Impact of Climate Change on Flooding in the Comoro River Basin Dili, Timor-Leste

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ABSTRACT

The Comoro River is the main river running through the city of Dili, the capital of Timor-Leste. The Timor-Leste Disaster Database (BDDTL) contains records of severe flooding over the last 20 years, with Dili most affected (Table 1). Flooding is a serious problem in the Comoro catchment area of Dili, Timor-Leste. Every year, floods cause damage to public infrastructure and properties. To investigate the impact of climate change on the frequency and severity of flooding in the Comoro River Basin including the urban areas. Analysis of past and future rainfall using the Global Circulation Model (GCM) to project future climate conditions, three models of GCM indicate a 4% to 19% increase in the average annual precipitation, which is expected to exacerbate flood risk and lead to more frequent and severe inundation events in built-up areas of the river basin in the 25-yr and 50-yr return period. The result from frequency analysis indicates that 25-year and 50-year return periods have an increase of 1.40 and 1.54 times, respectively, and are affected by the built-up in Comoro River Basin, Dili, Timor-Leste by 1.62 sq km and 1.88 sq km from the inundation depth 0.5 m to >1.0 m, although the Comoro River stream would not be overflown in those extreme rainfall events. We recommend implementing countermeasures, such as constructing or rehabilitating the drainage system in urban areas and clean-up the drainage channel to minimize flooding in the future and protect the communities in these catchment areas.

Keywords: Climate Change, Flood, RRI model, Inundation Map, Frequency Analysis.

INTRODUCTION

Timor-Leste is a Southeast Asian nation located between 8.5 S and 10.8 S latitude and 123 E and 128 E longitude. The climate of Timor-Leste is classified as tropical, dominated by two well-defined seasons rainy and dry (Costa et al., 2012). The northern part experiences a rainy season from November to April, while the southern part has a bimodal rainy season between November and June (Anderson and Deutsch, 2001).

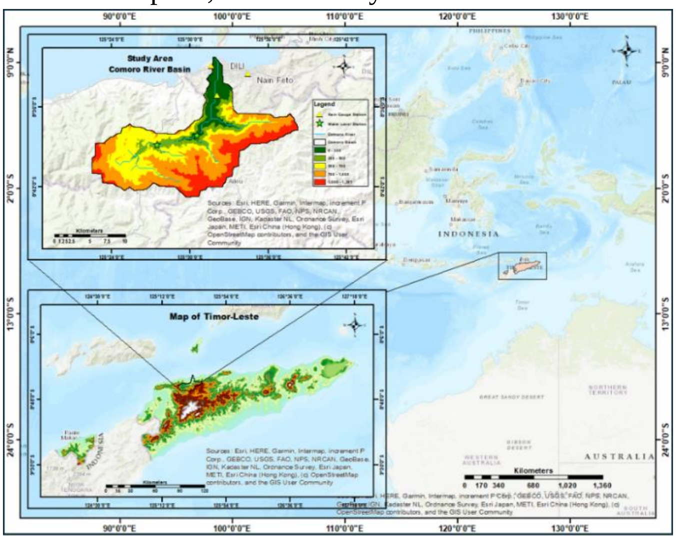

Figure 1. Map of Timor-Leste and study area

Timor-Leste is highly susceptible to natural disaster such as floods, landslides, tropical cyclones, droughts, earthquakes, and tsunamis, ranking 20th globally in disaster risk. Floods are the most common disasters, drought, and storms. The country experiences both riverine and flash floods due to heavy rains, and rapid runoff from mountainous regions. Climate patterns

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such as El Nino Southern Oscillation (ENSO) further intensify droughts, floods, and Cyclones (World Bank 2021). Inundation has had the greatest impact on communities over the last 20 years, and flooding has been most damaging natural disaster in Dili (table 1). The city is located on the northern coast of the island of Timor. The water availability in Dili comes from groundwater and surface reservoirs BeeMos and Becora (Takeleb et al., 2020). The RRI model simulation for extreme events in 2021 indicates that the flooding was not caused by overflow from the river but rather by inland flooding in Dili urban area. According to the Japan International Cooperation Agency (Source: JICA report 2022), in 2021 inundation was not due to overflow from the Comoro River. Additionally, research conducted in 2017 by Letigia found that the Comoro River is wide enough to accommodate peak discharge despite being overestimated for a 50-year return period.

Table 1. Showing the number of houses affected by natural disasters (strong wind, inundation, and landslide events) from 1992-2023 in the Dili area.

Strong Wind Events		**Flood Events**		**Landslides Events**	
Houses Destroyed	Houses Affected	House Destroyed	Houses Affected	Houses Destroyed	Houses Affected
2.527	11.528	6.831	39.834	611	935

Source: Timor-Leste Disaster Database (BDDTL).

THEORY AND METHODOLOGY

The aim of this study was to analyze of climate change impact on flooding in the Comoro River basin including urban areas by comparing past and future conditions.

1. Rainfall selection

Data from a rain gauge station over a period of 21 years (2003-2023) were used for bias correction and four Global Climate Models (GCM) was selected, as well as past climate data and estimated future climate from the Representative Concentration Pathways (RCP 8.5) scenario.

2. Model preparation

The Rainfall-Runoff-Inundation (RRI) model, a diffusion wave approximation model, was used to simulate the discharge and flood extent. The RRI model is a two-dimensional model that can simulate rainfall-runoff process and flood inundation simultaneously (Sayama et al., 2016).

3. Frequency analysis

Frequency analysis was conducted to determine the rainfall amount for the return period of 25-year and 50-year using the DIAS system based on the rain gauge data and GCM projections from CMIP5.

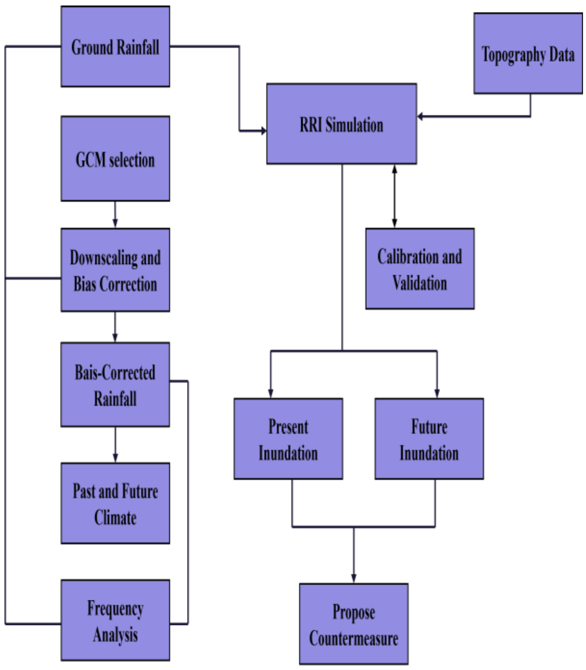

Figure 2. Flow chart of the methodology for this research.

DATA

The data are categorized into two types:

1. Hydrometeorological data:
   - Rainfall observation data (mm): Daily data were obtained from the National Directorate of Meteorology and Geophysics (DNMG) and National Water and Sanitation

Authority (ANAS) and recorded in the catchment area downstream (Aeroporto Comoro, EDTL, and BeeMos stations).
  - Water Level Observation Data (m): Daily data were obtained from ANAS, using sensors placed in the catchment area and recorded in the Comoro River.

2. Topography data:
  - Topographic Data: These data were obtained from HydroSheds such as Digital Elevation Model (DEM), Flow Direction (DIR), and Flow Accumulation (ACC) with the resolution of 3 sec (90m x 90m). The data were used input to RRI model and visualize the topography in the catchment area.
  - Land Cover Data: Dataset were obtained from ESA WorldCover (tree cover, shrubland, grassland, cropland, built-up, bare/sparse vegetation, permanent water bodies), which is essential for analyzing the built-up area affected by inundation.

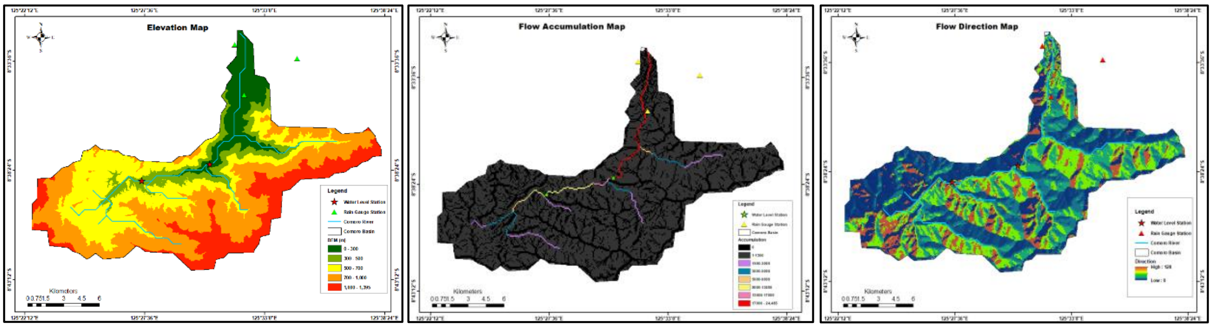

Figure 3. Topography input data: a). DEM, b). ACC, c). DIR for simulation by RRI model.

The municipality of Dili is the capital of Timor-Leste, and the Comoro River is the largest in Dili. The river flows between the International Airport and inner Dili city. The total catchment area is approximately 219 square kilometers (sq km), and the catchment system is mainly sandy soil.

RESULTS AND DISCUSSION

Calibration and Validation of RRI model

The RRI model parameters related to the soil characteristics of the Comoro River Basin catchment were calibrated to align or represent the real conditions (table 2). This calibration process used water level observation compared with water depth simulated by the RRI model for flood events occurring between January and April 2012. The hydrograph patterns of both the observed and simulated water levels were well-calibrated and effectively representing the actual conditions of the Basin’s slopes and river (fig.4).

Table 2 RRI Model Parameters

	Parameters	**Notation**	**Default**	**Calibrated**
1	n(River) ($m^{1/3}$ s)	ns_river	3.000d-2	3.000d-2
2	n(Land) ($m^{1/3}$ s)	ns_slope	4.000d-1	4.000d-1
3	Ka(m/s)	ka	0.000d0	3.400d-3
4	Soil depth (m)	Soil depth	1.000d0	1.000d0

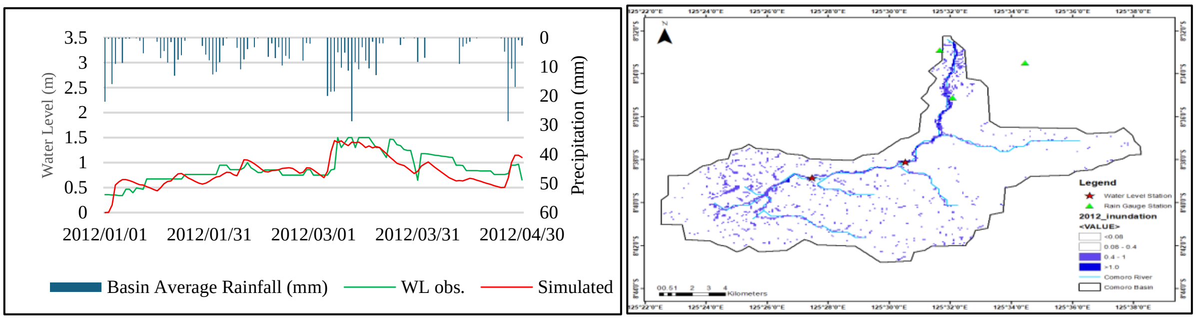

Figure.4. Calibration of RRI model for flood events from January to April 2012.

The RRI model was validated for a 2021 flood event. The simulation results were compared with observation, and the observed peak water level was consistent with the simulation by RRI models; however, the simulation underestimated the values most of the time (fig.5).

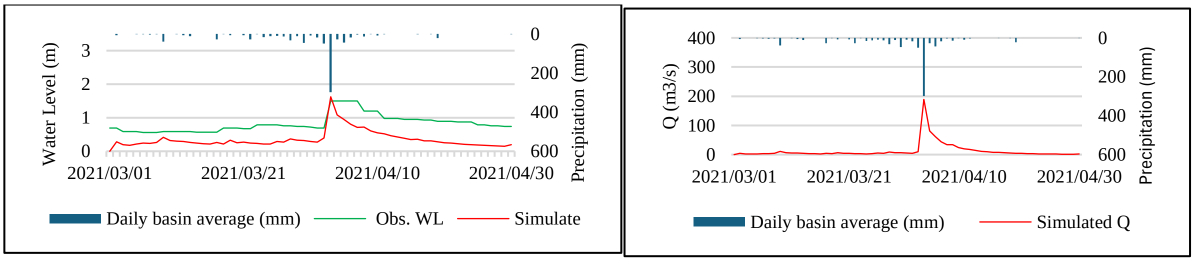

Figure 5. Validation of the RRI model for flood events from March to April 2021

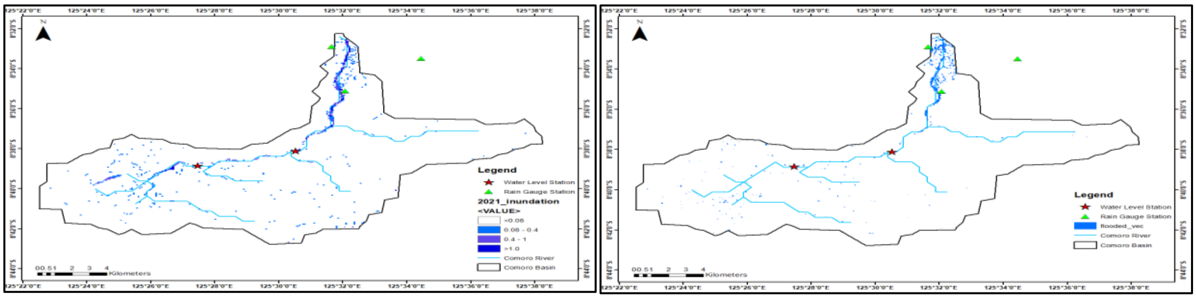

Figure 6. Validation of RRI model simulated (*left*) and Sentinel 1 (*right*) for the flood events in 2021.

Figure 6 shows the validation of the RRI model for the 2021 flood event, comparing the simulated flood extent with satellite-detected flood extent in urban areas of the city. The results indicate significant flood extent along the river channel in the downstream area.

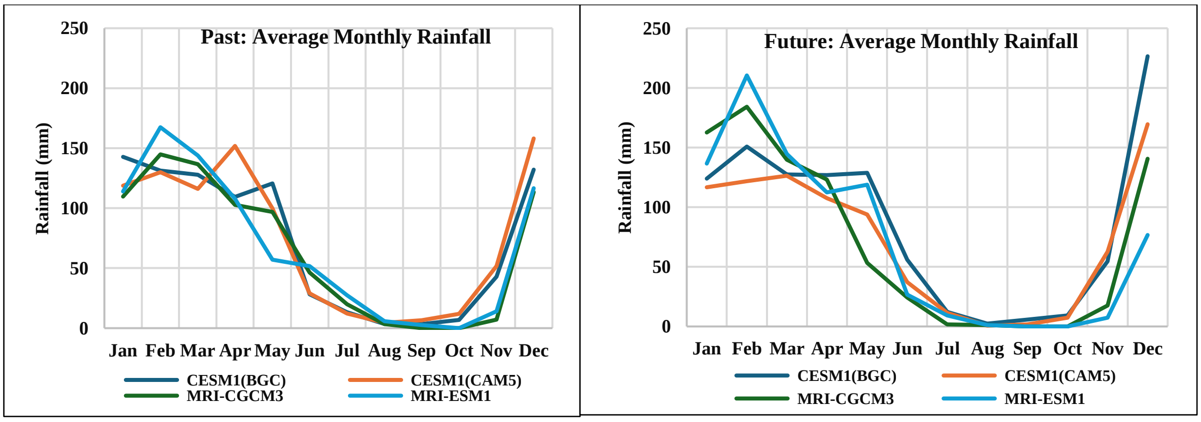

Figure 7. Comparison of past (*left*) and future average monthly rainfall (*right*).

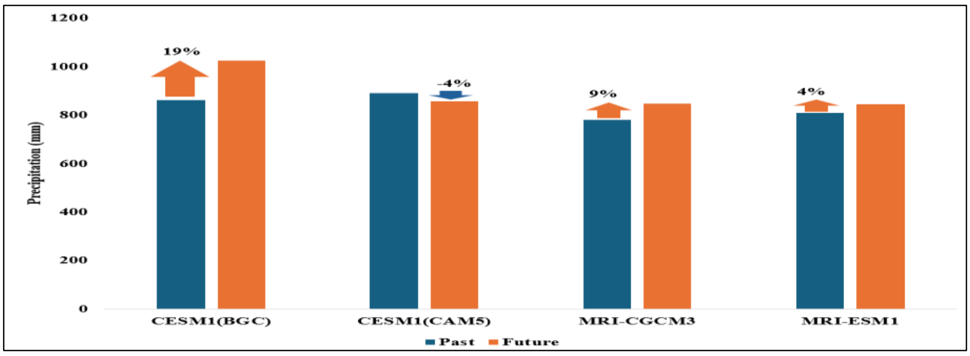

Figure 8. Average annual rainfall past and future of the models

To assess the effects of climate change, we utilized the Data Integration and Analysis System (DIAS) to statistical downscale climate projections by using in-situ daily precipitation data over 21 years to analyze past (1980-2000) precipitation trends and create future (2072-2092) climate projections. We analyzed the average monthly precipitation to evaluate future flood conditions. Generally, average monthly rainfall is expected to increase in the future. From the Global Climate Model, four models were selected CESM1 (BGC), CESM1 (CAM5), MRI-CGCM3, and MRI-ESMI, to compare the past and future rainfall; in three of these models, an increase in future climate conditions (figure 7 and 8).

Table 3. Basin average rainfalls for different return periods and increasing factors for future climate scenarios.

GCM	**25-year return period**			**50-year return period**		
	GEV			**GEV**		
	Past	Future	Factor	Past	Future	Factor
CESM1(BGC)	221.05	227.21	1.02786	282.60	266.98	0.94
CESM1(CAM5)	231.75	195.02	0.841482	301.92	233.98	0.77
MRI-CGCM3	177.98	428.12	2.405375	209.27	620.13	2.96
MRI-ESM1	185.87	244.86	1.317405	225.07	331.82	1.47
Average			**1.40**			**1.54**

Frequency analysis was conducted to determine the rainfall intensities for 25-year and 50-year return periods, considering present and future climate conditions. As shown in Table 3, four models were selected from the Global Climate Model (GCM). An average factor was applied to represent the impact of climate change on future rainfall at each rain gauge station in the Comoro River Basin.

Table 4. Return periods 25-year and 50-year for the past and future inundated areas affect built-up.

		PAST		**FUTURE**	
		Return Period 25-year	Return Period 50-year	Return Period 25-year	Return Period 50-year
	Inundation Depth (m)	Area Inundated (km2)	Area Inundated (km2)	Area Inundated (km2)	Area Inundated (km2)
1	0.5 - 1.0	0.039	0.072	1.55	1.73
2	> 1.0	0.018	0.018	0.11	0.15
	Total	0.057	0.091	1.65	1.88

Frequency analysis for the 25-year and 50-year return periods was conducted using the RRI model to simulate flood maps (fig.9). The analysis revealed an increase in flood-affected built-up areas. The extent of this area indicates expand from 1.65 and 1.88 square kilometers in the future (table 4).

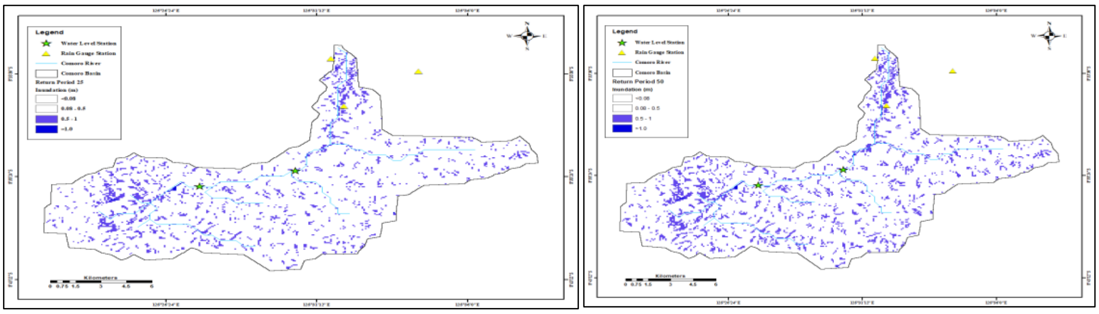

Figure 9. Inundation distribution for the return periods of 25-year (left) and 50-year (right).

CONCLUSION and RECOMMENDATION

The result of this study in the Comoro River Basin Dili, Timor-Leste, shows the significant impact of climate change on inundation distribution based on the GCMs from both past (1980-2000) and future (2072-2092) climate projections, bias-corrected by in-situ rain gauge data. The analysis indicated a considerable increase in average monthly rainfall and average annual rainfall in the future, with a 4% to 19% rise in average annual precipitation (figure 8). The frequency analysis conducted for 25-year and 50-year return periods for the future indicates a significant increase in flood risk, with return period factors rising by 1.40 and 1.54 times, respectively. This increase exacerbates the risk of flooding, leading to more frequent and severe inundation events in the future. The inundation maps generated for these return periods indicate that flood-prone areas in built-up regions are projected to expand by 1.65 sq km for the 25-year return period and by 1.88 sq km for the 50-year return period. These flood extents correspond to inundation depths from 0.5 m to >1.0 m in the future and the built-up area is mostly located downstream of the catchment. These projections, it is recommended that countermeasures be put in place to protect the public infrastructure and community properties in the catchment area; in particular, drainage systems or channels in urban areas should be constructed and rehabilitated, and regular clean-up of drainage channels in the urban city.

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