FLOOD INUNDATION AND RISK ASSESSMENT IN THE WELOLO RIVER BASIN, TIMOR-LESTE

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ABSTRACT

The main objective of this study was to propose and assess the effectiveness of flood control measures, to minimize the impact of floods in the Welolo River basin using the Rainfall-Runoff-Inundation model. The Welolo River is the second-largest river in the Viqueque municipality, Timor-Leste, and its catchment has been suffering from frequent floods due to a tropical cyclone event of 2021. In this study, flood inundation scenarios were simulated with and without considering the influence of countermeasures. The total damage was estimated through analyzing the targeted 100-year flood return periods, and scenarios with and without the proposed countermeasure conditions were compared. The results showed that the levee was the most effective structural flood countermeasure.

Keywords: *Welolo river basin, RRI Model, Flood inundation, Flood risk management*

INTRODUCTION

Timor-Leste is a mountainous Southeast Asian Island country that lies at the eastern end of the Indonesian archipelago, 400 km north of Australia, across the Timor Sea, and on the Lesser Sunda Islands. The total area is 14,874 km^2, and the population (based on the 2022 census) is approximately 1.34 million. Administratively, the island comprises 13 municipalities (Figure 1.1). Geographically, the country is vulnerable to several kinds of natural hazards, and floods are the most common natural hazard among all kinds of hazards, caused by a combination of heavy rainfall, steep topography, and widespread deforestation. The impact of natural hazards in this country is grave, including losses of human lives and properties. Most recently, the heavy rainfall resulting from Tropical Cyclone Seroja in April 2021 caused large-scale landslides and floods, with a total of 25,022 households affected by the floods across all 13 municipalities. In Dili municipality alone, 82%, or 11,558, households were affected, and 46 fatalities were recorded (UNICEF Timor-Leste Floods Response, 2021). Therefore, risk assessments and appropriate countermeasures are important for effective flood mitigation and risk management.

The main objective of the research is to propose and assess the effectiveness of countermeasures to reduce flood risk. This research encompasses a comprehensive approach to flood management in the Welolo River basin such as Developing a rainfall-runoff-inundation (RRI) model simulation to facilitate effective decision-making for flood mitigation and management in the basin, conducting a comprehensive assessment of the consequences resulting from flooding on households and agricultural land, and propose countermeasures, such as the implementation of levee construction and riverbed dredging, as potential strategies to mitigate flood impacts.

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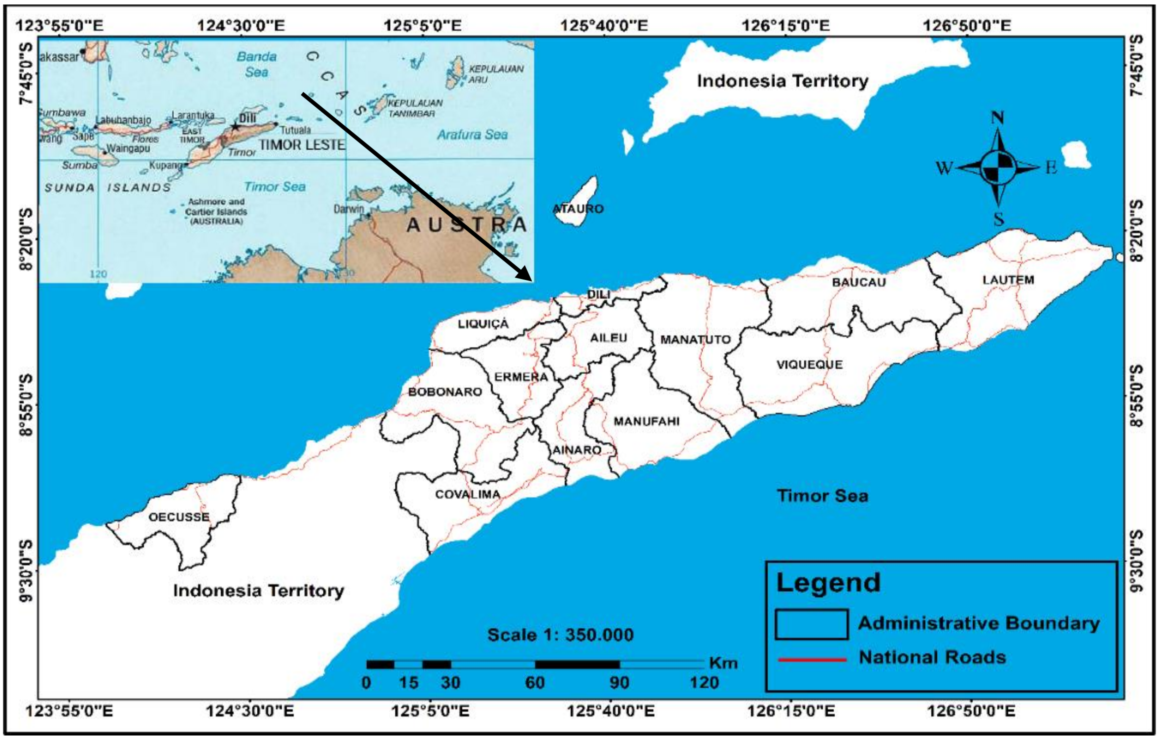

Figure 1 Location of Welolo River Basin (WRB)

STUDY AREA

The Welolo River basin is located in the southeastern part of Timor-Leste, and the low-lying area includes three sub-districts such as Viqueque, Ossu, and Lacluta. This basin is situated close to Buicaren and Bibileo villages in Viqueque sub-district. The WRB extends over 242.060 km2 located between latitude 8° 49' 0.346" South and Longitude 126° 16' 46.237" East. There are two rain gauge stations close to the catchment: Lacluta and Ossu Stations. The Welolo River basin receives an annual precipitation of approximately 2500 mm. During the flood event in April 2021, the catchment encountered a critical situation characterized by a peak flow rate of approximately 1600 m3/s. In the study area, agriculture plays a central role as the primary source of income. Around 80% of the population in Buicaren village depend on agriculture to sustain their livelihoods. The primary focus of agricultural activities in this area centers around the cultivation of paddy, which serves as a staple crop.

METHODOLOGY

Based on the analysis of flood inundation in the Welolo River basin, I used topographic data such as the digital elevation model (DEM), flow direction (DIR), flow accumulation (ACC), land cover, soil data, building footprint and observed rainfall data from two stations. Furthermore, rainfall data and topographic data such as the digital elevation model (DEM), flow accumulation (ACC), flow direction, land cover (DIR), and soil data are used as inputs to the rainfall-runoff-inundation (RRI) model simulation.

In this study, the Rainfall-Runoff-Inundation (RRI) model is employed to simulate both the depth and distribution of inundation. Using The RRI model in this research is vital to comprehensively address the dynamics of flood occurrences within the Welolo River basin. For the process of model calibration, the simulation result by the RRI model is compared with the actual inundation map of the Welolo River basin, this approach is taken due to the absence of available discharge data. This process of model calibration ensures that the RRI model effectively meets the agreement between the simulation result and the actual inundation map. Frequency analysis is conducted with the ground-based observed rainfall data of 10 years from 2012 - 2022 by Gumbel and GEV analysis. The results predicted rainfall of the 25, 50, 100- year return periods are obtained. To obtain the damage assessment and flood risk maps, the RRI model's output for the 2021 flood, along with building footprint and land cover data, is imported into ArcGIS software to estimate the affected household and agriculture land under different depths of inundation for 2021 flood event. Similarly, RRI simulation results for 100-year return period, along with building footprint and land cover data are added to ArcGIS software to estimate the inundation of household and agricultural land under different inundation depths for 100-year return periods flood.

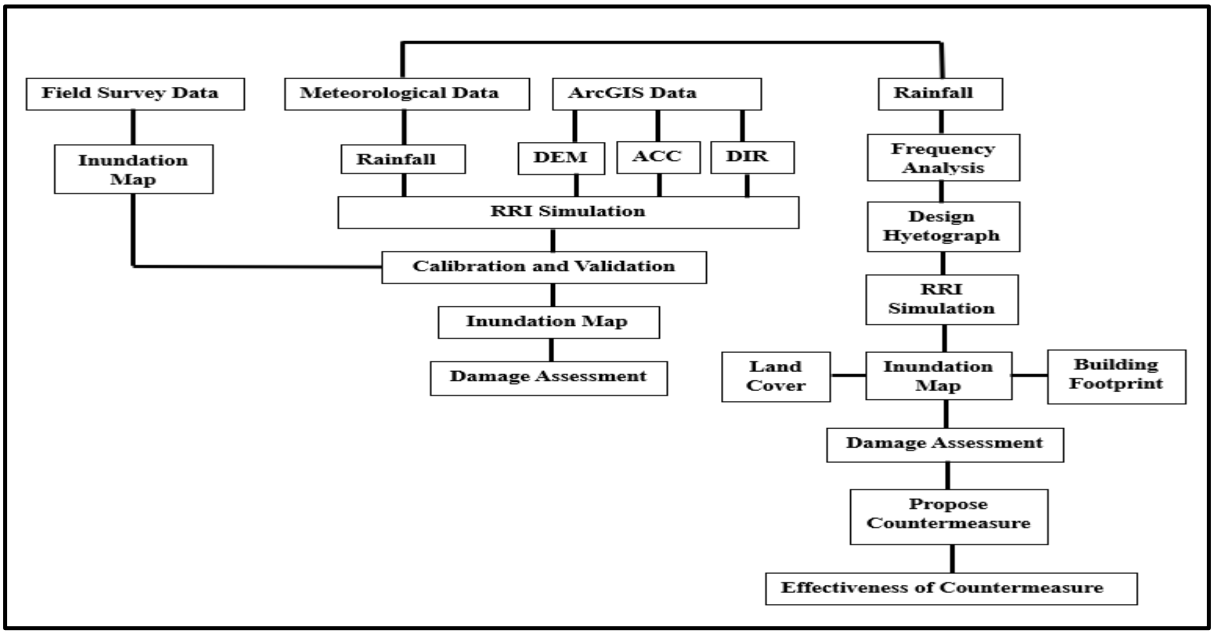

Figure 2 Schematic diagram of the study approach

DATA

In this study, the rainfall data were obtained from the National Authority of Water and Sanitation (Figure 3 (a). The topographic data, such as the 80-meter resolution data of the Digital Elevation Model (DEM), Land cover, and soil data, were provided by the Institute of Petroleum and Geology, as shown in Figures 3 (b) and 3 (c). In addition, the building footprint data was downloaded from the Open Street Map website.

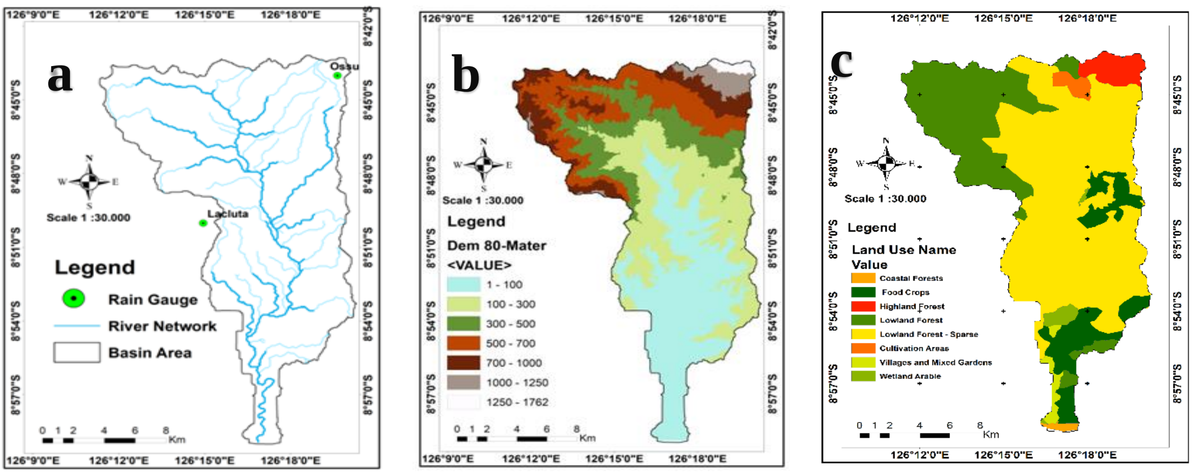

Figure 3 (a) Meteorological station and river network, 3 (b) digital elevation model (DEM), and 3(c) land cover map.

RESULTS AND DISCUSSION

In this research study, the process of calibrating and validating the model's simulations is conducted by comparing the simulated results with the actual flood inundation maps. This approach is taken due to the absence of available discharge data. Furthermore, the development of the actual inundation map was predicated on a field survey undertaken during April 2021 flood event in the Welolo River basin. For the calibration process, The RRI input parameters had been modified as a result of the adjustments made following the 2021 flood event. Rainfall data observed at two stations from 2012 to 2022 was taken for frequency analysis by Gumbel and GEV methods. The catchment's average yearly maximum rainfall of 10 years was considered for the frequency analysis. The projected rainfall for a 100-year return period was estimated at 430.4 mm. I chose to use the GEV Method for a two-day probability scenario with a conversion factor of 1.6, aiming to create a custom hyetograph that shows a 100-year return period event. The inundation analysis In Figures 4 (a) and 4 (b), respectively demonstrated that the proposed countermeasure, involving levee construction, considerable reduced flood inundation in the entire study area.

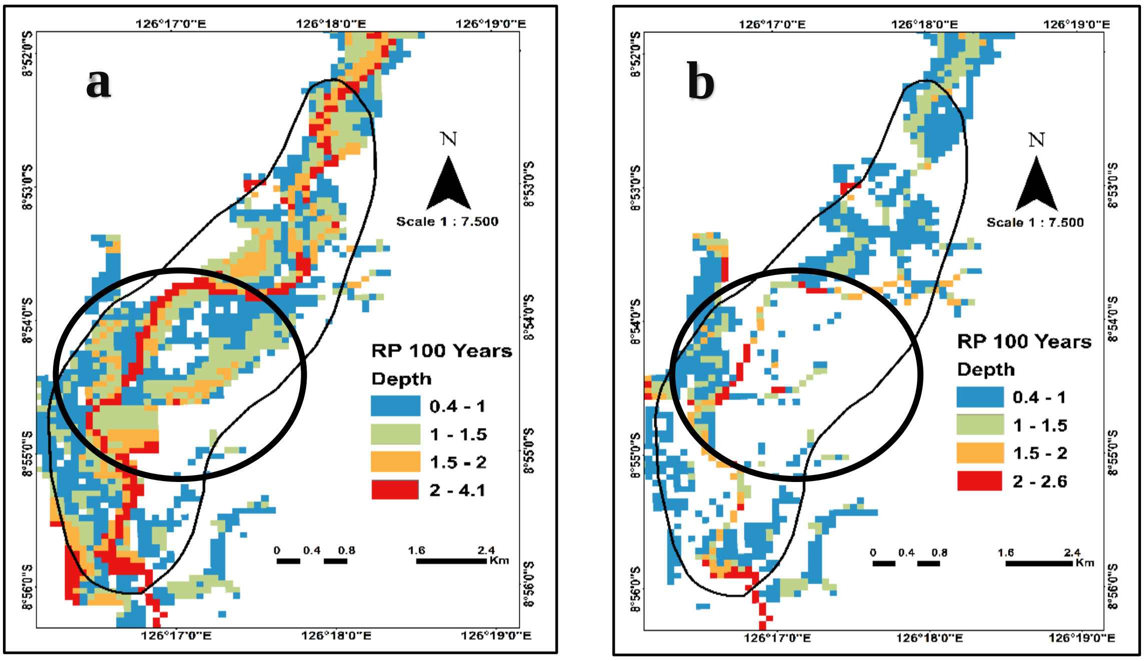

Figure 4 (a) 100-year return period without countermeasure and 4 (b) 100-year return period with countermeasure.

Table 1 shows the inundation area and affected households for 100 years return period without the proposed countermeasure.

Inundation Depth in (m)	Inundation Area in (ha)	Affected household	Affected Population
0.4 - 1	382	124	620
1 - 1.5	239	297	1485
1.5 - 2	122	114	570
> 2	100	100	500
Total Inundated	**842**	**635**	**3.177**
Total Overall	**1225**	**1288**	

Table 2 shows the inundation area of paddy fields and cropland for 100 years return period without the proposed countermeasure.

Inundation Depth	Paddy field in (ha)	Cropland (ha)
0.25 - 0.50	15.95	28.52
0.50 - 0.75	20.73	21.06
> 0.75	48.96	57.56
Total Inundated Area	**85.64**	**107.14**
Total Area off Paddy and Cropland	**234.02**	**354.47**

The total damage of households, paddy fields, and croplands for 100-year return period floods is presented in Table 1 the comprehensive assessment of the cumulative impact, revealing a total inundated area of 842 hectares, with 635 households affected and an approximate population of 3,177 people adversely affected. Moreover, paddy fields experienced total damage of 85.64 hectares, and cropland was impacted over an area of approximately 107 hectares, as detailed in Table 2.

Table 3 shows the inundation area and affected households for 100 years return period with the proposed countermeasure.

Inundation Depth in (m)	Inundation Area in (ha)	Affected household	Affected Population
0.4 - 1	92	16	80
1 - 1.5	39	8	40
1.5 - 2	0	0	0
> 2	0	0	0
Total Inundated	**53**	**20**	**120**
Total Overall	**1225**	**1288**	

Table 4 shows the inundation area of paddy fields and cropland for 100 years return period with proposed countermeasure

Inundation Depth	Paddy field in (ha)	Crop land (ha)
0.25 - 0.50	2.73	14.54
0.50 - 0.75	3.43	18.28
> 0.75	6.16	32.64
Total Inundated Area	**21.32**	**65.46**
Total Area off Paddy and Cropland	**234.02**	**354.47**

The analysis presented in Tables 3 and 4 illustrates the effects of 100-year return period floods and proposes countermeasures. The result reveals notable reductions in inundated areas, contracting from 842 ha to 53 ha; affected paddy fields experience a reduction from 85.64 hectares to 21.32 ha; and impacted cropland diminishes from 107.14 he to 65.46 ha.

CONCLUSIONS

Flood inundation maps with historical data were developed for flood risk management, preparedness, and mitigation against the design return period of flood events. Using simulation results from the RRI model simulation, the effectiveness of the proposed countermeasures was looked at in terms of the area of flooding and the depth of flooding. The simulation of a 100-year return period of flood as per the 2021 flood pattern was conducted with the levee construction condition, and the total damage is estimated using the same assumption and information used for the non-levee condition. It is observed that the total damage is estimated to reduce by almost 85% by constructing levees.

RECOMMENDATION

The levee construction is strongly recommended as a fundamental measure for enhancing flood protection and flood management. Needed a discharge station in the downstream area for effectively monitoring and measuring river discharge, and needed to Perform a comprehensive detailed survey within the designated survey area to verify and confirm the obtained results.

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