Article, Published Version

Lasarte, Alejandro E.; Tomicic, Berislac; Jensen, Roar A.

Climate change adaptation to water related challenges in latin America

Hydrolink

CLIMATE CHANGE ADAPTATION TO WATER RELATED CHALLENGES IN LATIN AMERICA – COMBINING QUANTITATIVE ASSESSMENTS AND QUALITATIVE RANKING OF ADAPTATION MEASURES

BY ALEJANDRO E. LASARTE, BERISLAV TOMICIC & ROAR A. JENSEN

Resumen

La adaptación al cambio climático es considerada, por las principales instituciones financieras, por ej, BID, como un desarrollo prioritario para el sector del agua en América Latina. El enfoque que se presenta en el presente artículo consiste en identificar y clasificar las medidas de adaptación y evaluar su eficiencia mediante el uso de modelos numéricos para cuantificar los impactos. Se verificó esta metodología utilizando estudios de casos en América Latina abarcando diferentes tipos de impactos como aumento del nivel del mar, derretimiento de glaciares tropicales, sequías y eventos extremos de tormentas.

Adaptation to climate change is recognized by the main financing institutions, such as the Inter-American Development Bank (IADB), as a development priority in the Latin America (LA) region for the entire water sector. The approach presented in this article addresses, identifies and ranks adaptation measures, and assesses their efficiency by using numerical models to quantify their impacts. This methodology was verified by using case studies in the LA region covering a range of different types of climate change impacts including sea level rise, tropical glaciers retreat, threatened eco-systems (Figure 1), droughts and high intensity storms.

There is a large gap between the global (and more recently regional) assessments of climate change and the need for local approaches at basin scales and exchange of experience with those. This poses a serious challenge to water resources managers who need the appropriate knowledge in order to find practical climate change adaptation solutions.
The overall objective of this article is to present a methodology to generate experience and an approach to formulate general local scale guidelines to be used in climate change adaptation studies in LA.

For each case study, quantitative climate change impact assessments were prepared, and initial adaptation plans were outlined to support the local water resources institutions in their climate change adaptation strategies.

Climate change adaptation case studies are presented for three locations in three Latin American countries:

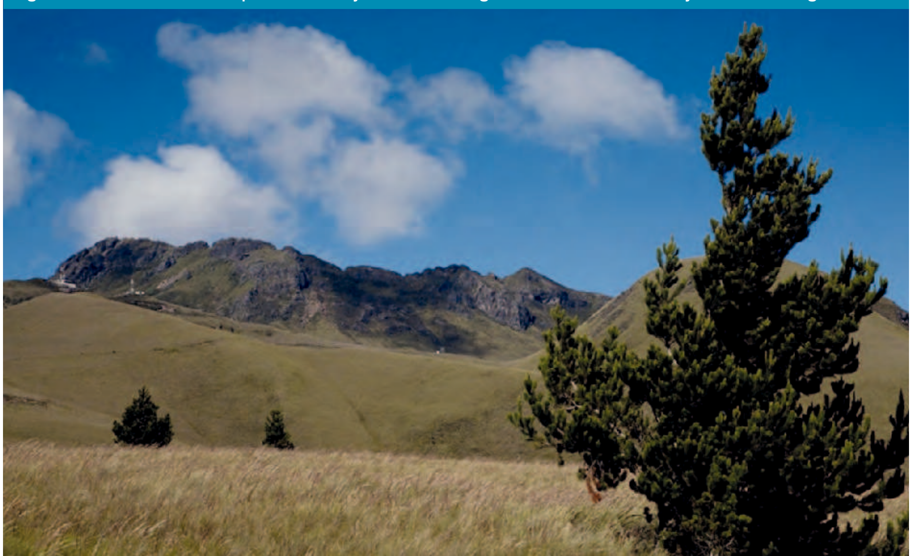
- Uruguay's capital: Montevideo (focusing on storm water drainage);
- Ecuador's Capital: Quito (focusing on impacts on water supply from glacier retreat and mountain ecosystems changes);
- Trinidad and Tobago (focusing on sea level rise and urban drainage)

The same overall stepwise approach to the assessment has been applied in all case studies. This approach has proven flexible enough to cope with the diverse issues and the different quantity and quality of available data in each case. Large uncertainty, particularly in the projected rainfall changes makes adaptive management necessary, and highlights the importance of building resilience into all project stages i.e. in the initial planning stage, in the feasibility phase and in the final design.

To address inherent uncertainty in climate change assessments, appropriate adaptation measures were identified and evaluated and an initial ranking (or screening) was performed considering their win-win characteristics, the creation of resilience, flexibility given to future system changes, costs and political acceptability. This exercise recognised the possibility that plans and priorities may need to be changed after some years, and that investments made should be sufficiently flexible to cope with such changes. The case studies presented here are rapid assessments conducted with limited man power input. They have relied on readily available data while avoiding time consuming and costly new model developments. Therefore, the applied approach and methodologies could be carried out as part of many practical water resources projects.
In spite of the uncertainties imbedded in the available climate change assessments it was possible, to screen projects or existing schemes for climate change impacts and devise solutions for their alleviation. Furthermore, it was possible to quantify the potential impacts on the water resources and flood frequencies. In some cases, the analyses identified the need for more detailed local climate assessments as one of the most important first steps in the local climate adaptation strategies.
The lessons learned from these practical case studies applications are:

- Climate change impacts on water related issues might in many developing countries be less significant than those originating from the increased anthropogenic pressure on land use and water resources. Nevertheless,

Figure 1. Run-off favorable páramo ecosystem in the High Andes under threat by climate change



climate change is expected to further exacerbate an already challenging situation.

- Local climate change impacts have to be analysed quantitatively in each case. In some cases, the most eye-catching and globally highlighted effects are not always those with the most significant local impacts. An example of this is the analysis of the water supply of Quito where the retreat of the glaciers due to their limited areal coverage, showed to have much less impact on water availability than the surrounding fragile ecosystems that may also be under threat by the changing climate.
- Qualitative assessments that prioritize win-win and no-regrets solutions are useful to guide planning and ranking of adaptation options particularly if the uncertainty associated with climate change assessments is significant
- Options for adapting to climate change are often well-known as traditional solutions to general water scarcity and flood protection problems e.g. traditional structural solutions re-designed to cope with a changed future climate.
- Even small screening studies can reveal important information on the necessity for adaptation and provide guidance to the detailed planning.

The Case studies

The Pantanoso Urban River Catchment, Montevideo (Uruguay)

This study included climate change impacts (sea-level rise and extreme rain storms) into an overall analysis of the storm water drainage system and a natural stream in the sub-urban catchment of the Pantanoso River, in the city of Montevideo, the capital of the Oriental Republic of Uruguay. The Pantanoso River is 15 km long, with its catchment (67 km^2) located centrally in the Montevideo metropolitan area. In its lower reaches, the river flows through wetland areas before entering the Bay of Montevideo.
The catchment is a transitional area, changing from a densely urbanized part in the East, towards sub-urban relatively scarcely populated in the West. The area is subject to extensive environmental problems and the catchment hosts many irregular settlements, even in areas exposed to floods. The main environmental concerns are the handling and disposal of domestic solid waste and industrial wastes, as well as the pollution of local water resources and streams.

More recently, serious concerns related to climate change have been added to the list of "conventional" challenges in the catchments, and the possible environmental effects of climate change in the medium and long term have come into focus for investigation.
The future operation of the Pantanoso River drainage system has been studied under the impact of relevant projected climate variables (extreme rainfall and tides) and demographic and socio-economic changes in the system (represented conceptually by the catchment runoff coefficient and hydraulic network capacity).

Climate change projections

As the current climate change projections for Uruguay do not include extreme events with 10 to 100 years recurrence intervals, estimates were made, based partly on the extrapolation of the existing knowledge (extreme rainfalls) and on available historical trends (sea levels). The future scenarios, with a time horizon of the year 2100, include the climate change variables at two levels: low climate change and high climate change. The "low climate change" was derived by extrapolations and the "high climate change" by introducing additional uncertainty (extreme rainfalls) by adopting recent, more pessimistic, global forecasts (sea level). For the year 2100, sea level rises of 17 cm and 110 cm have been adopted as low and high estimates, respectively.

For extreme rainfall, increases in peak intensities (and volumes) by the year 2100 by 15% and 21% for 10-year and 100-year rainfall, respectively, have been adopted as "low", while corresponding changes of 38% and 45% in these rainfall intensities are used as "high" climate change. The future socio-economic development was introduced in the analyses through two variables representing runoff characteristics of the catchment (permeability) and the hydraulic conductivity (blockage) of the channels. These variables were included in two possible future states associated with good and poor management practices, respectively

Impact assessment

A dynamic mathematical simulation model (MIKE URBAN), which is capable of simulating storm runoff, river and overland flows as well as flooding in the Pantanoso catchment, was used to model the impact of extreme rainfall and tides.

The simulation model was based on available physical data. However some important elements lacked the necessary level of detail and accuracy (terrain topography) or were mostly unavailable (e.g. river cross-sections). The model was not calibrated due to lack of appropriate historical records for operational variables (flows and water levels). Instead, default model parameters were used. All this implies that the model has a demonstration character only. However, despite these deficiencies, the model represents the major characteristics of the system well enough to allow usage of its results for qualitative analysis of the system behaviour under various scenarios.

Adaptation measures

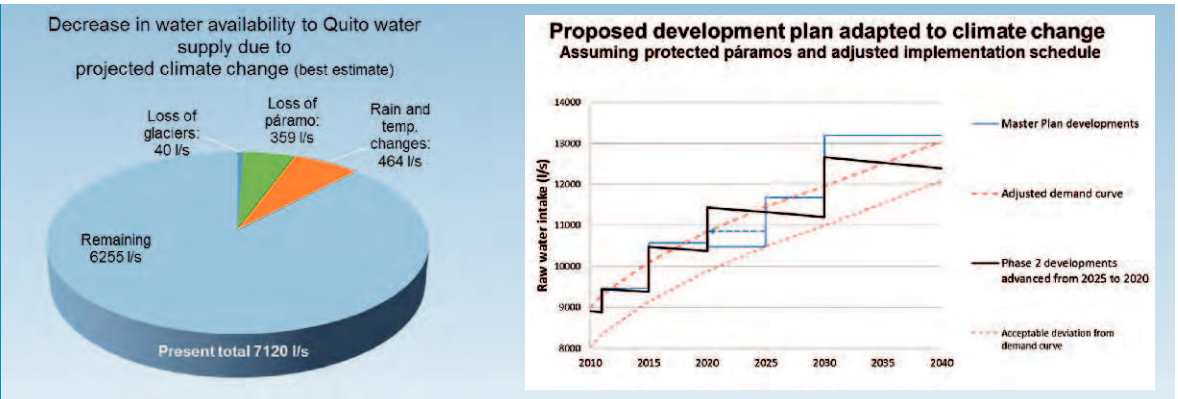
The climate change impacts were superimposed on the demographic and socio-economic development impacts in the catchment. Both climate change and man-made changes increased the flood risks, which in combination with water-borne pollution could significantly increase the vulnerability of the area.

Alejandro E. Lasarte **is Senior Hydraulic Modeler, Engineer and Project Manager at DHI. Mr. Lasarte has more than 30 years of experience on the fields of river hydraulics, flood management, hydrological modelling, water resources modelling, information systems and climate change.**

Berislav Tomicic **is Senior Hydraulic Engineer and Project Manager at DHI, with more than 30 years of experience on modeling of urban hydrology, hydraulics, urban floods and climate change impacts.**

Roar A. Jensen **is Senior Water Resources expert at DHI with more than 30 years of experience from numerous water resources planning, hydrological and hydraulic modelling projects, worldwide.**

Figure 2. Decrease in water availability due to climate change and adaptation of the proposed water supply development plan for Quito



A range of scenarios were developed and analyzed, featuring various combinations of "low" and "high" future changes, in both climate and non-climate variables. These analyses showed that the impact of climate and non-climate changes were of comparable magnitude, but had different impacts in different parts of the catchment.
The lower part of the catchment – Pantanoso Bajo – is subject to a strong tidal influence, which means that its vulnerability is mainly due to sea level rise, i.e. larger extreme tide peaks. The upper and central parts of the catchment are beyond tidal reach, but are sensitive to extreme rainfall increases, as well as to the uncontrolled socio-economic development. In the worst-case future scenario, the flooded area in this part of the catchment could increase more than three-fold compared to the present. The most effective measures to reduce the vulnerability in the Pantanoso Bajo area include re-settlement of people and valuable assets from the flood-prone zones, and physical protection of the most valuable assets. Various general catchment management measures can contribute to the situation improvement here, but not significantly.

Climate Change Impacts on Glacier Retreat and Mountain Hydrology and Implications for the Water Supply of Quito (Ecuador)

This case study concerned climate change impact on mountain hydrology and glacier retreat and its implications for the water supply to the City of Quito. Quantitative GIS analyses in combination with hydrological modelling and field study results were performed to assess the future impacts on ecosystems and water availability.

The Ecuadorian capital of Quito has a population of 1.6 million and is located almost on the equator at an elevation of 2800 m in the Guayllabamba Valley. Quito's Public Water and Sanitation Company EPMAPS (Empresa Pública Metropolitana de Alcantarillado y Agua Potable de Quito) supplies the city with surface water, captured at high elevations from sparsely populated and almost natural mountain catchments, which is supplied to the city by gravity pipelines.

At present, these catchments are dominated by ecosystems known as páramo (see Figure 1). These high elevation moors and wetlands cover extensive areas above the tree line while the areal extent of the glaciers residing only on the highest elevations is much smaller. From a water harvesting point of view, the páramo constitute an ideal combination of soils with very large water retaining capacity and vegetation with good erosion protection and low evaporative losses. However, field studies have shown the páramo to be a highly fragile ecosystem and both afforestation, cultivation and intensive grazing have been found to lead to the collapse of the sensitive soil matrix, and therefore to a significant reduction in the water retaining capacity. Ecosystems similar to páramo are known to exist in other Andean countries, such as the puna in Peru.

There is a well-founded concern that generally increased temperatures may lead to transformation of larger páramo areas to forest (by the rise of the treeline), or to cultivated fields and grazing areas, all of which will have negative consequences for water harvesting.
The glacier retreat is very well documented in the area and is found to have a negative impact on the yield of the intake catchments.

Assessed Impacts

The impacts of climate change on the resources availability were quantified by combining findings from previous field studies with GIS analyses and hydrological modelling. The analyses focused on three important aspects:

1. Changes in runoff due to changes in the extent or degradation of páramo ecosystems,
2. Changes in runoff due to the retreat of the glaciers in the area and
3. Direct hydrological impacts on the runoff due to projected trends in precipitation and temperature.

The average loss in water availability from all three aspects was assessed at 12% for all of EPMAPS' supply systems (using a central climate projection estimate) of which 1% originates from glacier retreat, 5% from degraded páramo and 6% from changes in rainfall and evaporation. More pessimistic climate estimates resulted in reductions in the present availability of 34 % with almost the same distribution between the three analysed aspects.

Adaptation measures

EPMAPS' existing water supply master plan focuses on how to cope with increasing water demand and how to make the supply more resilient to volcanic activity. The plan aims at reducing demand and losses in the system, but also includes new structural developments to increase the water capture area. The projected decrease in water availability due to climate change will put the water supply under further stress. In addition to measures already included in the water supply master plan, extensive protection of páramo areas from forestation, grazing and cultivation should be introduced to avoid their degradation. Even with such protection measures in place the water availability will gradually decrease due to lower rainfall and to a smaller extent due to glacier retreat, which in turn calls for adjustments in the planned investments, e.g. advancing some of the scheduled developments to keep the supply security at the same level as in the existing master plan as indicated in Figure 2.

Port of Spain, Trinidad & Tobago

This study focused on investigating and solving the problem of urban flooding in Port of Spain, capital of Trinidad and Tobago, under the impact of relevant climate change variables - sea level rise and extreme rainfall.

In response to repeated serious flooding in downtown Port of Spain, the Government of Trinidad and Tobago initiated an urgent action including a number of individual projects – called "packages", focused on improving the drainage facilities at specific locations in Port of Spain, subject to flooding. Due to the scale of the problem, IADB was asked for financial assistance.

IADB was seeking a more comprehensive and integrated approach, comprising a solid understanding of climate change and environmental impacts, rather than a number of individual, essentially independent local solutions. In addition, the entire catchment of 45 km^2, with two rivers and an urban drainage network, were to be included in the analysis. The need for such an integrated approach was highlighted by the initiative to develop public spaces and traffic connections along the urban stretch of the St. Ann's River – the so-called "Linear Park".

Successful realization of the "Linear Park" is highly dependent on full understanding of the St. Ann's River catchment hydrology, its hydraulic capacity and pollution loads. DHI recommended an integrated catchment management approach, including updating of the catchment hydrology, performing integrated modelling of the drainage system, accounting for climate change and carrying out an environmental impact assessment. The work was divided in some well-defined blocks:

- Flow and Rainfall Measurements Campaign;
- Integrated Hydrological and Modelling Study;
- Supply of the Modelling Platform and Training;
- Climate Change Design Manual;
- Environmental Impact Assessment;
- Re-evaluation of the preliminary design for individual packages

The work performed demonstrated that the flooding problems are the compounded result of various inappropriate urban management practices, with climate change impacts acting as an additional exacerbating factor. It was found that the development of a modelling framework integrating the urban drainage hydraulics with the simulation of the hydrological response of the entire contributing catchment to present and future rainfall events was essential for establishing an understanding of the relative contribution of the various factors to the flooding problems of Port of Spain.

Through the modelling framework, it was possible to demonstrate the influence on the flooding of past urban developments and to compare them to the impacts imposed by the changing climate. The primary cause of flooding problems could be clearly linked to the uncontrolled urbanisation of upstream catchments, while climate change will impose significant additional strain on the drainage infrastructure in the future. The established simulation model was used to analyse a number of solution scenarios, which in turn led to a series of well-founded general and specific recommendations for future adaptation actions. ■

References

- Water Resources Climate Change DHI Guidelines – How to achieve Sustainable adaptation – January 2012 (http://www.dhigroup.com/areas-of-expertise/climate-change)
- Urban Climate Change – DHI Guidelines - How to achieve Sustainable adaptation in urban areas – January 2012 - (http://www.dhigroup.com/areas-of-expertise/climate-change)
- Marine Climate Change – DHI Guidelines - How to achieve Sustainable adaptation in marine areas – January 2012 (http://www.dhigroup.com/areas-of-expertise/climate-change)
- Knowledge and Capacity Building Product: Climate change adaptation case studies for IDB, Inter-American Development Bank, Technical Note, May 2013, Elaborated by DHI
- MIKE URBAN – User Guide and Reference Manual, DHI. July 2012