M	7	HIGH		-	9	63
	4	ROBUSTNESS AND/OR FLEXIBILITY OF THE SOLUTION	8.9	HIGH	8	0.8	H	10	HIGH		-	9	90
	5	LEVEL OF AUTONOMY (IN DECIDING AND ACTING)	7.1	HIGH	8	1.5	M	6	MEDIUM		-	5	30
	6	PROPORTION OF BENEFICIARIES	7.1	HIGH	8	1.6	L	9	HIGH		-	8	72
	7	CONTINUITY IN TIME OF PROJECT OUTCOME	7.8	HIGH	8	0.9	H	8	HIGH		-	6	48
	8	LEVEL OF RESILIENCE	8.4	HIGH	8	1.2	M	10	HIGH		-	8	80
	9	INTEGRATION WITH OTHER POLICY DOMAINS	7.5	HIGH	8	1.4	M	8	HIGH		-	8	64
	10	PARTICIPATION OF TARGET POPULATION	8.5	HIGH	8	1.1	M	9	HIGH		-	6	54
B SUGGESTED "COMPLEMENTARY" VARIABLES	1	ATTENTION TO MOST VULNERABLE GROUPS	7.9	HIGH	8	1.2	M	9	HIGH		-	9	81
	2	LEVEL OF ENVIRONMENTAL PROTECTION	6.8	MEDIUM	8	1.0	M	7	HIGH		-	7	49
	3	REPEATABILITY	5.6	MEDIUM	8	1.8	L	5	MEDIUM		-	8	40
	4	INCORPORATION OF LOCAL/TRADITIONAL KNOWLEDGE	6.0	MEDIUM	8	1.9	L	4	MEDIUM		-	2	8
	5		-	not defined				-	not defined		-	-	-
	6		-	not defined				-	not defined		-	-	-
	7		-	not defined				-	not defined		-	-	-
	8		-	not defined				-	not defined		-	-	-
	9		-	not defined				-	not defined		-	-	-
	10		-	not defined				-	not defined		-	-	-
C USER ADDED VARIABLES	1	STRENGTHENING COOPERATION AMONG STAKEHOLDERS	-	not defined				8	HIGH		-	7	56
	2		-	not defined				-	not defined		-	-	-
	3		-	not defined				-	not defined		-	-	-
	4		-	not defined				-	not defined		-	-	-
	5		-	not defined				-	not defined		-	-	-
	6		-	not defined				-	not defined		-	-	-
	7		-	not defined				-	not defined		-	-	-
	8		-	not defined				-	not defined		-	-	-
	9		-	not defined				-	not defined		-	-	-
	10		-	not defined				-	not defined		-	-	-
								IUPA - integrated scores			0.0		7.4

Figure 91. The Index for the Evaluation of the Usefulness of Adaptation Practices (IUPA)

Different steps were undertaken in order to address the topic of change impacts and associated vulnerability: ***(i)*** outcome obtained from the activities conducted under Work Package 3 was analyzed, and based on this analysis a feasible and meaningful strategy – within the context of TWINLATIN – for activities under Work Package 8 was defined; ***(ii)*** climate change scenarios for the Cocibolca Lake Basin were generated and discussed, based on results indirectly obtained from GCMs as well as those directly obtained from a regional RCM run; ***(iii)*** a basic interpretation was made of these climate change scenarios in terms of their potential hydrological consequences; ***(iv)*** the role of the previous steps for the evaluation of the exposure component of the vulnerability equation was briefly described; ***(vi)*** information from the work under TWINLATIN was shared with stakeholders in the Basin, and an exercise was conducted in which the perception of the adaptive capacity among stakeholders was evaluated; ***(vii)*** an index was developed which may help identify optimum adaptation options in future projects; ***(viii)*** to conclude, important aspects and topics that could not be addressed under TWINLATIN and which should be considered for inclusion in ongoing or future research on the Cocibolca Lake Basin are summarized.

The wide range of values for the change signals that can be obtained in an impact assessment study such as the one presented for the Cocibolca Basin (this conclusion was also obtained for most other case study basins under TWINLATIN) is a direct consequence of the uncertainties that persist with respect to the intensity and even direction in which change in climatic variables will manifest itself at the local and regional level, under global warming: information based on different GCMs provides different regional change patterns for a single change value in mean global temperature (MAGICC-SCENGEN). On top of this, the existence of a multitude of scenarios for the future emission of greenhouse gases adds additional uncertainty with regard to the magnitude of this change in global mean temperature. Additionally, for a given study site, change results obtained from a finer-scale modelling exercise (RCM runs) may also differ considerably from what is obtained from the GCMs (although in this case, only the magnitude and not the direction of change was affected).

In the case of the Cocibolca Basin, considerable uncertainties were also associated with the outcome of the hydrological modeling exercise conducted under Work Package 3, as a result of uncertainty with regard to input and calibration/validation data sets; therefore in the current context scenario impact modeling by means of a calibrated and validated hydrological model was not conducted under TWINLATIN. Instead, directly from the change scenario information itself qualitative projections were made with regard to possible impacts: higher temperatures will affect evapo(trans)piration; if this occurs in combination with lower precipitation rates, the water balance in the Cocibolca Basin may be seriously affected, as well as the physical-chemical and biological characteristics of the Cocibolca Lake.

Stakeholders in the Basin seem to perceive a high vulnerability due to a combination of the magnitude of possible change/variability and a low adaptive capacity. Frequency of phenomena such as ENSO and extreme events such as tropical storms and hurricanes may further contribute to increased vulnerability, and this aspect should be further addressed in future research.

Table 47. Some important tasks for ongoing research in the Cocibolca Lake Basin

protocol for the systematic generation and storage of metadata
collection + quality control + incorporation in the SIGACC database of hydrometeorological time series from the Costa Rican part of the Basin
collection and incorporation in the SIGACC database of the reference and future time window time series of temperature (and other variables) from the RCM model run for Central-America and the Caribbean
development of a bi-national, well-established and agreed-upon protocol and uniform classification scheme for the preparation of land use data layers for the Cocibolca Basin; this should be developed as a function of the use that will be given to the information, in such a way as to maximize its usefulness and guarantee its compatibility with other datasets
generation of maps/data layers for the Cocibolca Basin representing the different water balance components under plausible future climate change scenarios based on the RCM time series of meteorological variables
evaporation calculations from the lake surface area with the aid of remote sensing data in order to enable the establishment of a full (terrestrial area + lake) water balance for the Cocibolca Basin

larger-scale application of the vulnerability assessment exercise + inclusion of the topic: climate variability versus climate change, extremes (e.g. ENSO, hurricanes,…)
updating of the results from WP 8 using the new version of the MAGICC/SCENGEN tool
improvements to the hydrometeorological monitoring network (rating curves, station coverage, lake water temperature,…) combined with alternative information sources (remote sensing, …)

CUAREIM - QUARAI (Brazilian side)

The assessment of change effects carried out in WP8 focused largely on hydrological changes, linked to the presence of a large number of small reservoirs in the basin, and the consequences of widespread water abstraction for rice irrigation. (i) During WP4 (Public Participation) activities it also became clear that the local community is worried about the possible change effects of large scale plantations of eucalyptus, which would replace pastures. The general fear is that large eucalyptus plantations might lead to lower stream flows in the basin, leading to an increase in conflicts concerning water use. (ii) Local stakeholders also would like to know what the effect would be of the construction of a larger reservoir, located upstream of the cities of Quaraí and Artigas. This reservoir would be used at the same time for flood control during winter and regularization of low flows during the summer period. (iii) A final analysis of change effects is related to the hydrological impacts associated with climate change.

The whole basin area down to the confluence with the Uruguay River was modelled, and special attention was given to the influence of the small reservoirs and rice fields on the hydrologic behaviour of the basin.

Scenario creation

Scenario modelling was necessary from the start of the hydrological modelling activities in the Quaraí river basin. This is due to the fact that observed stream flow time series are strongly influenced by the presence of reservoirs and by water abstractions for rice irrigation.

Additional scenarios concerning land use change and climatic change were also simulated.

The analyzed scenarios of water resources development, including the objective of the simulation, are summarized in Table 48.

Table 48. Scenarios analyzed in the Quaraí river basin

Scenario	**Reservoirs**	**Reservoir water abstractions**	**River water abstractions**	**Return flow from rice fields**	**Climatic change**	**Land use change**	**Objective**
1	X	X	X	X			Model calibration; actual situation
2							Natural situation of the basin
3	X						Analyze effects of reservoirs
4	X	X		X			Analyze effects of reservoirs and reservoir abstractions
5	X	X	X				Analyze effects of return flows
6					X		Analyze effects of climatic change
7						X	Analyze effects of land use change

Climate change

The climate change impact assessment is separated in two analyses. The first is a sensitivity analysis of the river discharge due to hypothetical changes in the annual mean precipitation and temperature. The second analysis is based on climate change scenarios obtained from the generator MAGICC/SCENGEN. In both cases, the water model MGB-IPH (Collischonn, 2001; Collischonn et al., 2007) was used to simulate the watershed considering the observed disturbed series of precipitation and temperature and keeping the observed series of other climatic variables (relative moisture, insolation, wind speed). Following, the observed stream flow time series were compared with simulated ones. The 20 year period from 1980 to 2000 was used during the simulations of climatic change scenarios.

Climate change scenarios for the Quaraí watershed were obtained from the MAGICC/SCENGEN generator of climate changes scenarios. Figure 92 shows predicted changes in mean temperature (y-axis) and precipitation (x-axis) in the region of Quaraí River basin for year 2050. These are results based on MAGICC/SCENGEN and reflect different climatic models and development scenarios. Each point on the chart is a result related to one of nine GCMs and one of the scenarios of greenhouse gas emission. These data are grouped according the GCMs. The results refer to a space of 30 years with one year of reference.

Most of the GCMs in all emission scenarios show that both temperature and precipitation will increase in the Quaraí basin. There is only one result suggesting a decrease in precipitation, by the GFDL climatic model. With this only exception there is more or less a consensus among the models, scenarios and prediction periods suggesting that temperatures will increase by as much as 3°C in the next 80 years, and that annual precipitation will increase by as much as 40%. Therefore, according to the results of IPCC's TAR and the GCMs, the probability to increase the annual mean temperature and precipitation is high in the watershed of Quaraí River.

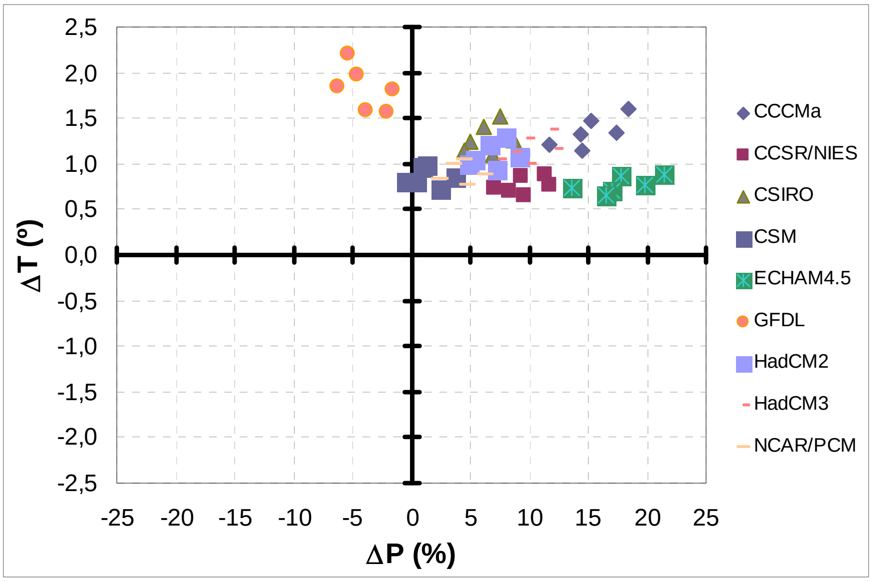


Figure 92. Changes in mean temperature and precipitation in the region of Quaraí watershed for 2050

Although most of the results are coherent concerning the direction of modification and indicate an increase both in temperature as in precipitation in the region of the Quaraí basin, these are disparate regarding the magnitude of this modification, mainly in the precipitation. The uncertainty associated with the results is very high, since the difference between the values of different models (for the same emissions scenario) is much larger than the difference in the predictions of a single model, considering different emissions scenarios (when observing charts, it can be observed that the points related to a determined model are all grouped and distant from the groups of points related to the other models). The difference between the results of different models has the same order of magnitude as predictions of climate changes. From the results of the climatic models it is expected that changes in stream flow will be small, because the predicted increase in temperature will increase evapotranspiration and decrease stream flow, while increases in precipitation will lead to increases in stream flow. The two effects will probably cancel each other.

Land use change

Currently, the major concern related to land use change in South Brazil is the plantation of forests. Two types of trees (*Eucalyptus* and *Pinus*) are being cultivated for decades now in the State Rio Grande do Sul, mainly for paper and wood production. The extent of eucalyptus plantations will probably grow in the near future in consequence of the setting up of two new paper mills and the enlargement of an already existing one. One of those industries will be located on the border between Brazil and Uruguay, not far from the Quaraí river basin, and part of the forests to sustain this industry will probably be planted in the basin. The plans of increasing area used for eucalyptus plantations coincide with heap criticism on eucalyptus plantations by environmentalists around the world and specifically in Brazil for its high water consumption, and for alleged impacts on biodiversity.

Eucalyptus trees certainly have an impact on water yield as was shown by paired catchment studies and analysis of stream flow data after afforestation or deforestation in several regions in different climatic regions (Andréassian, 2004; Cornish and Vertessy, 2001; Engel et al., 2005; Scott and Lesch, 1997; Sikka et al., 2003). In this sense eucalyptus plantations have similar impacts as other types of forests (Andréassian, 2004).

The impact of vegetation change seem to be more pronounced in watersheds with deep or very deep soils, where deep-rooted trees have advantages over shallow-rooted grass species in terms of access to water during droughts. The effects of reforestation or deforestation tend to be higher in regions with seasonal rainfalls, when soil water reserves are replenished, and periods with water deficits, when deep soil water is only available to deep-rooted trees (Andréassian, 2004).

There are suspicions that eucalyptus forests can impact water resources more than indigenous forests. Several studies carried out at different regions of the world lead to a suspicion of eucalyptus being major water consumer vegetation. These opinions are based on several studies and by local observation or anecdotal stories of drying out of swamps, wells or springs.

Most of the published studies were carried out in regions outside South America and in climatic regions which do not resemble that of the Quaraí basin, as South Africa, Australia and India. A study by Soares and Almeida (2001) in Brazil showed that evapotranspiration of a eucalyptus plantation was of the same order of magnitude as annual rainfall (~1400 mm) in a region of very deep soils and located in a more tropical region than the Quaraí river basin. Engel et al. (2005) describe a study carried out outside of Brazil, but in a region closer to the Quaraí river basin (in Argentina) than the one described above, where a very old eucalyptus forest has been monitored and compared to the neighbouring grassland vegetation in terms of water use. Their results showed that eucalyptus trees undoubtedly use more water for evapotranspiration than grasslands. Evapotranspiration from eucalyptus was so high it could only be maintained by reducing groundwater levels by more than 50 cm with respect to surrounding grassland.

From the results and reviews found in the recent literature the impacts of eucalyptus plantations on water balance of river basins seem to be more pronounced when some of the following characteristics are fulfilled:

- Deep soils
- Seasonal rainfalls
- Permeable soils
- Access to groundwater
- Forest management

The extent of the impacts will probably be related to the actual eucalyptus species that is planted, since there are a huge number of different species.

Concerning the extent of land use change, a very drastic land use change scenario was defined in which it was considered that 10% of the area currently covered with grasses or pasture in the Quaraí river basin would be turned into eucalyptus plantations. This would mean a profound change in land cover over 1312 km^2 of the 14800 km^2 large drainage area. This area ought to be as much as necessary to feed a pulpwood processing industry unit, which is estimated to be 120 thousand hectares – or 1200 km^2 – in this region.

A preliminary estimate of the impact of this change on the annual water runoff can be made by using the rough figures by Bosch and Hewlett (1982). These authors suggested a 300 to 400 mm yr^{-1} reduction in stream flow due to afforestation with eucalypt or pine. If we consider that the change affects less than 10% of the basin area, an annual stream flow reduction of not more than 30 to 40 mm should be expected. At the gauging station of Artigas/Quaraí the average annual runoff is of the order of 660 mm $year^{-1}$. This means that a reduction of 35 mm in annual runoff in this region would represent a 5% decrease in average stream flow.

Changes in water demands

Population is expected to grow very slowly in the Quaraí river basin. Cities in Uruguay and Brazil are experiencing a standstill in population during the last decades, and rural population is possibly more close to a tendency to decrease than to increase.

The most impacting water demand in the basin is rice irrigation, and this use is already limited by water availability. Therefore water demands can hardly be expected to rise.

Scenario impact assessment

For the assessment of change effects related to water use the MGB-IPH model was specially adapted to represent the small farm reservoirs and the water use in rice fields. For the assessment of change effects related to land use the parameters of the vegetation were changed in order to represent the new type of vegetation. For the assessment of change effects related to climate change, the model inputs were changed and the differences in outputs were assessed.

Climate change

In the Quaraí river basin the sensitivity of the stream flow was evaluated by: changing the input data (precipitation and temperature) by a scaling factor; running the model with the optimized parameter values; and then comparing the modelled stream flow for the changed input data with the modelled stream flow using the original data (using data from 1980 to 2000).

The results suggest that the Quaraí river basin is sensitive to rainfall change; however most of the changes are perceptible in medium to high flows. This result may be related to the characteristics of the basin (shallow soils and low base flows).

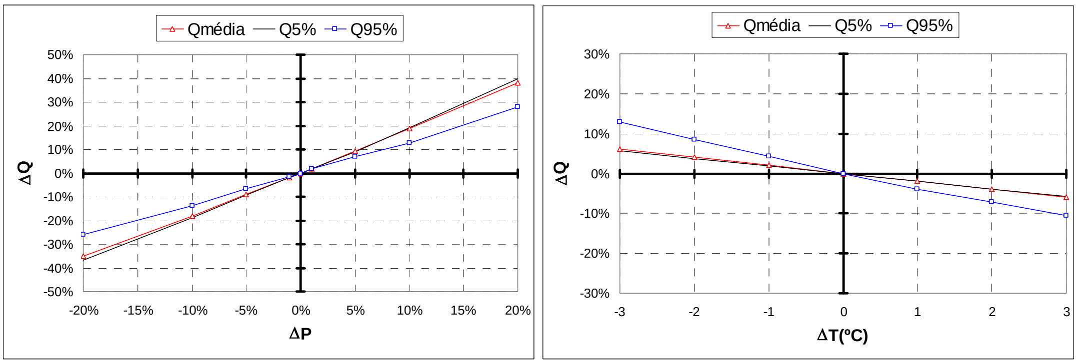


Figure 93. Relative changes in stream flow of the Quaraí River related to changes in rainfall; b) Relative changes in stream flow of the Quaraí River related to changes in temperatur

Low flows are more sensitive to modifications in the temperature. The stream flow elasticity related to changes in precipitation can be as high as 4 for basins with low runoff coefficient, meaning that a 10 % decrease in precipitation would lead to a 4 0% decrease in stream flow. It seems, from these results, that the Quaraí river basin has relatively low sensibility to changes in both precipitation, and this is probably related to its high runoff coefficient.

Especially important in the Quaraí river basin are low flows during the austral summer months, during which a water deficit often occurs in the basin, due to the huge amount of water that is used to irrigate the rice fields. Therefore, the climatic change results have been calculated for low flows observed during different months. Flow duration curves have been constructed for each month of the year and the changes in the Q95 flow from the duration curve have been calculated for each climatic model, scenario and month. The most distinctive changes are increases of the low flows during the summer months; however the dispersion of the results is large during these months.

From the climatic change results it seems that both increases and decreases can be expected in low flows of the river Quaraí during the more critical part of the year – the summer. The sensitivity analysis showed that due to its high runoff coefficient the basin is on the lower range of susceptibility to climate change. The model runs with climatic change scenarios drawn from MAGICC/SCENGEN suggest that the future climate will result in increases of stream flow in the Quaraí River. Low flows, however, will experiment only slight changes, if any.

It should be noted that this analysis has several limitations. In particular, no assessment of a possible change in rainfall probability distribution was made. It is sometimes stated that climate change will be more clearly observed in terms of changes in the extremes, instead of average values of variables.

Land use change

It can be deducted from Table 49, that the most impressive change would happen in low flows if the eucalyptus forests had access to groundwater. In scenario 7B (moderate access to groundwater) the reference discharge Q_{95} would be reduced from 1 to 0.71 $m^3 s^{-1}$ while in scenario 7C the new Q_{95} would be only 0.09 $m^3 s^{-1}$.

Table 49. Summary of land use change scenario impact assessment at Quaraí (gauging station) values are in $m^3 s^{-1}$

Scenario	Mean stream flow	Q_{95}	Q_{10}
Natural (scenario 2)	98.4	1.00	253
Eucalyptus no access to groundwater (scenario 7A)	92.3	0.96	235
Eucalyptus moderate access to groundwater (scenario 7B)	91.6	0.71	233
Eucalyptus facilitated access to groundwater (scenario 7C)	90.9	0.09	233

Table 50 shows the same results in terms of relative change from the natural condition. It can be seen that changes in average stream flow will be of 6% to 8% reductions, depending on the scenario. Impact on relatively high flows (Q10) would be slightly higher, while impacts on low flows are very dependent on the adopted scenario.

In scenario 7A the reduction of low flows following the eucalyptus afforestation would be of 4%. This reduction is due to larger interception, lower surface resistance and to the other parameter values adopted to represent eucalyptus forests, which boost evapotranspiration. However, the impact is relatively limited because soil moisture deficits restrict evapotranspiration. In scenario 7B it was allowed that upward flow from groundwater to the soil layer partially replenishes soil moisture. As a result the impact on low flows was much higher (29%). Finally, in scenario 7C a very easy access to groundwater was considered and the land use change in less than 10% of the basin drainage area had an impact of more than 90% in low flows.

It is remarkable that results obtained with the hydrological model confirmed that the change in stream flow would be of the order of 5%, as predicted using the values suggested by Bosch and Hewlett (1982).

Table 50. Summary of land use change scenario impact assessment at Quaraí (gauging station) values are in % of change compared to the natural scenario

Scenario	Mean stream flow	Q_{95}	Q_{10}
Eucalyptus no access to groundwater (scenario 7A)	-6%	-4%	-7%
Eucalyptus moderate access to groundwater (scenario 7B)	-7%	-29%	-8%
Eucalyptus facilitated access to groundwater (scenario 7C)	-8%	-91%	-8%

The results of the land use change scenarios confirm that afforestation with eucalyptus will reduce average stream flow, as is expected for any other kind of forest replacing grasslands. The extent of this impact is relatively low if the forests are planted and managed in order to avoid access to shallow unconfined aquifers. In this case the impact will be more pronounced as a reduction of storm flows than as a reduction in base flow. It can be said that without access to groundwater large scale eucalyptus plantations will have an impact on stream flow that will be undistinguishable, due to the year to year variability and the uncertainty of discharge measurements.

On the other hand, if the eucalyptus forests will be planted in areas of shallow groundwater, the impact will probably be higher. In this case the impacts will be clearly visible on the low flows, which are already very low in the region. If this happens the water availability during the summer, which is already critical, will become worse.

From the hydrological point of view it should be emphasized that planted forests should be avoided in riparian areas, and areas close to the wetlands or swamps. Due to the shallow soils of the basin, the impact of afforestation should be minimal if this recommendation is to be followed.

Water resources developments

The conclusions about the scenario analysis related to water resources development in the basin is that the use of water already has a large impact on the river Quaraí. The very low base flows of the main river and its tributaries very early motivated the local farmers to build reservoirs for individual use. The impact of the use of the water of these reservoirs seems to be relatively small; however the impact of the presence of the reservoirs is not negligible.

The most important impact related to water resources use in the Quaraí river basin is the direct withdrawals of the rivers, which are drying the river out sometimes. The model results confirm the presence of conflicts among different water users (farmers and public supply) and between the users of the two involved countries. Results of the water resources development scenario confirm outcomes of a prior analysis, which suggested that water is the most important limiting factor to rice growing activity in the basin.

Combined effects

Due to the high number of simulated scenarios, and due to the complexity of each scenario, no combined effects have been explicitly simulated. However, an assessment of combined effects can be preliminary made considering that:

- Climatic changes will probably lead to increases in stream flow.
- Land use changes will probably lead to decreases in stream flow.
- Water availability already limits agriculture in the region, and farm reservoirs are used to store water during the winter to use it during the summer.

If the effects would be combined it cannot be clearly stated what the outcomes would be, because the effects of land use and climatic change could counterbalance each other. Nevertheless the uncertainty in results of climatic change is high.

Vulnerability assessment

The people in the Quaraí river basin are exposed to changes in water availability and use. The region faces a situation where its most important economic activity - irrigated rice agriculture - is already limited by water availability. Any decrease in stream flow, especially during the summer months, will result in more frequent crop failures.

Considering that agriculture is the most important economic activity in the basin, the whole region is very sensitive to changes. Should climatic changes lead to lower stream flow availability, or should widespread changes from pastures to forests occur, possibly leading to reductions in base flows, than the local society will face a reduction in income.

In the case of land use change one could possibly consider that part of the reduction in income from agriculture will be counterbalanced by the earnings from forestry.

Farmers in the Quaraí river basin deal with frequent water shortages and droughts, and during the last decades they have learned to overcome this difficulties by storing water in small reservoirs distributed all over the basin, showing that they have the capacity to respond or handle the critical situations.

Conclusions

Scenarios of changes have been simulated for the Quaraí river basin. Changes of land use, climate and water resources use and reservation have been considered. The most important conclusions are summarized in the following paragraphs.

Results of the water resources development scenarios show that water is the most important limiting factor to rice growing activity in the basin. The sensibility of the Quaraí river stream flow to changes in temperature and precipitation was assessed, and compared to published analyses for other basins in the world. From this comparison it can be said that the Quaraí river basin is relatively less sensitive to climatic changes, and this is related to its high runoff coefficient.

The model runs with climatic change scenarios suggest that global warming will result in increases of stream flow in the Quaraí River. Low flows, however, will experiment only slight changes, if any. The results of the land use change scenarios confirm that afforestation with eucalyptus will reduce average stream flow. The extend of this impact will be relatively low if the forests are planted and managed in order to avoid access to shallow unconfined aquifers. In this case the impacts will be undistinguishable, due to the year to year variability and the uncertainty of discharge measurements. On the other hand, if the eucalyptus forests will be planted in areas of shallow groundwater, the impact will be clearly visible on the low flows, which are already very low in the region.

If the effects would be combined it cannot be clearly stated what the outcomes would be, because the effects of land use and climatic change could counterbalance each other. Nevertheless the uncertainty in results of climatic change is high.

Large uncertainties obviously exist in the analyses shown here. The largest uncertainties are probably present in the climatic change scenarios. Although most climatic models agree suggesting that the region's future climate will be moister and warmer, large differences exist between models and scenarios. Base flows can be reduced or increased in the future in response to the predicted climatic changes, depending on the relative impact of temperature increase, which has a negative impact of stream flow, and precipitation increase, which has a positive impact on stream flow.

Uncertainties are relatively lower in the land use change scenarios. At least in this case the direction of change is known: stream flow will decrease if forests will substitute pastures. However the amount of change is not known accurately.

Relatively lower uncertainties are present in the simulation of water management strategies, however some important questions remain vague, as is the case of the evapotranspiration in rice fields, and the return flows from those fields.

If land use changes would occur in the basin, with eucalyptus plantations partly replacing pastures, than a recommendation should be drawn from this study: access to groundwater by the trees should be avoided by planting the trees far from natural drains and wetlands.

CUAREIM - QUARAI (Uruguayan side)

The objective of this study is to contribute to the integral assessment of agro-climate risk in the current production system (individual reservoirs for rice and rain-fed grasslands) and of an alternative system (irrigation system at the basin level with two big reservoirs for rice and grasslands), considering the Tres Cruces basin as a study case, based on the analysis done by Crisci et al. (2007). It is also sought to estimate the value of water in the basin and to do a first approximation to the economic actors, determining who would be potential winners and losers if the alternative system were to be implemented.

Although the availability of water is already a limiting element in the production development the region, it is easy to prove that it is the result of insufficient storage capacity and not because of low water production.

The Tres Cruces basin has the following characteristics:

- (i) The area of the Tres Cruces basin is 1.466 km²
- (ii) The annual average rainfall is 1.400 mm
- (iii) The runoff coefficient can be estimated (in a conservative way) as 0,35

The average water production in the basin is therefore, approximately, 7,2 x 10^8 m^3, while the sum of all the existing reservoirs in the basin is 4,2 x 10^7 m^3, less than 10 % of average total water production. Although it is not recommended and even not possible to store all the water production, the basin is still far from depleting the resource.

That is why it is of interest to work with an expansion scenario of the storage capacity that is represented by the “alternative system”. This alternative system would approximately quadruplicate the storage capacity of the basin, increasing it to just above 20 % of total average water production estimated before. The alternative consists of two big reservoirs at the upper area of the basin (with much poorer and less expensive lands) and an ample gravity irrigation system that reaches an important area of the basin. It is interesting to examine the alternative system of multisite reservoirs as a future scenario, in particular because it will not develop spontaneously without a governmental policy and intervention, since the management of the water in the basin at the basin level is beyond the possibilities of private agents.

Climate change

The most vulnerable production sector is the livestock industry, since it depends almost entirely on precipitation for forage and drinking water. Summers show a climatologic deficit in the soil water balance, but droughts are becoming more severe and more frequent, generating social turbulence and claims to the central government. Irrigated crops, mostly rice and also sugar cane, are much less vulnerable to variability in precipitation because they depend on reservoirs and growers make annual decisions according to the available water.

Overall, water production in the basin is far from being the limiting factor, at least on the Uruguayan part. Shallow soils, steep slopes and relatively few reservoirs contribute to a large runoff. Under these circumstances, the most urgent need is to assess the vulnerability of current agricultural practices to climate variability and to analyze how better management of water resources (i.e. improved decision making, increased reservoir capacity) can generate a more resilient production system. In this context, climate change is extremely important, as it influences climate variability, and the basin does not suffer from a mean water deficit but rather from the complexity to deal with year to year variations. Climate scenarios were therefore synthesized reproducing relevant statistics from the past two decades to which the current production system is far too vulnerable.

Land use change

A scenario was constructed assuming that all the land with suitable soil characteristic for farming will change from livestock breeding into summer crops in the Tres Cruces basin. Fortunately, a detailed study to this point was readily available (Molfino et al., 2000). In this study, the work was only done with rice crops since it is by far the most extended in the region and also the most water intensive crop. Figure 94 shows current cover of rice fields and its potential to expand in a sub-basin of the Cuareim River.

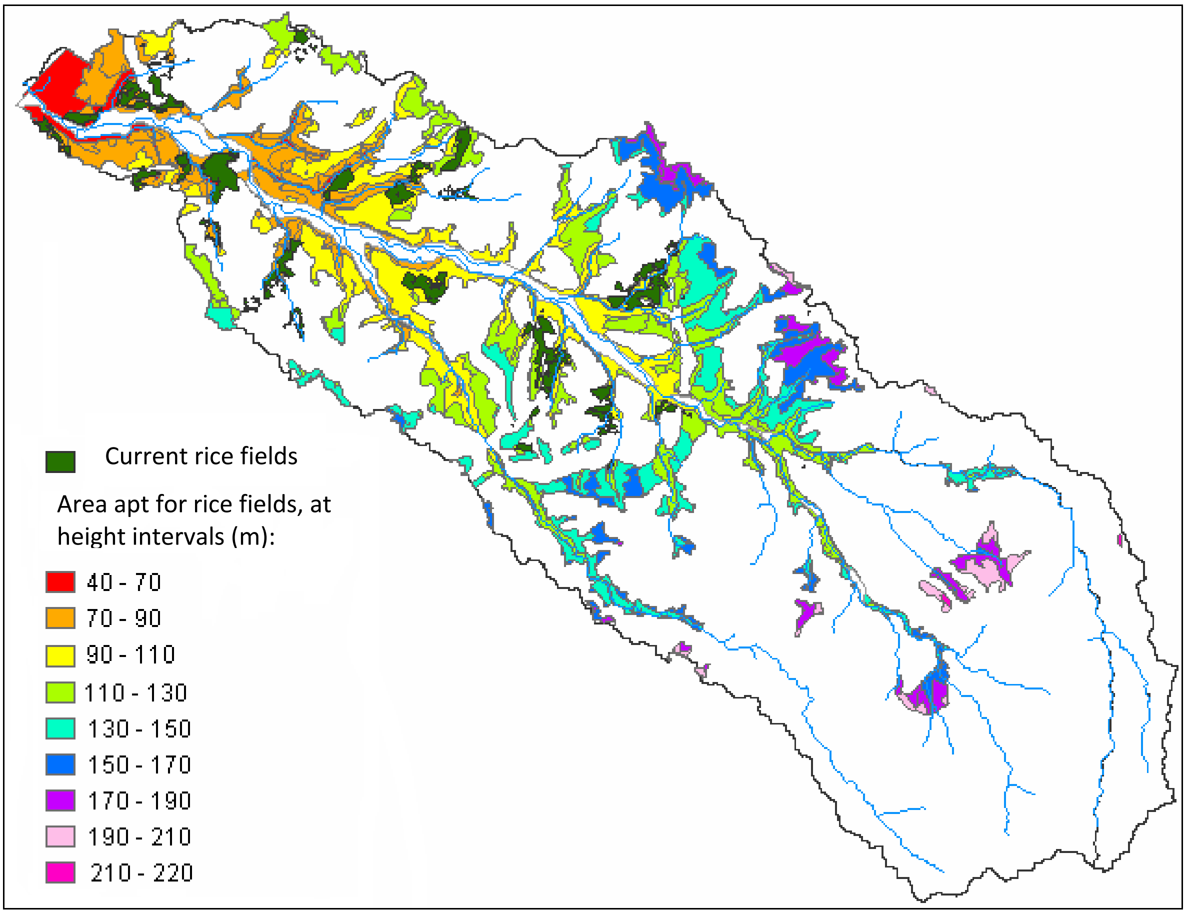


Figure 94. Current rice crops (dark green) and potential expansion in the Tres Cruces basin (classified by height intervals)

Changes in water demand

From the land use changes described in the previous section it can be inferred that water demand has increased and will most probably keep on growing. The water demand change scenario was constructed based on the land use change scenario and further assuming that the present rotation practice of 2 years of rice and 4 years of grassland remains unchanged. However, grasslands are assumed to be irrigated, which represents a major technological change from current practices. Even though irrigated grasslands are only starting to develop in Uruguay, market incentives and increased climate variability are steadily pressuring the sector in that direction, especially if we consider grasslands in rotation with rice crops where the irrigation infrastructure is already available. Irrigated pastures are critical to render the livestock industry in the region more resilient to climate variations. Water demands per hectare were fixed at 14.000 $m^3\ ha^{-1}\ yr^{-1}$ in the case of rice (current standard) and 3.000 $m^3\ ha^{-1}\ yr^{-1}$ for grasslands (based on expert judgment).

Water resources developments

The land use and water demand scenarios require an increase of irrigation capacity, which in the region can only be attained through the increase of water storage capacity in reservoirs. Currently, all reservoirs are privately owned and serve single farms, or at most a couple (***Figure***). They are usually quite close to the rice pads and therefore on the most valuable land with richer soils. If market forces and individual initiative is left on its own, the only possible outcome is the multiplication of small, individual dams on lowlands (the Brazilian part of the basin serves as an example, see report section and onwards). However this scenario is not optimal from a basin wide perspective. Therefore, an alternative development scenario was constructed, with much larger reservoirs in the upper part of the basin where the soil is shallow and unproductive and therefore less valuable. A careful analysis of water production and demand was performed for each sub-basin and the optimal locations of potential reservoirs were identified, so that they could serve the largest possible expansion area by gravity. Results of the water resources development scenario for Tres Cruces basin are shown in Figure 109.

Current system

All the information of the existing reservoirs in the Tres Cruces basin based on the information available at DNH was gathered: height of the reservoir, spillway level, and characteristics of the reservoir for 14 reservoirs that all together correspond to 42 10^6 m³ stored water. In Figure 95 the location of the 14 registered reservoirs in the Tres Cruces subbasin is precised.

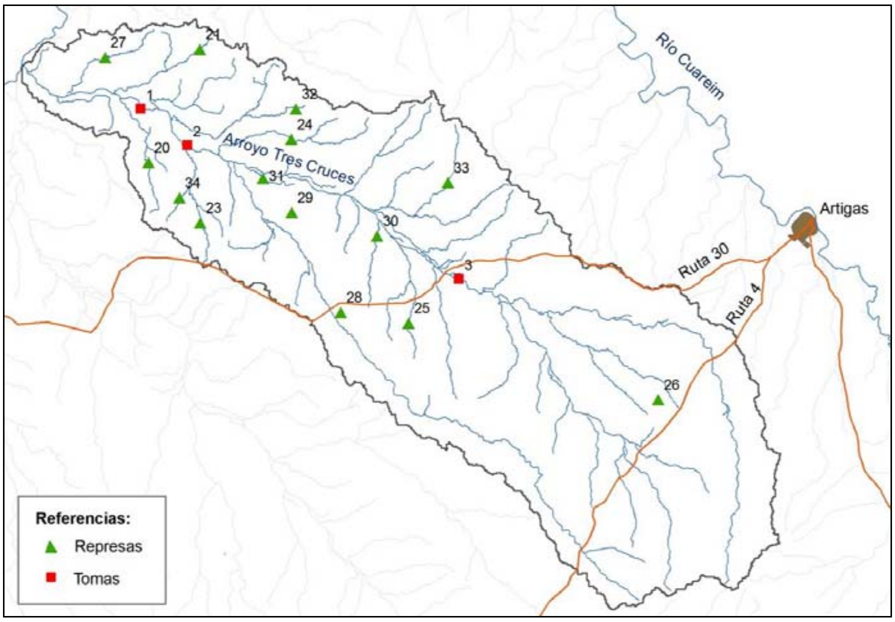


Figure 95. Location of the reservoirs and direct intakes in the Tres Cruces basin

In order to calculate the cost per ha, what will be done later on, it is necessary to estimate the volume of the body of the dams. Therefore, it is necessary to know the height, the length, the crest, and the slopes. The cost of the structure was also calculated.

Although the cost per ha was calculated, and criteria were used to maximize the net returns, these analyses are subject to the huge variations in prices (and relative prices) that have occurred recently. Therefore and when it is possible, the analyses that do not depend on prices are prioritized.

Alternative system

The motivation for constructing a scenario with two big reservoirs at the upper area of the basin to feed a multisite irrigation system (Figure 96) as an alternative system for the basin was explained in the introduction.

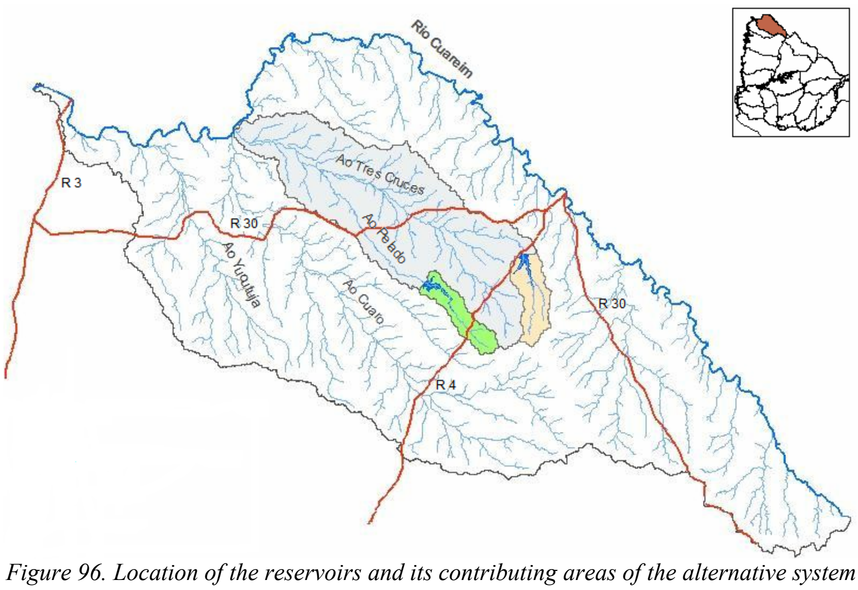


Figure 96. Location of the reservoirs and its contributing areas of the alternative system

Details on the climatic, hydrological, hydraulic aspects and of the structure that justifies the selection of those two reservoirs are described in Crisci et al. (2007). In this report, the key information is presented to visualize the system and to be able to do the calculations for risk assessment.

Table 51 Parameters of the projected reservoirs in the Tres Cruces basin

Name	Reservoir Area (ha)	V max (10^3 m³)	Dam Max height (m)	Crest width (m)	Largest Base (m)
TCch1	620	73,390	36.3	10.3	228
TCp4	651	62,090	36.8	10.4	231

In table 51 one can observe that the capacity of both reservoirs is higher (although of the same order) than the total current storage capacity in many small reservoirs in the Tres Cruces basin. The table also gives an idea of the size of the structures.

Scenario Impact Assessment

A first approximation to the value of water

The total net return for the whole system can be calculated summing up the net returns for all reservoirs. A weight factor proportionate to the size of the reservoir was used. The total net return is the net return of the whole system, whose total storage capacity was 42 10^6 m³.

Beyond the small net return differences obtained using the different criteria to select the area of rice to plant, a net return per m³ of water storing capacity can be computed. This calculation has to be done as a function of the capacity of the reservoir and not of the water that was effectively used, because this is the way how irrigation is hired, not mattering whether the water is or not used, because that depends on the climate during the irrigation season.

The net return per m³ of storing capacity is **0.025 US$ m^{-3}**

It is interesting to compare this value with the current price of water, that is hired generally by bags of rice, generally around 20.

Price of water = 20 bags ha^{-1} · P_{bag} / 14.000 m³ ha^{-1} = **0.012 US$ m^{-3}**

This analysis suggests that currently the water gets half of the net returns of the system, and the other half for the land is the other resource not mentioned yet. Nevertheless, the net return of the rice producers (that provide the planting services) and that of the mills are excluded in this calculation.

Summary

Current system

In Table 52 a summary of the results obtained for the different criteria to determine the area to plant (with or without information of seasonal climate forecast) and for the climate change scenario for the current total water storage system in the Tres Cruces Basin is presented.

Table 52. Parameter λ, percentage harvested area and percentage maximum net return for the different planting criteria under the current irrigation system

	λ	Average Harvested Area / Max area of rice	% Max Net Return
Ii: Stored water - evaporation	0	70.8%	70.7%
i: Stored water	-	82.2%	75.7%
iii: No failure	0.26	78.9%	78.3%
iv: Maximum net return	0.34	81.2%	79.2%
V: No failure with climate forecast	0.37	82.1%	81.2%
vi: Max. net return with climate forecast	0.39	83.1%	81.4%
iii: Climate Change	0.21	82.5%	81.9%

The different criteria have a different impact on the reservoirs (some of which have already been mentioned), mostly dependent on the relationship between the reservoir capacity and the size of the contributing area. This is not reflected in Table 52. In this section attention is paid in particular to the average effect on the system as a whole. These are the principal results:

- The option of not having any runoff during the irrigation season is too conservative and it is far from producing a maximum net return. The λ optimum values for the different criteria indicate a use of 26 % to 39 % of the rainfall.

- The criterion of growing rice as a function of the stored water at the end of October (somehow assuming the cancellation of the evaporation with the runoff during the irrigation season) is much closer to the best criterion, but it is not recommended either as it does not take into account the characteristics of each reservoir. Comparing it with (**i**), we see that in (**iii**) we have less harvested area but higher net return. This reflects that in (**i**) much more of the initially planted area was lost, which indicates that for many reservoirs (with worse relationship of contributing area to capacity) the criterion is excessively risky.

- Both with and without climate forecast, the criterion of maximum net return (where risk is taken growing areas somewhat bigger), gives marginally better results; the difference is more noticeable in the case without climate forecast.

- Both with the criterion of no failure and with the criterion of maximization of net return, the incorporation of the seasonal climate forecast based on the N3.4 index, improves the net return for all the reservoirs, with a global impact of a little more than 2 % increase in the net return.

- In the climate change scenario, the efficiency of the system slightly improves due to the small increase in the precipitation and, because of that, there is improvement in the relationship between water production in the contributing areas and the volume of the reservoirs, whose capacities were not changed.

Alternative system

Below the results of the historical balances of the basins and the reservoirs of the alternative system with the same methodology used previously is shown. Table 53 and Table 54 are results for the 2 large reservoirs TCch1 and TCp4 respectively and therefore comparable with Table 53 for many small reservoirs in the current system.

Table 53. Parameter λ, percentage harvested area and percentage maximum net return for the different planting criteria (reservoir TCch1)

TCch1	λ	Average harvested area / Max area of rice	% Max net return
Ii: Stored water - evaporation	0	87.2%	87.1%
i: Stored water	-	90.1%	89.6%
iii: No failure	0.2	91.4%	90.7%
iv: Maximum net return	0.2	91.4%	90.7%
V: No failure with climate forecast	0.2	91.7%	91.5%
vi: Max. net Return with climate forecast	0.3	93.5%	92.0%

Table 54 Parameter λ, percentage harvested area and percentage maximum net return for the different planting criteria (reservoir TCp4)

TCp4	λ	Average harvested area / Max area of rice	% Max Net Return
Ii: Stored water - evaporation	0	86.2%	86.2%
i: Stored water	-	89.7%	89.6%
iii: No failure	0.1	86.3%	88.5%
iv: Maximum net return	0.2	90.6%	89.9%
V: No failure with climate forecast	0.2	90.9%	90.7%
vi: Max. net Return with climate forecast	0.3	92.6%	91.3%

The values in TAble 53 and Table 54 are approximately 10 % higher than those in Table 52, which reflects a better relationship between the contributing basin and the reservoir capacity. This was taken into account in the design of the alternative system: to have a higher guarantee of water availability to promote the change in the production system to have grassland under irrigation.

Using the same costs and prices to plant and sell rice, the net return is **0.032 US$ m^{-3}** of water used. In the current system with an average efficiency of 79 % it is 0.025 US$ m^{-3} of reservoir capacity. The alternative system with two large reservoirs has an average effectiveness of 90 % and a water yield of **0,029 US$ m^{-3}** of reservoir capacity, due to its greater efficiency.

In relation to vulnerability assessment, today's livestock industry's high risk as a result of climate variability is eliminated in the alternative production system, with both rice and grasslands under irrigation. It is also verified that water production in the basin, the storage capacity, and the difference in levels for the conduction of water under gravity are enough to eliminate the climate risk of the system.

CEH-W

Water balance in South America

In order to understand the complex spatial and temporal relationship between water supply and water demand an integrated modelling approach has been applied to the mainland South American continent. The Global Water Availability Assessment (GWAVA) model (Meigh et al., 1998) enables a consistent modelling approach to be applied across the South American continent using continuous datasets and a consistent methodology. This approach has the advantage of being able to explore the wider spatial patterns of climate change that affect the partner basins.

Scenario Creation and Impact Assessment

Climate change

The Fourth Assessment Report on Climate Change (IPCC, 2007) examined results from 24 different Global Circulation Models (GCMs) and four standard emissions scenarios. The range in global warming by the models under these four scenarios shows that the choice of SRES scenario has an increasing influence on global surface warming towards the later half of the 21st century (Figure 97).

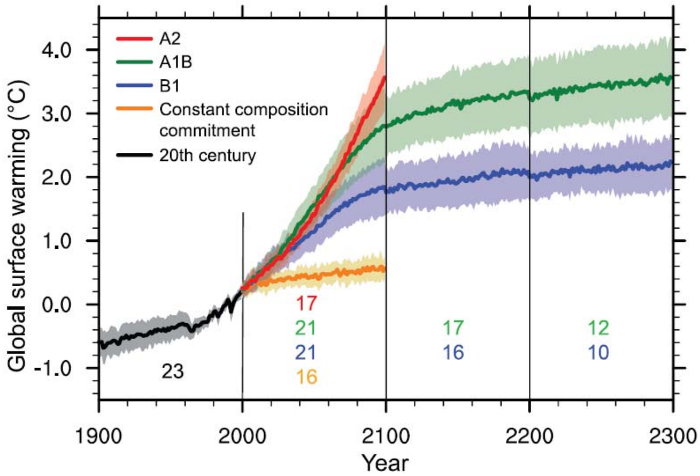


Figure 97. Summary plot of the global rise in surface temperatures for the three SRES scenarios. Source: Meehl et al. (2007)

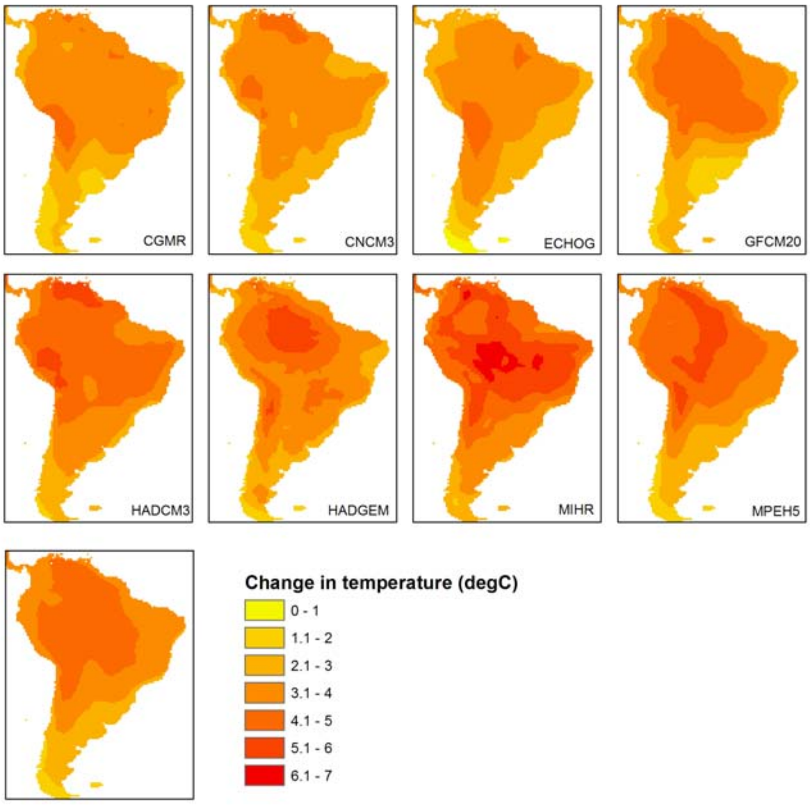


Figure 98. Absolute change in annual air temperature for eight GCMs (A1B scenario) and mean change of the eight models (bottom left)

Changes in mean annual temperature (Figure 98) and precipitation (Figure 99) are plotted for eight GCMS for 2080 and the SRES scenario A1B, to illustrate the variation between models. The pattern of warming is broadly consistent between models with greater warming predicted over the Amazon. The models CNCM3 and ECHOG3 show the least amount of warming annually over the continent, and MIHR the greatest. In contrast, for precipitation, there is little agreement even in the sign of the changes for the Amazon, north-east Brazil and southern Brazil/northern Argentina and northern pacific countries e.g. Columbia, Ecuador and Peru. There is some degree of agreement for a large part of Chile and Patagonia where all models show a decrease in precipitation and for the southernmost reaches of South America which shows an increase in precipitation by 2080. Assuming the model can be given equal weighting the model means indicate little change in annual precipitation over the Amazon but significant decreases in Chile, Argentina and Venezuela.

Precipitation estimates produced by GCMs are still too unreliable to be input directly into a hydrological model. However it is possible to examine the changes in precipitation and compare the models and scenarios accordingly. To this end, a control run and future run are required for each GCM from which to calculate the change. The GWAVA model is set up to take input in the form of percentage changes in the mean monthly precipitation, potential evaporation and absolute change in temperature. These changes are applied to the observed means and a time series reconstructed using the observed anomalies. Sub-monthly data are not readily available so the number of raindays is unchanged from the baseline.

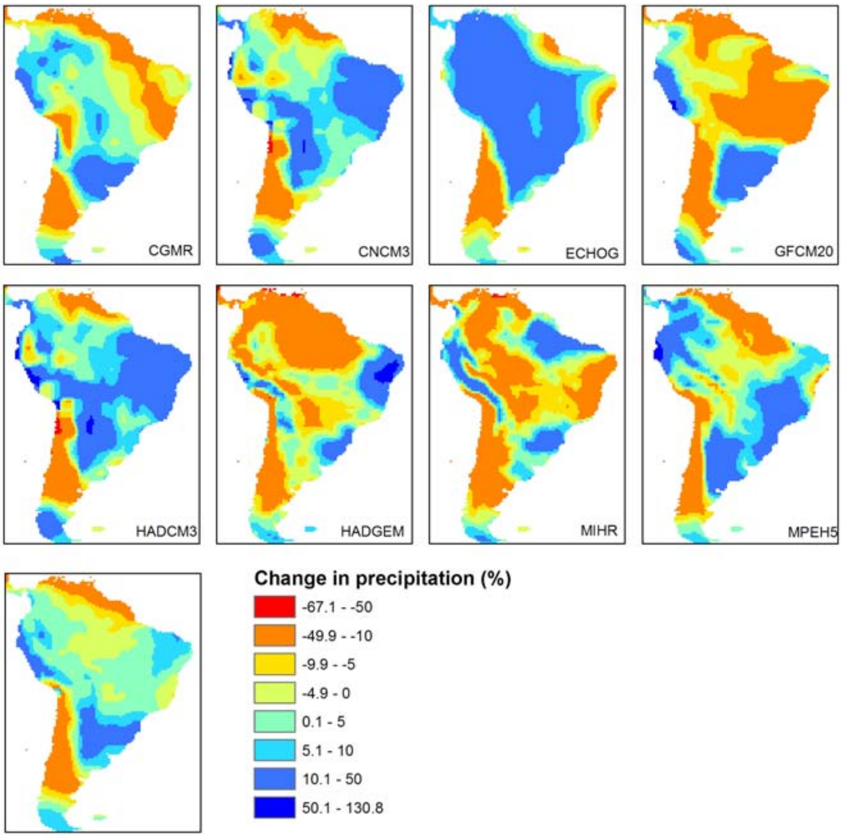


Figure 99. Patterns of change in annual precipitation by 2080 for eight GCMs. Blue colours indicate an increase in precipitation, the bottom left figure represents the mean change of the eight models

It was initially hoped that the data from MAGICC/SCENGEN v 4.1(Hulme et al., 2000) could be used for input into GWAVA in common with the TWINLATIN partners, however this method has a main disadvantages in that :

- they provide data only at 5 degrees which requires greater downscaling than many of the available GCM outputs

Climate change scenarios have therefore been examined using the results from the more recent set of experiments performed for the IPCC Fourth Assessment report. There are a great many combinations of models and scenarios that could be considered. However the aim of this analysis is to examine as broad a range within a sensible timeframe. The scenarios/models for which summary control and future precipitation and temperature data are available from the IPCC are summarised by model in the Table 55.

Table 55. Summary of GCM modelling group/model name and resolution for the eight models examined

Institute(s)/Model Name	Model Acronym	Model resolution*	Scenarios
Canadian Centre for Climate Modelling and Analysis (CCCMA), Canada / CGCM3	**CGMR**	~2.8° x 2.8°	**A1B**
Météo-France/ Centre National de Recherches Météorologiques, (CNRM) France /CM3	**CNCM3**	~1.9° x 1.9°	**A1B**,A2
Meteorological Institute of the University of Bonn, Meteorological Research Institute of the Korea Meteorological Administration (KMA), and Model and Data Group, Germany/Korea ECHO-G	**ECHOG3**	~3.9° x 3.9°	**A1B**,A2
U.S. Department of Commerce/National Oceanic and Atmospheric Administration (NOAA)/Geophysical Fluid Dynamics Laboratory (GFDL), USA /CM2.0	**GFCM20**	2.0° x 2.5°	**A1B**, A2
Hadley Centre for Climate Prediction and Research/Met Office, UK HADCM3	**HADCM3**	2.5° x 3.75°	B1,**A1B**,A2
Hadley Centre for Climate Prediction and Research/Met Office, UK / HADGEM	**HADGEM**	~1.3° x 1.9°	**A1B**
Center for Climate System Research CCSR (University of Tokyo), National Institute for Environmental Studies NIES, and Frontier Research Center for Global Change FRCGC (JAMSTEC),Japan / MIROC3.2_HI	**MIHR**	~1.1° x 1.1°	B1,**A1B**,A2
Max Planck Institute for Meteorology(MPI),Germany /ECHAM5	**MPEH5**	~1.9° x 1.9°	**A1B**,A2

* Model resolution refers to the GCM atmospheric resolution and is that from which the climatological parameters such as precipitation and air temperature are interpolated.

Data processing

Climate change data were obtained from the IPCC data distribution website (www.ipcc-ddc.org) for all model/scenarios for the control period, 2010-2039, 2040–2069 and 2079–2099 thirty year averages. The data for each model scenario were interpolated to a 0.5 degree grid using the program Xconv (available from British Atmospheric Data Centre (BADC)) which also enables the Netcdf file format to be viewed.

The three sets of experiments were carried out to understand the likely trend in changes that will affect South America. These involved running GWAVA with the changes in precipitation, potential evaporation and temperature with baseline demands isolating the climate impact. The impacts are considered in terms of changes to average flows, an index low flow and also in terms of the Water Availability Index Type 4.

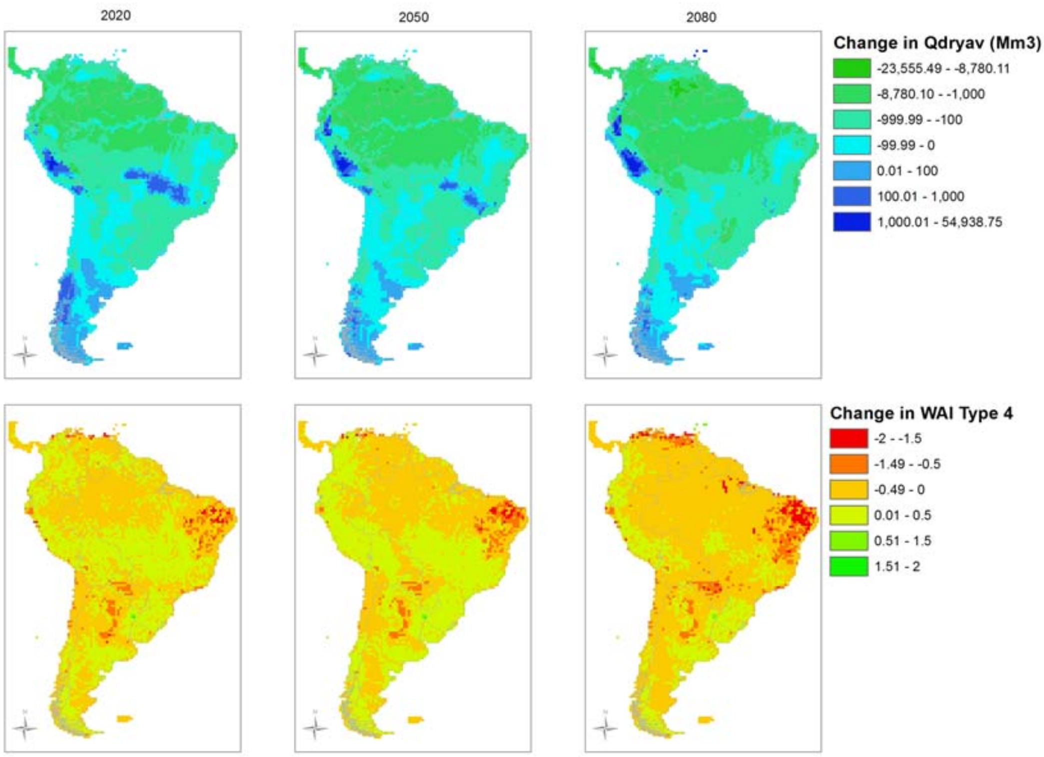


Figure 100. Changes in the low flow index (above) and WAI 4 (below) for 2020, 2050 and 2080.

Comparison of the HADCM3 A1B future climates for 2020, 2050 and 2080 with the 1961–1990 baseline show increases in the average continental temperatures of 1.36 ºC, 2.72 ºC and 4.22 ºC, respectively, and very modest increases in precipitation of 1.44%, 3.13% and 3.57%, respectively, yet impacts on the index low flow volumes are greatly affected with respective decreases of 21%, 34% and 54%. These dramatic reductions are due in part to the reduction in winter precipitation and to increasing temperatures and soil moisture deficits in the summer months. The plots in Figure 115 show the distribution of changes in the low flow index (Qdryav) with dark blues indicating an increase in flows and greens a decrease. The plots of changes in Figure 115 show the change water availability index from the baseline with orange and reds indicating a reduction in the Type 4 index i.e. moving towards or becoming increasingly water stressed, whereas greens indicate cells becoming less water stressed. The total number of cells experiencing insufficient water to meet demand are summarised in Figure 101. In terms of the Type 4 index there are a larger number of cells more severely affected between 2050 and 2080 than for the first half of the 21st century although the average Type 4 index of all cells in a water scarce situation is largely unchanged. The cells most affected are located in the northern Venezuela, north east Brazil, Paraguay and northern Argentina.

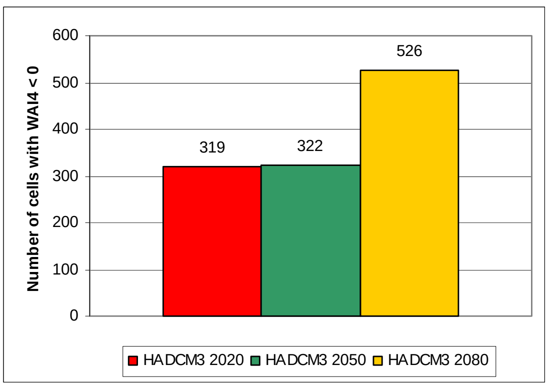


Figure 101. Summary plot of the number of cells experiencing water stress under one GCM (HADCM3) for three timeslices: 2020, 2050 and 2080.

To understand how much the above results are affected by the choice of model statistics focussing on water resources for eight GCMs for the year 2080 and the A1B emissions scenario are compared to the baseline values in Table 56. The value of mean flow represents the annual average flow as an average of all cells and shows a wide degree variation between models with the model ECHOG actually showing an increase in both the mean annual flow and the low flow index. The index low flow show a similar level of change again with the ECHOG model showing increases while HADGEM shows the largest decline. Figure 102 shows how this translates to the number of cells that are water stressed and shows that the HADCM3 and MIHR models yield the most water stressed cells and, despite increases in annual flows the ECHOG model indicates an increase in the number of water stressed cells.

In terms of the Type 4 index all models show a worsening situation by 2080. In a comparison of the three emissions scenarios using the Type 4 index, although the A2 scenario leads to greater warming and lower mean flows, the index indicates a slightly larger area being affected by deficits in water supply for the A1B scenario.

Table 56. Comparison of flow statistics and water availability indices for eight climate scenarios in 2080

GCM	Mean annual flow (Mm^3)	Qdryav (Mm^3)
Baseline	62529	2784
CGMR	44355	2224
CNCM3	43766	2141
ECHOG	62643	3158
GFCM20	37656	1629
HADCM3	26494	1266
HADGEM	19912	1028
MIHR	32160	1712
MPEH5	41399	1859

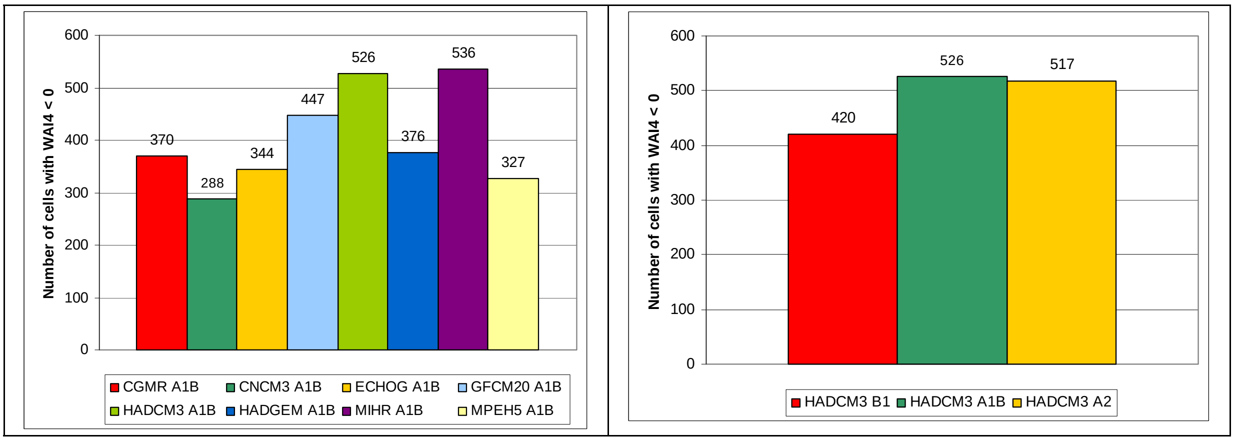


Figure 102. Summary plots comparing the number of cells in a water stressed state for eight GCMS (left) and the three SRES scenarios (right).

Land use change

Although land use changes were examined by some of the partner groups, the level of detail was greater than could be adequately represented within the 0.5 degree resolution of this model.

Changes in water demands

The water demand scenarios considered under human development relate to the water demand from the domestic sector encompassing water for drinking, subsistence farming, municipal services such as hospitals, etc. The rising trend in domestic water demand is driven upwards, primarily by the increasing population exerting a larger demand for drinking water, as well as, increasing standards of living, particularly in growing economies where there are improvements in access to reliable water supply and ownership of devices such as washing machines. Trends of increasing per capita water consumption with growing economic activity as indicated by economic measures such as Gross Domestic Product (GDP) are well known. Migration of populations from rural to urban dwellings also contributes to increases in water demand in cities.

This scenario does not include other indirect impacts such as increased irrigation to provide food for growing populations.

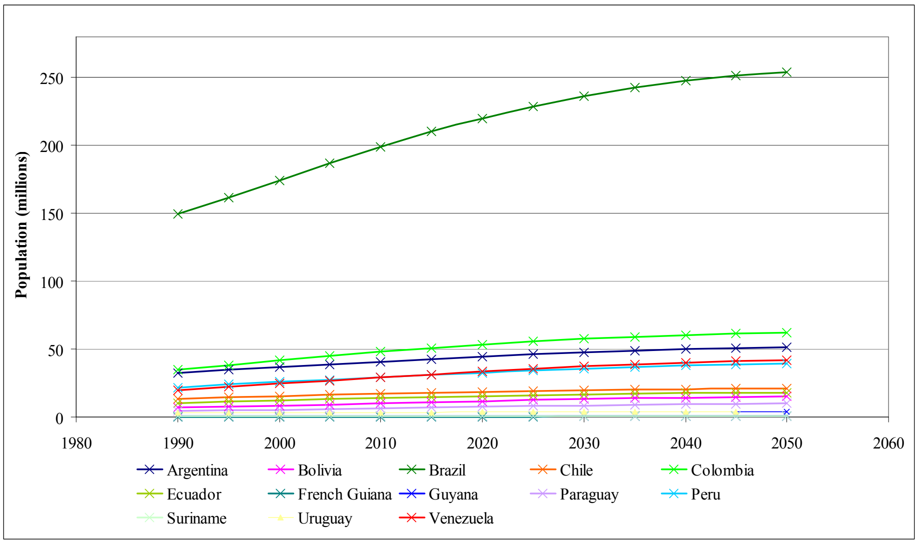


Figure 103. Population projections (medium variant) for South American nations to the year 2050

Human populations are, in general, expected to continue rising with growth rates plateauing towards the latter half of the 21st century (UN, 2004). The UN World Population Projections (WPP) (UN, 2006) produce low, medium and high variant estimates of future populations for each country based on modelling fertility, birth and death rates. Projected population (medium variant) for South American countries up to 2050 (Figure 103) indicate a steady increase. The estimated total population for South America is 523 million for 2050.

Method

The changes in population were mapped using the 1990 spatial distribution of population derived from the Gridded Population of the World (CIESIN et al., 2005) dataset and an urban fraction derived from the Global Rural-Urban Mapping Project (GRUMP) (CIESIN et al., 2004). The future population scenarios were applied as percentage changes from 1990 values at the data resolution of 0.083333 degrees for urban populations and rural population applied to the remaining pixels before being upscaled to 0.5 degrees.

There are few very accurate data on per capita water use either for the baseline or for future projections or urban or rural populations. More easily obtainable are estimates of per capita water resource availability which are simply an estimate of the total freshwater resources divided by the country's population. However this is a rather different quantity that does not reflect the water people actually consume or take account of network losses and returns. An estimate applied in an earlier study in Southern Africa (Meigh et al., 1998) and given by the World Health Organisation as a minimum water requirement for human consumption of 23 l/capita/day (but rounded to 25 l/capita/day) is used as a baseline value for rural populations. This value is likely to be lower than that actually used in many parts of South America particularly as access to water (90% of the population) is significantly higher than that in Sub-Saharan Africa (56% of total population) (WHO and UNICEF, 2006). However, the inability to meet this minimum requirement indicates a genuine water scarcity. The future estimates used here are best estimates as provided in the methodology by Meigh et al. (1998) and it is therefore assumed that per capita consumption across Latin America will continue to grow. The values shown in Table 57 are applied to all countries.

Table 57. Values of per capita water use estimated for baseline and two future scenarios

	Rural (l/capita/day)	**Urban (l/capita/day)**	**Special/Large Urban (l/capita/day)**
1990	25.0	50.	140.
2020	50.0	140.	160.
2050	50.0	140.	160.

The plots (Figure 104) of the Type 4 index highlight the cells facing increasing water stress for 2020 and 2050. As for the baseline the cell experiencing water stress fall into two distinct clusters: one in north-east Brazil and the other in Southern Argentina with some smaller areas in Paraguay. It is quite difficult to distinguish major differences between the two plots in terms of the scale of the deficits as indicated by the Type 4 index. There is a significant increase in the number of cells experiencing a deficit from the baseline, 152 compared with 204 and 215 for 2020 and 2050 respectively, which can be attributed to the much larger increases in urban water demand which are fairly localised compared with the more extensive rural water demands.

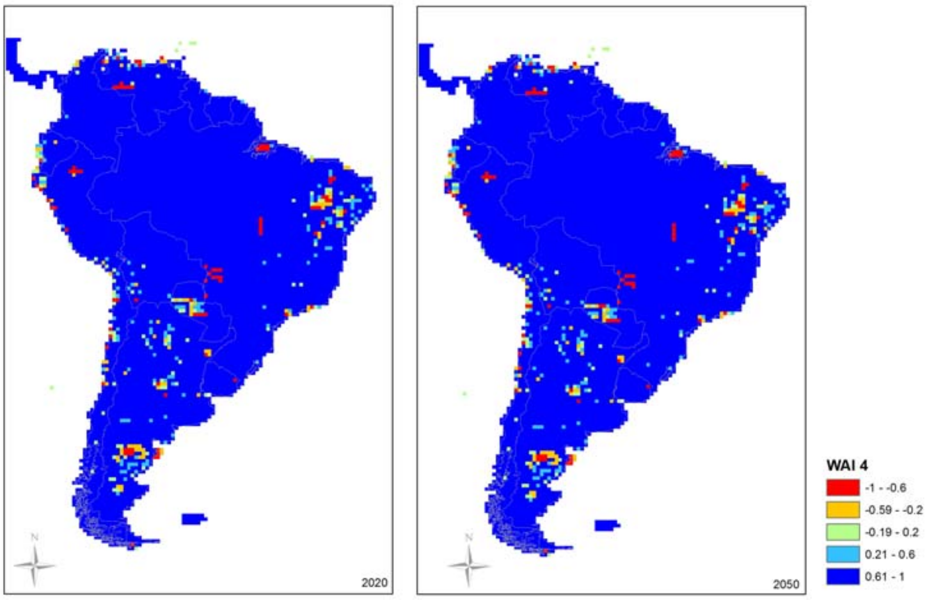


Figure 104. Mapping the Type 4 Water availability index for South America for two water demand scenarios of popluation growth for the years a) 2020 and b) 2050

Combined effects

The climate change scenarios do of course have implied assumptions about the future global populations and in this section the effects of a combination of climate change and growing demand for water due to population growth are considered. Three combined scenarios have been examined to provide 'realistic' snapshots of water availability for the years 2020, 2050 and 2080 as set out in Table 58. As medium variant population estimates show a levelling off of population growth after 2050, the 2050s population grids have used for the 2080 simulation.

Table 58. Summary of the three combined scenarios performed and the driving data for each

Scenario	Human Development	Climate change
Combined 2020	2020 population (medium variant)	HADCM3 A1B – 2020
Combined 2050	2050 population (medium variant)	HADCM3 A1B - 2050
Combined 2080	2050 population (medium variant)	HADCM3 A1B – 2080

The results of these three scenarios are shown as maps of the Type 4 index (figure 105) with blue areas indicating supply meets demand at all times whereas orange and red cells are those whose water supply fails to meet demands. It is very clear from the maps that there is an intensification of deficits in cells experiencing water stress moving from 2020 to 2050 as well as an extension of the area that is affected in particular by 2080. It is very clear from Figure 106 that the combined effect is much greater than for either climate or demand changes alone.

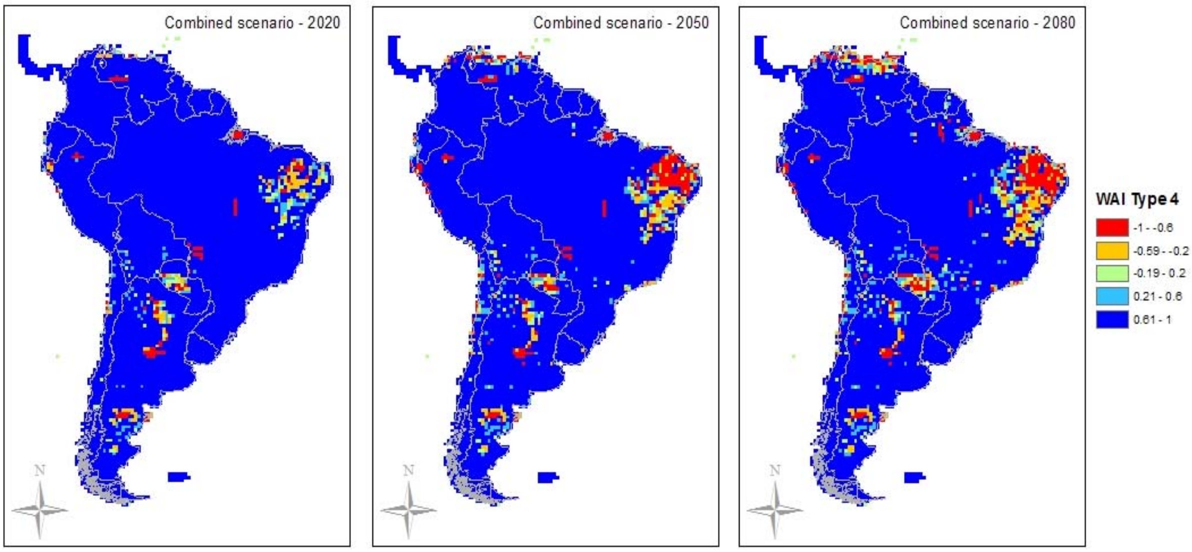


Figure 105. Plots of the Type 4 index for South America for the three combined scenarios

The combination of climate change and increasing water demands due to population growth and development show very clearly the worsening situation that both effects will have, with a higher number of cells, 371 compared to 319 under climate change alone, by 2020 are water stressed.

Vulnerability assessment

The key model outputs from GWAVA can be used to inform water planners and policy makers of the potential scale of water deficits or surpluses and areas of concerns. In addition, time series of flows can be examined for particular river basins or, in the case of this study, particular flow statistics may be mapped both for the baseline and the future. However, issues such as sensitivity to change and vulnerability cannot be addressed directly by modelling alone but require alternate approaches such as the Climate Vulnerability Index (CVI) (Sullivan and Meigh, 2005; Meigh et al., 2005) which considers socio-economic factors such as access to, and effective management of, water, as well as physical factors such as availability of resource and climate. The GWAVA model may be used to examine the effect of some mitigating strategies such as improvement to irrigation efficiency and can help stakeholders, planners and managers understand more fully the consequence of certain changes be they in the climate or to the demands.

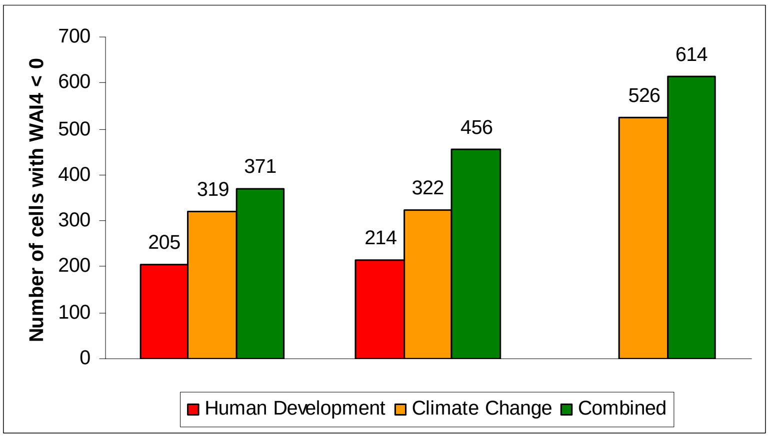


Figure 106. Summary plot comparing the number of cells experiencing deficits for single and combined scenarios

In a simplistic approach it is possible to use to results from GWAVA to determine, for example, some measure of vulnerability on a broad scale by expressing the impacts rather than as a water stress index but in terms of total populations or total irrigated land experiencing water deficits across South America region. An example is given in Table 59 in which populations are summed across all the cells which are classed as water stressed according to the Type 4 index.

Table 59. Comparison of the WAI4 Index and the total population at risk of water deficits

Scenario	Number of cells with a Type 4 index < 0	Total population (millions)
Baseline	157	1.8
2020 combined	371	10.0
2050 combined	456	72.1
2080 combined	614	88.8

In Table 59 the total populations deemed to be vulnerable are compared for the baseline and the three combined scenarios and highlight a dramatic increase in the numbers of people at risk by 2050 as highly populated areas experience deficits.

Summary

A macro-scale hydrological model, GWAVA has been applied to mainland South America encompassing four TWINLATIN basins: Baker, Catamayo-Chira, Cauca and Cuareim/Quaraí, three of which are transboundary basins. The model was calibrated against observed streamflow data and replicated flows for much of the continent, the main exceptions are the very small catchments on the Pacific side of the Andes for which the grid resolution was too coarse to extract single basins and for which there are generally insufficient observed data against which to compare the model.

The model was run for a baseline period of 1961 to 1990 against which all scenarios are compared. The changes have been examined in terms of changes to the index low flow and the water availability indices, in particular the Type 4 index. Under baseline conditions 152 cells experience water deficits i.e. are water stressed appearing in two main regions: north east Brazil and southern Argentina.

Scenarios are a useful tool in understanding the possible outcomes of change and in the context of this study enables consideration of the effects of climate change combined with water demand changes. Scenarios are essentially a means to examine the response of a system to 'natural' patterns of change rather than simple sensitivity tests and there are, of course, numerous uncertainties associated with these types of scenarios which are discussed below. These scenarios therefore provide indications of response that may be experienced and should not be taken as absolute predictors of change.

Climate change scenarios have been examined through the use of information derived from the outputs of Global Circulation Models, applying changes in mean monthly temperature, precipitation and potential evaporation to baseline means. The climate scenarios in general show increased annual warming and hence potential evaporation across South America and all models indicate small increases in annual precipitation. The pattern of change in precipitation is particularly mixed around approximately the line of 30 degrees latitude however, precipitation is likely to decrease in Venezuela, and Chile, whilst there may be modest increases in the southern parts of South America.

Scenarios of increasing water demand due to population growth have also been considered. Changes to human populations are more certain in terms of patterns and direction of change, but exact future water demand estimates are still imprecise. Much of the increase in population and therefore water demand will occur in existing urbanised areas and the effects of water shortages are therefore very localised, with relatively few additional cells moving into water stressed states. Examination of the populations in cells that are classed as water stressed in some ways confirms this results and reveals the vulnerability of large conurbations to climate change.

One important conclusion is the need to take the effects of climate change in combination with demand changes and, crucially, that these should take account of the seasonal changes which impact on both the supply of water and the water demand. The results of the combined scenarios show that areas most at risk are Venezuela, north east Brazil, much of Paraguay and two regions in Argentina.

Uncertainties in the water availability estimates arise from both estimation of the hydrological cycle and the water demand itself. Another approach is to think broadly of uncertainties in data, model structure or the processes represented by the model. Data uncertainties arise from not knowing the true value of the water demands per cell for every month of the simulation. To reduce these uncertainties data from as many sources as possible are used to validate model inputs however some errors will remain. Model uncertainties arise from the ability of the model to capture to processes being modelled. In examining climate change scenarios uncertainties in the hydrological model are compounded by the uncertainties and approximations made associated with the GCMs themselves. It is clear that are considerable uncertainties in the predicted future climates, with models showing both positive and negative trends in future rainfall patterns across South America. Finally there are uncertainties introduced by use of a simplistic method used to examine climate change and which very likely leads to an underestimation as to the true variability of the future climate and this in turn would lead to an underestimate of the extreme events of droughts and floods. Unfortunately this last point is one that is still to be addressed by the improvement of rainfall generating processes in climate models; downscaling techniques such as the use of regional climate have shown some promise but there are currently no simulations that cover the whole South American continent.

Recommendations for the future include representation of groundwater sources to provide a fuller picture of water use and water stress particularly in southern Brazil and Argentina. It is also important to understand impacts not only on human beings but on environmental impacts and such a model may also be used identify area at risk e.g. from a reduction in environmental flows. In order to more accurately examine impacts of climate change a new method to understand and incorporate changes in variability is required which would in turn lead to better estimates of future extremes and assessment of water resources.

3.9 WP9 Optimal actions and their Socio-Economic impact

- To transfer and adapt means for analysis of the economy of water use and cost recovery for water services to the Latin American basins, and to provide this analysis for the five river basins.
- To provide means for and conduct selection of combinations of mitigative actions addressing the major flooding/drought and water quality problems in the Latin American basins based on physical/chemical efficiency in the water bodies and socio-economic impact. This includes development of a baseline economic scenario and identification of gaps between this scenario and scenarios in which combinations of actions have been implemented.
- To expand the knowledge on the effect of abatement actions in the ecosystems, and to further develop the scientifically based information set on costs and cost-efficiency for different types of actions produced in other projects.

Main approaches in the river basins.

The main concerns in the river basins are connected to resolving problems connected to water quantity and providing people and agriculture with access to water. This has also in large part been the focus of the reports. The structure proposed which has as goal to reach a full program of cost-efficient measures has therefore not been completed in all the river basins. Nevertheless, most of the river basins have been able to follow structure of the European WFD, which is the steps prior to cost-efficieny analysis; economic analysis of water uses, cost-recovery and baseline scenarios. The different approaches are summarized in Table 60 and described below in more detail.

Table 60. Economic approaches used in WP9

River basin	Problem/ Objective	Approach
Catamayo-Chira	Reduce potential risks on quantity and quality of hydrological resources.	Baseline scenario 2020 on water demand. Action program.
Cocibolca	Poor access to water.	Calculation of demand and supply of water. Valorization of water.
Cauca	Satisfy future water demand	Cost/benefit calculation of construction of dam / use of aquifer.
Rio Baker	Valorization of loss of landscape in Rio Baker	Willingness to pay study.
Cuareim-Quarai	Access to water for irrigation and treatment of waste water.	Costs and social effects on different actions to meet future water demand and waste water.

The focus of the study in the Baker follows a different path than what is suggested in the WFD. This is due to the problem approach in the basin. The discussions are not based on quantity or quality of water but rather on the possible construction of a hydroelectric plant. After several discussions at the introductive workshop it was decided that an interesting focus of the report would rather be a cost-benefit analysis including an economic valuation of the loss of landscape as a consequence of the construction of the plant. Therefore, a contingent valuation study was conducted in a number of municipalities estimating how much people were willing to pay to preserve the landscape.

The Catamayo-Chira river basin has during the last years experienced a growing demand for irrigation and drinking water and simultaneously a deterioration in the quantity and quality. This is mainly due to an increase in population and agricultural areas as well as other economic activities. The Catamayo-Chira report follows the proposed methdology and starts with a detailed economic analysis of the water uses and the development of different drivers until the year 2020. Further, the study includes an analysis of the cost-recovery of water services and finalizes with an ambitious action program. However, costs or cost-efficiency for these actions have not been possible to calculate.

In the Cauca river basin in Colombia the use of water is of vital importance for the agriculture, and especially the sugar cane crops which is the main activity in the basin. There are also important industries which obtain their water from the Cauca and its tributaries or from underground water. The Upper Cauca Basin is enormous and information is scarce why a pilot basin was chosen for the WP 9 where social, environmental and economic information has been available. The focus of the study is to analyse the impact from optimization of surface and underground water and includes a cost-benefit analysis.

In the Cocibolca Lake basin there are approximately 50% of the households that don't have access to drinking water. The report includes an economic analysis of water uses, cost-recovery analysis and a base-line scenario. Due to insufficient information on current contamination and potential impacts from the implementation of measures, the cost-efficiency analysis has not been possible to do. Rather, the focus on this study has been on the scarcity of drinking and irrigation water and an attempt to find an equilibrium charge for irrigation water.

In the river basin Cuareim / Quarai the most relevant water-intensive economic activity is rice production. There is very scarce information about water quality but according to TWINLATIN Work package 2 it is relatively good at the Cuareim river basin. In the Cuareim river basin in Uruguay the report has therefore focused on finding measures to take care of the provision of sanitation and the need to seek for alternative sources for drinking water. The report includes an economic analysis of water uses and cost-recovery of the current services. There is a discussion of different alternatives to provide for safe drinking water and one of these alternatives are analysed in more detail with a cost-benefit study.

In the Quarai river basin there has been a rather strong focus on stakeholder involvement. The baseline study was eveolved together with the stakehodlers in the basin as well as the future impacts from econoic growth and development and its socio-econoic impacts.

Different action programs are discussed in the report to solve the problems related to water quanituty as well as water quality. The costs of these actions were calculated and an analysis of their respective socio-economic impact was discussed. Based on these costs and impacts-the optimal actions were chosen and discussed in the river basin meetings with stakeholders. Another important aspect in Quarai river basin is that the agriculturers today only pay for the service of distribution of water, they do not pay for the quantity of water used. Therefore a contingent valuation study was done to find a price which the users would be willing to pay for the water used.

Proposed actions have for example been connected to municipal services, construction of dams, change of cultivation patterns, improvement of agricultural technology etc. Further in the Baker river basin, the water problem has neither been water quantity nor quality but the possible use of the river basin to produce energy with a hydroelectric dam. Here the focus was on estimating the economic value of the loss of landscapes.

In the table 61 a summary of the different tools addressed in the Water Framework are summarized and information given on which of these that have been used in each river basin.

Table 61. Economic tools used in WP9

River basin	Econ. analysis of water use	Baseline scenario	Cost-efficiency	Cost-benefit	Cost-recovery	Socio-econ. impacts
Catamayo-Chira	x	x	-		x	-
Rio Baker	x	-	-	x	-	-
Cuareim/ Quarai	x	x	x	x	x	x
Upper Cauca	x	x	(x)	x	(x)	x
Lago Cocibolca	x	x			x	-

There is no river basin that completed a full program of cost-efficient actions and its socio-economic impact analysis and the reasons are mainly as mentioned problems to find detailed data on costs and effects on each action and that the problems have been more directed to water quantity.

The structure of the final report has continuously been discussed and developed together with IPH. The preliminary results of the economic work were presented at the final TWINLATIN meeting held in Rio de Janeiro in November 2008. After the presentation, a discussion followed concerning specific difficulties experienced in implementing the economic analysis in each river basin.

BAKER

Economic Analysis of the Watershed

The relationship between the environment and economic activity can be established by the existence of environmental services that are used to generate economic value[5]. In this sense, and according to the AGIES 2008 study, the following users of the watershed were identified: industry, mining, tourism, livestock and agriculture, forestry, and hydroelectric generation. Table 62 presents the users of the water and its respective environmental services.

Table 62. Users of the Water and its Associated Environmental Services

Industry	Regulation	Use of the hydric component for productive processes; dilution of industrial wastes
Mining	Regulation	Use of the hydric component for productive processes; dilution of industrial wastes
Tourism	Habitat	Use of the hydric component for recreation, landscape value, etc.
Livestock and Agriculture	Regulation	Consumption of water by animals, irrigation, and dilution of fertilizers
Forestry	Production, Regulation	Growth capacity for forestry species, soil fertility, erosion control, and water quality maintenance
Hydroelectric Generation	Regulation	Fresh water from glacial melting contributes to maintaining flow

Source: AGIES, 2008.

Dams

The eventual development of hydroelectric projects in the area includes the construction of two dams on the Baker River and three on the Pascua River. The total estimated surface of their reservoirs is 5,910 ha. These installations are intended to take advantage of the hydrological stability of the Baker River through the use of non-consumptive water rights.

One of the objectives of the TWINLATIN project is to generate relevant information for decision-making in sectors with scarce or non-existent information. Because there is a range of information available on mining, industry, agriculture, forestry, and tourism, this project deals with hydroelectric generation, one of the main users of the water resource. Information on this sector is scant or completely lacking.

Theoretically, the use of the cost-benefit criterion to guide both public and private investment decisions is very well documented. The main point of the theory – that all costs and benefits associated with a project

[5] The concept of environmental services comes from the economic theory of externalities; in this context, environmental services are positive externalities that the environment generates over certain productive activities.

be considered – presents measurement problems due to the existence of intangible costs and benefits. This situation is especially delicate when performing environmental evaluations of investment projects.

In an attempt to perform an integrated cost-benefit analysis, this study proposes approximating the value of the environmental cost of lost landscape implied by the construction of the HIDROAYSEN hydroelectric complex. The methodological approach used for this relies on the contingent valuation method[6].

This study is based on the FONDECYT study "Los Paisajes del Agua en la Cuenca del Río Baker: Evaluación de sus Potencialidades para el Desarrollo de Circuitos Turísticos y la Integración Territorial" (Muñoz, 2006), carried out by the EULA Center of the Universidad de Concepción. This study characterizes a total of 108 water landscapes in the Baker River watershed: 46 lake and 62 river landscapes. The landscapes were described in terms of their social and territorial characteristics, scenic value, and environmental value. This research only considered river landscapes, specifically those of the Baker River (9). Of these, the two most important landscapes were Baker River Waterfall (Very High Importance) and the Baker-Nef River Confluence (High Importance). Both landscapes will be affected by the construction of the Baker 1 plant of the HIDROAYSEN project. Therefore, the present study sets out to determine the economic value of these landscapes.

HIDROAYSEN Project

The objective of the project Aysén Hydroelectric Plants S.A. (HIDROAYSEN) is to generate electricity by taking advantage of part of the hydroelectric potential of the Baker and Pascua rivers. The hydroelectric potential of the Aysén Region is estimated to exceed 8,000 MW. This project expects to take advantage of 30% of this potential; that is, it would contribute 2,710 MW, which would imply a one-third increase in the present capacity of the national electric system (HIDROAYSEN, 2008).

Currently, the HIDROAYSEN project is made up of five plants that have capacities ranging from 360 to 770 MW and would flood between 710 ha and 3,600 ha.

Economic Valuation methods

Contingent Valuation

The contingent valuation method consists of estimating the economic value of environmental goods and/or services by surveying those who perceive some benefit from this good or service; that is, those who assign some of the types of value mentioned previously. In this survey, we propose certain mechanisms for avoiding possible damage to the valued services. Since the mechanisms or markets that would allow the prevention and/or repair of negative effects are proposals that do not necessarily exist and that will not necessarily be implemented, this model is known as the hypothetical markets method.

Two possible approaches can be taken in terms of the economic value of environmental goods and/or services. In the first, respondents are asked about their willingness to pay (WTP) to avoid possible environmental damage (or to obtain a favorable change in environmental quality). The second, on the other hand, consists of asking the survey subjects about their willingness to accept (WTA) compensation for environmental damage (or to relinquish a favorable change).

a) Format: One and One-half Bounded

The OOHB contingent valuation method (Cooper, Hanemann, & Signorello, 2002) consists of measuring well-being based on how the survey participant responds to a two-stage question, taking a range between two values from the BID vector and choosing one of these at random. The second value offered depends on the first response.

[6] For details, see the Methodology section.

b) Survey Design and Sampling Strategy

Sampling Design

Since the objective is to determine the economic value of the loss of landscape due to the construction of the BAKER 1 plant of the HIDROAYSEN project, and since the value of the landscape presents an important value of non-use, we considered the affected universe to be all the households in Chile, given the understanding that all society will be affected by this loss of natural capital. Nonetheless, due to budgetary limitations, surveys were carried out in four cities: Puerto Aysén-Coyhaique, Puerto Montt, Greater Concepción (5 townships), and Greater Santiago (33 townships). The demographic details are shown in Table 63.

Table 63. Cities Surveyed

City	Region	Population	No. of Households	Surveys Applied
Puerto Aysén-Coyhaique	Region XI	73,607	17,484	112
Puerto Montt	Region X	734,379	166,526	188
Greater Concepción	Region VIII	1,528,306	340,380	160
Greater Santiago	Met. Region	5,875,013	1,296,912	191
Total		8,211,305	1,821,302	651

Greater Concepción includes the townships: Concepción, Talcahuano, Penco, Chiguayante, San Pedro de la Paz

Greater Santiago includes the townships: Santiago, Cerrillos, Cerro Navia, Conchalí, El Bosque, Estación Central, Huechuraba, Independencia, La Cisterna, La Florida, La Granja, La Pintana, La Reina, Las Condes, Lo Barnechea, Lo Espejo, Lo Prado, Macul, Maipú, Ñuñoa, Pedro Aguirre Cerda, Peñalolén, Providencia, Pudahuel, Quilicura, Quinta Normal, Recoleta, Renca, San Joaquín, San Miguel, San Ramón, Vitacura, Puente Alto

Source: (CASEN, 2006).

Stratified sampling was used in each city, following the socioeconomic classification of ADIMARK (ADIMARK, 2004) for the corresponding regions.

The survey was applied to heads of household in the form of an individual interview in the aforementioned cities between January and July 2008. Its approximate application time was 25 to 35 minutes and included a total of 37 questions. The survey was complemented by 22 cards and photographs of descriptive visual material. Moreover, it was applied in digital format, making it necessary to program the instrument in Excel. A digital format was selected in order to make the transfer of information between the surveyors and the technical team more agile and to reduce typing errors by the surveyors.

The results of this study are useful in the measure that they contribute information to an area in which this is scarce or lacking. The fact that society values an environmental good to which many have not had access reveals clearly that the landscapes affected by the construction of the Baker 1 plant have an important economic value. This study presents an approximation of this value (US $210 million). The investment in the Baker 1 plant, considering its capacity for generation, is around US $720 million. According to the estimates performed, the amount of the loss of natural capital is equivalent to 29% of the amount to invest, or its equivalent; thus, the Baker 1 plant presents a 29% underestimation of the necessary investment.

This exercise of valuation has shown that the landscape affected by the construction of the Baker 1 plant has an economic value for society and that society would be willing to pay to avoid the generation of damage to this landscape. It is not within the scope of this study to determine the exact monetary value of the landscapes affected by the construction of the HIDROAYSEN project, since one of the limitations of the method is that it is not able to capture the inter-relationships existing between environmental components, making it nearly impossible to estimate its value with certainty.

On this point, it should be clarified that the value found represents an approximation of the lower bench mark rather than the true value of the natural capital affected by the HIDROAYSEN project. In the first place, this is because it considers only a small part of the hectares flooded by the Baker 1 plant. In the second place, it only considers the effect on the landscape, without quantifying the effect on biodiversity or other productive activities such as tourism. Finally, it does not consider the effect of the other plants on the Baker River watershed.

We feel that determining the real effect of the project on the economy of the watershed is a main priority. At an aggregated level, an estimate indicates that the construction of the Baker 1 plant implies an increase in the GNP of 4.5% for the Aysén Region during the construction stage, with a limited effect on employment (Martínez, 2008). At the sector level, a wide range of studies have been done regarding the tourism sector; unfortunately, according to the author, the methodology used results in widely disperse values (US $12-50 million). In this field, a serious study is lacking that considers the effect on the tourism sector from an integrated point of view, considering current and potential tourists, and considering the watershed of the Baker River as the unit of analysis rather than just the sites directly affected.

We estimate that, in the future, the demand for this type of study will increase due to the need to approach the true costs of the investment projects. In this sense, the economic sectors susceptible to analysis using this methodology are energy, mining, and forestry. Nevertheless, this route will only be possible in the measure that the Chilean environmental legislation adapts to the new environmental demands of the population, given the growing conflicts between communities and the productive sector. Moreover, this type of tool could be used to complement the existing compensation mechanisms

CATAMAYO-CHIRA

The area under study is limited to the spatial sphere of the river Chira, downstream the Poechos reservoir up to its mouth. It is one of the rivers in the Catamayo Chira cross border basin, one of the most important rivers for Piura region and one of the most critical rivers from an environmental point of view, with a high degree of pollution because of domestic discharges from populated centres along the river bed; and where agriculture is one of the economical activities developed with a strong growth.

Objective

General:

To have a study that warns on potential risks concerning the quantity and quality of hydrological resources that are being generated in the low part of the river Chira, by means of a cost efficiency action program to face the prioritized environmental problems, as well as to support a set of actions that orient authorities and actors in the basin to correct them in order to maintain a sustainable basin in the medium term.

Specific:

- To perform an analysis on economic water utilization in the zone under study.
- To develop a reference scenario (Baseline Scenario), focused on the impact of quality and quantity of water, related to agricultural and population utilization in the zone under study, forecasted to the year 2020.
- To identify cost efficiency actions to overcome the issues of quality and quantity of water in the river Chira formulated based on prioritized pressures.

Expected scenarios for user demands

There is an analysis for the three types of expected scenarios by type of use (agriculture and population). The first scenario refers to the TREND, a second scenario refers to the IDEAL, and a third scenario is the POSSIBLE ONE. All this information refers to the general state of the river Chira system, in the future forecasted to the year 2020. This information allows the identification of the central elements possessed by each one of them and with this, defines the actions or alert to the managers of the hydrological resources in the Chira system for a possible scenario.

Agriculture

Scenario N° 01: KEEP THE TREND

For the following scenario, the current consumption trends found in the study have been assumed: an increase in the agricultural area, traditional irrigation technology, types of cultivations –rice, bananas. With them, we can present the following chart of analysis, where we can point out the fact that there will be lack of water to serve the agricultural activity, so, there will be higher pressure from the agricultural activity for the utilization of the hydrological resource.

Table 64. Features current and projected demand for water for agricultural use

Features	Year 2007	Year 2020
Area (Ha)	53 509,0 (64,6%)	83 643,1 (100%)
Mass water (MMC)	1 140,4	1 782,6
Offer of water (MMC) (*)	1 401,9	1 401,9
Balance of water (MMC)	261,5	-308,7
Amount (USD)	120 943 426,0	189 050 992,0

(*) The minimum mass of water is being assumed to the 75% of persistence, information from the Master Plan Study for the integrated management of the river basins in the department of Piura. In normal years, there would be an annual mass of 3 363.6 MMC.

Scenario N° 02: AN IDEAL ONE

For this scenario, ideal conditions have been assumed to face current consumption trends that have arisen in the study and a forecast to the year 2020. These conditions refer to the agricultural area increase, technology improvement and irrigation efficiency, the type of cultivation – more profitable (chili) and water-saving (pulses), increase in the price of water. Therefore, we present the following chart:

Table 65. Features current and projected demand for water for agricultural use

Features	Year 2007	Year 2020
Area (Ha) + expansion border	53 509,0 (64,6%)	989 643,1 (119%)
Mass water (MMC)	1 140,4 (0%)	1 681,9 (80%)
Offer of water (MMC) (*)	1 401,9	1 401,9
Balance of water (MMC)	261,5	-280,0
Amount (USD) (increase the price by 25%)	120 943 426,0	222 964 254,0 (25%)

(*) The minimum mass of water is being assumed to the 75% of persistence, information from the Master Plan Study for the integrated management of the river basins in the department of Piura. In normal years, there would be an annual mass of 3 363.6 MMC.

Scenario N° 03: WHAT IS POSSIBLE TO BE DONE

In order to work scenario 03, the following elements of analysis have been assumed: increase of agricultural area, change of irrigation technology and increase in the price of water. We can present the following chart, where we can stand out that there will not be enough water to serve that activity.

Table 66. Features current and projected demand for water for agricultural use

Features	Year 2007	Year 2020
Area (Ha)	53 509,0 (64,6%)	83 643,1 (100%)
Mass water (MMC)	1 140,4 (0%)	1 426,1 (80%)
Offer of water (MMC) (*)	1 401,9	1 401,9
Balance of water (MMC)	261,5	-24,2
Amount (USD)	120 943 426,0	173 929 352,0

The new demands for resources including purchase and sale operations of land being carried in the zone, will come with state-of-the-art technology (dripping or sprinkling) and cultivations of less use of water (grapes, chili), which will allow the optimization of the hydrological resource and to reach factors of conversion and higher profitability of water, with cultivations of less demand of water and higher productivity.

Population

Scenario N° 01: KEEP THE TREND

In this scenario, the current trends presented in the study diagnosis have been assumed, such as population increase, bigger served population, and 50% of water loss in the system has been kept as well as the current water rate.

Table 67. Features current and projected demand for water for population use

Features	Year 2007	Year 2020
Residents served	585 564 (72,8%)	764 435 (72,8%)
Mass water (MMC)	108,5	141,2
Offer of water (MMC)	1 401,9	1 401,9
Amount of sale (USD)	481 008	626 553

Scenario N° 02: AN IDEAL ONE

In the ideal scenario, it has been assumed that 100% of the population is served by the Chira system; and due to the government policy of providing water service to everyone, water distribution and transportation efficiency have improved in 80%, and the water rate increases its current value in 50%.

Table 68. Features current and projected demand for water for population use

Features	Year 2007	Year 2020
Residents served	585 564 (72,8%)	1 050 049 (100%)
Mass water (MMC) defendant and efficiency	108,5 (50%)	121,5 (80%)
Offer of water (MMC)	1 401,9	1 401,9
Amount of sale (USD) price increased	481 008	808 706 (50%)

The population is expected to increase by 23.4%; therefore, it will increase from 804,161 inhabitants in the year 2007 to 1´050,049 in the year 2020, this means an increase in water demand, as well as more pressure for the hydrological resource, concerning its quality and quantity to 155.5 MMC.

Scenario N° 03: WHAT IS POSSIBLE TO DO

For this scenario, 90% of the population in the Chira system is expected to be served towards the year 2020, because of the State's prioritization to provide water supply to the towns, as part of its compromise to comply with the objectives of the millennium. To that end, the National Program of Water and Rural Drainage (PRONASAR for its Spanish acronym) must be used.

On the other hand, it is possible to improve water distribution and transportation efficiency up to 65%, and the water rate is expected to increase its current value by 35%. This water must have standard quality foreseen by EPS Grau.

Table 69. Features current and projected demand for water for the population

Features	Year 2007	Year 2020
Residents served	585 564 (72,8%)	945 044 (90%)
Mass water (MMC)	108,5 (50%)	134,6 (65%)
Offer of water (MMC)	1 401,9	1 401,9
Amount of sale (USD) price increased	481 008	806 310 (35%)

With both possible proposals to be executed, 1,560.7 MMC of annual water mass are required, which would generate a gross production value including the water rate payment of S/. 506´733,419 nuevos soles or US $ 174´735,662 American dollars. On these scenarios and alternatives, the action proposals will work to avoid putting the Chira system in jeopardy.

Table 70. Characteristics of water demand to 2020 for agricultural use and population

Features	Year 2007	Year 2020	Features
Area (Ha) and residents served	83 643,1 (100%)	945 044 (90%)	
Mass water (MMC) defendant and efficiency	1426,1 (80%)	134,6 (65%)	1 560,7
Offer of water (MMC) (*)	1 401,9	1 401,9	1 401,9
Total amount (Soles/.)	504 395 120	2 338 299	506 733 419
Gross value production	495 256 275	0	495 256 275
Water rates	9 138 845	2 338 299	11 477 144
Amount (USD)	173 929 352	806 310	174 735 662

ACTION PROPOSALS FOR THE SUSTAINABILITY OF THE BASIN

Following the description of characteristics of the area under study, the baseline and probable scenarios of change in the river Chira system, probable scenarios of change have been identified within a 12 year-term forecast; that is, towards the year 2020.

Water sources, appraisal of the resource and rate

The water sources of the Chira system have a supply of 7,018 MMC/year in rainy years, 3,363 MMC in normal years and 1,401 MMC in dry years. In the February- June period, it experiences an excess of supply, with a consequent loss of the hydrological resource into the sea. This situation requires investments for the storage of this resource.

Agricultural utilization – technology, cultivation, profitability

a) The first alternative is on the re-orientation of a new plan of more profitable cultivations, of short terms (such as chili, pulses), which save water and improve the soils.
b) The second alternative is to improve the agricultural technology in order to allow increasing yields between 20 and 40%; to that end, the use of irrigation technology is also important to save and make good use of water in order to increase the efficiency by 30% (gravity irrigation) to 70%.
c) The third alternative refers to the construction of small structures for control and distribution of irrigation water.
d) The fourth alternative refers to an increase in the rate of water.
e) The fifth alternative refers to the construction of underground water wells.

A final comment is about the need to start work for the implementation of these proposed alternatives and to achieve results; only then, can the regional government start thinking of building another reservoir or elevating the storage crest of Poechos as it nowadays intends to do. Otherwise, it is a mistake to continue with the same thing, praising bad management and inefficiency of the system and its hydrological resources.

Population's use

The river Chira currently serves 585,564 inhabitants (72,8% of the whole population). It provides potable water to 4 provinces, through EPS Grau. It currently demands 108.49 MMC/year. The growth rate of the population is 0.02036 (2007 Census - INEI). The State has prioritized as policy, water supply for the whole population; that is why, for the year 2020, 134.6 MMC will be required to serve 945,044 inhabitants (90% of the population), within the framework of objectives for the millennium.

a) A first alternative refers to better investment in the production system of potable water.
b) A second alternative refers to investment by EPS Grau – users, to implement in the medium term, a system of micro measurement in the property, which allows decreasing bad utilization

and achieving real payment for water consumption. Each house must have its own meter, enabling real invoicing due to consumption. The meters must be acquired by the company and charged to the users in the monthly water invoice.

c) A third alternative is related to permanent sensitization campaigns given to the population. The main incidence should be on mothers as they interact in a direct manner and can help control the resource inside the house.

d) Identify and know on a periodic basis, the situation of properties or houses, which considers the type of use. To that end, the properties will be visited; we expect to find houses that have become businesses, inhabited by more than two families, where there is bad water management, with more levels of drainage contamination. All of this will allow defining a real value for the use and management of potable water.

RECOMMENDATIONS

It is necessary to highlight the importance of the Chira system, as superficial water source for economic – social development of the region; therefore, it is important to stress on the appraisal of the resource and its rate exception to promote a better management of the basin that allows responsible management (to save and take care of water, and to achieve a change of culture on water). So far, the analysis and execution have taken place in a biased manner, not so well articulated with the high part.

CAUCA

The Tuluá River basin, under the jurisdiction of CVC, was selected as the pilot basin in which to carry out studies related to integrated water resource management. Therefore, this report incorporates the socio-economic impact and optimum actions on water management made by CVC through the "Social, Economic and Environmental Evaluation of the Technical Alternatives of Joint Usage of Water Resources of the Guadalajara and Tuluá River Basins and the San Pedro and Chambimbal Creeks".

This study focuses its analysis on optimum actions and socio-economic impacts in the study zone between the drainage areas of the Tuluá and Guadalajara Rivers, the foothills of the Central Mountain Range, and the Cauca River. The municipalities in the study zone are: Tuluá, Guadalajara de Buga and San Pedro. Only the main characteristics of the Tuluá River Basin will be considered in this report.

SERVICE RECOVERY COST

The Ministry of Environment, Housing and Territorial Development, MAVDT, established the regulated rate for the use of water, using a methodology that gradually allows an annual adjustment of the value for a period of ten years. According to this methodology, the regulated rate for the use of water for 2006 is $ 0,55 Colombian pesos per cubic meter (a very insignificant amount in dollars). This value must be associated to the value currently demanded. Considering the system and method regulated by the MAVDT, all water users must pay the Environmental Authorities, in this case, the Corporación Autónoma Regional del Valle del Cauca, CVC. Each environmental authority must make the corresponding offer and demand analysis in their region, considering the socio-economic conditions of each basin.

The current water demand in the Tuluá River basin is established in order to determine water costs in the basin. Based on the basin regulations, we established the assigned flow in liters per second for each derivation and later this value was converted into volume per year in cubic meter units. The calculation of the current water demand in the Tuluá River basin is shown in Table 71.

Table 71. Current Water Demand in the Tuluá River

. Derivation	Assigned Flow (l/s)	Daily Volume Conversion Factor (m3/día)	Daily Volume (m3/día)	Yearly Volume (m3)
El Rumor Plant Canal	4,000	86.40	345,600.00	126,144.000
“Grande” Canal	5,900	86.40	509,760.00	186,062,400
“La Rafaela” Canal	376	86.40	32,486.40	11,857,536
Derivation 1- El Rumor Plant – “Grande” Canal	77	86.40	6,652.80	2,428,272
Derivation 2 El Rumor Plant – “Grande” Canal	66	86.40	5,702.40	2,081,376
Total Demand in m^3				328,573,584

Source: Prepared by the author of this document.

To obtain the current cost, you must multiply the total water demand in cubic meters times the usage rate of 0.55 per m^3, which totals $180,715,471 per year. CVC has to charge the water use rate from the users of the canals. Revenues obtained shall be invested in the in-process water resources planning and management projects.

BASIC SCENARIO

To determine the basic scenario, CVC considered the actual water use situation and analyzed the different scenarios for the optimization of the water distribution by CVC, based on the Aquatool support system decided for the central part of the Department of Valle del Cauca. Once the criteria for each of the scenarios were reviewed, Scenario 3 was chosen for Ground Water reservoir *SP1 for the demands of Tuluá and San Pedro and Aquifers for the demands of Chambimbal and Guadalajara.* This scenario proposes joint usage of the surface water supply using a smaller dimension reservoir at the San Pedro Stream (19 Hm^3) and an underground resource (homogeneous rectangular aquifer) to satisfy the demands of the Chambimbal Stream and the Guadalajara River.

COST-EFFICIENCY OF THE MEASURES TO BE TAKEN

Measures considered for the improvement of water supply in the study zone are the construction of a reservoir in the San Pedro Stream to satisfy the demands of Tuluá and San Pedro, and the usage of aquifers to satisfy the demands of Chambimbal and Guadalajara. Costs involved include the construction of wells necessary to obtain the required annual water volume to satisfy the demands of the corresponding zones, as well as the costs for the reservoir construction, the irrigation system, and costs for an increase in sugar cane production in the areas covered by the reservoir. Costs associated with greater agricultural production in the areas of Chambimbal and Guadalajara are not presented since the additional volume of water required would not be generated.

In order to understand the consumers’ savings concept, it is important to clarify that the demand function indicates the amount of water that the community is willing to consume at a certain price. The demand function shows that the consumer is willing to pay a value equivalent to the level of benefits obtained from the asset or service. This means that whenever the additional quantities represent a benefit, the consumer would be willing to pay[7].

The analysis of the benefit of consumer savings has to take into consideration the willingness to pay for the water service and the rate that is effectively being paid. The rate effectively being paid corresponds to usage rates for each basin and the willingness to pay for the water (DAP) was taken from the article: “The

[7] MIRANDA, Juan José. 1998.

economic value of irrigation water: A contingency appraisal study" written by the economists Luis Alfonso Escobar and Álvaro Pío Gómez.

The econometric model concluded that the DAP assigned to surface water by the users in the Tuluá River Basin correspond to **DAP= $3.667**[8] for each liter per second assigned. With this rate, it is possible to evaluate the financial viability in the works and the operation expenses necessary to guarantee water supply from the perspective of the offer. This assigned value, established in liters per second, was converted into the cost per cubic meter to be able to compare it with the actual usage rate. The amount is equivalent to $1.415 (one peso and forty one cents) at 1997 price rates. This rate was updated to December, 2006 rates, with a result of $2.78 (two pesos and seventy eight cents) per cubic meter. The obtained value is compared to the 2006 regulated water usage rate of $0.55 per cubic meter, and is associated with the currently demanded volume and with the additional water volume that would be generated with the regulation reservoir project. These calculations are clearly defined in each evaluation.

In this manner, benefits obtained by users with the controlled flow reservoirs correspond to the additional water volume available throughout the year, to expand the regulated area with certain supply reliability.

Productivity Increase: Change in Productivity.

Benefits obtained through productivity increase once the water supply increases to cover irrigation needs, will produce revenues from higher production. This allows calculating the numbers with and without the implementation of the project. Irrigation benefits listed, with and without the implementation of the project, were taken from the methodology used for the social and economic feasibility assessment of this project:

An analysis of the relation between the benefits obtained by the agricultural exploitation vs. production costs at economic prices was made, forecasting its behavior, in case the Project is not implemented.

In case the Project is implemented, the benefits obtained by the increased production related to the costs necessary for the obtention of the higher production index generated by the irrigation was evaluated. The investment required to build the project, as well as the land preparation, are also included in the evaluation.

According to each basin's regulations, it can be observed that the greatest percentage of cultivated area corresponds to sugar cane. Therefore, the analysis of the situation with vs. without the Project was made to determine the productivity increase of this crop in case the water flow regulation Project is implemented.

The economic benefit was calculated assuming a 20% increase in the yield per hectare for this crop, with an actual yield of 128 tons per hectare. The value per hectare at 2006 prices is $16,819. Under the socio-economic scope, the main impact is identified as the change in economic activities due to economic dependence derived from the use of dragging material from the river. Although it is a vulnerable population having this as its only survival means and not having another solution alternative, it is feasible, making the proper management plan, to propose actions to mitigate such impact. According to this, it can be established that in the Projects studied, the environmental impact of greatest relevance in its viability is the displacement of the population settled in the area to be flooded and the exploitation of alluvial material for the construction of the dam.

BENEFITS-COSTS ANALYSIS IN THE CHANGE SCENARIOS

Benefit Calculation in Joint Use Scenarios

As explained before, the benefits to the areas whose demands are covered with ground water correspond to the consumer's calculated saving. The base scenario has the consumer saving as a benefit for the entire sector[9] and the increase in the production value for the zone of Tuluá and San Pedro. Table 72 describes the benefits from the base scenario.

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[8] Value estimated in 1997 Col. Pesos.

[9] Calculated for the actual water demand and for the additional volume regulated by the reservoir.

Table 72. Benefits for the Joint Use Scenarios (Col.$ MM)

Scenarios	DAP Benefit	Increase in productivity	Total
Base scenario	974.67	4,842.36	5,817.02

Source: Prepared by the author of this document.

Economic Appraisal of the Joint Use Scenarios

The revenue flow of the scenarios during the determined period of time is established with the increasing costs and benefits obtained in the previous sections. That is the criteria used to determine the best of the three options for joint use of surface and ground water. Table 73 shows the result of the cost-benefit analysis in the base scenario.

Table 73.Economic Appraisal Criteria for the Scenarios of Joint Use of Surface and Ground Water

Profitability Criteria	Base Scenario. San Pedro Reservoir (SP1) and Aquifer
Benefit/Cost Ratio (B/C)	**0,60**
Savings rate	**12%**

Source: Prepared by the author of this document.

Reviewing these criteria, it is concluded that the base scenario is not socio-economically feasible since the costs are higher than the benefits. The benefit-cost B/C ratio is 0.6, less than one (1). Therefore, the project is not economically feasible because the society has to invest more that what it is expected to receive by using such alternative.

SUMMARY AND CONCLUSIONS

The selected base scenario includes the main technical alternatives for joint use of surface and ground water in the study zone, and also satisfies the water demand in the entire sector. In terms of profitability, the conclusion is that the surface and ground water regulation project **is not feasible from a socio-economic point of view.**

The benefit-cost ratio B/C of this scenario is 0.60, or less than one (1). Therefore, the Project is not economically feasible because the society has an investment higher than the benefits received for such alternative. There is lack of up-to-date and segmented information on aquifer construction costs, as well as the social and environmental benefits related to ground water extraction. Since the joint use alternative is a relatively new topic, it is important to select and adapt an economic, social and environmental appraisal methodology.

The assessment of joint use scenarios presented in this study was made taking into consideration the investigation work made by the CVC Water Resources Group (2006). This appraisal was performed under the assumption of a parallel use of the alternatives. However, in the literature review it was found that at the international level, joint use scenarios use the reservoir to meet the demand and reload the aquifer during rainy seasons, using the aquifer to satisfy the demands in the dry seasons.

In order to make this a more economically feasible Project, studying the possibility of using multipurpose reservoirs is recommended. This means that apart from irrigation and human consumption, hydroelectric power may also be generated.

From the stand point of the Corporation, a more detailed study of the economic appraisal of the environmental benefits of this alternative is recommended. The appraisal of joint use of surface and ground water can be optimized through modeling such scenarios with the AQUATOOL module designed for economic appraisal.

COCIBOLCA

The determination of the water demand by householders and rice crop producers as well as the water supply per "Departamento" is performed in this study. The objective is to calculate the water cost service to households. It was also established a fee for water service to rice crop producers by using the methodology on producer surplus, which is based on microeconomic theory.

Population within the Lake Cocibolca Basin

In 2008 there were a total of 1, 303,121 people. It is estimated that the population will increase by year 2015 to 1, 408,722.

Water Consumption in the Municipalities within the Cocibolca basin

Based on 2007 data from the National Enterprise of Aqueduct and Sewerage Company (ENACAL) and the Agricultural Census, 2001, the water consumption in the municipalities is 340,412,131 cubic meters per year. 57,129.131 cubic meters is the household consumption through the ENACAL network, and 283,283,000 is the estimated consumption per year by rice crop producers in the basin under irrigation system, according to the Agricultural Census and consultations with experts on irrigation water consumption. It has to be estimated because there is no record in Nicaragua on the amount of water consumed under irrigation. In this investigation, it was estimated the consumption on 14 to 17 thousand cubic meters per manzana (1 manzana = 0.7 ha). It is important to mention that, at the present, farmers are not charged by the use of water from the basin, for irrigating their crops.

In the Lake area there are 43,550.36 manzanas under irrigation, of which 46% is for rice cropping. The departamentos of Granada, Rivas and Boaco have the greatest number of cropped manzanas under irrigation.

The six largest departamentos of Lake Cocibolca basin have 137 wells for extraction of groundwater. The departamento of Chontales has 44 wells, and Rio San Juan has 6 wells. The departamento of Chontales has the greatest number of wells. However, in Masaya and Granada are the highest levels of water production.

Prices and costs of water services

Based on the resolution which states that the "departamentos" within the lake basin, have three types of users (Subsidized, household, and subsidies generators), who are charged with different variable drinking water fees per cubic meter (C$/m^3). 94% of total customers belong to the household level with consumption that ranges between 0 – 20 cubic meters. The fixed charge (CFC C$/Conex/month) and the sewage (CVAS C$/m^3) will remain constant for our analysis of price, since many municipalities within the basin have no sewage service.

Production costs, on average, are 5.34 C$/m^3 in the "departamentos" within the basin. The 83% of customers do not pay the really costs to produce one cubic meter of water. This means that household category of users consuming 0-20 cubic meters will be subsidized, because they do not cover the cost of producing one cubic meter of water (see Table 74). This is a major problem, since 80%[10] of customers in the basin belong to the household category with an average consumption of 17 cubic meters per household; therefore, the company is not financially viable.

[10] Billing information ENACAL 2007

Table 74: Production costs of drinking water in the departamentos of the watershed

Departamentos	Production costs C$/M^3
Managua	3.81
Granada	3.14
Masaya	5.91
Carazo	6.53
Rivas	4.04
Chontales	6.59
Boaco	6.62
Río San Juan	6.08
Average	5.34

Source: Author based on the costs of producing drinking water. ENACAL 2007

In 5 out of the 8 departamentos, the costs of extracting one cubic meter of water are greater than the setted fee. This can be observed in the fee specifications and production costs. The model used for price adjustment in Nicaragua is indexing, approved by law, and taken to the Regulator entity, INAA.

The TWINLATIN Project presents the indexing scenarios, the model of a single bidder developed in the microeconomic theory, and a proposal to the government for household users in order to achieve the covering of operating costs. It was estimated the equilibrium price by estimating the supply and demand using data from ENACAL on 2007.

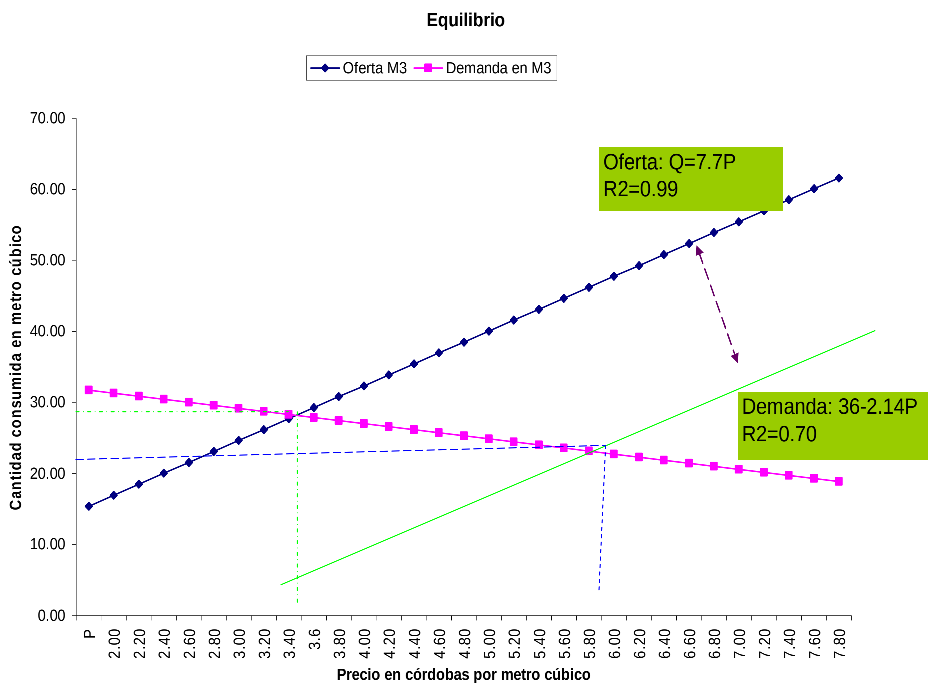

Figure 107: Equilibrium price

The main problem is that the company is invoicing 50% of the amount of water it produces. It is not known whether the loss is through illegal customers use or the distribution network is very old. This requires a more rigorous study. The equilibrium price, if the company billed for everything it produces, would be 3.60 Cordobas per cubic meter, but by shifting the losses to consumers, it should be 6 Cordobas per cubic meter. If the recovery is not correct, it will be difficult to satisfy the number of housing without water, especially in the rural area of the lake.

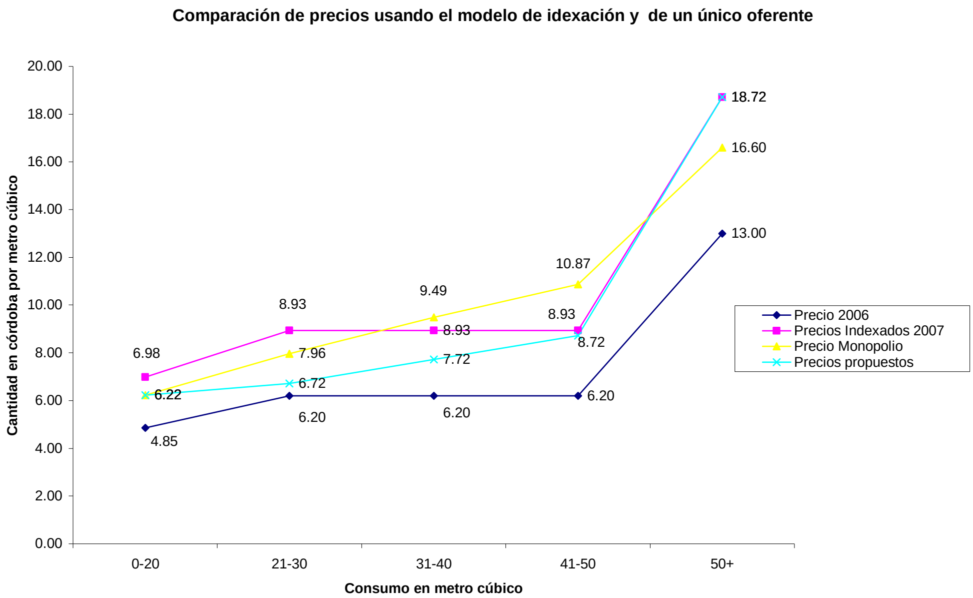

Figure 108. Price of Water for Household Category in the Departamentos within the Basin

Establishing a Water Consumption Fee to Producers of Irrigated Rice.

It is necessary to consider that a fee for the use of water at the source, should try to properly reflect inter-sectoral and inter-regional differences regarding the economic value of water use. It is also essential to take into account the need for periodic updates of water value estimations occurring at different regions and for various uses, so that, over time, fee values are adjusted and that, eventually, be charged for its catchment in their natural sources. It also requires moving gradually into the development of database and indicator systems to align monetary quantification of indirect use values and non-use of water, in order to properly reflect changes in social preferences in relation to the environmental services of aquatic ecosystems, which generally, are not considered explicitly in policy management and resource allocation.

The methodology: Use *producer surplus* approach to estimate water use value in agriculture, as a *proxy* for the availability for farmers to pay for water in this region. The measure of the producer surplus is the marginal income attributed to water in irrigated agriculture. This income is calculated as the difference between long-term benefits of agriculture in rainfed versus net income in the same conditions of irrigated agriculture. The difference of net benefits per hectare per harvest, divided by the quantity of used water, allows estimating the value of water per m^3.

Water Demand

The *departmentos* with the highest consumption of water are Masaya and Granada. They have the highest concentration of population. For year 2015, it is expected a water demand of approximately 51 million cubic meters per year. ENACAL, in 2007, had a production of 52,828,089.44 cubic meters per year. The problem is that ENACAL does not cover the demand, as it loses 50% of its production.

To projected water consumption by 2015, it was based on the assumption that a person consumes 3 cubic meters of water per month. It was developed the model of population growth of people in the basin, based on the population census. The demand price elasticity for water is $|-0.43|$.

Cost - Efficiency

To meet water demand, it is needed to identify the losses of the resource (drinking water). It is expected that the main cause be the pipeline system, which is very outdated. Therefore, until this phase of the project, one can say that it is necessary a millionaire investment to identify the unaccounted water by the Company at the time of billing and, thus, to meet demand.

There is no environmental impact information to be able to establish cost-effective measures.

Socio-economic Effect of Actions and Cost -Benefit Analysis.

The project achieved to estimate the surplus for rice producers and if the fee is approved. Central planners will have 7 million dollars a year for the integrated management of the basin. Probably, these 0.5 C$/$M^3$ will be transferred to the consumer and, the quintal (100 lb) of rice will be increased by 100-140 Córdoba. The important thing is to improve the welfare of society as a whole. So far, with an efficient implementation of income, it can be assumed a qualitative improvement and, with this action there will be a continuous monitoring of water quality, tighter controls on deforestation and on pesticide use in the basin.

Conclusions

1. It can be set a price policy lower than the indexing model and to the model that would use a single bidder, recovering the cost of the drinking water.
2. The water demand price elasticity allows establishing that, through pricing policies, it can be reached an optimal use in household water consumption located in the basin.
3. The water supply is greater than the demand. However, the main problem is that more than 50% of it is lost, so the current demand is not achieved. The water company, based on 2007 production, can cover the amount demanded in 2015. Nonetheless losses have to be reduced, either legalizing users o reducing leakages in the network.
4. The fee for using the resource in rice irrigation will generate incomes to the central planner approximately equivalent to 7 million dollars. It would assist projects to protect the basin.

CUAREIM - QUARAI (Uruguayan side)

This study aimed to shed light on the characteristics of the Cuareim-Quaraí River basin regarding the identification of cost-efficient actions compatible with a sustainable river basin management. Conceptually, this report is based on the European Union Water Framework Directive and on the guideline for its implementation. The focus was on the Uruguayan perspective and the Uruguayan side of the Cuareim River basin so the analysis complements the work done by the TWINLATIN Brazilian partner, IPH.

The second section, entitled *economic analysis of water use,* sketches the main features of the region. It considers urban regions and the most relevant water-intensive economic activity at the Cuareim River: rice production.

Economic analysis of water use

Agricultural production in Artigas Department is closely linked to irrigated agricultural production. In Bella Unión city, sugar cane is the most important crop and plantations are located in the Cuareim River basin. While this production is significant, economic activities in Bella Unión mostly depend on the Uruguay River, rather than the Cuareim River. For this reason, we will not deal with this. On the other hand, the region is the second largest area of irrigated rice production in Uruguay, and corresponds to the Cuareim River basin and its tributaries. Rice production is a very important activity in Uruguay's economy. Uruguay is the 6th rice exporter in the world, producing 4 percent of the commercialized rice. Moreover, rice is one of the principal products that Uruguay exports.

The rice sector has the peculiarity of having strong integration between agricultural and industrial segments. There are Rice-Producer Associations (Asociación de Cultivadores de Arroz, ACA) and Rice-

Mill Manufacturer Associations (Gremial de Molinos Arroceros). The Rice Sectoral Commission is integrated by the two mentioned Associations, the Office of Planning and Budget (OPP), some Ministries and the Governmental Bank of Uruguay (BROU) and it establishes the main economic conditions of the relationship between chain members.

Cost recovery of water services

The analysis of cost recovery was addressed in two stages. First, it was conceptually established how to assign economic value to the water as a natural resource that is associated to some uses (the cost of the natural resource). Secondly, the costs of providing water for such uses (private costs and environmental costs) and the determination to what extent these cost are currently being recovered. The hypothesis used is that both subjects are separable as there are no evidences that one activity impacts on the other one and vice versa.

The analysis of drinking water is confined to the area of the City of Artigas (Uruguay) and Quaraí (Brazil). The river basin is sparsely populated and the inhabitants are concentrated in Artigas's capital and Quarai. Therefore, the analysis is limited to this bi-national urban agglomeration.

Surface-water value of the Cuareim River for human use.

Artigas city is currently supplied in roughly equal quantities by surface water taken from the river and groundwater. Considering the volumes of water required to supply the city of Artigas, the availability of groundwater (Guarani aquifer) can be considered almost infinite. Consequently, the value of that water is not significant. The water extracted directly from the Cuareim River appears to be more interesting to be valued due to the fact that its quality is affected by other activities (externalities).

The value of water for human consumption is determined by the cost of providing for it with the cheapest alternative. Water is essential to life, with no water supply there is no sustainable development. For this reason, it is clear that if it is not possible to use surface water for human consumption, it is necessary to look for an alternative way to get it. In the case of water supply for the City of Artigas, the value of the surface water is given by the cost of extracting if from groundwater.

Value of surface water.

US$ 0.35 per m^3 is the estimated value of one cubic meter of surface water. Technical calculations indicate that the cost of a well to supply 15 m^3 of water per month to 2,800 houses is US$ 1 million and with an annual operation cost of approximately US$ 60,000. Considering an inter-temporal discount rate of 12 percent and assuming that the well has a lifespan of 20 years we reach to the mentioned value of water. It is worth noting that the average tariff per cubic meter charged by OSE is US$ 0.47. Therefore the Governmental Company is recovering the marginal cost of water.

However, the total water cost is 26 percent higher than OSE's revenues. With the current form of exploitation, the water can be described as a private good. Runoff water is retained in small reservoirs that supply water for rice production to the adjacent producers; the water is distributed through canals. The investor who builds the reservoir uses it partially for his/her own needs and partly for sale. During the cultivation of rice, the stored water is a scarce resource that: (i) is rival in consumption and (ii) consumption exclusion is possible. Water is rival in consumption when it is used for agriculture or for drinking water and it is not rival when for example it is used for recreation. Moreover, water consumption exclusion is also possible because the amount of water is small and supplies few fields near the reservoirs. Those are technological conditions that allow the investor to decide whether the reservoir will provide water to one rice producer or to another one. Those two characteristics -rivalry in consumption and consumption exclusion - turn into a private good the water used for agriculture.

Value of irrigation water

It is not possible to state that the value of water for irrigation is not zero. In aggregated terms in the Cuareim River basin, the amount of water running off annually is well above the maximum volume of water needed for rice producers; moreover it is also more than enough to reach the maximum of production based on other production factors. However, the low water-storage capacity of the soil in the basin makes water to drain quickly without being retained for the periods of agricultural demand.

Therefore, on an annual basis, there is an excess of water production in the basin (even in drought years); and even if there is excess of demand in the summer period. Reservoirs allow storing water to the latter period. If they did not exist, water would flow from the area to the Uruguay River and then to the Atlantic Ocean, with no other alternative use. Reservoirs allow making water available, storing it during the period when there is no alternative use for the period when its value is high given its demand for agricultural use. Ultimately, the value is not intrinsic to the resource but it is given by the service provided by the reservoir.

Administration and social costs.

The base for charging for water should be linked to the recovery of administrative costs associated with managing the system rather than providing incentives for efficient use of the resource. The above analysis is relevant to establish some price or fee for water access. If we accept this analysis; the recovery of costs should be associated with the recovery of costs of a regulated system of water rights, rather than a Pigouvian tax that looks for the establishment of suitable incentives to avoid the over-use of the water resource.

The service of storing water in reservoirs recover, at least, the private costs of providing that service. The construction of reservoirs for self-consumption or selling is an entirely private activity that is carried out by the owner of the field that is flooded. The Government authorizes the construction of the dam so that: 1) it is assured a permanent minimum flow of water in the river and 2) the rights of those who already have a water right are guaranteed (so as to ensure a reasonable certainty to new investors); the Government does not intervene in the investment and selling of water. Therefore, the construction of a dam is a profitable private business that recovers all private costs and generate an appropriate return to the risk taken.

Baseline scenario

The baseline scenario is the most likely to occur if the measures proposed in this report are not implemented.

Population.

There is only one relevant urban area, the cities of Artigas and Quaraí. The former is located in Uruguay and the latter in Brazil; at both sides of the Cuareim River. Artigas' population is estimated in 40,000 inhabitants. In Uruguay, the population growth rate is particularly low, being less than 1 percent per year. This phenomenon is more remarkable in departments different from Montevideo; this is due to internal migration towards the capital. However, Artigas Department has the characteristic of not expulsing people, therefore its population growth rate is estimated until 2020 at 0.5 percent (on cumulative annual terms), similar to that for the whole country. The Municipality of Quaraí, on the other hand, has 25,000 inhabitants that are concentrated in Quaraí city. Population growth rate is substantially higher in Brazil and the estimation for Quarai is 3 percent (on cumulative annual terms).

Water and Sanitation.

According to data from OSE, drinking water coverage is higher than 98 percent in Artigas city, while the coverage at Quaraí Municipality is close to 85 percent (this data comes from the Brazilian Ministry of Cities). In the baseline scenario, it is estimated that the gap (until full coverage) will be covered by the action of the companies as part of their short-term investment programs. Additional connections will be made according to population growth. The sanitation situation is radically different. While in Artigas city only 42 percent of the houses with drinking water have sanitation the ratio is down to 22 percent for Quaraí city.

Table 75. Baseline scenario – water and sanitation

	2009	**2015**	**2028**
Artigas			
Dwellings with drinking water	21307	21499	21922
Dwellings with sewage	8175	8261	8411
Quaraí			
Dwellings with drinking water	7371	7965	9421
Dwellings with sewage	1226	1237	1261

Rice Production growth in Uruguay.

The baseline scenario growth rate is assumed to be 3.1 percent (on cumulative annual terms) because this is the medium-term growth rate, until reaching the limits imposed by the availability of resources (water and land).

Water quality

According to expertise's opinions who believe that this impact is not extremely significant, it will not be valued in this analysis, although we stress that further research on this issue is needed.

Identifcation of cost-efficient actions and their socio-economic impacts.

Some actions were identified for water and sanitation services and some others for storing-water services in reservoirs. This is consistent with the hypothesis that both issues could be separated because there are no cross effects.

Drinking water and sanitation

Regarding the provision for drinking water for the cities of Artigas and Quaraí and given the current level of pollution in the basin close to the water intakes, there are two groups of actions: (i) the provision for sanitation and effluent treatment for both cities and (ii) the migration of water supply from surface sources to groundwater sources.

If we restrict the analysis to the target of providing for safe drinking water, the gradual migration to the provision for drinking water from underground sources is cost efficient; and is a better institutional and technological option. It was estimated that the cost of complete migration to water supply from underground sources (including water wells, pipes, pumps, water reservoirs, etc.) in Artigas city is around US$ 1 million. On the other hand, a complete system of sanitation, drainage and effluent treatment to allow reasonable levels of water quality in the river (Artigas and Quaraí) would require an investment not lower than US$ 20 million. The first option not only does it have a lower cost but also has technological advantages because every invested dollar has a direct and immediate effect on producing some cubic meters of clean water. The alternative option of sanitation requires a good advance in its implementation in order to obtain reasonable results in terms of being the water suitable for human consumption. Last but not least, in a bi-national scenario like the one analyzed, the sanitation option requires that both countries invest, but each one has no control on the other's decisions and if one did not invest, the desired results would not be reached. This institutional aspect is very relevant and could mainly drive the decisions to a non cost-efficient alternative (this is not the case, though).

The provision of sanitation is socially efficient (Economic IRR is 16 percent). Beyond the preceding analysis, to invest in sanitation has several environmental benefits to society that outweigh the use of the resource for drinking water. Taking into account data from a recent sanitation project in Montevideo, the cost of a sanitation connection, operating cost and maintenance cost of the system were considered. It was analyzed the benefits taken into account in similar projects in Uruguay where Contingent Valuation methodology was applied, but it was corrected considering the differences in average income of the region. This methodology took into account the full set of benefits for individuals from having sanitation and drinking water. The Annex shows a detailed description of the cost-benefit analysis for sanitation in Artigas and Quaraí cities.

Water stored in reservoirs for irrigation

The only identified alternative that would increase the amount of water available for rice production is the construction of large reservoirs per sub-basin that would replace the current small reservoirs. This alternative has been discussed in the region for years, although there are just a few studies that have focused on its feasibility. The alternative is the construction of reservoirs located upstream where land is not suitable for rice production (and therefore less valuable) (Crisci et al, 2007). Those dams could retain more water in better conditions in terms of efficiency. Ground conditions in Brazil and Uruguay are different, so this measure may not be generally applicable in the whole basin.

The study examines the alternative of constructing a dam in a high area, in Tres Cruces Creek basin (tributary of the Cuareim River). The subsequent distribution of water would be by gravity through canals. Crisci *et. al.* (2007) analyzed the technical possibilities of carrying out such dam and its costs.

Moreover, the authors also studied the potential impact on agricultural production with more secured water.

To our knowledge, this is the first thorough study in Uruguay which evaluates a technological alternative of this nature. As the feasibility of the proposed alternative depends on the characteristics of the area, the results cannot be extrapolated to other areas without further studies. The rest of this chapter therefore refers to the Tres Cruces Creek basin (subbasin of the Cuareim River basin) and not to the entire basin, and it is based on an economic analysis done by the authors.

The project of the dam at the Tres Cruces Creek basin is socially efficient (Economic IRR is 14.5 percent). Cost-benefit analysis was applied to the reservoir and irrigation system proposed by Crisci et al (2007). The project is not financially feasible at current water prices. If those prices were maintained, a public subsidy would be required to make it feasible.

The public subsidy could be justified if policy makers look for the development of less developed areas. Public subsidies may be justified for several reasons. When an investment is socially profitable but it is not financially profitable, it is suggested that the investment should be done with a public subsidy. However, there are many projects of this kind and policy makers take into account other elements such as distributional impact, etc.

Conclusions

The main conclusions of this study are:

1. In the Cuareim-Quaraí River basin, water is used not only for human consumption but also for irrigated rice production. All other uses employ smaller quantities of the resource (including the main economic activity in the region: extensive livestock production).
2. There is not enough technical information about the impact of rice production on the environment. Expert's opinions do not rule out the possibility of any impact, but in the absence of studies and measurements of this, they do not confirm the existence of a significant negative impact.
3. Given the small population size of the region and the concentration of it in two cities: Artigas and Quaraí, the problem of universal access to potable water is located in both cities. The problems of water quality that is taken from the river for human consumption comes from the low sanitation coverage at both cities. Agricultural activities do not seem to generate significant impacts on water quality in the main water course.
4. The diagnosis identifies two problems: (i) the problem of drinking water quality in Artigas - Quaraí and (ii) the availability of cheap water for rice production and other agricultural activities. Both problems can be independently analyzed because there is no significant conflict in those water uses.
5. The companies that are responsible for water supply and sanitation in Brazil and Uruguay have reasonable drinking water coverage but are far from covering the sanitation needs of the area. Cost-benefit analysis was conducted for the potential project to hike sanitation coverage taking into account parameters of willingness to pay (from similar studies) and we obtained acceptable social returns. The extension of the sanitation system is not considered in the baseline (due to it is not in the investment plans) and it is proposed as a measure to tackle global environmental problems in the area.
6. By focusing solely on the objective of ensuring the provision of drinking water in Artigas and Quaraí, the substitution of the surface sources (Cuareim River) for groundwater sources (Gurararí Aquifer) is a cost-effective option, among other advantages.
7. We identified a possible measure to improve the capacity of maintaining water in reservoirs that will allow increasing the availability of water for rice production: the construction of larger dams. We analyzed the economic aspects of constructing a dam in Uruguay (Tres Cruces Creek, tributary of the Cuareim River). The results indicate that this construction is socially profitable but it would not be financially feasible at current water prices. Governmental intervention would be necessary to pursue this project given the coordination requirements. Moreover, a subsidy would also be needed. However, the justification for a public subsidy is not evident.
8. The case studied is a particular one. The implementation of a similar project in another area or sub-basin will require a local analysis.

Economic Evaluation

The principal results of this economic evaluation are reflected in the profit indicators, the Economic Internal Rate of Return (EIRR) and the Economic Net Present Value (ENPV).

Results are satisfactory, and the ENPV gets a positive value of nearly US$ 2.600 thousands at shadow prices 2007, what means that this project gives net benefits to the society as a whole, so from this point of view it would be of interest to implement it. The EIRR is 15% annual effective rate, greater than the 10% used as rate of return.

Table 76. Economic Profitability Indicators

Indicators	**Value**
Economic Net Present Value in thousands US$, 2007 (10% annual effective rate of return)	2.421
Economic internal rate of return (% annual effective)	14,5%

Financial Evaluation

The financial evaluation reflects the results from the point of view of a private pr public investor with a private vision. To the investment and operation and maintenance costs of the project, in this case the construction of the dam, at market price in constant currency 2007 it was added an external financing to the project of 50% of the investments. This financing was for a period of 10 years and at a 9% annual effective rate, with fixed amortization method.

Results show that this project is not profitable from a private perspective as the NPV has negative values of more than US$ 5.200 thousands and the IRR cannot be calculated. Therefore, this project sociably profitable, would not have an investor interested in it, except for possible intervention of the authorities to take advantage of its externalities.

Table 77. Financial Profitability Indicators

Indicators	**Value**
Financial Net Present Value in thousands of US$, 2007 (10% annual effective rate of return)	-5.094
Financial Internal Rate of Return (% annual effective)	. . .

It was calculated what would be the price of water for production use, rice in this case, and the result was 54 bags of rice, instead of the current value of 20 bags, so for the price of water to have a profit equal to the opportunity cost, which is 10% annual effective rate.

Therefore, the most attractive options for the basin are:

- The water charge for both sides of the basin, which will generate the values to confront the necessary inversions in run-off treatment
- The implementation of reservoirs on the basin to guarantee the water supply and reduce local conflicts
- The run-off treatment of Artigas and Quaraí
- The reduction of the most affected population through the displacement of households

As for the floods, it has to be considered the possibility of the implementation and operation of an alarm system that allows a coordinated and more effective action to reduce damages.

The economic conclusion is that the necessary inversion can be done with the own basin founts with governmental assistance and paid by its beneficiaries.

CUAREIM - QUARAI (Brazilian side)

The Quaraí river basin is dominated by agricultural use, precisely subirrigated rice farming, natural pastures and extensive livestock. Oriental Republic of Uruguay holds sugarcane exploitation of low productivity due to unfavorable climate conditions. Another low profit activity is that of precious stone exploitation (amethyst), which occurs in a few locations.

On the Brazilian side, the basin occupies the area of four municipalities: Santana do Livramento, Quaraí, Barra do Quaraí and Uruguaiana. From all these, Santana do Livramento and Uruguaiana are the regional poles, but their head offices are not located in the basin. Moreover, Santana do Livramento has a very small territorial part in the basin.

Table 78. Economy of the involved municipalities

Municipality	***GDP***		***GDP per capita***		GVA (Gross Value Added)[11] structure (%)			GVA departmental (%) participation		
	R$ 1000	***% RS***	***R$***	Populat.	Agricultural	Industrial	Services	Agricultural	Industrial	Services
Barra do Quaraí	124.501	0,09	29.671	4.196	78,92	3,90	17,18	0,42	0,01	0,04
Quaraí	199.371	0,14	7.679	25.963	51,88	5,34	42,78	0,46	0,02	0,15
Uruguaiana	1.288.237	0,90	9.651	133.482	31,28	25,88	42,83	1,72	0,54	0,94

The supply of water is not sufficient to its demands during December and January, a period that corresponds to the greatest hydrological necessity for rice farming. With its defective management of the water concessions in Brazil, conflicts are inevitable on the Brazilian side.

Objective
The main objective of this work package was to find a cost-efficiency program to reach a sustainable management for the river basin. In order to do so, the results of the other work packages were taken into account. Also, the relations between long term socio-economic development and environmental impacts of the river basin have been established.

Description of the performed activities

- ***Water use analysis.*** Basic data on demography, economic, social and technological development were collected in central or departmental agencies of economic planning. The package WP 1 obtained the total data of the river basin. Two other projects were considered: "Quantitative and qualitative evaluation of water resources in Quaraí river basin, right margin", divided into two parts (until Quaraí and between Quaraí and Barra del Quaraí), with execution date between 1994 and 1997.
- ***Baseline scenario development.*** The base scenario for the analysis was determined with the purpose of analyzing both future impacts derived from economic growth and development, and the social-economic impact of changes in water quality and its demand.
- ***Recovering of water services costs.*** Together with the river basin stakeholders, optimal actions for the development of the region were selected. The costs of those actions were estimated, having its costs of opportunity been calculated in order to contest the basic question: to which extent are financial, environmental and resources costs included in water services?
- ***Identification and analysis of the cost-efficiency of actions.*** The desirable actions and the indicators were consolidated according to a debate with the local basin population at

[11] N.T.: from the Spanish "VAN" – "Valor Agregado Neto".

an encounter that took place with this specific purpose and was supported by Brazilian stakeholders.

- ***Economical and environmental effects of the actions.*** It includes an analysis of the scenario with the purpose of estimating the effect of the actions in water quality and quantity, as well as an analysis of the social costs and effects. These effects are compared to the development described in the baseline scenario.
- ***Definition of water value for irrigation.*** Several researches were done among basin irrigators in order to identify the economical value of the water for the irrigation of rice, which is the main economic production of the region.

Presentation of combined actions to be discussed with stakeholders. Once the analysis of the effects was accomplished, a discussion with the basin stakeholders was held with the purpose of electing a combination of final actions. The result of this analysis is a condensed list of actions that reaches a final combination of actions.

In order to administer an economic analysis, the effect method was adopted. The effect method is an economic analysis tool from the 1960s. The adopted line was that of Chervel and Gall (Manual of economic evaluation of projects: the Effects Method. 1989. Ministère de la Cooperation, Paris).

This method considers the effects according to two levels:

- primary effects (direct and included) – related to the modification of production and consumption in the operational executer units and in related units
- secondary effects – related to modifications in the productivity levels of the economic agents related to the project.

Primary effects are measured by the variation of the up trading in all the productive units. Secondary effects are obtained by the influence of agents of up trading distribution in the department. The necessary data for the analysis are frequently not available. In such cases, the effects assessment can be based upon a matrix that interconnects economic sectors.

The Leontieff input-output tables analyze economy in a simplified scheme based in the premise that the distribution of economy in different sectors makes it possible to verify the necessary inputs to obtain each product. This makes it possible to perceive which sector/industry is responsible for supplying others. According to the Leontieff model, for each economic activity the sum of primary factors and intermediary consumption is equal to the amount of intermediary consumption and the final uses, i.e., the total input of each sector is equal to the total input.

The inputs of each sector are proportional to its total output. Generally, the intermediary consumption of a certain good or *i* factor necessary to the production of a *j* unit is given by $X_{ij} = a_{ij} * X_j$, in which a_{ij} corresponds to a technical coefficient. The analysis of the effects based on this matrix allows vast working hypothesis, if there is a significant disintegration of the sectors. Therefore, it becomes possible to:

- Verify the final search of initial variation regarding the project.
- Verify the succeeding indirect variations of intermediary searches that will be confronted with the final search.

The adopted matrix was the Insume-Product Matrix of Rio Grande do Sul[12], based in 2003.

The evaluated sectors for the formulation of Leontieff matrix were:

- Agriculture, Silviculture and Vegetation Export
- Livestock and Fish
- Vegetable Products Processing
- Animal Slaughter
- Production of Vegetable Oils
- Production of other food, including animal food.

[12] N.T. from the Portuguese “Matriz Insumo-Producto del Rio Grande do Sul”

This selection was based on the indicators of current and prospective scenarios. The baseline scenario was obtained with secondary data that was elaborated in previous packs. The future scenario was discussed with a small group of people who participated of the encounter held in the river basin, in June, 2008, and approved by its stakeholders in three meetings that occurred in November, 2008.

Conclusions

There are different measures that are possible to implement in the river basin. Here, four different action programs are presented and discussed.

Evolution in the ordering of water use in Brazil.
The first action program is an evolution in the ordering of water use in Brazil, which is reflected in the flow of the main channel of the Cuareim-Quaraí riverbed. In this way, the water quality increases, but there is a decrease of water for rice farming with reduction of local economy. There is a reduction in water treatment for human consumption. The costs should be assumed by water consumers, under the principal beneficiaries-pay principle, through which the ones who are beneficiated by any intervention in the basin should assume the costs.

Change in the production matrix

The second action program involves a change in the production matrix in the basin, in which 132.000 ha of eucalyptus will be planted in the natural pastures areas, corresponding to 10% of the basin's area.

Treatment /dilution of run-off water.

The third action program involves a dilution or treatment of run-off water from the cities of Artigas and Quaraí. Three different classes of treatments to reduce BOD are discussed. As a criteria, the Brazilian water classification and BOD (Biological Oxygen Demand) pattern is used.

A result of the treatment there will be a reduction of areas used for rice plantations which will be used for run-off dilution (2009). Today – Q 90% = 1.13 m³/s

Implementation of reservoirs

The fourth action program focused on the implementation of reservoirs in the basin, with the aim of increasing hydrological supply and flood control. The reservoir points in Brazil and Uruguay were selected from the the numeric model of the terrain, developed for the hydrological model MGB/IPH[13]. The selection of reservoir spots passed through two distinct moments. The first was held by the projects team. The second, by the Irrigation and Multiple Water Uses of Rio Grande do Sul, from the Brazilian side.

The second selection of spots is presented in Figure 109.

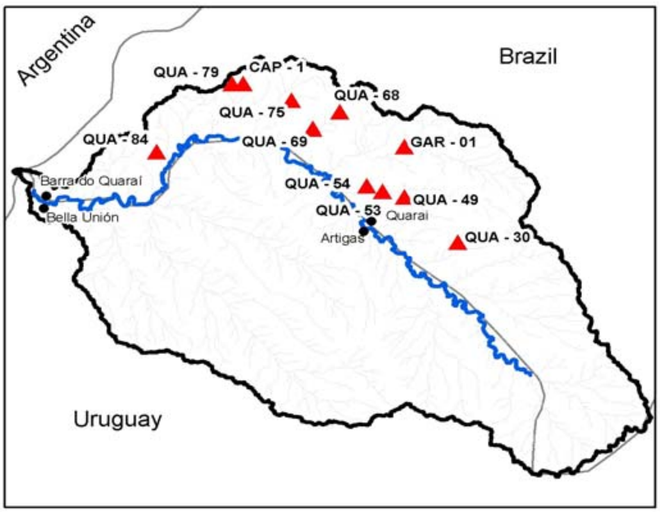

Figure 109. Spots selected by the Irrigation and Multiple Water Uses of Rio Grande do Sul for the localization of the reservoirs.

[13] T. N. from the Portuguese "Modelo de Grande Bacias do Instituto de Pesquisas Hidráulicas"

With the use of reservoir waters for the run-off dilution, it can be observed that its cost is very much reduced, which can lead to the option of not treating the run-offs, as the next table shows.

Conclusions

The economic evaluation of the basin Cuareim-Quaraí interventions indicates that the implementation of reservoirs is the most attractive option. There are three reservoirs on the Brazilian side which, according to the cost-functions adopted, present positive viability indicators for the cultivation of sub-irrigated rice. The other reservoirs do not present more favourable taxes.

The exchange in the productive matrix with the introduction of eucalyptus in an extensive surface of the basin generates impact in the minimal discharge of the main riverbed, whose importance lays in the dependence of water access in the soil. Therefore, this option is not indicated without the increase of the hydrological offer to compensate the discharge reduction.

The water stored in reservoirs for the dilution of run-offs is an attractive option, but the necessary volume for this dilution could meet the expansion of sub-irrigation areas up to 20% of the current area, with increase of the basin's economy to the same importance.

As for the floods, it can be observed that the cost of attention of the involved community is less than the presupposed generated with the charge for the use of water each year. That is, the basin can generate the necessary resources to sustain the damages caused by floods, which is the best option, making inversions to take the houses more likely to suffer from the river channel floods, thus reducing the costs involved in those events.

Therefore, the most attractive options for the basin are:

- The water charge for both sides of the basin, which will generate the values to confront the necessary inversions in run-off treatment
- The implementation of reservoirs on the basin to guarantee the water supply and reduce local conflicts
- The run-off treatment of Artigas and Quaraí
- The reduction of the most affected population through the displacement of households

As for the floods, it has to be considered the possibility of the implementation and operation of an alarm system that allows a coordinated and more effective action to reduce damages.

The economic conclusion is that the necessary inversion can be done with the own basin founts with governmental assistance and paid by its beneficiaries.

3.10 WP10 Twinning activities

The twinning workpackage served all other workpackages. Courses, on the job training, workshops, exchange of experts, etc; were organised within this package, addressing needs identified within the other workpackages. The following tools for twinning, i.e. capacity building and exchange of experience took place during the project:

- Courses and on-the-job training
- Workshops and joint on-the-job development
- Setting-up of a web discussion forum and communication routines
- Exchange of information with other twinning projects
- Twinning major authority stakeholders between the participating countries, by organisation of workshops that address specific stakeholder interests.

From the project kick-off meeting (October 2005), twinning activities were discussed and already during the first progress review meeting held in Coyhaique meeting (March 2006), the first main training focus was identified. This was the need of setting a common database strategy in almost all the basins.

The ArcHydro database structure was decided as the topic for the first training course activity in the project. This course was held at IPH Brasil, in Porto Alegre – Brasil, in April 2006. From this first activity a number of other twinning activities were carried out.

IVL had the experience of coordinating a previous twinning project, TWINBAS. Based on that experience the twinning aspect was considerably strengthened in TWINLATIN. A specific work package was created for twinning and more detailed activities were considered as well as a budget linked to the activities planned.

Three of the partners in TWINLATIN were also part of TWINBAS (IVL, CEH and EULA), being easier to develop twinning activities according to the partner needs due to their past experience, the knowledge about EU procedures, and the fact of having an specific work packages for twinning activities.

The legacy of the project has been a permanent vision of the twinning activities promoting the ensuring of the transfer of knowledge during the project duration as well as the promotion and implementation and use of the developed knowledge.

Objectives

The main objective of this work package was:

- To build capacity and exchange experience enabling launch of integrated water resource management in the case areas.

TWINNING ACTIVITIES

The activities have been divided into the following topics:

a) Training courses
b) International workshops
c) Expert engagement
d) Contacts with other projects/initiatives
e) Publications

Training courses:

First Database Training Course (Brazil)

At the Second TWINLATIN Project Meeting held in Chile in March 2006, it was suggested that partners should look into the possibility of implementing a common database structure for the LatinAmerican partner basins. This common structure could be based on ArcGIS / ArcHydro, on the SWAT model, on IVL's system Watshman, on the GWAVA model, or any other suitable model for storing river basin management information. This database should be in the form of a personal geo-database, which is an ESRI standard for storing spatial and tabular data in a Microsoft Access database. In order to access the personal geo-database the users have to have an ArcGIS 9 installation on their client computers.

There are several advantages of having a common project database structure, such as:

- Cheaper and faster to develop one database structure than several
- Better transparency and quality control within the project
- Faster to develop interfaces towards one well defined database for models like SWAT, Watshman or other applications.

IPH - The Hydraulic Research Institute at the Federal University of Rio Grande do Sul in Brazil offered to host the training activity 9-11 may 2006.

An important result of this twinning workshop was, apart from the knowledge transfer itself, the conclusion that ArcHydro is a suitable database structure for the TWINLATIN basins.

Second Database Training Course

A course in ArcGIS and ArcHydro was organised between IPH – Brasil and DNH – Uruguay in September 2006 at IPH. Ms. Silvana Alcoz from DNH – Uruguay was in charge of providing this course to 6 professionals at IPH.

It is important to mention that permanent contacts between all partners have taken place during the entire project duration concerning ArcHydro database implementation in the LA basins. Most of these contacts have focused on solving technical questions in relation to software usage.

IVL provided continuous guidance and technical support to the rest of the partners and later on to the Uruguayan partner DNH who continued with training activities to IPH professionals.

Modelling applications training course

A project proposal regarding modelling applications was sent to the TWINBASIN project in order to expand the twinning activities budget under TWINLATIN. This proposal was prepared by IVL, Unigecc, DNH and CIEMA partners and sent during December 2006. The main objectives were:

a) To start a training program held by IVL having as central topics database construction and Modelling Applications (simulation models for IWRM). More specifically, to develop a harmonised Database with connections to different model tools (SWAT, PCRaster, MODSIM, Watshman, other).
b) To strengthen technical capacities in the use and management of different models, supporting a more effective Integrated Water Resources Management.
c) To implement innovative communication tools in the basins: Nicaragua Lake (Nicaragua), Catamayo-Chira (Perú/Ecuador) and Cuareim (Uruguay) and to create links to the other basins in the Region.

This proposal was accepted by the TWINBASIN project and the training was held at IVL Stockholm during tree weeks in April-May 2007.

The activities were carried out with a suitable practical level and oriented towards problem solving in the process of setting up database structures. The theory and practice learnt at the course can be easily adapted and implemented in the participant's daily work regarding water resources management.

For the IVL experts this activity was an excellent opportunity to achieve better understanding of the competence and knowhow level in the LA basins. This knowledge is a key aspect when organising and dealing with knowledge transfer projects and local technological needs.

Other Training courses

a) ArcHydro training course at INETER (Nicaraguan Spatial Planning Institute), Managua, July 2007. Experts from EULA and CIEMA organised this course attended by 11 professionals from INETER and CIEMA (see table 4).

b) Archydro/water balance calculations training course at INETER, Managua – Nicaragua. This one week activity was executed by IVL, EULA, and CIEMA, with participation of 15 professionals from INETER and CIRA (Centro para la Investigación de Recursos Acuáticos / Water Resources Research Centre. The course was held in May 2008.
Both training courses served to establish technical cooperation between TWINLATIN-Nicaragua and INETER who is the main Nicaraguan end user of the information and knowledge gained through the project. Further construction and implementation of ArcHydro database was transferred to the INETER experts.

The courses are the first steps in the collaboration of both organisations and are the first efforts in trying to create a georeferenced database in the Cocibolca river basin. This will serve as an important tool under the new Water Code recently approved in Nicaragua, which gives INETER a high technical mandate.

Modelling (on-job training) - short term assignments

a) Expert from IVL (Tony Persson) at DNH – Uruguay (2 weeks, October 2007)

The objective with the on-job activity at DNH in Montevideo, Uruguay was to work with the implementation of a model system for reservoir management in the Cuareim River in northern Uruguay. The aim of the model system is to increase the capability of granting water rights for the numerous reservoirs in the river basin.

b) Expert from IVL (Peter Wallenberg) at UNIGECC, Piura – Peru (2 weeks, October 2007)

The activity in Piura – Peru was aimed to support UNIGECC with completing the setup of hydrological input files for the SWAT program. The complete amount of weather stations and data were now included in the model setup. Earlier problems with time series for meteorological data were solved. The model setup was completed successfully and now runs as expected.

c) Exchange of experts between CEH – UK and IPH – Brazil (March/October 2007)

This twinning activity focused on large-scale modelling and flood forecasting, and was carried out in Wallingford - UK and Porto Alegre – Brazil during March and October 2007. Walter Collischonn (IPH) and Fai Fung (CEH) were the experts involved. The main topics under this activity were the transfer of two different models: GWAVA and MGB created by CEH and IPH respectively.

This expert exchange was done during March 2007 with a two day technical visit from IPH (W.Collischonn) to CEH; and during October 2007 with a two day technical visit from CEH (F. Fung) to IPH.

d) EULA/CIEMA support to UNIGECC. Rainfall erosivity.

e) EULA/CIEMA/DNH/KULeuven: joint search for solutions for WATEM/SEDEM problem

International workshops

Testing the Economic Elements of the EU WFD in River Basins of the TWINLATIN project. Santiago, Chile 9-12 April 2007.

This four days Workshop was presented and organised by IVL in collaboration with three European experts on Economic implementation of the Water Framework Directive. The main objectives were:

1. Demonstration of the economic elements of the EU WFD and results from applications in river basins in Europe.
2. Discussions concerning the possibility of implementing the WFD economic elements in the river basins of the TWINLATIN project.
3. Design of approach and focus for WP 9 in each river basin
4. Development of preliminary work plans

TWINLATIN partner participants attending the workshop came from: IVL, EULA, DNH, IPH, CIEMA and UNIGECC as well as from other organisations such us CEPAL/ECLAC, Conama (Chile), DGA (Chile) and CIEP (Chile).

Public Participation and Gender in Water Management, Piura – Peru, May 2008

Public Participation and Stakeholder involvement: "Public participation and gender in water Management". Co-ordinated by UNIGECC and IVL. May 2008 in Piura – Peru.
The International Workshop “Public participation and Gender in the water management”, organised in Piura, Peru (with TWINLATIN partners’ participation), served as an excellent platform for reviewing the public participation objectives in TWINLATIN as well as a source of experiences, theoretical and practical examples and lessons learnt. This workshop was organised by UNIGECC in coordination with IVL and in association with the Gender and Water Alliance (GWA), the German technical aid service

(GTZ), PREDESUR, PROHIDRICO and Nature and Culture International (NCI). More than 100 people (mainly from Latin-American and European countries), attended this workshop and extents media coverage took place. The workshop was carried out the 20th and 21st of May 2008 in Piura, Peru.

The main objective of the workshop were:

- Tools and challenges in Public participation and gender in water Management as one of the key elements in the development project proposals towards sustainability

Specific objectives:

- To sensibilise private and public actors about the importance of an active public participation and gender approach in the water management

- To create a platform for discussion, debate, compromises between experts, researchers, technicians and social organizations

- To collect and systematize successful experiences and knowledge presented in the workshop

Presentations, discussions and conclusions are available in the following link "http://www.catamayochira.org/LIBRO%20SISTEMAT%20AGUA.pdf".

Sustainable Management Strategies: Experiences from TWINLATIN partners, Montevideo – Uruguay, June 2008
Workshop on water management, with participants from national water authorities. Current water management structures in TWINLATIN countries were presented, and strengths and weaknesses were openly discussed in a very constructive climate. TWINLATIN partners including researchers and authorities, as well as other authorities were represented. Jointly identified recommendations for management improvement were made.

The workshop consisted in a description of legal and institutional framework, decision processes and stakeholder involvement relating to actual river basin problems. Evaluation of effectiveness of legal framework, institutional capacity and decision-making processes was made, in order to identify:

a) Possible weaknesses in the institutional structure and in the decision-making process;
b) Reasons for possible disagreements on policies and current actions
c) Past or actual problems, solutions implemented and proposition of future actions.

Experts engagement

a) EULAs support to CIEMA. Permanent technical support. Patrick Debels part-time work for CIEMA from April 2007. According to DOW, on average 15% of the WP budgets were estimated for experts from other partners to be engaged in a particular basin.

From the beginning of the project it was noted the need of special support and building capacities at CIEMA – Nicaragua. . The main technical capacity detected needs at CIEMA were in: GIS expertise and modelling. According to the Coordination, the work done by CIEMA after the first year was limited and problems with the Management and technical staff availability. This situation was analysed and a final decision was taken during the progress meeting organised in Piura – Peru. During February 2007 started the permanent support of Patrick Debels from EULA to CIEMA. Mr. Debels moved to Managua in April 2007 and stayed there up to December 2008.

This long term on job training has been fruitful and made a strong impulse to CIEMA capacities and networking along the country. It is important to mention the experience of P.Debels in this type of projects (Twinbas and TWINLATIN EU WFD projects) and the positive effects provoked in the organization.

b) IVLs support to CIEMA. Database construction (ArcHydro), data analysis and modelling. Support in modelling aspects. Visits to Nicaragua by IVL-staff 2006, 2007 and 2008.

- **Workshop at CIEMA, May 2008**
  - Results from WP2

- Demonstration and training in programs for quality control and ArcGIS Geostatistical Analyst for interpolation of precipitation
- Evaluation of evapotranspiration data
- Introduction to model evaluation and uncertainty analysis
- Water balance calculations with simple and more advanced methods

c) EULA/CIEMA support to DNH. Metadata and WATEM/Sedem model application TWINNING visit of 1 EULA-Chile junior expert to CIEMA, Nicaragua (twinning on rainfall erosivity, ArcHydro implementation; August 2008)

- Short TWINNING visit of 1 EULA/CIEMA expert to DNH, Uruguay (twinning on metadata, ArcHydro, water body typologies; September 2008)
- TWINNING visit of 2 EULA-Chile experts to CIEMA, Nicaragua (field sampling of 210Pb sediment cores for dating of sedimentation/sedimentation rates; October 2008)
- TWINNING visit of 2 DNH experts to CIEMA, Nicaragua (twinning on WATEM/SEDEM implementation; November 2008)

d) EULA support to CIEMA/IPH/CVC: Classification of water bodies methodology.

e) KULEUVEN support. This support has been focused on the WATEM/SEDEM implementation. WaTEM/SEDEM is a spatially distributed soil erosion and sediment delivery model that is developed at the Physical and Regional Geography Research Group (K.U.Leuven, Belgium).

- To UNIGECC:
  - MSc thesis Stijn Van Kerckhoven: “Assessment of sediment yield and sediment production in a large basin affected by El Niño: the Catamayo-Chira basin, Ecuador-Peru”
  - MSc thesis Peter Gruber: “Analysis and modelling of land use changes in the ‘Río Quiroz’ river catchment, Peru”
  - Land use change modelling (IDRISI ‘Land Change Modeler’)
  - Application of WaTEM/SEDEM
  - Twinning on WaTEM/SEDEM with Bart Delvaux (UNIGECC) (Leuven, 05/09/2007)
  - GIS-support: data conversions, data quality, etc.
- To CVC: Application of WaTEM/SEDEM. GIS-support: data conversions, data quality, etc.
- To IVL: Application of WaTEM/SEDEM, Twinning on WaTEM/SEDEM (Stockholm, 01-03/09/2008)
- To DNH: Application of WaTEM/SEDEM, GIS-support: data conversions, data quality, etc.
- To CIEMA: Application of WaTEM/SEDEM. Twinning on WaTEM/SEDEM with Patrick Debels (CIEMA-EULA) (Leuven, 17/06/2008)

Contacts with other EC Twinning Projects/NETWORKS, OTHER

- TWINBAS: Use of results/experiences/lessons learnt/methodologies/technical documents, as a base for development of work under TWINLATIN.
- TWINBASIN: Project proposal sent for financial support. Project accepted (IVL-DNH-CIEMA-UNIGECC).
- TWINLATIN top-up: Project proposal as extension of TWINLATIN, including Venezuela and Dominican Republic partners. Not accepted by the EC.
- Bi-Regional meeting LA-EU: Meeting in Brasilia June 2006 for discussions on the EU 7th Framework Directive and the LA research needs.
- SARIBA project proposal. EU twinning project. DNH/UNIGECC as partners to continue the concept.
- CLIPP project proposal. EU 7th Programme. TWINLATIN used as a concept for implementing results as
- World Water Week 2007, Stockholm - Sweden. Presentation of results and contacts with other EU projects. Twinning European and third countries river basins for development of integrated water resources management methods" (TWINBAS, www.twinbas.org) and

"Twinning European and Latin-American River Basins for Research Enabling Sustainable Water Resources Management" (TWINLATIN www.TWINLATIN.org/). August 2007.

- FRIEND (Flow Regimes from International, Experimental and Network Data): TWINLATIN publicised at 5th international FRIEND conference in Cuba in December 2006. AMIGO: contact made with UNESCO FRIEND network for Latin America, called AMIGO
- Water Sector Programm Workshop: February 2007 (1 week) in La Paz, Bolivia. This workshop was prepared for the EC Delegations in LA. TWINLATIN experiences and study cases were presented.
- Chilean National Strategy for Water Resources. Possible links and input from TWINBAS and TWINLATIN with CONAMA – Chile (National Commission for the Environment). Several meetings have been taken place in Santiago, Chile.
- BID Training course: Water resources course presenting results and methodology to 50 IDB experts. Panama, July 2008. Study cases from TWINLATIN as well as the project concept were presented at this one week training course.
- LANBO/RELOC meeting in Rio de Janeiro. Presentation of main results. Nov. 2008. The Latin American Network of Basin Organizations – LANBO (www.ana.gov.br/relob), created in 1998 in Bogota/Colombia, is the regional chapter of the International Network of Basin Organization – INBO (www.riob.fr). During its General Assembly, realized in Debrecen/Hungary in June 2007, INBO decided, with the support of the Latin-American representatives, for the LANBO´s restructuring, asking the National Water Agency – ANA – of Brazil to assume, on a temporary basis, the role of Technical Secretariat. During the meeting in Rio de Janeiro/Brazil on 11 and 12 November 2008 in line with the 10th National Meeting of River Basin Committees (www.rebob.org.br), the General Assembly had the opportunity to discuss and approve LANBO´s Statutes and Work Plan and to elect members of the Board of Directors and Executive Secretariat. TWINLATIN project organised a side event for presenting the main project finding and results where 35 people attended this event.
- **IAI Seed Grant** [TISG-P-1] (US NSF Grant GEO-0436199): Development of Index for evaluating usefulness of adaptation measures to climate change (Inter American Institute for Global Change Research)
- **MNP** Project (Netherlands - Nicaragua): Development of model for the Cocibolca Lake (PCLake)
- **WB CEA-Nicaragua**: World Bank Technical Assistance for the preparation of the Nicaragua Country Environmental Assessment – Chapter on Cocibolca Lake Basin: will depart from results obtained under TWINLATIN.
- **Cuban Institute of Meteorology INSMET**: precipitation time series from RCM model run for Central America and the Caribbean at INSMET were provided for use under TWINLATIN
- **Department of Geophysics, Universidad de Chile**: Outcome from RCM runs has been obtained from DGEO
- **ECOMANAGE** (EC 6th FP): assistance of 1 EULA-TWINLATIN member at workshop on river basin management organized by ECOMANAGE, Coyhaique, Chile
- Assistance of 1 EULA staff member at **UNESCO Conference**: River Basin Management: bridging the gap between Science and Policy", Paris, June 2008.
- Assistance of 1 member of EULA to the **Panamerican Advanced Study Institute** "Balancing Hydropower Development and Biodiversity: Is Sustainability in an Adaptive Management Framework Achievable" Concepción, August 2008
- Presentation given by EULA on the European Water Framework Directive (WFD) and its relation with the TWINNING projects (TWINBAS/TWINLATIN) during a **Regional Workshop on the Reforms to the Chilean Water Code**, organized by **DGA, GWP SAMTAC** and the University of Concepción, and with participation of a large number of stakeholders from Biobío. The idea of a basin committee was launched.
- 1 participant from EULA trained in impact/vulnerability assessment to climate change (climate, land use) through participation in **regional training workshop (IAI scholarship)**
- Presentation at **IPCC TGICA Workshop** (Fiji, June 2008) on results from TWINBAS/TWINLATIN (invitation by WMO)
- Presentation at **UNESCO** Conference on Water and Climate (Montevideo, Uruguay, 2008)
- Presentations at VI and VII **International Symposium on Ecohydraulics (IAHR, IAHS, IWA)**

A number of scientific publications, training material, and presentations in different events in Latin America and Europa.

CONCLUSIONS

The main conclusions of the Twinning activities are:

- A permanent dialogue has been established that will continue after the project. Twinning activities have been a permanent and continuous activity in the project, with active participation of all partners.

- This permanent dialogue and activities has helped to fill the gap in knowledge and methods to implement more integrated water approach in the LA basins.

- Database construction (WP2) and modelling (WP3) issues have been the activities most intensively demanded by the partners. The twinned actions towards the creation of a harmonised geodatabase in the basins have been one of the main achievements of the project.

- A scientific-decision makers interfacing platform has been promoted and in some of the basins has been established.

- TWINLATIN has been well connected with other EU and regional initiatives and has served as an important input to identify problems and needs in non-EU river basins to improve IWRM.

- An operational interface has been created between the project technical team promoting WFD knowledge and its implementation in order to ensure the transfer of knowledge.

- Promotion of new twinning programmes/projects between EU and other LA basin organisations has taken place helping to develop and transfer the WFD knowledge and concepts.

- A number of publications and participation in different forum assured the dissemination of knowledge and findings to other regional initiatives.