MULTI CRITERIA ANALYSIS (MCA) METHOD USING A GIS TO MODELED FLOOD RISK MAP ZONES OF CALABAR RIVER

J. G. Egbe[1*] and S. E. Ubi[2]

[1]Lecturer, Department of Civil Engineering, Cross River University of Technology, Calabar, Nigeria

[2]Lecturer, Department of Civil Engineering, Cross River University of Technology, Calabar, Nigeria

Corresponding author email: jeromelina2011@yahoo.com

Abstract

The frequency with which floods occur, their magnitude, extent, and the cost of damage are escalating all around the globe, is of immense concern. A flood is a water provoked disaster that prompts a short-lived surge of dry land and makes veritable mischief to lives, property, and structures. Flood has made a lot of unsafe effects in Nigeria, occurring to the end of people, breakdown of designs, structures, destruction of properties, agrarian produce, loss of land, and extended government use. To fill this opening, a sporadic investigation was carried out in this study on selected, families, neighborhoods, communities, and ministries that were affected by flood in Cross River State, Nigeria. Relative Important Index (RII) was used for situating the parts and the preventive measures. Multi-Criteria Analysis (MCA) is used to model the flood danger map examination and Sentinel-1A SAR pictures are generated to design flood loosen up and to decide if the resulting guide from the MCA connection is a close-by depiction of the flood slanted zones in the investigation region. The results show that the multi-measures examination approach was reasonably suitable in coupling the parameters, including high, slope, precipitation, land cover, and soil geography to make a flood risk map danger of the location. From the result, the normal factors that causes flooding have been identified to include the nature of the drainage system, heavy precipitation, indiscriminate building along flow channels and rash trash evacuation routine. Preventive measures to avoid flooding were constant dumping of waste, lack of awareness of individuals overall on the need to adhere to environmental rules, enforcement of government agency to screen private design improvement, execution of government policies on flood control, and cleansing of town/city by Community Urban Development Agency (CUDA) is ineffective in Cross River State.

Keywords: *Flood, Danger map; Multi Criteria; Risk*

1.0 INTRODUCTION

Floods are amongst the most prevalent natural disasters, and the frequency with which floods occur, their magnitude, extent, and the cost of damage are escalating all around the globe. Accordingly, Jeb and Aggarwal [1] describe flooding as a general impermanent condition of incomplete or complete inundation of normally dry areas from the overspill of inland or tidal waters or unusual and rapid buildup or runoff. According to the Oxford dictionary [2], flooding refers to an overflow of a large amount of water beyond its normal limits, especially over what is normally dry land. There are different types of floods these include coastal flooding flash Flooding, flooding due to rising of groundwater, and flooding due to the opening of a dam, [3], [4].

Similarly, between 80-90% of all documented disasters from natural hazards during the past 10 years have resulted from floods, droughts, tropical cyclones, heatwaves and severe storms. Floods are also increasing in frequency and intensity, and the frequency and intensity of extreme precipitation are expected to continue to increase due to climate change.

In 2007, the European Commission [6] indicated that floods were natural occurrences that could not be avoided. However, there is an escalation in the probability and adverse impacts of flood events due to some human undertakings such as growing human settlements and economic resources in floodplains and a decrease of the natural water retention by land use coupled with climate change.

A gauge of 1.3 million individuals was dislodged and around 431 individuals lost their lives with more than 1525 square kilometres of farmland obliterated [6]. In particular, Cross River State is a continuous victim of flooding. Similarly, in 2012 flood debacle influenced 212 networks in Cross River State, executed 13, dislodged 49,918, annihilated 1,800 houses, 82,361 homesteads, etc. [7].

Likewise, in 2017 [8] revealed that 25,000 individuals were influenced by a specific flood occasion in Boki Local Government Territory (LGA). More so, between July and August 2017, the state was accounted for to have seen 217 flood cases with 15 mortalities in 21 networks of 12 LGAs (Obudu, Yala, Ogoja, Boki, Etung, Ikom, Obubra, Abi, Biase, Akamkpa, Odukpani, and Calabar South) as documented by [7]. In the equivalent vein, in 2012, Ikom LGA (Alesse and Osokora) were visited by rising waters delivering scores of residents destitute and formless. An aggregate of 43 structures was obliterated, a large portion of which was assembled near the waterway bank, making it simpler for water to overwhelm them [8]. The pictures as depicted in Figure 1 explains the scenario of the flooding conditions in Calabar.

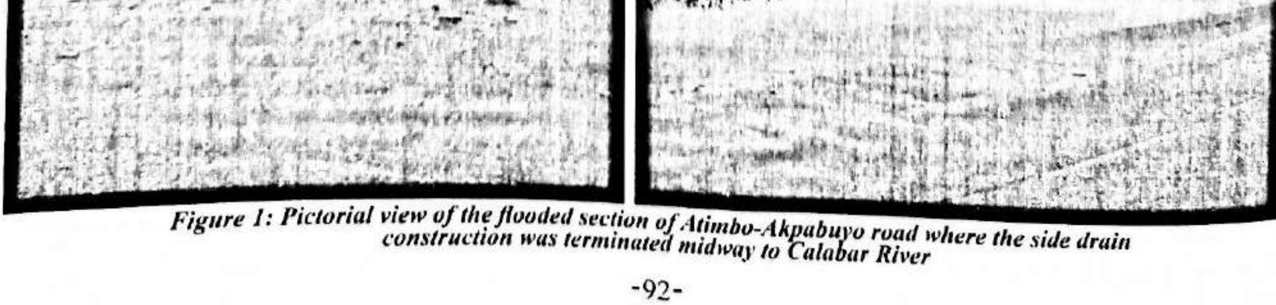

Figure 1: Pictorial view of the flooded section of Atimbo-Akpabuyo road where the side drain construction was terminated midway to Calabar River

2.0 RESEARCH METHOD

The objective of this research work is to develop an application of geoinformatics in flood risk danger map model for the Calabar River area using remotely sensed data in the ArcGIS environment. The site visits across the study area were carried out to ascertain the elements that may have causative influence over flooding in the area. The following elements were deemed to have such influence; Flow Accumulation (Drainage/stream network), Elevation, Slope, Land use/cover, Geology (soil type) and Rainfall intensity (precipitation)

To determine the flood vulnerable areas, Multi-Criteria Analysis (MCA) is used. The MCA analysis is done in two phases. The first phase is the use of the Analytic Hierarchy Process (AHP)multi-criteriaeria decision tool, to determine the weights of the criteria. The AHP constructs a hierarchy of decision criteria using comparisons between each pair of criteria formulated as a matrix. The paired comparisons produce weighting scores that indicates the hierarchy of importance of selected criteria. The second phase then incorporates the determined weights in a weighted overlay process to produce the flood hazard map. Figure 2 is the flow diagram of the methodology.

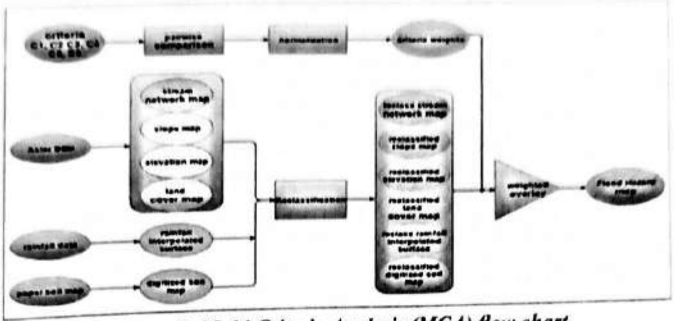

Figure 2: Multi Criteria Analysis (MCA) flow chart

2.1 Spatial Data Preprocessing

Spatial data is required for the criteria being used for the weighted overlay process. The criteria are; Elevation, Rainfall intensity (precipitation), Flow Accumulation (Drainage/stream network), Slope, Geology (soil type) and Land use/cover. Raster maps for elevation, slope, and drainage are derived from ASTER DEM. A raster map is created for precipitation through surface interpolation. A polygon map for land cover is created from a Landsat 8 image and a polygon map for soil type is digitized from a paper map.

2.2 The Stream Network (Flow Accumulation)

The stream network is derived from the ASTER DEM.

The Figure 3 shows the conceptual overview of watershed and stream network delineation. However, for the watershed delineation, a depression-less DEM is needed hence the sink tool in ArcGIS hydrology is used to locate sinks in the DEM and the fill tool is used to fill the identified sinks. Similarly, the flow direction tool is then applied to compute the direction that water would flow for every cell and flow accumulation calculates the number of cells flowing into each cell of the filled DEM. The areas with very high values may possibly be perennial streams or rivers, areas with lower values may be sporadic streams. The flow accumulation grid allows for the determination of areas draining to points on the DEM. The Basin tool is then used to create watersheds. The basin tool finds its own pour points and creates watersheds for the whole map.

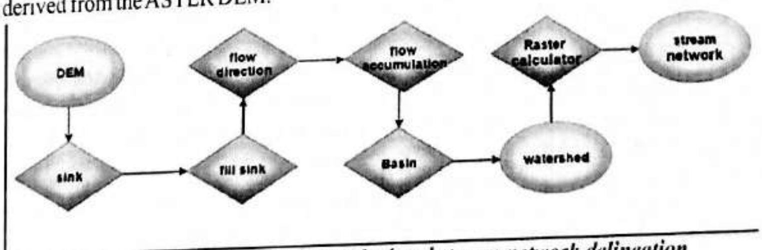

Figure 3: Flow chart for watershed and stream network delineation

3.0 RESULT AND DISCUSSIONS

To determine the stream network a conditional statement is applied to the flow accumulation raster.

The idea is to reclassify all cells that meet a certain accumulated flow threshold to be 1, and all other cells to be no data. The threshold used for this analysis is 1500 which implies that all cells with a value greater than 1500 are reclassified as 1. The threshold of 1500 was chosen because it gave the best representation of the drainage basin.

The conditional statement "Con ("FlowAcc_Flow1" > 1500, 1)" is created with the Raster Calculator. This produced a detailed stream network raster for the area covered by the flow accumulation grid which is then reclassified to the predefined rankings. In the reclassification of the flow accumulation grid, flow accumulation between 24528 and 32408 were deemed to have the highest flood causing influence and hence was assigned the ranking "very high".

Nevertheless, the flow accumulations between 15378 and 24528 were deemed to have the next highest flood causing influence and therefore, assigned the ranking of "high". The flow accumulations between 6863 and 15378, 1652 and 6863, 0 and 1652 were then subsequently assigned moderate, low and very low rankings respectively.

The elevation and slope are determined from the ASTER DEM using surface analysis tools under the spatial analyst tool bar in ArcGIS. The contours of the study area are extracted from the DEM and this is used to generate the slope and elevation maps. The steepness of the slope affects the flow and inundation of a particular area. In the same vain, low-lying areas with gentle slope angles have the tendency to be inundated first as compared to areas with steep slope angles during flooding. Likewise, the flat terrain decreases water runoff and this causes high infiltration where there is open soil, or stagnation where there is impermeable surface leading to water logging condition.

The land use activity of the basin of the study area integrated data collected through available topographical map and aerial photographs. This served as a basis for interpretation and comparison of the change of the different land use types in the study area. The satellite imageries' interpretation of the study area covered four epochs: 1980, 1990, 2000 and 2010 on a scale of 1:500, 000. The study also integrated the available topographical map of the study area on a scale of 1:160,000.

The study adopted data from different sources and used different methods and approaches to analyze the long term land use/cover changes and trends in the four decades of the study area. The approaches included imageries from different satellites (Landsat), multi-temporal dates (MSS 1980, TM 1990, ETM 2000 and ETM+2010), fieldwork surveys and forest inventory application. The pixel-based classification was applied as a new approach of imagery classification. The Earth Resources Data Analysis System (ERDAS) Imagery version 9.1, Integrated Land and Water Information System (ILWIS) software version 3.7 was used for image processing, masking and classification. Meanwhile ArcGIS was employed for database development, spatial data analysis, producing thematic maps. The coordinates of different locations in the study area were obtained by the use of a Global Positioning System (GPS) using the WGS84 32N Minna Datum. The landsat satellite imagery of the study area was acquired for four epochs: 1980, 1990, 2000 and 2010 from Global Land Cover Facilities (GLCF) and United State Geological Survey (USGS). The approach included imageries from different satellites (Landsat), multi-temporal data such as Landsat 1-5, the Landsat Multi-Spectral Scanner) 60m resolution in multispectral (MSS 1980), Landsat TM 1990 (Landsat 4 and 5 Thematic Mapper) 30m resolution in multispectral (TM 1990), Landsat 7 Enhanced Thematic Mapper 30m resolution in multi-spectral (ETM 2000) and Landsat ETM + 2010 (Landsat Levell Enhanced Thematic Mapper Plus) 30m resolution (ETM+2010).

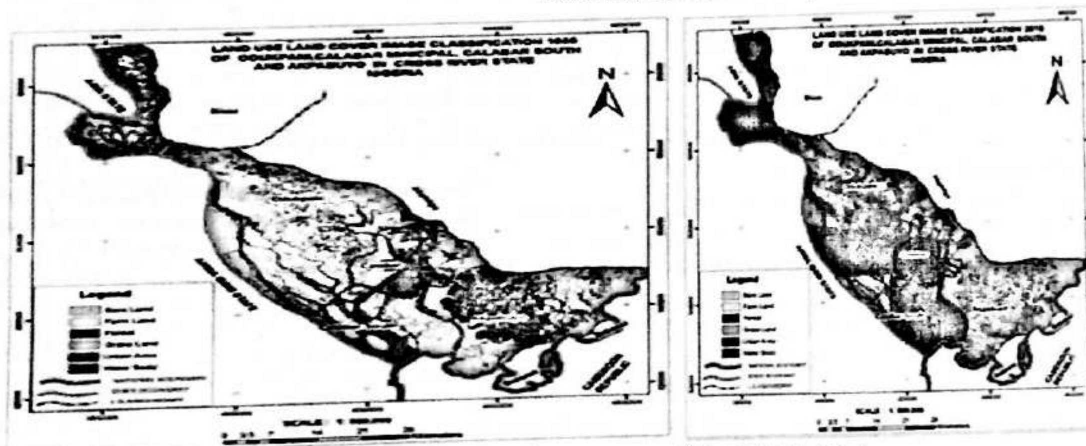

Figure 4: The land use/cover map of the study area

The land use/cover map of the study area is classified from a Landsat-8 OLI satellite imagery acquired on March 22, 2019. The Iso cluster Unsupervised classification was carried out to generate the land use/cover map. In unsupervised classification, clusters are created from pixels with similar statistical properties [9]. The created clusters have no definite meaning and classification is done by the user. Thirty spectral classes are defined for the classification of the image. This is because although five land cover classes are to be defined, these classes may contain a range of spectral identities. The five cover classes are color coded and the colors for the thirty spectral classes are changed to fall into one of the five colors, the Table 1 explains the selected station data.

Table 1: Station data

Station-Name	Latitude ⁰	Longitude ⁰	Precipitation Mm	Station-Number
Ga South	5.545453	-0.34517	787	6
Ga Central	5.646343	-0.34521	789	8
Ga West	5.728451	-0.33651	792	3
Ga East	5.74523	-0.24092	786	4
Accra	5.578651	-0.20826	770	1
LadMA	5.570503	-0.1356	772	10
LekMA	5.600953	-0.08789	784	9
Tema	5.672105	-0.00245	775	2
Ashalman	5.706812	-0.0738	771	5
Kpone	5.75582	0.034773	780	12
Adentan	5.669136	-0.14067	781	7
LaNMA	5.706099	-0.17978	788	11

The rainfall data is then classified into two classes; class 1: 770 – 780, class 2: 780 – 789 and then ranked very high and high (Table 1).

3.1 Image Pre-Processing

The image is prepared by sub-setting it to get the study area. Once the study area is obtained, the image is then pre-processed through calibration and speckle filtering.

This is then followed by binarization; a process to separate water from non-water. Figure 5 shows the workflow for image processing. Two images are processed for analysis. Image A was acquired on 12th June 2020, nine days after a flooding event and image B was acquired 6th June 2021, three days after a flooding event.

Figure 5: Radar image processing

Figure 6: An example flooded area is highlighted in the red circle

3.3 Multi-Criteria Analysis Results

The results from the pairwise comparison process is re-shown in Figure 7 reveal that the umn W contains the criteria weights. This is an indication of the level of influence each criterion flood in the study area. C1 = elevation has the most influence of 29 per cent and C6 = land cover has the least influence of 5per centt.

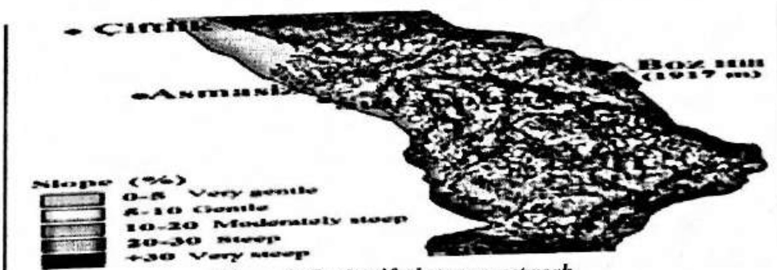

Figure 7: Reclassified stream network

Figures 8 and 11 below are the slope map, reclassified slope map, elevation map and reclassified elevation map of the study area. Elevation and slope play essential roles in the flood vulnerability of a terrain. The slope influences the amount of surface runoff or subsurface drainage, infiltration and the direction of flow, [10], [11].

Slopes with low gradients are extremely susceptible to flood occurrences since flat terrains allow for waterlogging conditions. The slope was classified using natural breaks and it can be noticed that majority of the study area is nearly flat. The flat nature of the terrain of the study area coupled with the high clay content of the soil, leads to rapid accumulation of rainwater leading to floods

Figure 8: Slope of Study are

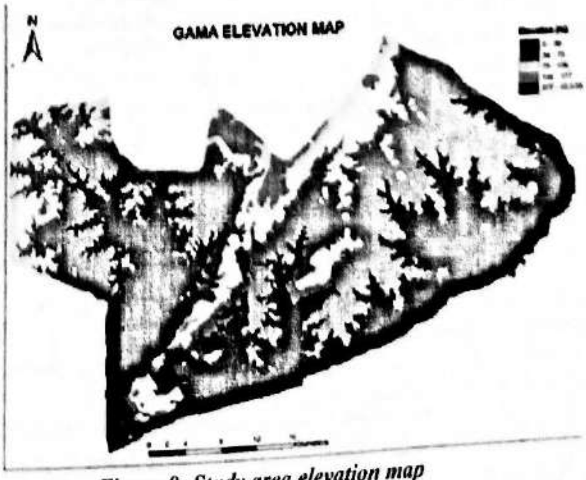

Figure 9: Study area elevation map

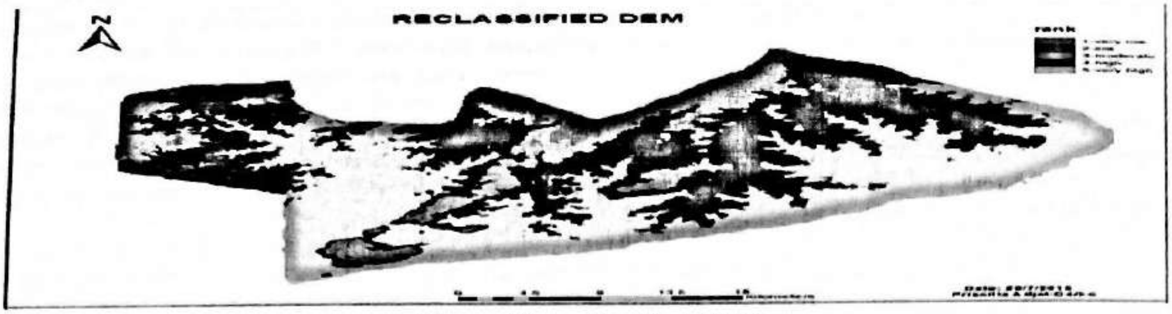

Figure 10: reclassified DEM

Figure 11: land cover map

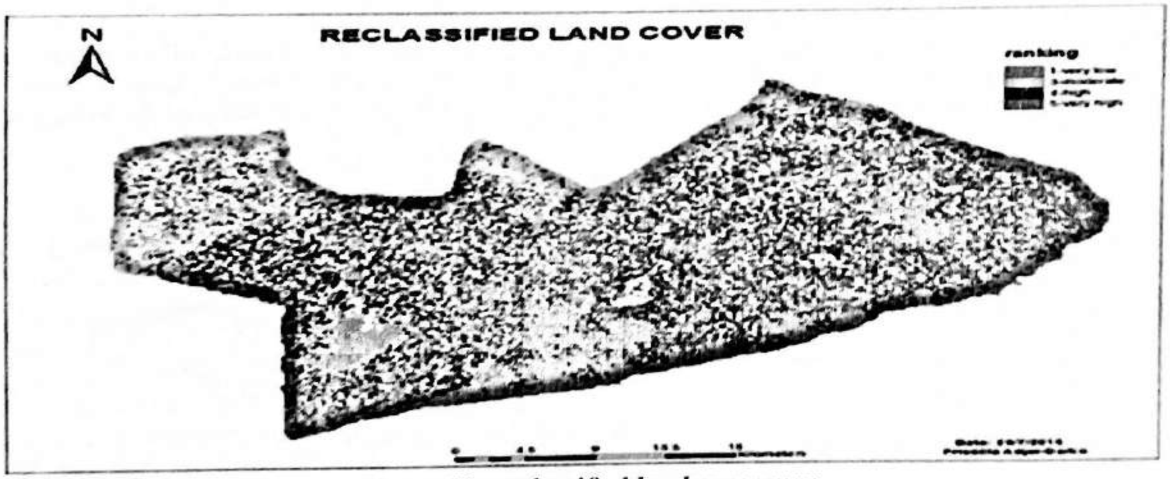

Figure 12: reclassified land cover map

Figures 9 and 12 above are the land cover map and reclassified land cover map respectively. The land cover of an area is important because it reflects the current use of the land and gives an indication of the soil infiltration ability.

A vegetation or forest cover, slows down and reduces the amount of runoff while urban land cover which is characterized by paved and impermeable surfaces absorbs no water and increase runoff and therefore increases the probability of flooding.

Figure 12: Random Points Map

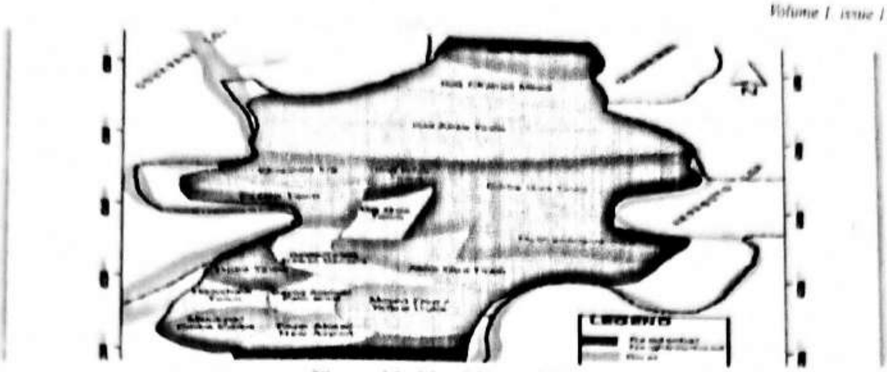

Figure 13: Flood Hazard Map

Field investigations in the study area revealed that majority of the area lacked proper drainage systems and existing drainage systems are characterized by inadequately sized culverts which are often blocked by deposition of garbage and an accumulation of silt caused by years of neglect and lack of maintenance. Investigations also revealed that due to increased residential, commercial, and infrastructure developments, there is an increase in impervious surfaces which results in an increase in storm water runoff. It was also observed that obstruction of flows by buildings across natural stream courses and inadequate capacities of culverts and stream channels also contributes to flooding, [12], [13].

The flood hazard map which resulted from the multi criteria analysis is shown in figure 30 above and Table 1 indicates the percentage coverage of hazard zones. The resulting map suggests some level of flooding is experienced in all areas under the study area.

CONCLUSION

Application of Geoinformatic in Flood Risk model is an essential component for relevant land use planning in flood plain areas and it aids in the efforts of city planners and administrators to prioritize their mitigation or relief response. The basic notion of flood risk mapping undertaken in this Project research work is to efficiently delineate flood prone areas in Calabar and environ. It is achieved through a multi criteria evaluation method within a GIS environment based overlay analysis

The multi-criteria analysis approach used in mapping flood hazard areas required the combination of the following identified decision criteria; elevation, slope, rainfall, drainage, land cover and soil geology. Several GIS operations and image processing techniques were employed in the methodology. And the resulting map indicates that over 50 percent of the study area is likely to experience a high level of flood.

Sentinel-1A SAR data was also used to map flooding extent after two flooding events. The results show that SAR data acquired immediately after the flooding event could better map flooding extent than the SAR data acquired 9 days after. This highlights the importance of near real-time acquisition of SAR data for mapping flooding extent and damages. The flooding extent map based on the near real-time SAR data matches the high risk areas identified by the MCA map very well.

Whereas the radar analysis map shows the areas actually covered with flood waters, the MCA map gives an indication of the expected level of flood hazard but the radar analysis method is much effective when there is access to real time satellite imagery. The resulting map of MCA analysis can be used as a guide for decision makers and city planners for better land use planning and flood risk management while the radar analysis is best used for managing disaster and directing relief measures since it shows exactly where flooding had occurred.

The methodologies presented in the research work are applicable to other flood prone regions. The accuracy and visualization of the MCA work presented can be further improved by using high resolution DEM data which will generate flood inundation map with high accuracy and extensive rainfall data for accurate flood prediction analysis. Future work that can be carried out would be to examine different land cover categories that were flooded by overlaying the flood extent map derived from SAR with the land-use/cover classification from landsat-8 OLI data.

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