# An approach to the hydrological modelling of urban wetlands under climate change scenarios. Case study: Jaboque wetland, Bogota, Colombia.

## Une approche de modélisation hydrologique des zones humides urbaines sous des scenarios de changement climatique. Étude de cas : Zone humide de Jaboque, Bogota, Colombie.

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## RÉSUMÉ

L'entreprise d'eau et d'assainissement de Bogota (*Empresa de Acueducto y Alcantarillado de Bogotá* EAAB) réalise des plans et des travaux de restauration écologique dans les écosystèmes des zones humides urbaines en vue de récupérer ses fonctions biologiques, paysagères et environnementales. Le plus remarquable est la reconfiguration hydrogéomorphologique pour stocker de plus grands volumes d'eaux de ruissellement et pour contrôler l'acheminement et le stockage des crues et des inondations. Cette étude aborde une modélisation hydrologique globale du bassin afférent à la zone humide de Jaboque, de résolution journalière. Ensuite, le changement de stockage a été simulé en utilisant la méthode de pool level routing. Les entrées du modèle sont le modèle numérique d'altitude de la zone humide ainsi que les séries de données journalières sur les précipitations et les températures. Les niveaux d'eau simulés par jour ont été comparés avec aux données observées à l'aide de différentes fonctions objectives pour réaliser l'étalonnage du modèle hydrologique. Une fois le modèle etalonné, les séries chronologiques de précipitations et de températures projetées par les modèles climatiques régionaux pour la ville de Bogotá ont été utilisées pour corriger leur biais en utilisant des données statistiques des stations météorologiques de la ville. Ces séries ont fourni le modèle etalonné assemblé, afin de prédire les cartes d'inondation de la zone humide.

## ABSTRACT

Bogota Water and Sewerage Company (*Empresa de Acueducto y Alcantarillado de Bogotá* –EAAB-), is carrying out plans and works of ecological restoration in urban wetland ecosystems aimed to recover its biotic, scenic and environmental functions. The most outstanding is the hydrogeomorphological reconfiguration to store bigger volumes of runoff water and to control the routing and storage of rises in waters and flooding. This study approaches a simple lumped hydrological modelling of the afferent catchment to the Jaboque wetland, of temporary daily resolution. Next, was stimulated the change of storage utilizing the pool level routing method. The model inputs are wetland digital elevation model DEM and both daily rainfall and temperatures data series. The daily-simulated water levels were matched to observed data using different objective functions to accomplish the calibration of the hydrologic model. Once the model was calibrated, time series of precipitations and temperatures, projected by climatic regional models for the city of Bogotá, were used to the ones that corrected its bias using data of weather stations of the city through statistical methods. These series supplied the assembled calibrated model, in order to forecast the wetland flooding maps.

## KEYWORDS

Climate change scenarios, Hydrological modelling, Urban wetlands, Water level

# 1 INTRODUCTION

Nowadays Bogota city has a 700 ha-complex of urban wetlands (from 50.000 ha at the beginning of 1900s (Byron Calvachi Zambrano, 2016)) recently designated as Ramsar sites by the National Government of Colombia, which make part of storm sewer system. According to Ramsar Convention Secretariat (RCS) worldwide wetlands are experiencing environmental degradation as urbanization, contamination, loss of biodiversity, drought and uncontrolled growth of grass among others (Tiwari & Upadhyay, 2017), specially urban wetlands are threatened by alarming levels of degradation and loss (Hettiarachchi, Morrison, & McAlpine, 2015). Wetlands fulfil different and varied functions inside a watershed as flood mitigation, storm abatement, water quality improvement, regulators of biogeochemical cycles, habitat of waterfowl and other birds, which depend on the measurement ecological scale (Mitsch & Gosselink, 2000). As part of the efforts made by the Mayor of Bogota, forced by law to comply with judgements in favour of social and community organizations, EAAB as responsible for managing storm water (DAMA. Environmental Authority of Bogota, 2006), have been developing infrastructure to restore some of wetlands from ecological, hydraulics, geomorphic aspects, consisting of a wetland reconfiguration according to criteria above mentioned.

The aim of this work is carry out the calibration of a daily, lumped, simple hydrological model of an urban wetland for later incorporate regional climate change projections of precipitation and temperature to determinate flooding levels and overflow probabilities. The modelling is performed on two different topographic scenarios according to restoration levels. First scenario is a non-intervened wetland, i.e. whit a zero level of restoration and second scenario is a future-intervened and restored wetland with a different topography (reconfigured), usually with a greater storage capacity to routing higher storm hydrographs.

# 2 METHODS

## 2.1 Case study and hydrologic modelling.

The analysed case study is placed in Bogotá, an urban wetland placed in an Andean, big sized and above 2600 m city of 9.000.000 of inhabitants (shown in figure 1) with two marked rainy seasons by year. Jaboque wetland is located at western of Bogota, has 152 ha area. It is part of the storm sewer system and receives discharges from a 1270 ha catchment. When wetland water reaches discharge level, pours into the Bogota River by means of two concrete 20 in-diameter pipes.

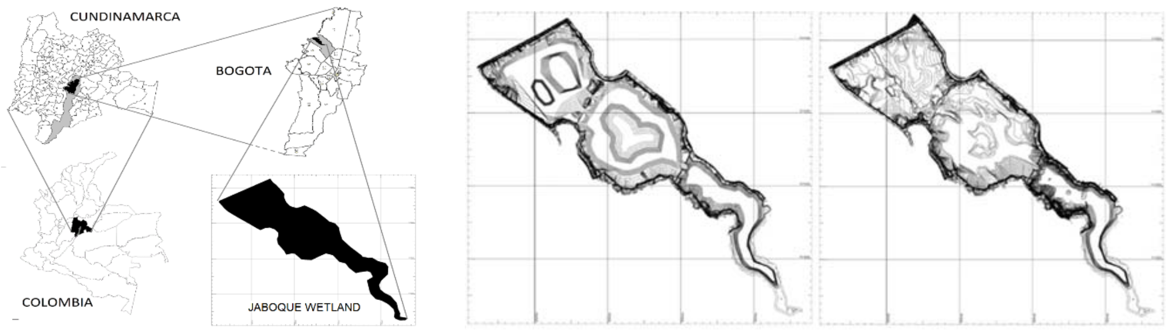


Figure 1. Left, Case study location. Centre, DEM scenario future-intervened wetland. Right, DEM scenario non-intervened wetland

A simple level pool routing model was used to simulate daily water levels in the wetland as a function of daily water budgets (Mitsch & Gosselink, 2000; Villa & Tobón, 2012) using balance equation $dS/dt = I(t) - O(t)$. Rain falls directly on the wetland and streamflow from catchment computed using the rational method were model inputs. Both wetland and catchment evaporation and discharge to Bogota River using Manning's equation were model outputs. For calculating daily water levels in the wetland, both storage-water surface elevation and elevation-outflows curves were developed processing Digital Model Elevation DEM in GRASS GIS software. Process above mentioned were carried out over the two DEM scenarios of Jaboque wetland (a non-intervened wetland and future-intervened and restored wetland). In order to calibrate the model, water level measured data series were used (eight-month daily data measured). Runoff coefficient $C$ and $n$ Manning´s coefficient (discharge pipes) were evaluated between minimum and maximum values reported until best model performance (minimum RMSE, Nash efficiency criteria NSE -Nash & Sutcliffe, 1970- and maximum R) was found.

## 2.2 Climate change scenarios.

General circulation models (GCMs) supply scenarios of future climate projections and aspects of climate variability and extremes. Future climate simulations are performed for different IPCC emission scenarios (IPCC, 2007); the result of these models indicate that future rainfall and temperature are likely to change but that the magnitude of these changes will be different in areas with different climatic regimes (Rajbhandari, Shrestha, Nepal, Wahid, & Ren, 2017). RCP 2,6, RCP 4,5 y RCP 8,5 CORDEX projections (COordinated Regional climate Downscaling Experiment) data series were bias corrected using hydrological local stations by means of R kernel package to be coupled to the hydrological model.

Once bias is corrected, both historic and projected precipitation data series can be coupled to model developed over two DEM scenarios of Jaboque wetland. Historic period is between 1951 and 2005 (data series from hydrological stations) and projected period is between 2006 and 2100 (data series from future regional model).

# 3 RESULTS AND DISCUSSION

Figure 2 shows simulated flood levels between 1951 and 2100 in non-intervened wetland and future-intervened and restored wetland in RCP 8.5 scenario (flood levels were simulated for 2.6, 4.5 and 8.5 RCP). Probability of flood occurrence was calculated for each climate change and DEM scenario. Minimum flood level was above 2543.13 m for RCP 8.5 in future-intervened and restored wetland and maximum was above 2543.61 m for RCP 2.6 in future-intervened and restored wetland.

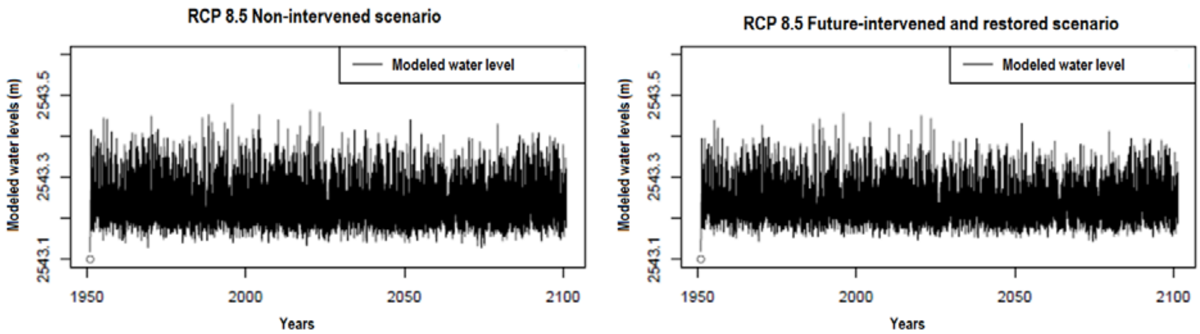


Figure 2. Left, Change of water level scenario RCP 8.5 non-intervened. Right Change of water level scenario RCP 8.5 future-intervened and restored wetland

Figure 3 shows flood maps for RCP 2.6 non-intervened wetland and future-intervened and restored wetland and flood maps for RCP 8.5 non-intervened wetland and future-intervened and restored wetland. Routing different runoff from climate change scenarios did not have appreciable influence over water levels but did have over discharge flows. Non-intervened wetland is surrounded by a perimeter land wall built in order to protect neighbourhoods from flooding as in 2012 occurred, making the only effluent is the two concrete pipes to Bogota River. However, outflows volume increased with climate change scenarios. We found hydraulic retention periods between 30 and 60 days and were calculated based on the storage volumes and routed and discharged flows. The area with the highest probability of flooding is located at the southern side of the wetland, according to the figure 3 that shows floods and historically is an area where the wetland has sporadically overflowed.

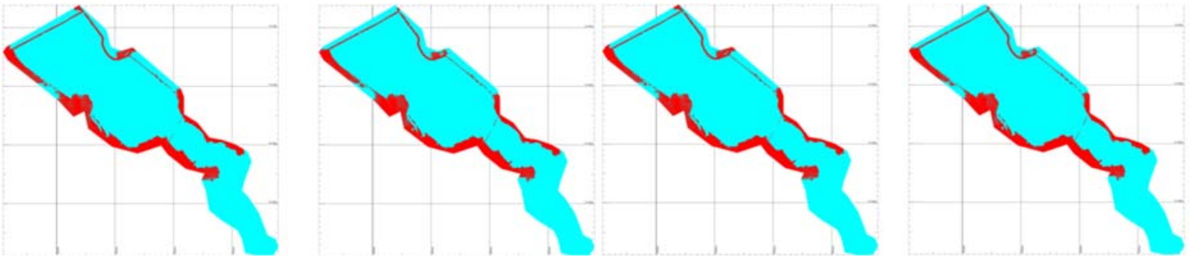

Figure 3. Left, Flood maps RCP 2.6 a) non-intervened wetland b) future-intervened and restored wetland. Right, Flood maps RCP 8.5 a) non-intervened wetland b) future-intervened and restored wetland

## 4 CONCLUSIONS

Urban wetlands are important components of storm sewer system due to storage of high volumes of runoff additionally ecological, social, and environmental values. In order to enhance next hydraulics and hydrological modelling is recommended to measure more accurately and consistently either the water levels or the discharge flows. Bias-correction is not intended to match observed data series with projected data series by regional models but is aim to find behaviours and trends and determinate if regional projected data can be used in local models. Although is very difficult to reproduce exactly the behaviour of water levels with a lumped model, this modelling was made because patterns of water level were the goal, more than exact values. The most important parameter found in this modelling was the discharge level, either the pipes in non-intervened scenario or the weir structure in future and restored scenario, because that structure control and regulate flooding levels. The future and restored scenario shows that is important because increase storage of runoff and could attenuate high peaks flow caused by extreme rainfalls.

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