Supplementary Materials

Bayesian Network Based Evaluation and Comparison of the Urban Flood Risk Factors for the 2016 Flood and a 100-year Return Period Flood Event in Baton Rouge, Louisiana

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Why we choose 2016-flood event?

- The largest rainfall was recorded during a 48-hour period at a stretch in Livingston, East Baton Rouge, and St. Helena Parishes, according to the rainfall statistics of NOAA. This area experienced rain of 20 to more than 31 inches, above the 0.2 percent annual exceedance probability (AEP) **(NOAA 2016)**.

- An estimated total of $10 billion in losses were caused by the flood event in southern Louisiana and southern Mississippi **(Report by Coastal Sustainability Studio)**.

- Of all the parishes hit by the storms in 2016, East Baton Rouge Parish offers the broadest range of storm-related scenarios. Furthermore, of all the families affected by the storm in August 2016, East Baton Rouge Parish had the highest number of damaged houses in total of which 24,255 were for homeowners and 12,683 for renters, a total of 36,938 **(Report by Coastal Sustainability Studio)**.

Bayes Theorem

$$P(Y|X) = \frac{P(X|Y)P(Y)}{P(X)}.$$

"The posterior probability in a hypothesis Y after observation of some evidence X is equal to the likelihood of observing X given Y , times the prior probability of Y , divided by the prior probability of X **(Koiter 2006)**."

Who is at High Flood Risk?

- Nationwide flood modeling of USA has indicated that non-Hispanic White populations currently face disproportionately high flood risks, which is partially due to exposures concentrating in the United States' Southeastern region **(Wing et al., 2022)**.

What is our objective?

- FEMA flood map is prepared based on only riverine flooding, but in reality floods are mostly from pluvial and fluvial conditions.

- So, we compared the Bayesian diagram with different variables where child node was 100-year return period flood depth and 2016-August Louisiana flood depth(from hydrodynamic model run).

- Our research question is to identify the topmost risk factors in sensitivity tornado diagram.

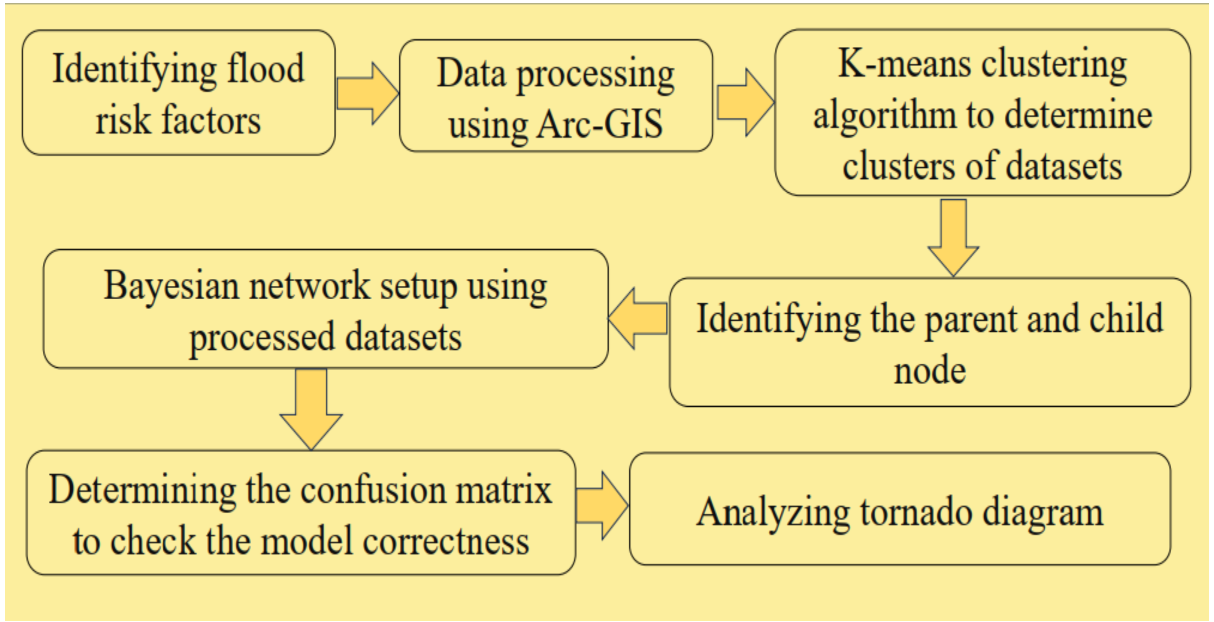
- We also identified, white population identified as facing high risk in FEMA flood zone, is it true or not in case of real flood scenario like August 2016 flood?

FEMA Flood Zone Description (FEMA Report)

Zone	Description
A	Area inundated by the base flood with no base flood elevations determined.
AE	Area inundated by the base flood with base flood elevations determined.
AO	Area inundated by the base flood with flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths determined. Velocities are also determined for areas of alluvial fan flooding.

Data Source and Methodology

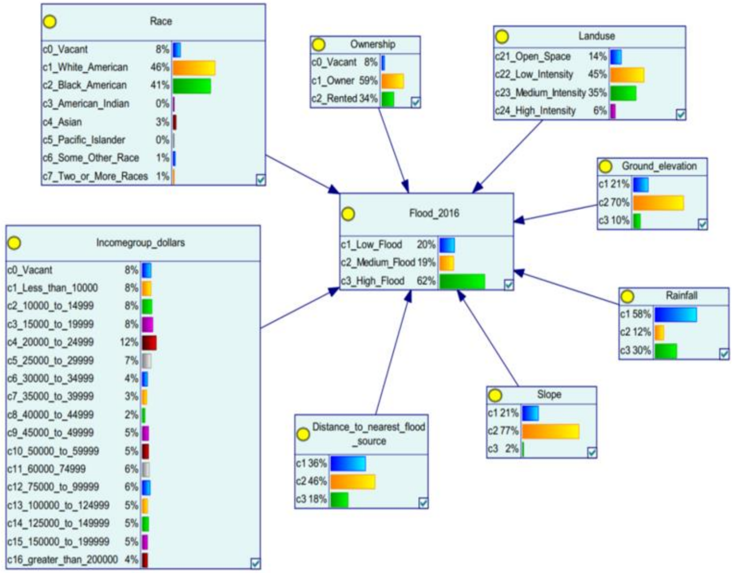
Classification	Variables	Data Source
Socio-Economic Variable	1. Ownership (Tenure Status)	IN-CORE and National Structure Inventory (USA)
	2. Race	
	3. Household Income Group	
Hydro-Geological Variable	1. Building Distance to Nearest Flood Source	Flood Safe Home Project Louisiana
	2. Digital Elevation Model (DEM)	USGS
	3. Ground Slope	
	4. Flood Hazard Area (2016 August Flood)	Amite River Basin Report
	5. Flood Hazard Area (100-year Return Period Flood Map)	FEMA Flood Center
Climatic Variable	1. Land use	National Land Cover Database (USA)
	2. Cumulative Rainfall	NOAA Gauge Stations



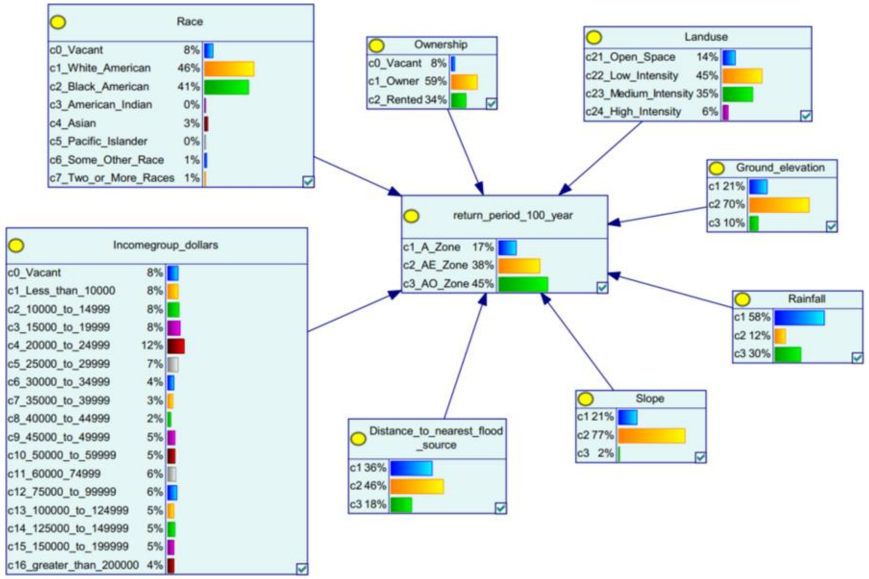
- All the datasets were converted to the form of raster files using ArcGIS.
- The building shapefiles affected by the 2016 flood and fall in the 100-year flood zone were used to extract the corresponding data from raster files of that location.
- Different algorithm techniques were used to classify the datasets, K-means clustering algorithm was used to convert the continuous data (i.e., elevation, rainfall, slope, distance of buildings to nearest flood source) to discrete data.
- Influential strength of distance of building to nearest flood source, land cover of the study area, and percent slope were highly influential to the child node(Euclidean distance measurement technique).

Bayesian network

- Variables for parent nodes are considered based on expert opinions.
- Classification ranges are based on In-CORE**[4]** data which uses the NSI (National Structure Inventory data) source to calculate race, income, ownership status to the building levels in the study area.
- For building distance to nearest flood source, we considered all the streamlines and rivers in the study area.
- For the land use, we considered only the urban areas, where the buildings are located.
- Flood zone for August 2016 are characterized based on flood depth of hydrodynamic model.
- From the confusion matrix, the model correctness for scenarios **a** and **b** are found 90% and 70% overall.



a. Bayesian Network for Flood 2016



b. Bayesian Network for 100-year return period flood

Major Findings

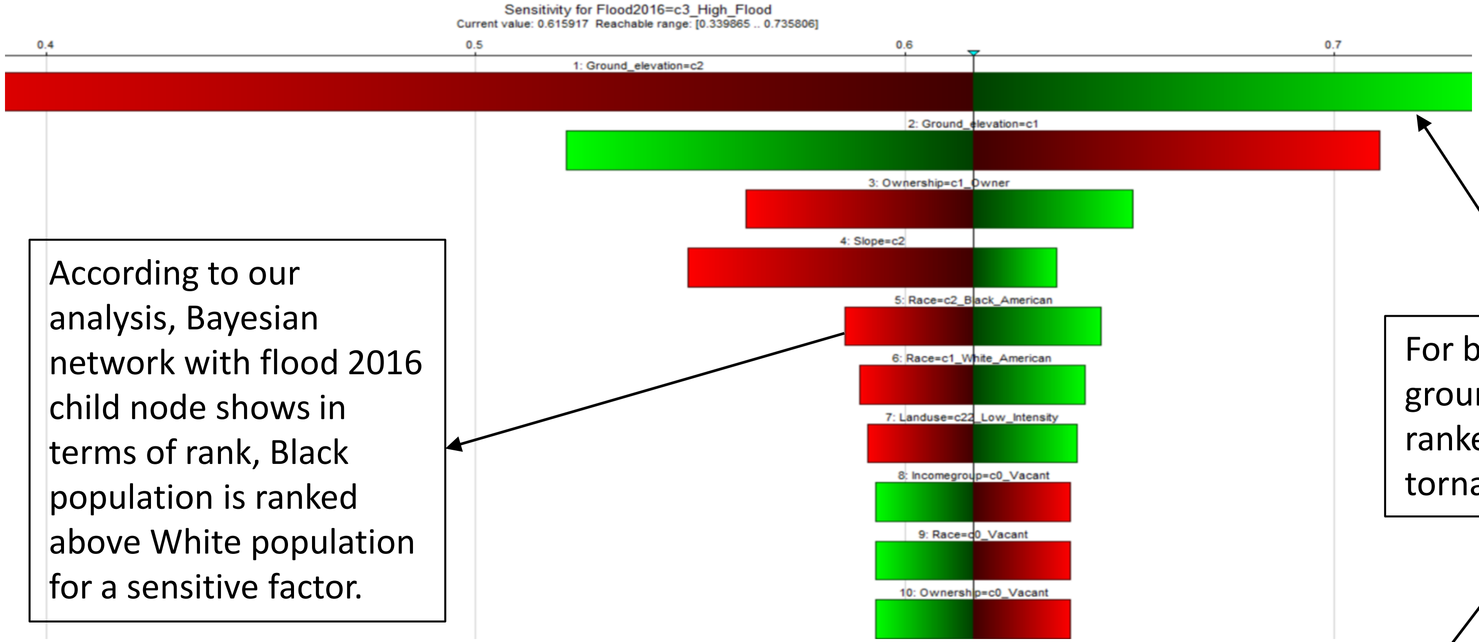


Fig: Sensitivity tornado diagram for high flood zone of August 2016 where most of the houses fall during flood.

According to our analysis, Bayesian network with flood 2016 child node shows in terms of rank, Black population is ranked above White population for a sensitive factor.

For both the scenarios, ground elevation is ranked high in sensitivity tornado diagram

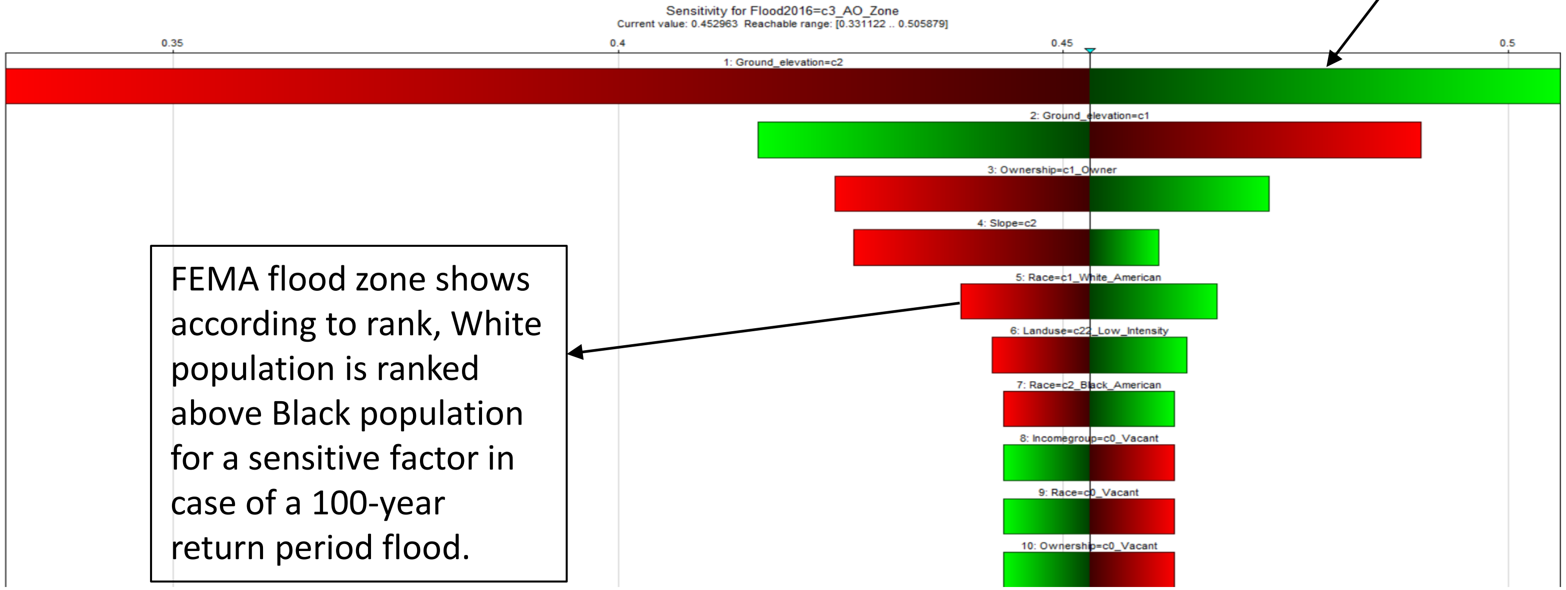


Fig: Sensitivity tornado diagram for AO zone of 100-year return period flood where most of the houses fall during flood event.

FEMA flood zone shows according to rank, White population is ranked above Black population for a sensitive factor in case of a 100-year return period flood.

Future Recommendations

1. This ongoing study will be carried out for Texas (Beaumont) and Mississippi State (Washington county) which are also situated in southern part of USA to figure out if the southern part of United States has similar flood risk factors ranking.

References

[1] https://repository.library.noaa.gov/view/noaa/35812.

[2] https://www.fema.gov/glossary/flood-zones.

[3] Koiter, J. R. (2006). Visualizing inference in Bayesian networks. *Dept. Comput. Sci., Delft Univ. Technology*.

[4] Rosenheim, Nathanael. (2022). "Detailed Household and Housing Unit Characteristics: Data and Replication Code." [Version 2] DesignSafe-CI. https://doi.org/10.17603/ds2-jwf6-s535.

[5] Wing, O. E. J. et al.(2022). Inequitable patterns of US flood risk in the Anthropocene. *Nat. Clim. Change* 12, 156–162.