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Effects of urbanization, deforestation and climate change on flooding in Cap-Haitien, Haiti

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Introduction

Cap-Haitien, the 2nd largest city in Haiti (Figure 1), is exposed to all kinds of risks, including sea-level rise, climate change, earthquakes, erosion, urbanization, deforestation, and flooding (CECI,2017) (Figure 2). These natural hazards often turn into disasters due to a lack of good prevention and preparedness measures, management structure, and inadequate infrastructures and services (MTPTC,2015). Furthermore, the lack of urban planning and infrastructure and difficulties observed among local authorities in the application of laws and regulations have resulted in the gradual encroachment of flood-prone areas. This practice intensifies the risk of flooding, increasing the exposure of people, property, and infrastructure. Reducing this risk appears now to be essential for the economic development of the city of Cap-Haitien and the recovery of its urban and natural environment. So, our objective is to examine the impact of drivers such as deforestation, urbanization, and climate change on Cap-Haitien's recurring problems of river flooding.

Methodology

We interconnect separately built hydrological and hydraulic models. On the one hand, the hydrological model used is the distributed, process-based and continuous simulation tool SWAT (Soil Water Assessment Tool) developed jointly by the USDA Agricultural Research Service (USDA-ARS) and Texas A&M AgriLife Research, Texas A&M University. On the other hand, the hydraulic model used is a coupled SOBEK1D2D developed by Deltares, formerly Delft Hydraulics (Netherlands), based on the complete Saint-Venant equations. We applied the models to different scenarios of urban growth and population pattern, deforestation in the mountains, and climate change, basing the latter on the rcp2.6 and rcp8.5 scenarios for greenhouse gas emissions. We used a DEM of 30 x 30 m^2 with a global soil and land use map to delineate the SWAT Hydrological Response Unit (HRU) under the baseline scenario (actual land use), modified land-use scenario (10% of urban area increase), and climate change scenario. Additionally, we modeled events with different return periods in SOBEK1D2D, including the November 2012 event.

Figure 1. Panoramic view of Cap-Haitien City, Haiti. The Haut du Cap River flows from the right to the sea on the left.

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Figure 2. Floods in Cap-Haitien, February 2022

Preliminary results

The results show that urbanization-deforestation is the main driver of the sediment production and transport mechanism and that the hydraulic capacity of the Haut du Cap River is lower than the estimated peak flows for 5, 10, 50, and 100 years of return period jointly with the November 2012 event (Figure 3). Also, we show that many mountain ravines are the source of flash floods since the drainage system is clogged with all kinds of fine sediment upstream and garbage downstream, adding to the very short response time of their waves. Although uncertain, we found that climate change has an overall impact on the frequency of extraordinary events than on the peak flow given that a temperature increase between 1° C to 5 ^{o}C is expected in Cap-Haitien under both climate change scenarios rcp2.5 and rcp8.5. Additionally, drier conditions are expected annually for the period 2022-2040 than the baseline scenario (1979-2014) despite the low level of confidence and that climate change would have a significant impact on the future water availability of the watershed.

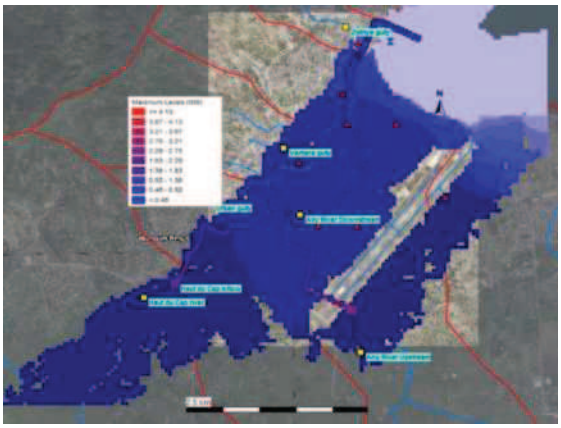

Figure 3. Flood extent of the November 2012 event

Conclusions and recommendations

The study concludes that, despite structural mitigation measures with drainage canal systems, a serious lack of governance has been playing a major role in the uncontrolled urbanization, lack of waste management system: main deep anthropogenic activities that cause flood threats. This study has data limitations and we think that serious water governance problems should be noted in the region. Therefore, it is recommended to install new climatological stations and to have continuous surveys of flow or water levels in strategic points of the city for a better understanding of how the Cap-Haitien hydrological system works and to anticipate better decisions.

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