FUOYE Journal of Engineering and Technology, Volume 3, Issue 2, September 2018 ISSN: 2579-0625 (Online), 2579-0617 (Paper)

Mapping and Evaluation of Flood Risk Areas along Asa River using Remote Sensing and GIS Techniques

*Kamoru A. Adeniran, Yinka A. Ottawale and Matthew S. Ogunshina

Department of Agricultural and Biosystems Engineering, University of Ilorin, Ilorin Nigeria
kadeniran_2003@yahoo.com|otayinkus@yahoo.com|segunogunshina@gmail.com

Abstract-Flooding in Ilorin city has become a yearly occurrence. Mapping and evaluation of flood risk areas along Asa River in Ilorin metropolis was carried out using the Geographic Information System (GIS) and remote sensing. The technique used includes conversion of Digital Terrain Model (DTM) to Triangulated Irregular Network (TIN) format. The geometric data was obtained from TIN through the use of United States Army Corps of Engineers, Hydrologic Engineering Centre, Geo River Analysis System (USACE HEC-geoRAS) in GIS. The obtained geometric data, Manning's roughness coefficient (n), Expansion and contraction coefficient values and steady flow data of the River were used in HEC-RAS. The n values of 0.035, 0.016 and 0.02 were used for the channel, 0.045, 0.016 and 0.03 were used for the overbank and 0.2 was used for the bridges. Contraction and expansion co efficient value of 0.1 and 0.3 were used for channel and 0.3 and 0.5 were used for the bridges. Gumbel equation was used to estimate the flow for return period of 10, 50 and 100 years and the values of 155.13, 213.44 and 221.43 m^3/s were obtained respectively. Delineated map was then compared with TIN terrain model to generate inundation map. The map revealed that some areas in Ilorin such as Coca-Cola Road, Baba Ode, Unity road, Obo Road, Taiwo-Isale, Amilengbe, Isale Koko, Mubo Phase 1, Mubo Phase 11, Royal Valley and Akerebiata prone to flood disasters. Estimated maximum top width for inundated area along the river ranges from 900.74 to 2375.11m.

Keywords-GIS, River Asa, DEM, Flood risk, HEC-RAS, Ground slope

1 INTRODUCTION

Flood is defined as a state of high water level along a river channel or on coast that leads to inundation of land which is not normally submerged (Panda, 2014). The devastating impacts of flood on human's lives and properties is becoming more worrisome in the world especially in developing countries where little effort can be made to control it. The occurrences of these phenomenon is often and could be due to heavy rainfall (from climate change), dam failure, river overtopping their defenses, blockage of river channels, improper planning of the settlement and lack of proper control measure to curb the occurrences (Eguaroje et al., 2012).

In a large area of land, the financial implications, lesser labour requirements couples with less time of operation were among other factors that gave Geographical Information System (GIS) the edge over conventional hydrological monitoring systems in mapping and assessments of flood risk. For this reason, Klemas (2015) opined that conventional hydrologic monitoring systems have limited use in flood forecasting and mapping flood area. Causes of flood has been reported by several researchers among which is Olabode et.al, (2014) who traced the causes to heavy rainfall, overflow of drainage channels due to its blockages and emergency release of water from dams. While Ogunlela & Adelodun (2014) noted the occurrence of heavy rain in the upstream usually leads to the unsteadiness in a river as well as breaches in the embankment system, Macchi & Tiepolo (2014) observed that sea level rise, rapid population growth and urbanization are key factor responsible for flood in all part of the world. Shiru et al. (2015) reported that flooding in Ilorin city has become a yearly occurrence.

Increasing population which results in competition for space and more generation of wastes, improper drainage design and insufficient drainage systems, paving of surfaces, refuse dumping in drainages and water ways are amongst the causes of flooding in the city. In 1997, Kwara recorded flood in Lafiagi, Patigi, Kpada and Gbogbondogi and this was traced back to heavy rainfall which resulted in serious flooding and the displacement of over 4,000 people in the Patigi, Edu and Moro Districts of Kwara State (Ogunbodede & Sunmola, 2014).

During rainy seasons in Ilorin, precipitation often falls as rain leading to changes in Asa river flows. The river often overruns its bank and resulted into recurrent flooding of the roads in Wahab Folawiyo Road popularly known as Unity and its environs, movements of vehicles and humans becomes impeded, offices and business activities and residential houses are often affected by the flood (Kolawole et al., 2011). Advent of computer technology in hydraulic modeling provide greater flexibility for engineers to execute engineering tasks such as floodplain mapping through the use of Digital Elevation Models (DEM) in the form of Triangular Irregular Networks (TIN) which has flexibility of affording engineers the ability to create geometric representations in a cost effective manner (Solaimani, 2009). There are several methods for hydraulic modeling process for floodplain mapping. One of them is the Hydrologic Engineering Centre River Analysis System (HEC-RAS), (USACE, 2006).HEC RAS support sediment transport computation, water transport analysis, steady and unsteady flow, water surface profile calculation in natural and constructed channels (USACE, 2002). The objective of the study was to analyze water elevation profile of Asa River in Ilorin metropolis and to identify the areas prone to flood disasters.

* Corresponding Author

2 METHODOLOGY

2.1 DESCRIPTION OF THE STUDY AREA

Ilorin is a capital city of the Kwara State in Nigeria. The city is located on latitude 8°30N and Longitude 4010E (Kwara State Diary, 1997). Ilorin is situated in the transitional zone between the forest and savanna region of Nigeria, the elevation varies from 273m to 333m in the West with isolated hill (Sobi hills) of about 394m above sea level and 200m to 364m in the East (Olabode et.al, 2014). The area has the mean annual total rainfall of 1.200 mm (www.kwara.gov, 2012). Ilorin City is crossed by one major river, River Asa which flow in South – North direction dividing the plain into two (western and eastern parts). The River Asa has average channel slope of 0.8% (Salami & Ayanshola, 2010) and catchments basin is about 1040 km2 which lies between latitudes 8°31N and 90241North and longitude between 4°361 and 4°101 East (Olabode et al., 2014). River Asa originates from Oyo State and has many tributaries in the city as seen in Fig 1.

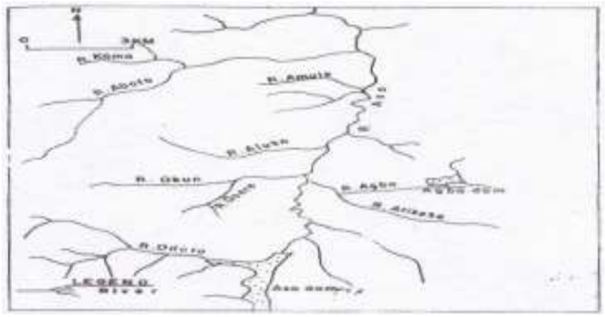

Fig. 1: River Asa and its tributaries (Source: Olabode et al., 2014)

2.2 METHOD OF OBTAINING THE DATA USED IN GEOGRAPHICAL INFORMATION SYSTEM

Digital Terrain Model (DTM) of the river system obtained from CGIAR (2012) was converted to Triangulated Irregular Network (TIN) format which was used to develop the geometric data in Geographical Information System (GIS). The resolution of the topography data is 5m and was extracted from the Shuttle Radar Topography Mission (SRTM) final version developed by Consultative Group for International Agricultural Research (CGIAR, 2012). The geometry data file entails vital information about cross- section, hydraulic structures, riverbank elevations and other physical attributes of the river channels. (Merwade, 2006).The geometric data which include river center line, bank lines, flow path, cross sections were created from TIN through the use of HEC-GeoRAS to create physical attributes in ArcGIS before its being exported to HEC-RAS. Cross- section cut lines were used to extract elevation data from the terrain and also used for establishing ground profile across the flow (Fig. 2)

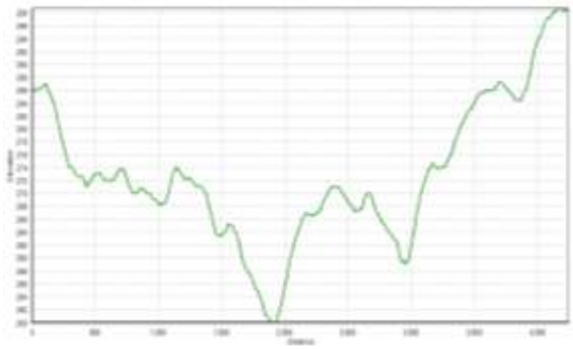

Fig.2: Ground profile across the flow

2.3 GEOMETRY DATA

Bridge cross-sections of five locations were drawn perpendicular to the stream flow and about eighty (80) cross-sections were digitized manually along the river center line with the use of HEC-GeoRAS. The other parameters that were added are roughness coefficient, contraction and expansion values. Roughness of the channel (Manning’s n) is an important calibration parameter needed for accurate computation of water surfaceprofile and this could be achieved by conducting a sensitivity analysis with appropriate manning’s values that give confidence in the model.

Sredojevic & Simonovic (2009) opined if there is no water surface data, values of obtained from another stream with similar conditions should be used. Therefore, using information obtained during site inspection as a guide and base overbank along the channel were chosen for upper region, middle region and lower region cross sections respectively. The n value of 0.2 was chosen for the boundary cross sections for bridge overbanks for marginal increase in flood profile and stability purpose (HEC, 2010). The contraction and expansion coefficient of 0.1 and 0.3 for all cross sections were maintained since the flow is gradual transition except at the bridges which is 0.3 and 0.5 respectively (USACE, 2002). Bridge cross sections were placed appropriately and HEC-RAS automatically added two more cross sections, that is immediately at both the upstream and downstream face of the bridge. The locations of the bridge in HEC-RAS modeling tool along Asa River include:

(a) Asa dam Bridge at river station (RS 13836)
(b) Unity Bridge at river station (RS 9803)
(c) Emirs Road Bridge at river station (RS 8928)
(d) Amilegbe Bridge at river station (RS 7943)
(e) Royall valley estate bridge river station (RS 4050)

There are ineffective flow areas at these hydraulic structures which provide little or no conveyance. The ineffective bridge height was set to an appropriate elevation and the ineffective flow areas become effective when the flow depth reach the larger height. Shown in Fig 3 is an example of upstream and downstream of bridge with ineffective flow.

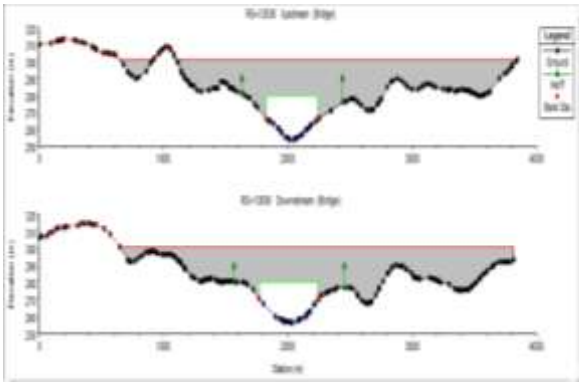

Fig.3: Bridge bounding cross sections with in effective flow area

2.4 Steady Flow Data And Boundary Conditions

Flow data is another important input requirement for appropriate flood modeling using HEC-RAS for steady flow condition. Boundary condition was set to normal depth with Average channel slope of 0.0008 (Salami & Ayansola, 2010). Flow data adopted for this study was obtained from Salami (2002) and was used to estimate the discharge for Q for the return period (T) for 10, 50 and 100 years using Gumbel equations (Raghunath, 2006). The estimated flow values of 155.13, 213.44 and 221.43 m^3/s were used for the simulation of floodplain in HEC-RASand the computation results for the 10years, 50years and 100 years were exported back to Geographic Information System (GIS).

2.5 Floodplain Mapping

The floodplain was mapped with the use of HEC-GeoRAS in concert with Arcmap. Water surface elevations in the cross section cut lines within the limits of bounding polygon were used to map floodplain.Water Surface TIN was created from the cross section water surface elevations for the three return periods (10, 50 and 100-years) and delineation map was then compared with TIN terrain model which was already in grid format thereby allowing differences in their elevation to be calculated. In this case, areas with water surface elevation higher than the terrain elevation (inundation depth grid) had positive result while dry land produced negative result as shown in Fig. 4.

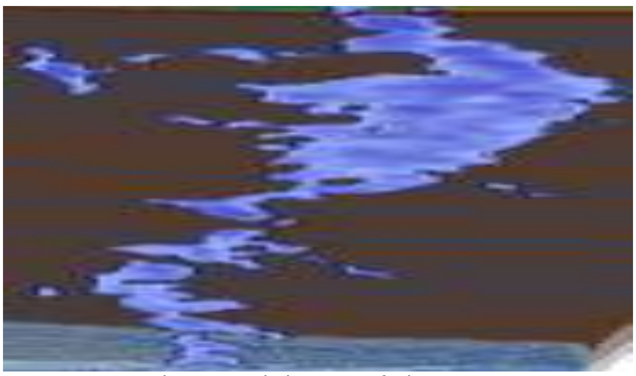

Fig. 4: Inundation Map of River Asa

3 Results and Discussion

HEC-RAS computer modeling results consist of water surface elevations generated for 100- year return periods. Apart from water surface elevations, some other hydraulic parameters such as flow velocity, flow rate, channel slope, flow area are available for each cross section as shown in Table 1. HER-RAS simulation result shows the variability in main channel and inundated floodplain velocities. Spatial distribution of flow velocity along the river channel revealed that there are higher flow velocities at the upstream and value decreases downward the river.

Flow velocity at the upper region is as high as 1.89m/s in the upper region with minimum of 0.09m/s in the region. The middle region has maximum and minimum velocity of 0.23m/s and 0.1m/s in the middle region respectively. However, the flow velocities in the lower region of the channel varied with a maximum value of 0.19m/s to a minimum value of 0.01m/s. Fig 5 shows the velocity profile of the river. Highest average minimum channel elevation of 261.34 m was obtained for the uppermost reach (A). This value drop spatially along channel and the lowest average minimum channel elevation value was also derived from reach F .the graphical representation is of minimum channel elevation against distance shown in Fig 6.

The results of average ground slope for each river reach is computed and the outcomes revealed highest average slope of 0.002328 and 0.001263for reach A and B respectively. Reach C and E had lower values for its ground slop. However, negligible slope was seen in reach D as it is shown in Fig 7. The map, modeled with 100-year return period identified that plain with relatively low relief would be flood and this will mostly occur in lower region where the water surface elevation is equivalent to ground elevation. In this region water spread across a wider areas than upper and middle region. Inundated area for 100 years return period were estimated for each reach, the result shows minimum value at the upper region with reach A having a least value of 8205.67m^2.

The affected areas increased in value downward the river and the highest value was attained in the lower region with reach E having 97746.11m^2 as the highest value as show in Fig 6.This was in line with maximum inundation width attained for the region. The inundated areas along the river includes Coca Cola Road, Baba Ode, Unity road, Obo Road, Taiwo-Isale, Amilengbe, Isale Koko, Mubo Phase 1, Mubo Phase 11, Royal Valley and Akerebiat. The result of flood plain area was shown in Table 2.

Table 1: Average profile output

Reach name	Av. Min. channel elevation (m)	Av. water suf. Elevation (m)	Av. ground suf. Elevation (m)	Ave. ground slope	channel velocity (m/s)
Reach A	261.3373	265.8600	265.9227	0.00233	0.4980
Reach B	255.3525	261.0395	261.0675	0.00126	0.3837
Reach C	250.9500	260.3425	260.3750	0.00010	0.5000
Reach D	251.3040	260.3343	260.3545	0.00007	0.3960
Reach E	252.8000	260.3200	260.3200	0.00003	0.1600
Reach F	247.1900	245.0900	245.2200	0.00080	0.0518

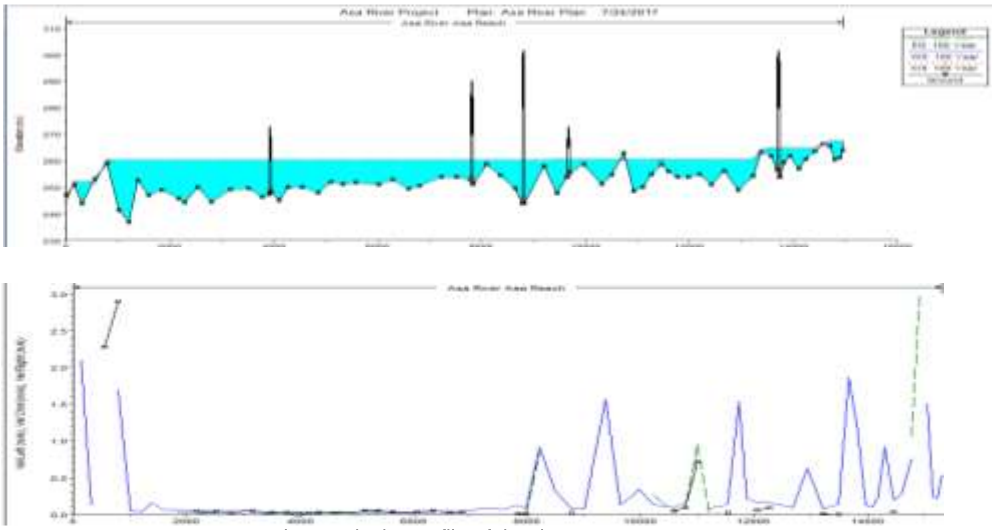

Fig 5: Velocity profile of the river

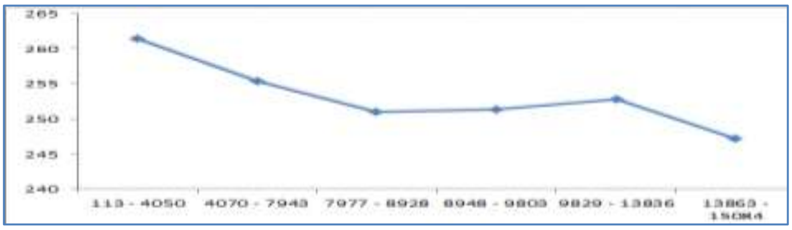

Fig 6. Graphical representation of minimum channel elevation against distance

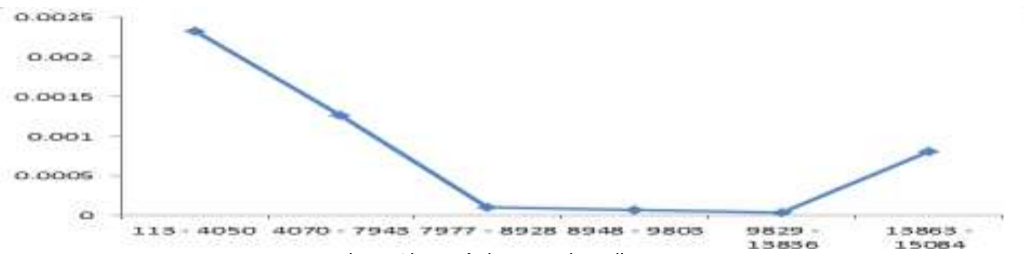

Fig 7. Chart of slope against distance

Table 2: Estimated Inundated Areas along Asa River 100 Years Return Period

Locations	Reach	Inundated Area (m²)	Inundated Area/Region (m²)	Total Inundated Area (m²)
Upper Region	Reach A	8205.67	36885.15	
	Reach B	28679.48		
Middle Region	Reach C	5790.27	15925.96	232530.69
	Reach D	10135.69		
Lower Region	Reach E	97746.11	179719.58	
	Reach F	81973.47		

4 Conclusion

Steady flow analysis of Asa River was modeled in HEC RAS.100 years simulation result produced highest discharge Q (221.43 m^3/s) and total estimated flood prone area of 232530.69m^2 which spread across the channel as 36885.15 m^2, 15925.96 m^2 179719.58 m^2 in upper region, middle region and lower region respectively. Thus areas such as Coca Cola Road, Baba Ode, Unity road, Obo Road, Taiwo-Isale, Amilengbe, Isale Koko, Mubo Phase 1, Mubo Phase 11, Royal Valley and Akerebiata prone to flood disasters.

References

CGIAR (2012). SRTM 5m Digital Elevation Data, http;//srtm.csli.cgiar.org/ (Accessed on 5th March, 2017).

Eguaroje, O.E., Alaga, T.A., Ogbole, J.O., Omolere, S., Alwadood, J., Kolawole, I.S., Muibi, K.H., Nnaemeka, D., Popoola, D.S., Samson, S.A., Adewoyin J.E.,Jesuleye, I., Badru, R.A., Atijosan, A. and Ajileye O.O. (2015). Flood Vulnerability Assessment of Ibadan City, Oyo State, Nigeria,WorldEnvironmen, 5(4): 149-159.

Klemas, V. (2015). Remote sensing of floods and flood-prone areas: An overview. Journal of Coastal Research, 31(4): 1005– 1013.

Kolawole O.M, Olayemi A.B & AjayiK.T (2011). Managing flood in Nigerian cities: Risk analysis and adaptation options – Ilorin city as a case study, Archives of Applied Science Research, 3 (1):17-24.

Kwara Diary (1997), Geographical Location of Ilorin, Government Press, Ilorin, Nigeria.

Macchi, S and Tiepolo M. (2014), Climate Change Vulnerability in Southern African Cities, Springer Climate, _ Springer International Publishing Switzerland 1-19.

Merwade, V. (2014).Tutorial on using HEC-GeoRAS with ArcGIS 9.1,web.ics.purdue.edu/~vmerwade/education/ georastutorial.pdf.

Ogunbodede, E.F. & Sunmola, R.A. (2014). Flooding and traffic management in Akure (Nigeria) metropolitan environment, European Environmental Sciences and Ecology Journal, December 2014 Edition Vol.1 No.2.

Ogunlela, A.O. & Adelodun, B. (2014).Kinematic flood routing of Asa River, ilorin, nigeria, International Journal of Engineering and Technical Research, 2(3): 1-5.

Olabode, A.D., Ajibade, L.T. & Yinusa, O.(2014), Analysis of Flood Risk Zones (Frzs) Around Asa River in Ilorin Using Geographic Information System (GIS) ,International Journal of Innovative Science, Engineering and Technology, 1 (9): 1-8.

Panda, P. K (2014).Vulnerability Of Flood In India: A Remote Sensing And GIS Approach For Warning, Mitigation And Management, Asian Journal of Science and Technology 5 (12): 843-846.

Raghunath, H. M. (2006), "Hydrology ,Principles. Analysis. Design" New Age International (P) Limited, Publishers, revised Second Editio, ISBN (10) : 81-224-2332-9.

Salami A. W. (2002) Influence of Asa dam on the Hydrometerological variables in Asa River Basin, Technical report submitted to the Department of Civil Engineering, University of Ilorin, Ilorin, Nigeria.

Salami, A.W. & Ayanshola, A.M. (2010). Evaluation of Methods of Storm Hydrograph Development for AsaRiver Catchment, Nigeria, Technical paper Submitted to the Department of Civil Engineering, University of Ilorin

Shiru, M. S., Johnson, L. M., Ujih, O. U. and AbdulAzeez, O. T. (2015). Managing Flood in Ilorin, Nigeria: Structural and Non Structural Measures. Asian Journal of Applied Sciences, 3 (05):507-513. (www.ajouronline.com)

Solaimani, K., 2009, Flood forecasting based on Geographical InformationSystem,African Journal of Agricultural Research 4(10): 950-956

Sredojevic, D. and Simonovic S. P.(2009). Hydraulic Modeling and Floodplain Mapping, Water Resources Research Report, (69): 1-147.

USACE (2002).HEC-RAS, River Analysis System, Hydraulic Reference Manual, Version 3.1.United States Army Corps of Engineers, Hydrologic Engineering Centre, Davis, California.

www.kwarastate.com (2012), Kwara State and Local Government Areas Information World Wide Website.

Yolas Consultant (2009). Draft Final Report on Channelization of Asa River and its Tributaries, Ilorin, Kwara State.