Instituto de Biología UNAM

FARN FUNDACIÓN AMBIENTE Y RECURSOS NATURALES

POLICY BRIEF

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THE ROLE OF NATURAL AREAS IN CLIMATE CHANGE VULNERABILITY FOR FLOODS AND WATER SCARCITY IN SÃO PAULO, MEXICO CITY AND BUENOS AIRES

Natural areas around cities provide ecosystem services, such as aquifer recharge, and reduction of water runoff speed on rainy season. Vulnerability of the cities depends on the resilience capacity of the surrounding ecosystems (IPCC- Field, *et al.* 2014). The urbanization of the metropolitan areas of São Paulo, Mexico City and Buenos Aires reduce these ecosystem services in quantity and quality, generating water scarcity and floods. Climate change will dramatically modify the rain regime in these three cities, potentially increasing floods as the water infiltration is reduced. To evaluate the function of the ecosystems as buffers for water supply and flood, we modeled the infiltration capacity of the watersheds and flooding risk for each city, considering land use changes and climate change on rain. These models help generate a new viewpoint on water management that considers the whole basin as a unit to reduce vulnerability risk brought by climate change.

KEY MESSAGES:

- Climate change modifies rain regime, which is a key factor on water vulnerability of cities related to flood and the sustainable use of the aquifer.
- The main vulnerability on Buenos Aires is flood on extreme rain events; São Paulo's main vulnerability is related to overexploitation of the aquifer; Mexico City's main vulnerability is related to both, floods and groundwater supply.
- Natural areas within or near the cities provide a buffer for climate change by reducing vulnerability of cities on water scarcity and floods.
- The vision of water management must include the basin perspective and natural areas since they increase resilience facing the climate change.

Water management in cities focus on water supply and floods prevention. Both are related to natural areas, since these increase water infiltration and reduce water speed in storms. Urban expansion is constant as cities hold more population in the world than rural areas. Urbanization builds a concrete layer on natural areas, reducing water infiltration to the aquifer, which results on a boost on water runoffs from highlands to lowlands, triggering floods on lower areas of cities.

Climate change is bringing a new rain regime that will increase the volume of rain and the number of storms and droughts. The new regime increases the vulnerability of cities, particularly if they have reduced the surrounding natural areas throughout urbanization.

São Paulo, Mexico City and Buenos Aires have uncontrolled population growth, resulting in an unorganized urbanization. In order to understand the climate change vulnerability of these cities, it is necessarily to consider a basin perspective of the metropolitan area to describe the water regime for water infiltration capability and floods at different levels of land use changes and rain regimes.

The Metropolitan Region of São Paulo's water supply is acquired mainly from surface water but there has been a constant growth on the water extraction by non-regularized wells that could compromise the quality of the water reservoirs (Banco Mundial, 2012). The abundance and quality of water partially limits overexploitation, but the increasing population growth rates, the lack of regulations on urban planning and the quick industrial development threatens the entire region.

In Mexico City's Metropolitan Area, near to 70% of water supply is obtained mainly from groundwater extraction. Nowadays, there is a serious shortage of the resource in spite of the overexploitation of the seven aquifers that constitute the area (CONAGUA, 2009). Also, the lake-shape topography were the city is based and increasing urbanization generates constant floods in the lowlands from the highlands' runoff. The city continues to expand on lowland areas that used to be covered by wetlands and lakes, which requires a massive investment on infrastructure to avoid flooding. The city's second airport plan is a perfect example of this.

The flat land and the high amount of streams in Buenos Aires expose the area to flood risk. The accelerated population growth in the last third of the twentieth century, resulting in and uncontrolled urbanization, and the lack of flood norms are increasing the flood risk in the whole area (Kreimer *et al*, 2001).

Accurate information of possible climate change effects on soil infiltration capacity and floods on these cities is scarce, which together hold more than 40 million people. Using topography and urbanization variables to understand infiltration and flood risk areas in cities, we generated maps based on models of land use change and climate change scenarios. These maps are a basin-centered vision in the water management of the cities to face climate change vulnerability.

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Method: How are we working?

Soil Infiltration Capacity

We gathered and identified the layers belonging to four features that were considered the most relevant according to previous works. Each was valued and reclassified in a quantitative way in accordance with its contribution to the infiltration process (Schosinsky *et al*, 2000; Burns, 2009) represented with a color of each pixel, equivalent to one hectare. The resulting map was reclassified into groups to provide a qualitative classification expressed on every region, facilitating the information presentation.

Ranks were different for each city since they have different ecosystem values, but we used the same classes for comparative reason. The bluest areas represent a greater infiltration capacity and the greener areas a lower one.

Once we had the infiltration capacity maps, we proceeded to model changes on this infiltration by modeling land use change scenarios in which the natural areas are turned into urban lands. We also modeled climate change scenarios obtained from NOAA, on 2046-2065.

Flood Risk Models

We adapted the flood risk model proposed by Vera-Pérez & López-Blanco (2009) using features such as the reported flood density. This method was adapted to available and relevant data from Buenos Aires and São Paulo. The risk is represented by dark green pixels for low flood risk to red for the higher risk areas. Flood risk models will be tested with climate change scenarios obtained from NOAA, on 2046-2065.

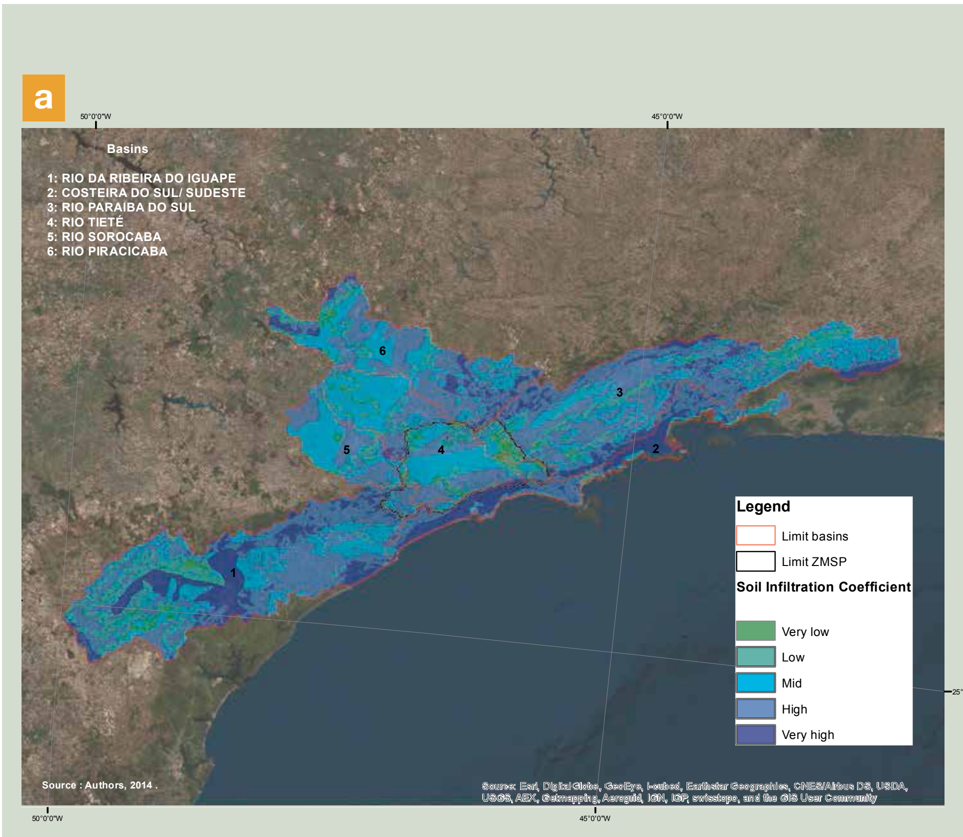
Results

Soil Infiltration Capacity

Each metropolitan region has different traits among each other in all used variables of the coefficient and their contribution and relevance is dependent to the region. The human activities that endangered the soil capacity to percolate water, such as the population growth, the urban sprawl and land use changes, are similar between the Metropolitan Area of Mexico City and the Metropolitan Region of São Paulo, but not so for the Metropolitan Area of Buenos Aires, in which the forest cover is low and the groundwater is recovering (AABA, 2014).

In São Paulo and Mexico City, the tree coverage areas at the surrounding mountains of each region are highly important for infiltration (Figures 1a and 1b). Still, precipitation constitutes a higher proportion of it. Nevertheless, mountainous areas have high slopes and failing to preserve its vegetation could lead to an increase in the superficial runoff that might flood the lower zones. Moreover, preserving natural areas could mean a short-term measure to maintain or increase water infiltration; although precipitation requires long-term efforts.

The Metropolitan Area of Buenos Aires is mainly flat and has a scarce forest coverage, compared to the other metropolitan regions (Figure 1c). The most relevant factor is the soil texture, mainly due to sandy soil. This results show that urban expansion must have limited growth on these areas.



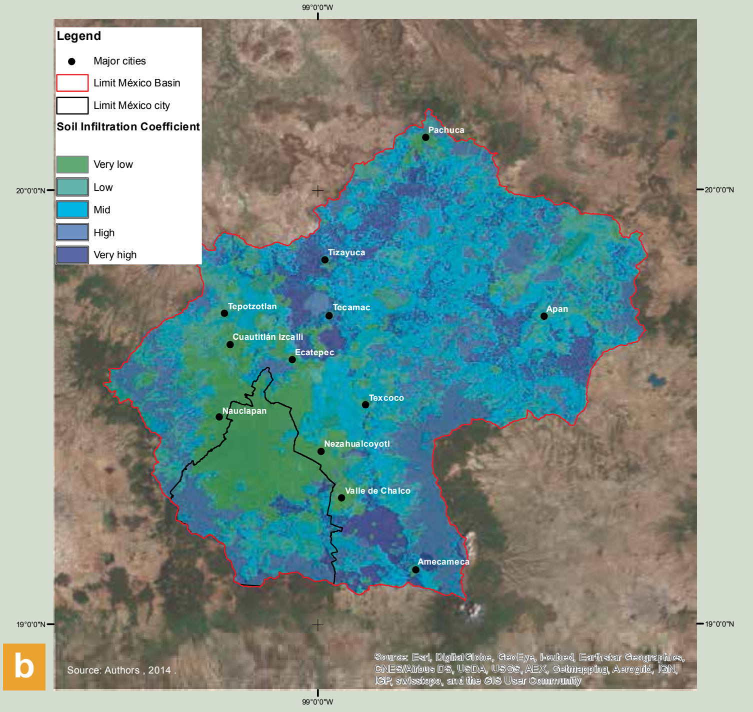
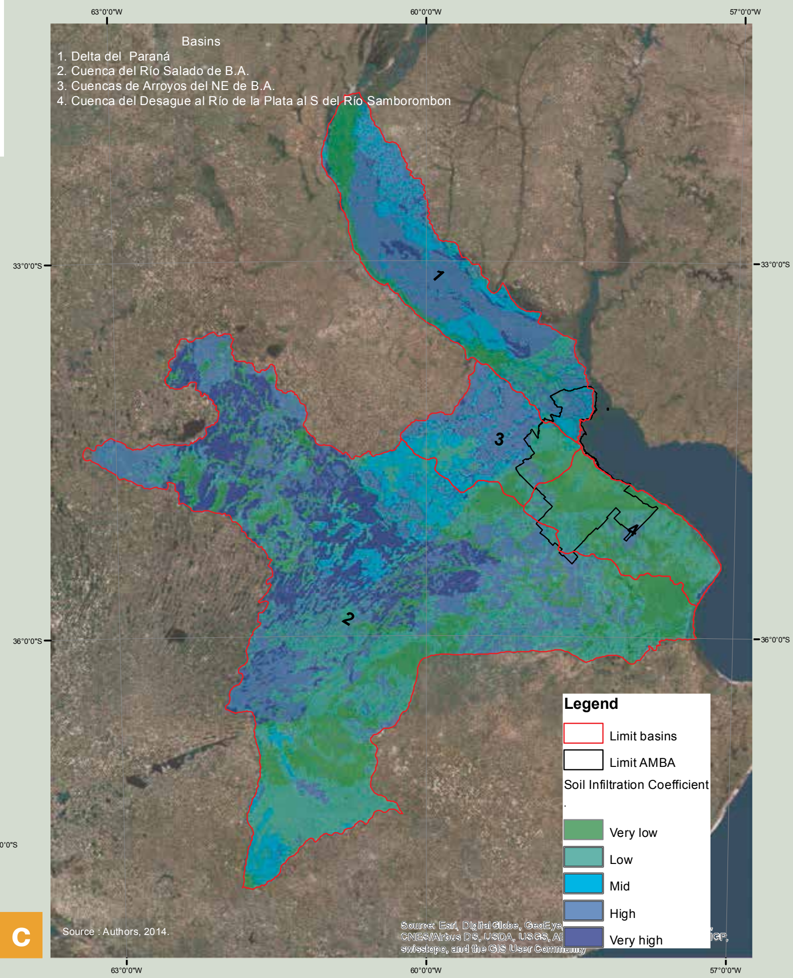


Figure 1. Resulting infiltration capacity maps for the metropolitan areas of (a) São Paulo, (b) Mexico Cityand (c) Buenos Aires.



Models of land use change and climate change on Soil Infiltration Capacity

Without climate change scenarios, turning forests into urban land affects infiltration capacities (figure 2). São Paulo shows a 21.29% loss, which is the most dramatic, and Mexico shows a 7.51% loss. Buenos Aires is the less affected, with a 2.03% loss.

When land use remains unchanged on the three metropolitan areas, infiltration capacities are different under the three climate change scenarios (A1, A2 and B1) (figure 2). São Paulo's changes its infiltration in small amounts (less than 3%). Buenos Aires infiltration capacity is reduced in all climate change scenarios. Mexico is almost non-affected on its infiltration capacity in one scenario, and increase in other two.

The models with land use change of forests into urban lands, under the three climate change scenarios, show varied results (figure 2). São Paulo shows the greatest change, with a reduction higher than 18% of its infiltration capacities. Buenos Aires shows a loss in all three scenarios. Mexico has the fewest scenarios resulting in infiltration capacity loss.

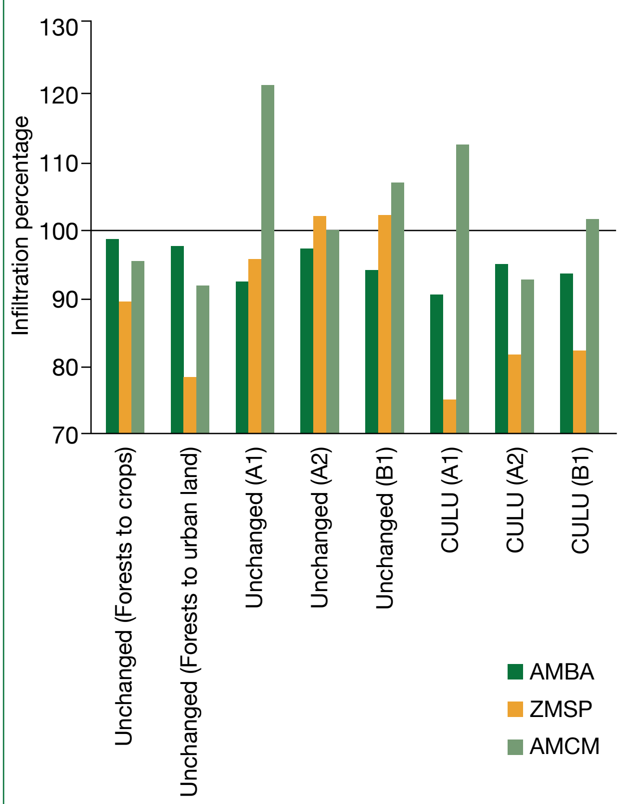


Figure 2. Percentage of the infiltration capacity of the three metropolitan areas under different scenarios relative to their respective current average infiltration capacity value (unchanged). Metropolitan Area of Buenos Aires (AMBA), Metropolitan Region of São Paulo (ZMSP) and Metropolitan Area of Mexico City (AMCM).

Flood Risk Models

We have seen two main traits in Mexico City's floods, in which the minor floods have a high relationship with the mean density of the solid residues produced per day. The larger floods have a proportional relationship with the ground sinking. Moreover, lower altitude districts tend to have a greater flood density than those on higher ground. The map presented on figure 3b corresponds to minor floods. At Buenos Aires, the lowland besides the Plata River have a high flood risk but small streams have a higher risk of flooding the surrounding areas, therefore, the flatness of the terrain results in a map showing a mid-risk dominance with high risk areas concentrated nearby small streams (figure 3c). São Paulo's resulting map was more heterogeneous with the higher flooding risk at the city center's lowlands and very low risk at the periphery associated with higher rain forest coverage (Figure 3a).

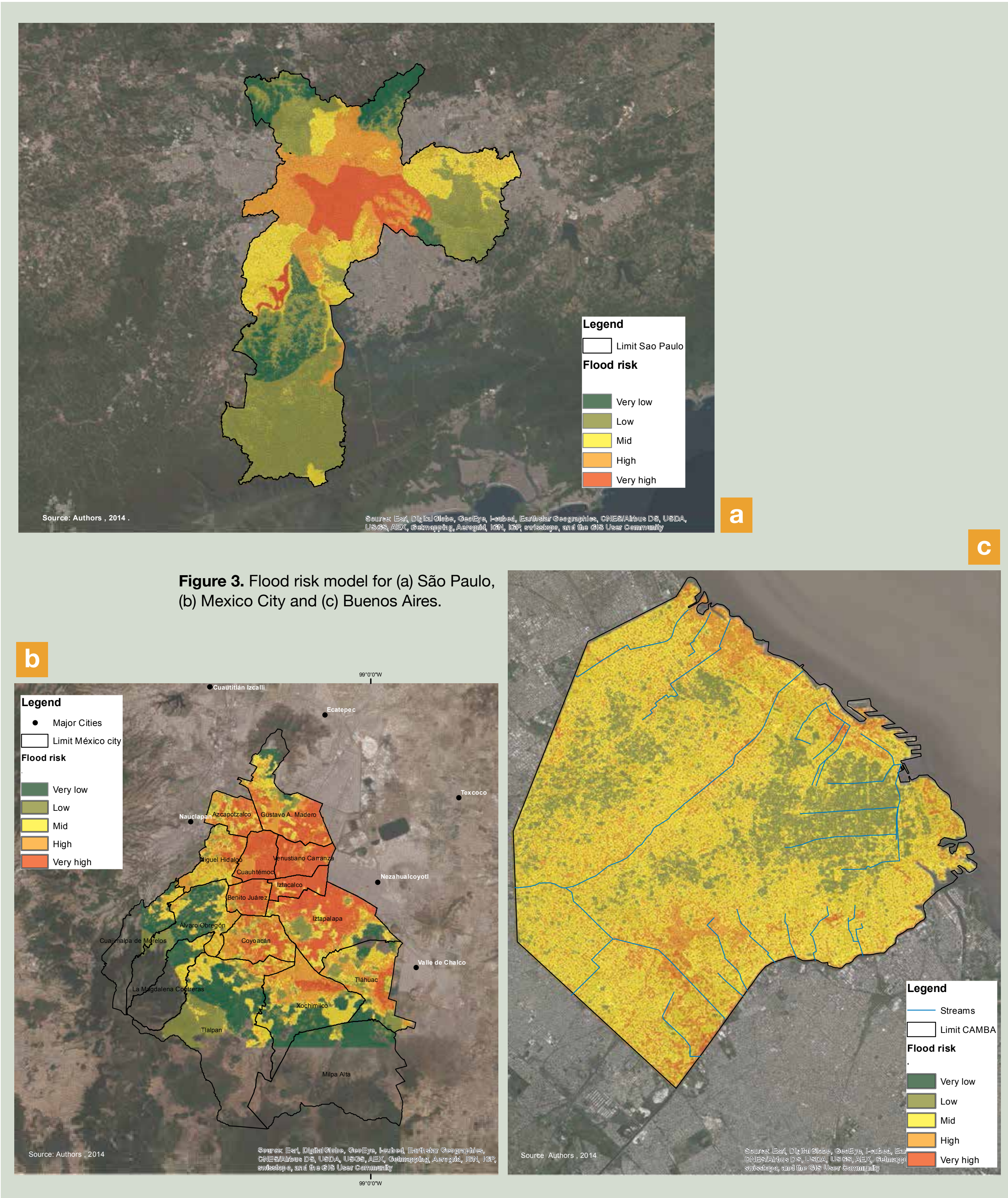


Figure 3. Flood risk model for (a) São Paulo, (b) Mexico City and (c) Buenos Aires.

Climate Change on Flood Risk

Our climate change scenarios on rain show a mean rain volume rise for all the scenarios on the period of 2046-2065 for each city, with the exception of Buenos Aires' A1 scenario.

Mexico City's major flood years have had the most rain volume and most extreme rain events (Figure 4); therefore, we can expect major flood events in the coming years. We are adapting this model to different scenarios in all three cities.

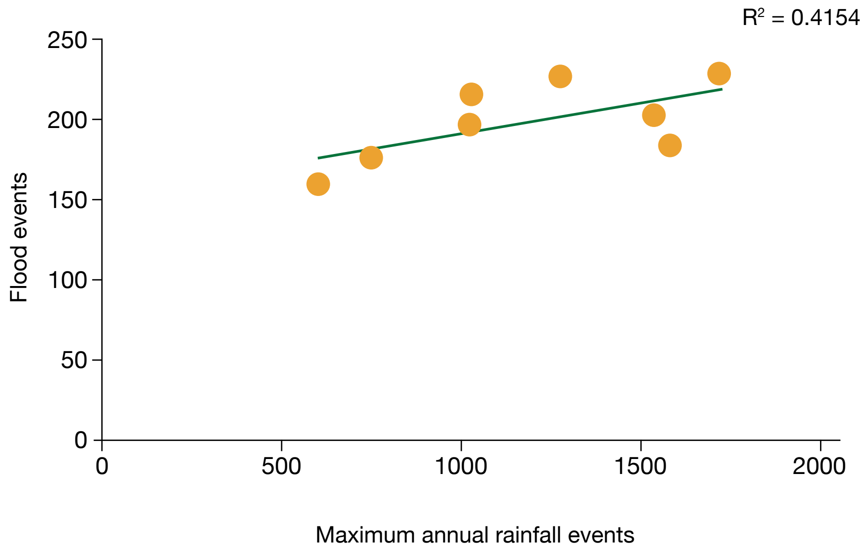


Figure 4. Relationship between the maximum rainfall events and number of floods in the period of 2005-2013.

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Conclusion

Climate Change will alter rain regimes in the watersheds of each metropolitan area, which may bring more floods and a different soil infiltration capacity. We suggest a watershed management plan with an integral perspective, considering climate change, urban growth, forest management and agricultural development.

The soil infiltration capacity needs to be considered as a complex system comprised by a diversity of factors. Moreover, highly vegetated areas, such as forests, are key to the water infiltration and they are a short term conservation option for a long term water supply.

Our models show that climate change will affect the infiltration capacity of the watersheds under different scenarios and land use changes.

Flood Risk will rise in Mexico City as a result of Climate Change and changes in public policy on conservation must be made to lower its vulnerability to lower its vulnerability.

This study emphasizes the importance of climate change vulnerability in cities. By integrating resource management, we can reduce cities´ vulnerability.

Instituto de Biología UNAM

About the Institute of Biology of UNAM

Founded in 1929, the biology Institute is one of the biggest and more complex university departments dedicated to research. Most of the projects in the Institute are oriented to increase our knowledge on biodiversity, with a particular emphasis on the study of the composition, distribution, origins and the potential uses of the elements of the flora, fauna and mushrooms of Mexico. The Biology Institute of UNAM is based in Mexico City, Mexico.

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Fundación Ambiente y Recursos Naturales (FARN) is a non-governmental organization, created in 1985, whose principal objective is to promote sustainable development through policy, law and the participation of society. FARN is based in Buenos Aires, Argentina.

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