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Incorporating wetlands in hydrologic and hydraulic models for flood zone delineation: An application to Durán, Ecuador

Ricardo Da Cruz E Sousa[a,b,*], Olga Lopes Miranda[b]

[a] PROURB-FAU, Federal University of Rio de Janeiro, Av. Pedro Calmon, 550 - 521 - Cidade Universitária, Rio de Janeiro - RJ, 21941-485, Brazil
[b] International Watershed Partners, 320 Alamo Ave., Santa Cruz, CA 95060, United States

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ABSTRACT

Extreme hydro-meteorological events such as hurricanes, storms and intense precipitation are already being felt in many coastal cities due to climate change causing major flood losses. It is time to implement alternative adaptation and mitigation solutions. In developed countries there is a growing appreciation of the benefits of wetlands as a flood protection strategy, however, there is still need for further research on quantifying the benefits of these solutions to justify the investment and replicate them in developing countries. Therefore, using the City of Durán, Ecuador, as a case study, this research develops an approach on how to incorporate wetlands in hydrologic and hydraulic modelling to quantify peak flows' reduction and delineate different flood zone scenarios for the city. The results of this study underline the importance of carrying out additional research in quantifying the benefits of wetlands and other ecosystem-based solutions, using hydrologic and hydraulic models, as these can prove to be efficient and sustainable strategies to mitigate flooding.

1. Introduction

Flooding is recurrent in many cities and with climate change predictions this is expected to become more frequent and of greater magnitude [28]. Urban floods are the result of a combination of meteorological and hydrologic events, together with the urbanization process [3,11]. On the coast, agriculture and urban expansion tends to occupy alluvial terraces and endanger important ecosystems, such as wetlands [16,23]. Informal or semi-formal settlements often occupy these areas, during periods where no major flood events occur. Flat, low-lying areas, with abundant building materials, are prone to inexpensive settlement, but are equally at the greatest risk from flooding. Left out of urban development plans, these areas are readily taken up by land traffickers.[1] When major flood events occur losses are significant and the affected communities demand the construction of traditional flood-control infrastructure, such as reinforced walls or levees, which severely impact ecosystems and often provide only costly short-term protection [14,20,26].

On the other hand, the informal status of many of these communities has had the positive side-effect of preventing further impairment of their ecosystems. These preserved many of their natural characteristics due to the lack of accessibility and intervention making restoration more feasible even with little resources.

Ecosystem-based solutions are emerging worldwide as cost-efficient, comprehensive, and multifunctional approaches to climate change adaptation [5,25]. Although these solutions are being increasingly promoted in policies and practices, for their multi-benefits, little information is available on their actual implementation at the urban planning level [9]. This is extremely important when discussing informal or semi-informal settlements who are worst hit by climate change and also disproportionately reliant on ecosystems and their services [19], often as the sole mechanism of protection against flooding.

Current research has proven that wetlands reduce peak flows by intercepting and temporarily storing water after heavy rainfall which consequently reduces flood zones downstream. Inland flooding reduction is one of the most tangible benefits of wetlands [2,4,27,29]. However, there is still need for further research in quantifying these benefits in order to lobby for stricter conservation, protection and restoration policies for wetlands and other ecosystems in developing countries.

Using the City of Durán, in Ecuador, as a case study, this research performed the hydrologic and hydraulic modelling of its three watersheds, La Matanza, San Enrique and Don Camilo, corresponding to a

* Correspondence to: Rua Álvaro Ramos 105/1002 Botafogo, Rio de Janeiro, RJ, 22280-110, Brazil.
E-mail address: cruzesousa@gmail.com (R. Da Cruz E Sousa).

[1] Land trafficking can be defined as the usurpation, illegal appropriation, and commerce of lands. It is closely linked with rural–rural and urban–rural migration and can be seen as an activity that organizes and facilitates migration (Shanee & Shanee, 2016, [31]).

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Fig. 1. Study area (1. Ecuador, 2. Guayas Province, 3. Durán Canton, 4. Watersheds of Durán).

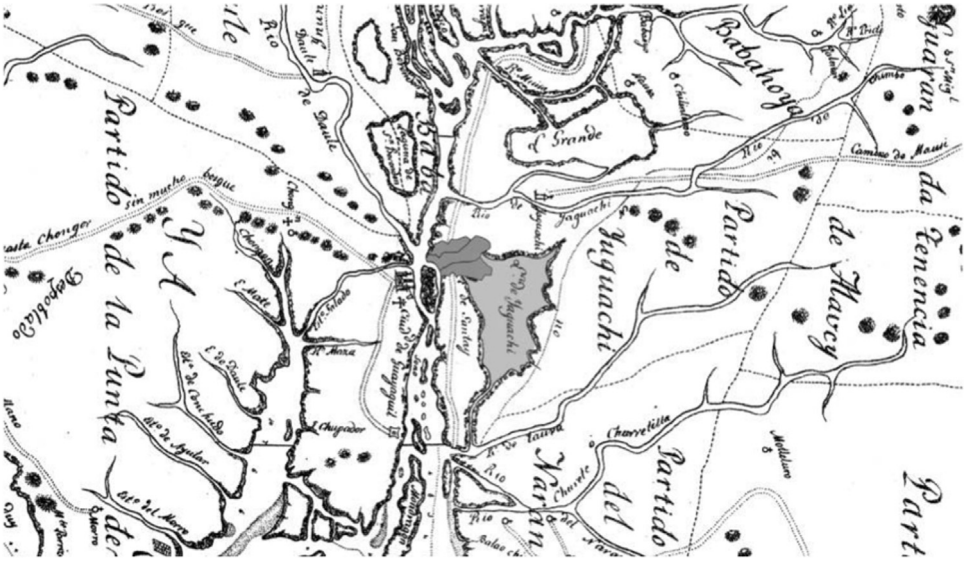

Fig. 2. Overlay of study area on historical map from 1804.
(Source: Historical Maps Archive, UC Berkeley, 2015.).

total area of 115 km^2 (Fig. 1). By incorporating hypothetical restored storage capacity of historical wetlands into those models we were able to quantify peak flows' reduction and delineate comparative future flood zone scenarios for a 100-Year flood event in the city.

2. Methods

2.1. Setting

Durán is located on the eastern margin of the River Guayas approximately 60 km from the mouth of the Gulf of Guayaquil to the Pacific Ocean. The high tide takes approximately 4 h from the mouth of the Gulf to reach Durán and the difference between high and low tides is 4 m. In these conditions, the lower parts of the watersheds with elevation less than 4 m are continuously affected by a combination of intense precipitation and high tide. That is, the drainage infrastructure fails because it discharges at a lower level than the high tide, causing flooding. The city is also affected by strong rainy season aggravated during the extreme climatic phenomenon, "El Niño". As a result of the latter, severe economic and social losses occurred during the period 1982–83 and 1997–98. In 1997–98 alone, there were about 300 deaths directly related to flooding in coastal Ecuador [24].

Due to its location in the lower watershed, Durán has poorly drained and saturated soil conditions year-round [21]. The territory is flat with elevations ranging approximately between 0 m and 10 m above sea level. The land is highly susceptible to flooding of its valleys and alluvial terraces, with the exception of the hills that haven't been cut down and their material used for landfilling the city. These hills are the remnants of an ancient mountain range ending at the banks of River Daule.

The landscape was originally dominated by estuaries, mangrove-lined tidal channels and mangrove swamps, vital to maintain the water balance and provide other ecosystem services (GAD [8]). Durán, like many other cities in the region, has had a close relationship with water