EFFECTS OF INFRASTRUCTURE CONSTRUCTION IN FLOOD DISASTER PRONE AREAS

CASE STUDY: CONSTRUCTION OF DUMILA-RUDEWA-KILOSA-MIKUMI ROAD

John Mathias Kiriwai[1]
MEE 17730

Supervisors **Assoc. Prof. Miho Ohara[2]**
Prof. Kuniyoshi Takeuchi[3]
Dr Mamoru Miyamoto[4]

ABSTRACT

In Tanzania, the eastern part of the country is very vulnerable to floods. Wami river basin in the eastern part experiences rainfall twice a year, which frequently causes flooding to Kilosa district in Morogoro Region. This study aims at assessing the impacts of infrastructure construction in a flood prone area. The government is constructing 142 KM which passes through flood prone area. Rainfall-Runoff Inundation Model was calibrated by using bias corrected GSMaP rainfall data for the floods of December 2009 to February 2010 and validated with the floods in 2014. Inundation maps for 5, 10, 20, 25, 50 and 100 years return period were prepared for the scenarios with and without road. It was found that there is increase in inundation height in some upstream road side areas with no bridges. It is recommended to have more culverts on roads and widen bridge to allow water to pass through normally

Keywords: Road, buffer zone, GSMaP, bridge, water level

INTRODUCTION

Tanzania has the total of Nine River Basins, which are Lake Victoria Basin, Lake Tanganyika Basin, Lake Rukwa Basin, Rufiji Basin, Lake Nyasa Basin, Ruvuma and Southern Coast Water Basin, Wami River Basin, Pangani Basin and Internal Drainage basin. Wami River Basin has total area of about 43,946 Km^2 and drains its water to the Indian Ocean. The basin has a bimodal rainfall characteristics, which are *Masika* and *Vuli*. *Masika* occurs between March and May and *Vuli* occurs between November- Decembers.

Kilosa district suffers flooding almost every rainy season. The recent floods were in 1998, 2009/2010, 2014, 2016, 2017 and 2018. Kilosa experiences two types of floods. The first type of floods is flash floods which always happen due to rainfall from upstream areas such as Mpwapwa districts and nearby areas of Dodoma Region. The second type is rain-fed floods which are more common in the area. This is because the area is lowland and the rivers don't have any protection such as embankment.

In Kilosa district, the government is constructing a 142 Kilometres road fom Dumila-Rudewa-Kilosa-to Mikumi, which passes through a very flood prone area.

[1] Disaster Management coordinator –Disaster Management department, Prime Minister's Office - Tanzania
[2] Senior Researcher International Centre for Water Hazard and Risk Management (ICHARM), Adjunct Associate Professor, National Graduate Institute for Policy Studies(GRIPS), Tokyo
[3] Advisor, International Centre for Water Hazard and Risk Management (ICHARM)
[4] Researcher**,** International Centre for Water Hazard and Risk Management (ICHARM)

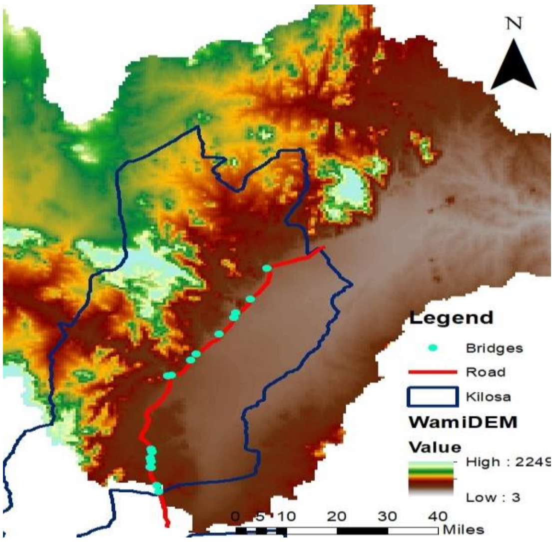

Figure 1. The location of road in the study area

Although the risk of frequent floods may require more bridges and culverts along the road, there is problem of high construction costs.

Objectives

The main objective of this study is to assess how construction of road infrastructures could increase vulnerability of flood disaster prone area. The sub-objectives are to estimate increase of vulnerable area due to road construction and urban development along the road, and to estimate loss due to floods with 5, 10, and 25, 50 and 100 years return period.

THEORY AND METHODOLOGY

To achieve the objectives, flood simulation is conducted by using Rainfall-Runoff-Inundation (RRI) Model (Sayama et al., 2012). The model is calibrated by using 2009/2010 floods (December 2009 – January 2010) and validated by using 2014 floods (December 2013 – February 2014).

Remote sensing analysis is conducted by using MODIS data. A Land Surface Water Index (LSWI) is calculated for comparison with model output.

Flood mapping is also conducted for the 5, 10, 20, 25 and 100 years return period.

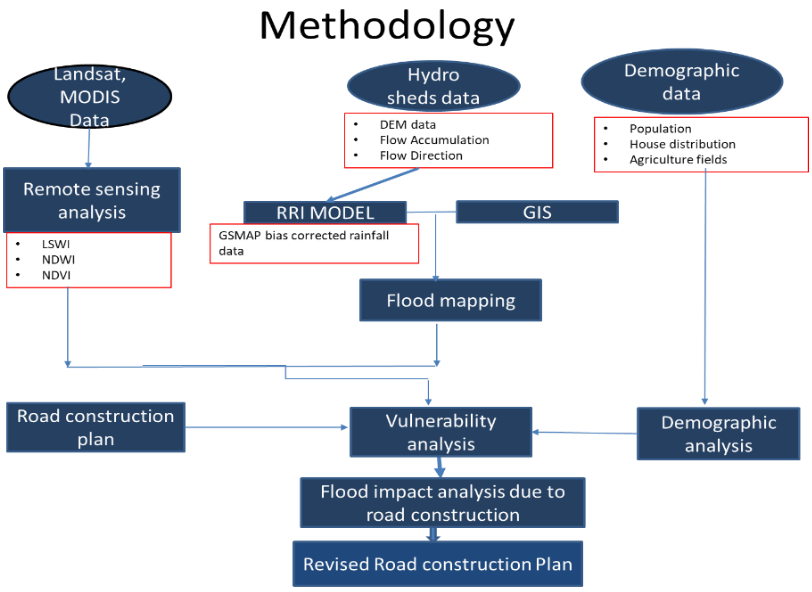

Figure 2 . Methodology flow chart

Finally, flood impact is assessed by comparing the inundation area and the number of affected people along the road with and without road construction. In simulating inundation with road, the cells which road passes through in DEM file were elevated by five meters. Cells with bridges were left un-changed.

DATA

The 30 Seconds DEM data (1 Km) obtained from HydroSHEDS was used. GSMaP rainfall data obtained from JAXA (0.25 degree, 28 KM) was used after biased corrected. For frequency analysis, monthly 24 hours maximum rainfall for 50 years at Ilonga station (6.80N, 37.00E, and 503m from the sea level**)** was used. For demographic analysis, Population data was obtained from Tanzania National bureau of Statistics. Road construction census data was obtained from Tanzania National Roads Agency. Other sets of data used in this study are water level data from Ministry of water and river cross section from google earth.

RESULTS AND DISCUSSION

Model calibration and validation

The RRI model was calibrated by using bias corrected rainfall for 62 days from December 2009 to February 2010 and validated by using bias corrected rainfall data for 90 days in 2014. The maximum rainfall recorded during the 2009/2010 flood was 107 mm/day while GSMaP had maximum of 16.35 mm/day. Then, GSMaP data was multiplied by 6.5 (ratio of ground gauged rainfall to GSMap maximums) to match ground observation. The water level from the river gauging stations was used for calibration and validation. For validation, station 1G37 which is located in the upstream of the basin was used and for validation, station 1G1 on the downstream of the basin was used.

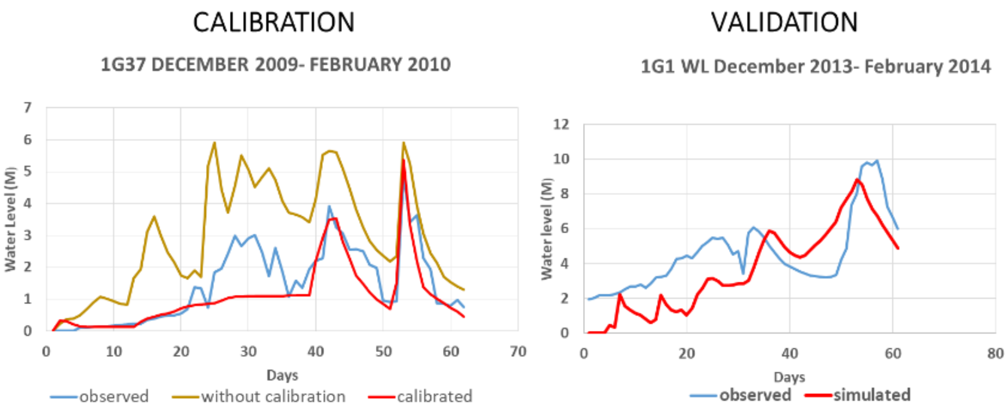

Figure 3. Calibration and validation hydrographs

From the calibration hydrograph the simulated graph has few peaks than ground gauged data. For validation the simulated peak is slightly lower than the ground gauged data. The statistical indices to measure model performance for both calibration and validation are shown on the Table 1 above.

Table 1. Model Performance Statistical Indices

Indices	2009/2010 (calibration)	2014 (Validation)	Optimal
NSE	0.86	0.18	1
RSR	0.37	0.9	0
PBIAS	-12.16	16.25	0

Frequency analysis

Gumbel distribution was used for conducting frequency analysis. Observed rainfall data for 50 years at Ilonga station was used to calculate rainfall values for 5, 10, 20, 25, 50 and 100 years return period. After model calibration and validation, simulation for scenario with and without road was conducted for the above return period.

Inundation before and after road construction

The impact of road construction was assessed by evaluating inundation increase versus road construction plan. The dfference in inundation before and after road construction was calculated for 2009/2010 floods. The difference value was obtained by subtracting inundation without road from inundation with road construction. Figure 5 shows the difference in inudation. Inundation increased in downstream more than upstream. From the point with bridges, there is increase in inundation on the downstream side and at the points where there is no bridges there is increase in inundation on the upstream sides.

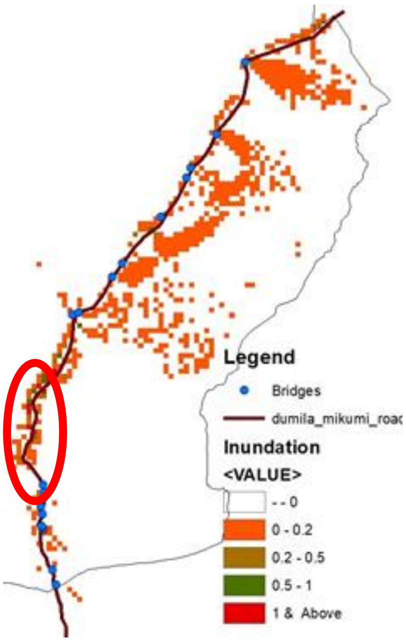

Figure 5. The difference in Inundation after road construction

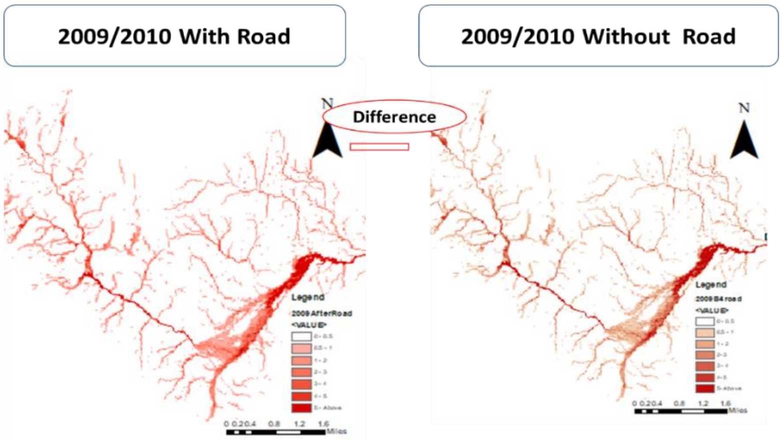

Figure 4. Inundation Map with and without road

Most areas incresead inundation by about 0.2 Meters or below and some small areas on the upstream with more than 1 Meter increase. Further analysis was conducted on the roadside area which has more increase in inundation in upstream area (the marked area). Inundation depth was calculated with and without road construction for different retrn periods.

Inundation in road proximity

Figure 6 shows changes in water level with and without road for 100 year return period flood in the road proximity.

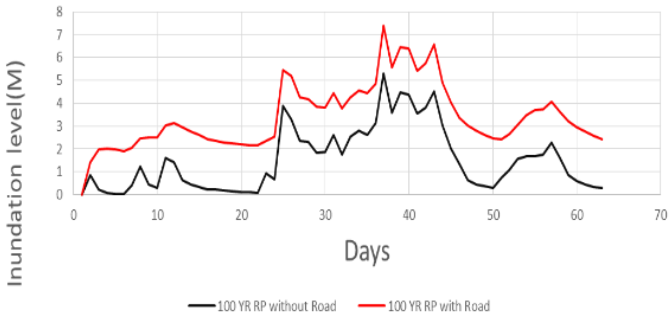

Figure 6. Inundation level with and without road (100yrs) in road proximity

Water level in different river water gauging stations was also calculated from simulation results with and without road construction. Results show that the water level at upstream gauges decreased while the water level atdownstream gauges increased.

Floods for different return periods

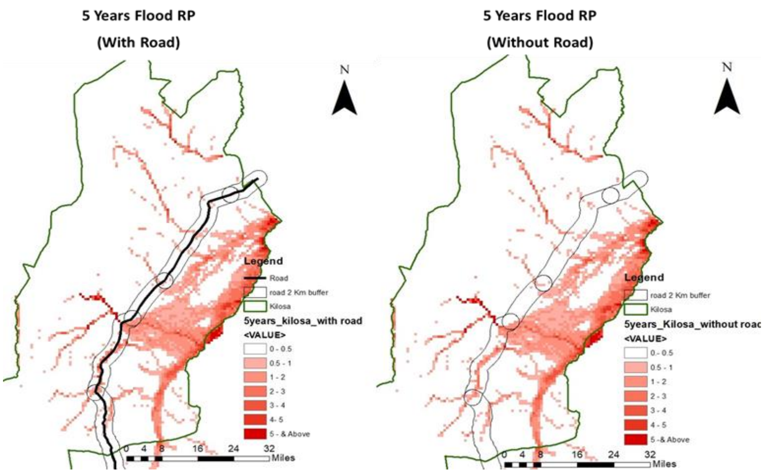

Figure 7. Inundation maps with 5 year return period

Inundation maps were made for 5, 10, 20, 25, 50 and 100 years return period with and without roads. Also for each scenario inundation area was calculated for a 2 KM buffer zone along the road.

The results shows that there is increase in inundation area for higher rainfall return period in general, however for 10 , 20, 25, 50 and 100 years return period in comparison with road happens to have less inundated area than the case without road. From the Figure 7 the 2 KM buffer zone was extracted and the inundation area was

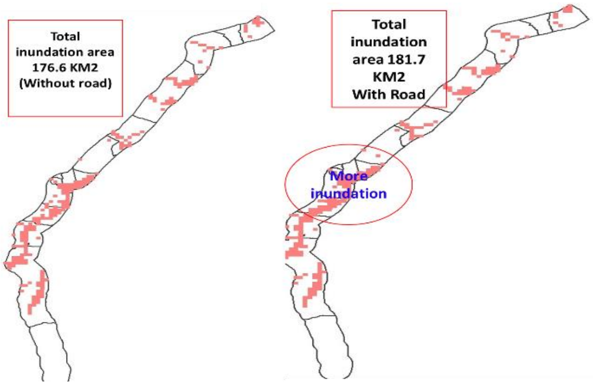

Figure 8. A 2 KM road buffer zone Inundation map

calculated for the two scenario with and without the road. The figure 8 for 5 years return period (is extraction from figure 7, a 5 year return period) shows an increase in inundation area in a 2 Km Buffer zone. The area with more inundation increase is marked. This is because there is water tributary passing through that area. A total length of inundated road was also calculated for each return period (Figure 9 below).

From the Figure there was slight increase in length of inundated road for lower rainfall return period (5, 10, 20 & 25 years) but for higher return periods there was sharp increase in length of inundation road.

Apart from calculating the length of inundated road the inundation area for each village where a road is passing through was also calculated. The road is passing through 16 villages and Rudewa village had more increase in inundated area for 5, 25, 50 and 100 years return period.

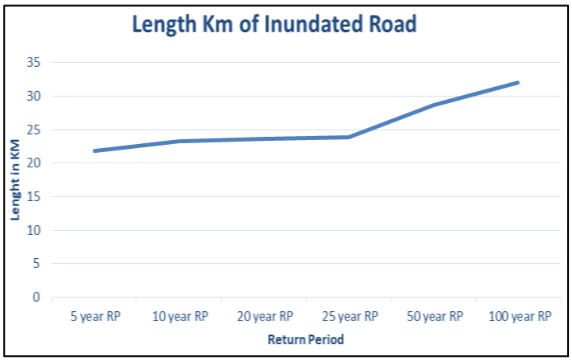

Figure 9. Length of Inundated road for different return periods

Changes in Water level at the Bridge

Bridge construction analysis was conducted. In the plan several bridges will be constructed,

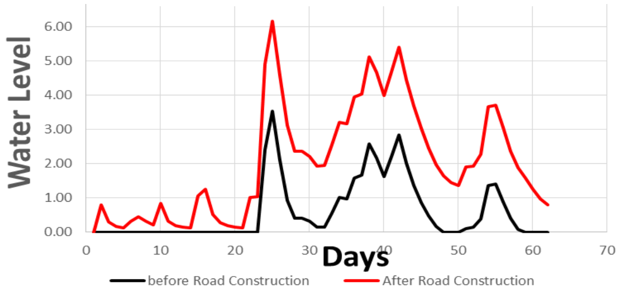

Figure 10 .Water level before and after road construction at bridge

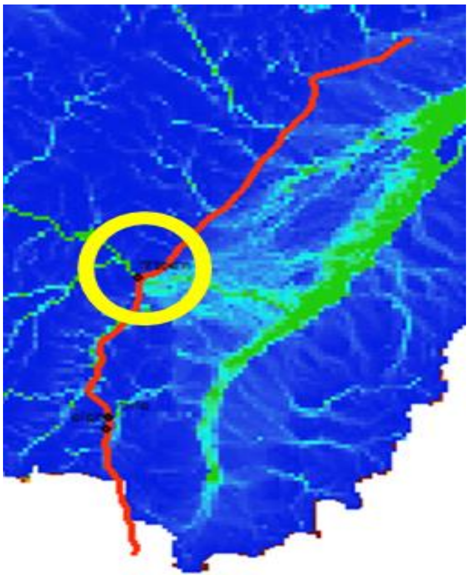

Figure 11. One of the bridges in the study area during 2009/2010 floods

according to the plan, the bridges which will be constructed in the downstream area (Figure 11) had the following dimensions: Bridge length 15 meters, width 9.1 meters and height 5.0 meters. The interest was on the brigde height. The simulation results for 2009/2010 floods show that the water level at the bridge was 3.53 metes with road construction, while After road construction water level increased to 6.18 meters. For the flood with 50 years return period, water level was 8.09 meters and for 100 years was 8.57 meters, these water levels are exceeding the proposed bridge height of 5 meters.

Population affected

Population affected by floods in Kilosa district was calculated by considering inundation with and without road. It was calculated for each return period. Figure 12 shows the population affected by different inundation depth for 100 years return period. Figure 13 shows the affected population for 5, 10, 20, 25, 50 and100 years return period with and without road. Similarly for population affected by inundation area, a comparison was made for each return period found there is no huge difference between afftected population wth and without the road. The number of damaged houses was also calculated by comparing with road and without road for each return period.

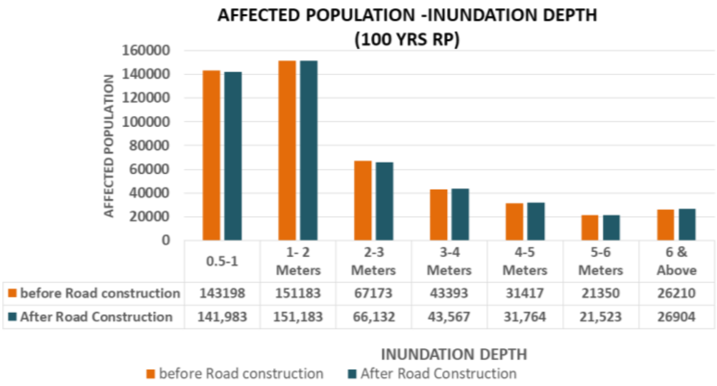

Figure 12. Affected population by inundation depth (100 years return period)

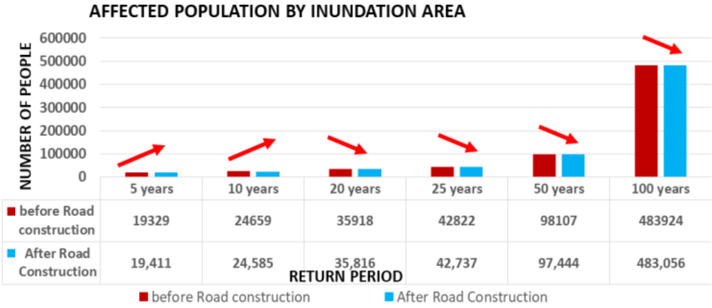

Figure 13. Population affected by inundation area

CONCLUSIONSAND RECOMMENDATIONS

This study assessed the impact of road construction in flood prone area. From the results, it is shown that more impacts are expected from increase in inundation level more than increase in inundation area. In comparing inundation with and without road, only the case with 5 years return period with road had more inundation than the case without road. In comparing inundation level, the case with road had deeper inundation than without road in areas with no bridges.

Basing on the results, it is recommended to have more culverts and wider bridges to reduce water accumulation.

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