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Projection of extreme river level in the slums of San Salvador, El Salvador, under climate change conditions, using a large ensemble climate simulation dataset

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Introduction

In El Salvador, 88.7% of the territory is considered at risk, and 95.4% of the population lives there. The Metropolitan Area of San Salvador (MASS), the country's capital, is home to 792 slums in which 32% of the population is settled. They occupy 45% of its urban land; unfortunately, 26% percent of them are in identified risk sectors, such as inside river channel slopes. This study addresses the necessity of analyzing the impact of climate change on these slums. The target research is a catchment of 87 km^2, where four slum locations inside river channels were selected as case studies: 1) El Tanque, 2) La Cuchilla, 3) Diez de Septiembre, and 4) Los Angeles B. The main objective is to assess the impacts of climate change on the Acelhuate River and tributary's flow level and water discharge and the consequent implications for the slums affected by the 2020 tropical storms in the MASS in a 4K (RCP8.5) warming scenario, using the database for policy decision-making for future climate changes (d4PDF). This study answers the following research questions: 1) How will the inundation probability of the selected slums change in the future? 2) How fast does the water level rise at the slum's location before a flooding event? 3) How will the flashiness of the selected slums' location in the river change in the future?

Research Novelty

Eccles R. et al[1] and Jahandideh-Tehrani, M. et al.[2] did a quantitative analysis on the climate change impact on riverine flooding and river streamflow in the tropical and subtropical regions and pointed out how there is no research on this topic in Central America or the Caribbean region and because of this, climate change impact projections are inconclusive in this zone. In general, Latin American research is skewed towards the Amazon River. In addition, they identified that small tropical basins (<1,000 km^2) are rarely studied, constituting only 4% of the analysis. This study focuses on filling these gaps.

Methodology

(1) d4PDF

Hourly precipitation extracted from the HFB 4K (future) scenario (90 ensembles) and the HPB (past) scenario (100 ensembles) was first bias corrected using a non-parametric method and local gauged rainfall as a reference. After that, rainfall events from both datasets were extracted using the Minimum Interval Time (MIT), which equals 9 hours for this basin. After that, extreme rainfall events were defined as the top three yearly rainfall events with the maximum cumulative precipitation in all the Catchment Response Time (CRT) windows. 36,055 and 31,708 extreme rainfall events were extracted from the HPB and HFB databases, respectively.

(2) RRI Model

The RRI Model is a two-dimensional, distributed hydraulic and hydrological model capable of simultaneously simulating rainfall-runoff and flood inundation[4]. The model was built using topography data from a locally sourced DEM, and more than 100 arbitrary river cross-sections were integrated into the RRI model. The model's manual suggested parameters that fit the soil texture of the target basin were tested using local data, and the best-performing set was chosen to run the model. The Kling-Gupta efficiency

(KGE), the Nash-Sutcliffe efficiency (NSE), and the relative Peak Error (PE) were used to evaluate the model performance. The results can be seen in Table 1. The chosen parameter set is sandy loam and clay for the mountain and city land uses, respectively.

Table 1. RRI Model Performance.

Mountain Param.	City Param.	r	α	β	KGE	NSE	PE
Sandy Clay	Clay	0.84	1.08	0.84	0.76	0.64	1.09
Sandy Loam	Clay	0.84	0.84	0.74	0.68	0.68	0.94

Results and discussion

In general terms, future river levels and water discharge at the four slum locations are expected to be higher than the extreme levels of the past.

(1) Research Question 1

This study considers a slum floods whenever the river flow level reaches the slum level. The change in inundation probability of each slum can be seen in Table 2.

Table 2. Change in Inundation Probability.

No.	Slum Name	Level (m)	Past	Future
1	El Tanque	2.0	1/581	1/281
2	La Cuchilla	0.2	1/5	1/5
3	Diez de Septiembre	1.5	1/54	1/46
4	Los Angeles B	2.1	1/26	1/25

(2) Research Question 2

The Delta Water Levels (ΔWL) three hours before the flood and at the time of flooding can be seen in Table 3. Slums 1, 2, and 4 have increased future ΔWL, whereas in slum 2, they remain the same. Extreme rainfall events show a significant difference compared to average values.

Table 3. Change in ΔWL.

No.	Slum Name	Level	Average		Extreme Events	
			Past	Future	Past	Future
1	El Tanque	2.0	1.17	1.29	1.76	2.02
2	La Cuchilla	0.2	0.17	0.16	0.27	0.28
3	Diez de Septiembre	1.5	1.23	1.26	1.73	1.91
4	Los Angeles B	2.1	1.49	1.57	2.26	2.50

Regarding the maximum water levels, the slums will have future flood water rising speeds of 0.67 m/h, 0.09m/h, 0.64m/h, and 0.83 m/h, respectively.

(3) Research Question 3

The Richards-Baker Index (RBI)[5)] was used to measure the flashiness of the studied locations. Table 4 shows how the basin has a medium-to-low general flashiness but increases to medium-to-high when it comes to extreme events.

Table 4. Change in RBI flashiness.

No.	Slum Name	General		Extreme events	
		Past	Future	Past	Future
1	El Tanque	0.30	0.31	0.48	0.68
2	La Cuchilla	0.38	0.37	0.74	0.77
3	Diez de Septiembre	0.35	0.35	0.65	0.69
4	Los Angeles B	0.34	0.34	0.78	0.79

Conclusions

This research found an overall increase in extreme river discharge and flow level in all slums, increasing inundation probability in three out of four slums, and increasing ΔWL in all slums, leading to increasing water speed in three out of the four slums. In addition, the flashiness of the basin has a significant variance in extreme rainfall events. Even though the study area is small, slum locations will face different impacts of climate change. In the future, it is crucial to identify these local characteristics of the rest of the slums in the city for the accurate formulation of relocation plans and disaster risk management.

References

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