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## GIS BASED FLOOD MODELLING FOR SUSTAINABLE DEVELOPMENT IN SULEJA, NIGER STATE.

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### Introduction

Flood occurrences have become an annual phenomenon globally resulting to irreplaceable loss of lives and properties. Associated with post flood events, is the outbreak of diseases, contamination and, pollution of the human environment and destruction of basic infrastructure. In developing world like ours, flood is estimating to have resulted to destruction of many lives and properties running into billions of naira annually ([Schachter et al., 2017](#)). The most devastating part of the scenario is that flood preparedness takes proactive measures rather than financial input after it occurrences.

[Turner et al. \(2003\)](#), [Brouers and Al-Musawi \(2018\)](#), [Zhang et al. \(2018\)](#), have attributed

### Abstract

*In recent times, flood occurrences have become an annual phenomenon resulting to irreplaceable loss of lives and properties. Associated with post flood events, is the outbreak of diseases, pollution of the human environment and destruction of basic infrastructure. This research utilized the potential integration of soil parameters, remote sensing and climatic data to effectively predict fluid dynamics and flood events over time space. The major factors considered as flood initiating factors are rainfall, elevation, Land use land cover type, drainage density; soil type and slope contribute to flood occurrences at different level. This research aim is to evaluate the contribution of multiple factors to flood occurrence flood using*

*modified analytical Hierarchy Process (AHP) in GIS environment for prospecting and mitigating a highly dynamic system with the following specific objectives: To Identify flood initiating factors and criteria using remote sensing and other auxiliary data, To Evaluate the identified factors impact using Saaty's Scale for subjectivity analysis, Determine spatiotemporal intensity of flood using AHP for objective decision making, Development of flood risk map using result from objective three in GIS environment. The research addresses among others, flood vulnerability areas to predict flood extend and magnitude of flood in Suleja. The identified parameters were rated and validated by experts in the field of hydrology, geology and soil science. A pair wise comparison matrix was excel base matrix for better decision making to determine the consistency index and ratio. Analytical Hierarchy Process (AHP) was used in GIS environment for vulnerability mapping. The result indicated the existence of five major flood vulnerability zones; the very high prone zone, high prone zone, mild potential prone zone, low zone and very low prone zone. Vulnerability flood map of highly prone area and low prone area are precisely estimated than the moderately prone area. The result from the Multi-criterial Decision Analysis attest for acceptable to accurate excellence of the model performance due to the incorporation of many intricate factors which enhance flood predictive capability and efficiency performance. This model will provide a tool for effective decision making and planning for policy makers and stake holders in environmental hazards mitigation. The study recommends the need for the implementation of green zone in urban planning and afforestation to reduce the modification of the subsurface storm water mechanisms which influences flood events. This method can be applied in area of similar geology and climate.*

**Key Words:** *Geographical Information System, Analytical Hierarchical Process, flood prediction*

*flood occurrences to the growing incidence of climate change scenario and lack of sustainable urbanization. In an attempt to mitigate the effects of flood occurrences, [Izham et al. \(2008\)](#), [Thakur et al. \(2017\)](#), [Kumar et al. \(2017\)](#), [Izham et al. \(2008\)](#) explored Remote Sensing (RS), GIS, insitu based measurements and other auxiliary data that has direct implication on flood events. [Izham et al. \(2008\)](#), [Thakur et al. \(2017\)](#), [Kumar et al. \(2017\)](#), [Izham et](#)*

[al. \(2008\)](#) offered useful conceptual framework for flood mitigation but severity, duration and quantitative volume estimation in term of flood were grossly lacking thus, making complex decision making difficult to come by. According to [Exner et al. \(2012\)](#), the designed drainage capacity of the Nigeria cities become so difficult to expand or redesign to suit unforeseen weather phenomena due to level of unplanned or unstructured urbanization that has taken place. Thus, flood preparedness becomes highly unrealistic.

In flood mitigation, knowledge regarding the complex parameters that do not only indicate the likely occurrences of flood but also provide inference regarding its magnitude and potential risk areas with detail evidence that shows severity based on evidence indicators parameters is required. [Bobryk et al. \(2018\)](#), integrate weather, pedology, elevation and auxiliary data in a GIS environment as a hybrid approach to enable sustainable decision making due to the versatile nature of GIS in handling multilayer information from different sources and regional generalization of result.

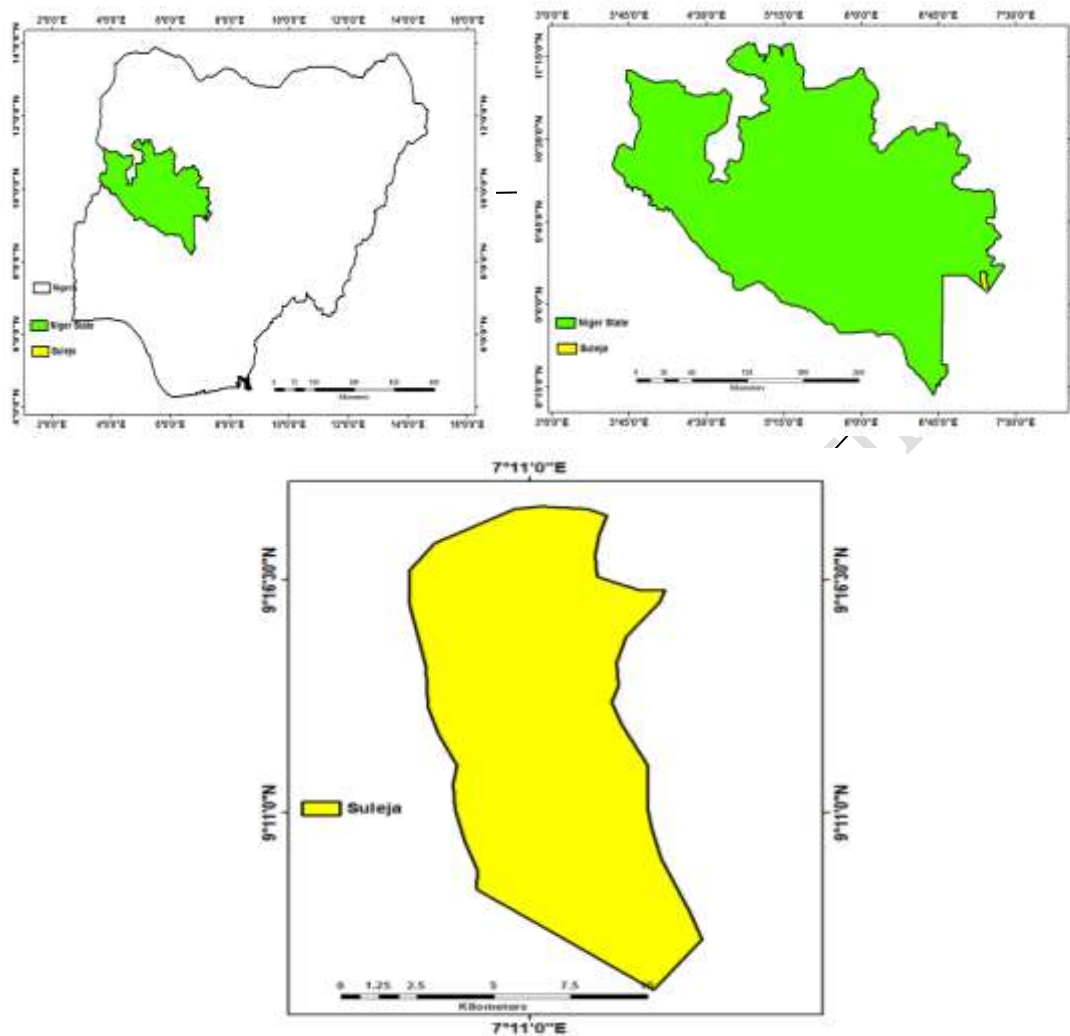
[Mojaddadi et al. \(2017\)](#), [Liu et al. \(2018\)](#), [Singh et al. \(2019\)](#), have utilized remote sensing, GIS and machine learning techniques to study floods. These researches are often deficient in reliable technique that is capable of addressing the sustainability in term of flood management although the spatial extend has been effectively managed in GIS environment. Thus, issues regarding spatiotemporal variation of rainfall intensity and duration within a local environment as well as clear definition of parameter contributions to flood events are not clearly defined resulting to ambiguous generalization which result to model applications

This research therefore, utilizes the potential of GIS in the integration of heterogeneous data to effectively predict fluid dynamics resulting to flood events over time and space. The effectively achieved spatiotemporal evaluation, multilayer information's regarding flood is being quantify and evaluated based on their perceived magnitude to flood initiation, where issues regarding the magnitude is highly considered.

### Study area

Suleja is located on Longitude.7° 08'to 7° 14'E and Latitude.9° 05'to 9° 17'N [Mailafia et al. \(2017\)](#) (Figure.1.1). Suleja is boarded by Gurara L.G.A by the North and West and by the East Tafa L.G.A and by the South, Abuja (Federal capital territory). The landmass of Suleja which can be accessed through

major roads covers the emirate's wooded savanna area of about 2,980 square kilometers (1,150 sq mile)



**Figure1: Map of Suleja Inset Niger state and Nigeria**

### **Identification of flood initiating factors and criteria using remote sensing and auxiliary data**

To achieve this objective, Land use Land Cover Types of Suleja was developed from Land Sat 8 thematic Mapper (LandSat TM). The LULC type data enable the identification of different land use types as each LULC types present a unique infiltration and subsequent flood events. Precipitation inform of rainfall were sourced from Nigerian meteorological agency and Agricultural Development Agency (ADP). Due to the need for accuracy, a 15m resolution DEM downloaded from SRTM was processed to generate the stream network

of Suleja due to the versatile nature of spaced based DEM. In addition, soil type information was gotten from geological map of Niger State in order to determine the characteristic of available soil types it relate to moisture and soil saturation.

### Data Analysis Technique for the Identification of Flood Initiating Factors

The generated Remote Sensing Data for the LULC type analysis was subject to image correction in order to remove dust haze, precipitation and other aerosols that can significantly influence image quality to avert ambiguous classification of object or features, in addition, the preprocessing allowed for the removal of projection related issues through coordinate transformation. The selection of criteria that has spatial reference is an important step in multi-criteria decision analysis([Charabi & Gastli, 2011](#)). The criteria used in this study were selected due to their relevance in the study area; they are as follows Rainfall, Drainage density, Elevation, Slope of the basin, Soil type and LULCT.

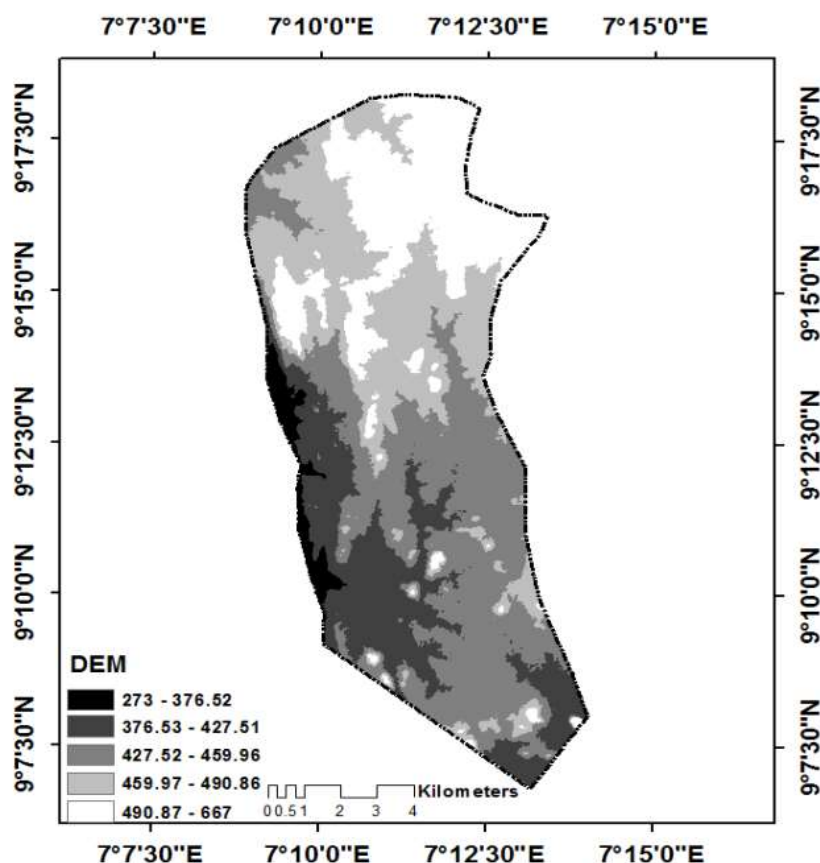


Figure 2 Digital Elevation Model



Figure 2 (DEM) was downloaded from SRTM and used to generate two major data sets; the drainage network characteristics and, areas of low and high elevations. The generated stream networks were converted into a data base file hosting information regarding length and the cross-sectional area. The obtained result was used in producing a raster layer map showing the drainage network density per square kilometers. The raster layer is more versatile to handle in geodata base and allowed for easy rating in analytical analysis of this nature ([Van Niekerk, 2008](#))

Elevation generated from the DEM on the other hand was classified into four classes each corresponding to: Low Medium, High and Very High elevated areas with each having a unique score based on it inferred inference to flood occurrences. From the classification of the acquired and preprocessed LULC image, features such as surface water, bare surface, rock outcrop, vegetation, built-up affect the rate at which flood occurrence take place because these features has different infiltration rate and capacity which predetermine the intensity of flood in a particular place in the study area after heavy rainstorm

### Evaluate the Identified Factors Impact using Saaty's Scale for Subjectivity Analysis.

In achieving this objective, a decision making framework was used for large-scale, multi-criteria decision analysis, and of the Analytic Hierarchy Process, its generalization to decision with dependence and feedback. MCDA technique allows parameters to be weighted in order to reflect their relative influence/ importance. [Saaty, T.L \(1980\)](#) AHP is used to determine the weights of the factors/criteria with successful evident in the work of; [Ishizaka and Labib \(2011\)](#) as a methodology for studying prioritized vectors and predictive model optimization. This is based on scores of relative importance for each factor/criterion in pair-wise comparison.

Nine-point intensity of importance scale modified from ,([Schoenherr et al., 2008](#)) as presented in Figure 3.2 was developed for parameter rating. The inferred impact of the identified parameters/factors is evaluated using a Saaty's scale that enable the relative description each factor proportional to it's influence to flood occurrences.

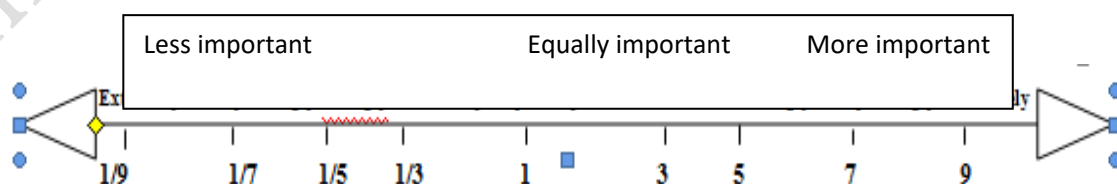


Figure 3: Saaty's Scale

### Determine spatiotemporal Intensity of Flood using AHP for Objective Decision Making

The process of AHP is summarized into Four steps: the first steps involves the construction of decision hierarchy where each of the factors is evaluated according to it inferred influences. Sequel to the construction of decision Hierarchy is the determination of the relative importance of attributes and sub-attributes using the Saaty's scale values of importance from 1-9 indicating relative influences. The evaluated alternatives are calculated to generate the consistency ratio of the assigned weight for the criteria. The overall weight regarding each attribute is evaluated to check the consistency of the subjective evaluations.

#### Determining criteria consistency ratio

The quality of the output of the AHP is strictly related to the consistency of the pairwise comparison judgments. The consistency is defined by the relation between the entries of the matrix.

The consistency index CI is given by Equation (3.1):

$$\text{Consistency index } CI = \frac{(\lambda - n)}{(n - 1)} \quad 3.1$$

Where, n= number of factors

$\lambda$ = average value of the consistency vectors

The consistency ratio (CR), which give room for conclusion whether the evaluations are sufficiently consistent, is calculated as the ratio of the CI and the random index (RI), as expressed in Equation (3.2)

$$\text{Consistency ratio } CR = \frac{CI}{RI} \quad 3.2$$

Where, RI is the random index

The row average provides an approximation of the eigenvector of the square reciprocal matrix. The eigenvector is an estimate of the relative weights of the criteria been compared.

Because individual judgment will never agree perfectly the degree of consistency achieved in the ratings is measured by a Consistency Ratio (CR) indicating the probability that the matrix ratings were randomly generated. The rule of thumb is that a CR less than or equal to 0.1 indicates an acceptable reciprocal matrix, a ratio over 0.1 indicates that the matrix should be revised([Nahayo et al., 2019](#)). Revising the matrix entails, finding inconsistent

judgments regarding to the importance of criteria, revising these judgments by comparing again the pairs of criteria judged inconsistently [Zardasti et al. \(2018\)](#). The suggested value of the CR should be no higher than 0.1. The value of CR=0.0964 falls below the threshold value of 0.1 and it indicates a high level of consistency. Hence the weights can be accepted ([Saaty, Thomas L, 1977](#)). The criterion weights were calculated as 0.36, 0.23, 0.13, 0.12, 0.10, 0.06, for rainfall, drainage density, slope, soil type, elevation and LULCT respectively. With the input values in pairwise comparison and weights calculated, consistency ratio (CR) was found as 0.0964. This indicated a reasonable level of consistency in the pairwise comparison of the factors. GIS act as the interface between technology and the decision maker with integrating MCE methods into the GIS.

**Table 1: pairwise comparison matrix**

Factors	rainfall	drainage den	slop	soil type	eleva	lulct
Rainfall	1.00	3.00	2.00	3.00	4.00	4.00
drain den	0.33	1.00	2.00	3.00	4.00	2.00
Slop	0.04	0.50	1.00	2.00	2.00	3.00
Soil type	0.33	0.33	0.33	1.00	3.00	3.00
Elevation	0.25	0.25	0.50	0.25	1.00	5.00
Lulct	0.25	0.50	0.33	0.33	0.25	1.00
Total	2.20	5.58	6.17	9.58	14.25	18.00

**Table 2: Normalised and Consistency Ratio Table**

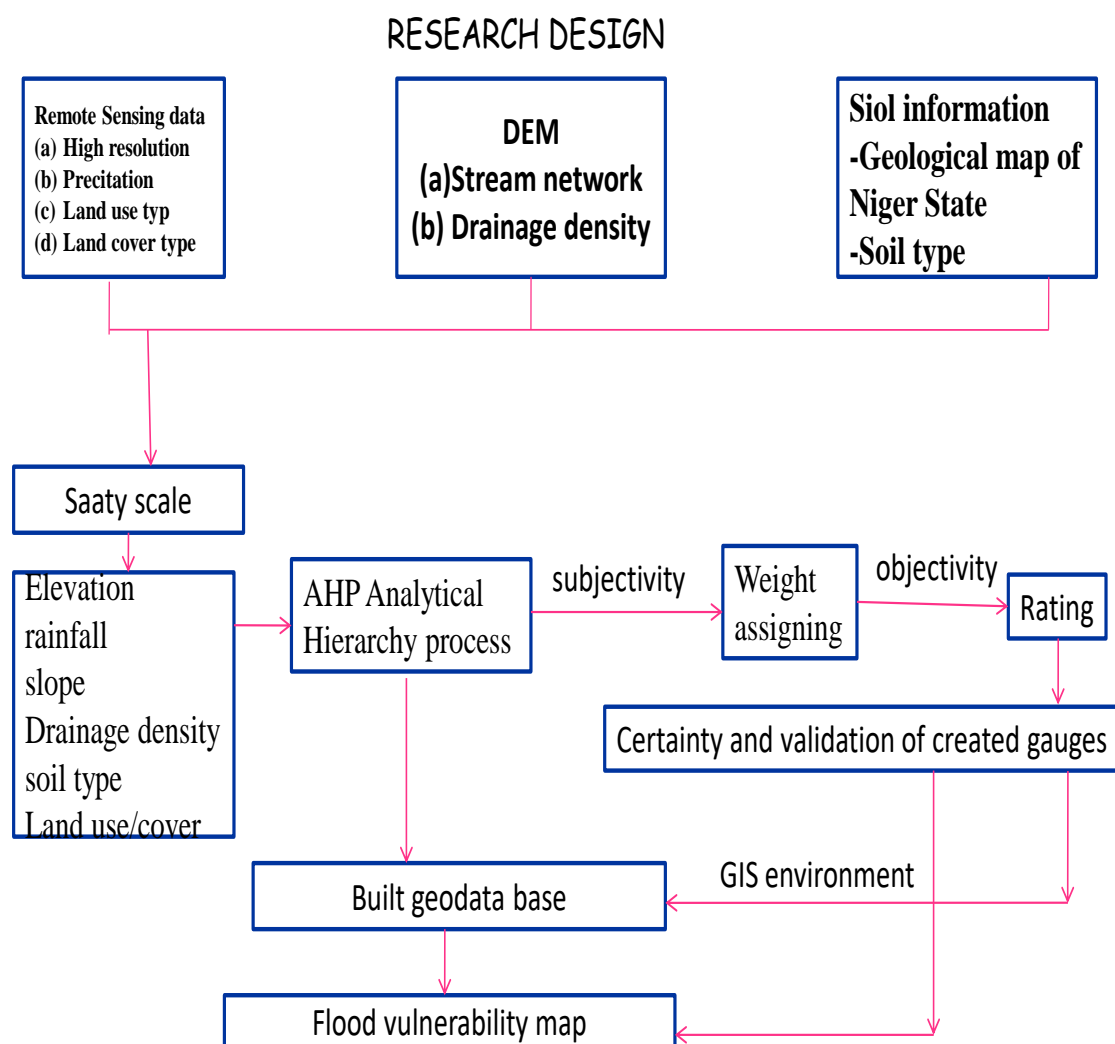
Factors	Rf	DD	S	ST	E	lulct	weight	eggen value	CI	CR
Rf	0.45	0.54	0.32	0.31	0.28	0.22	0.36	0.78	0.11958	0.09643271
DD	0.15	0.18	0.32	0.31	0.28	0.11	0.23	1.27		
S	0.02	0.09	0.16	0.21	0.14	0.17	0.13	0.81		
ST	0.15	0.06	0.05	0.10	0.21	0.17	0.12	1.19		
E	0.11	0.04	0.08	0.03	0.07	0.28	0.10	1.46		
lulct	0.11	0.09	0.05	0.03	0.02	0.06	0.06	1.09		
	1.00	1.00	1.00	1.00	1.00	1.00	1.00	6.60		

Note: Rf= Rainfall, DD= Drainage Density, S= Slope, ST= Soil Type, E= Elevation, LULCT= Land Use Land Cover Type W= Weight, Ev= Eggen value, CI= consistency index, CR= Consistency Ratio. Thus, the column average must sum up to 1 approximately

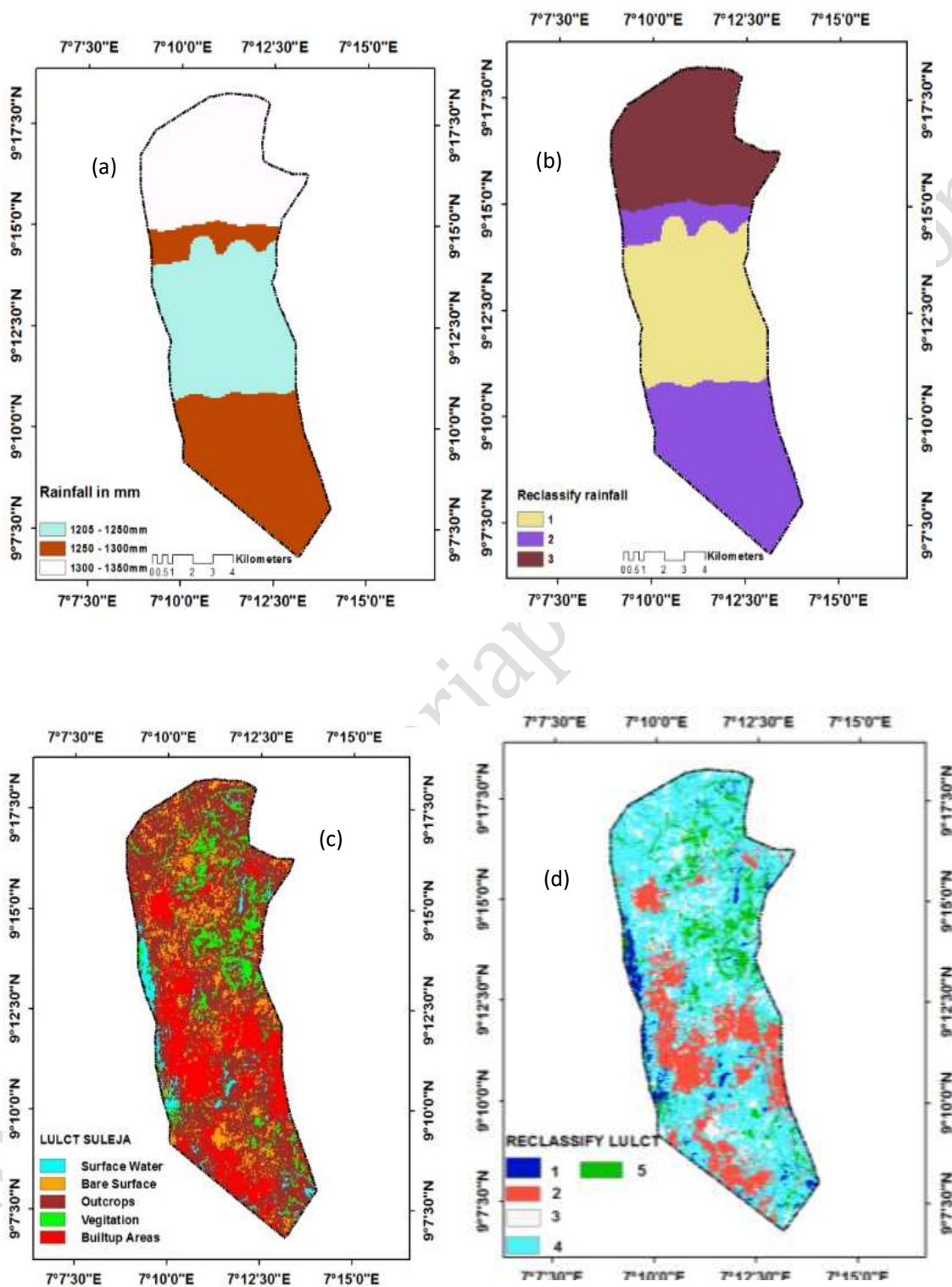


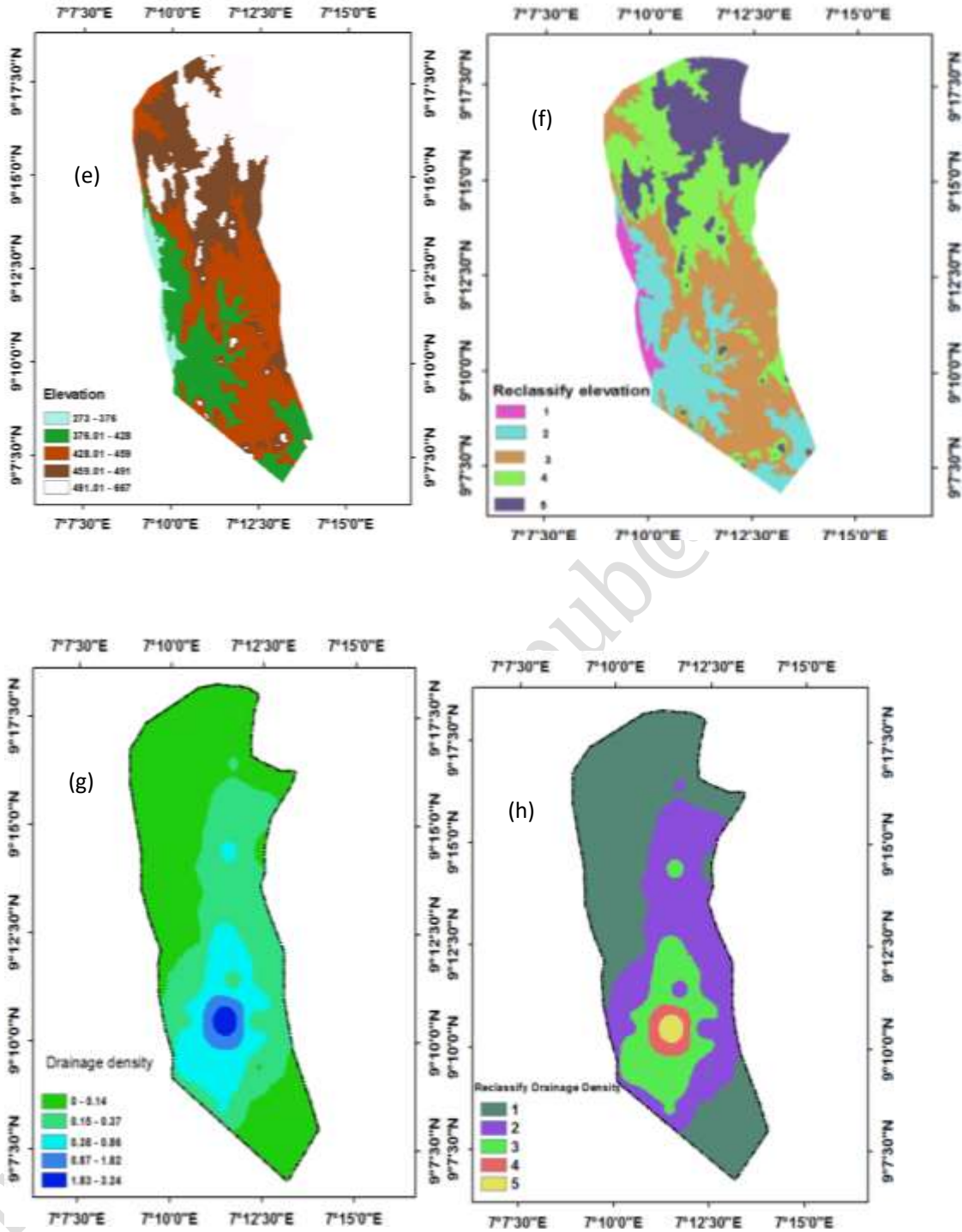
## Development of Flood Risk Map Using Result from above in GIS Environment

The generated results from the preceding sections were then incorporated into GIS environment to enable the Flood vulnerability map development. Prior to the development of the vulnerability map was, the design of evidential layer polygon to enable effective and accurate analysis of result from local to regional scale. In achieving this desire criterion, the map of the study area developed was subjected to grid construction in GIS environment using the grid tool in Arc catalog toolbox. The center of each grid was determined and coded as dbase file. The dbase file contains; X, Y and Z data.



**1 Classified and reclassified maps for the criterion in concerned flood'**





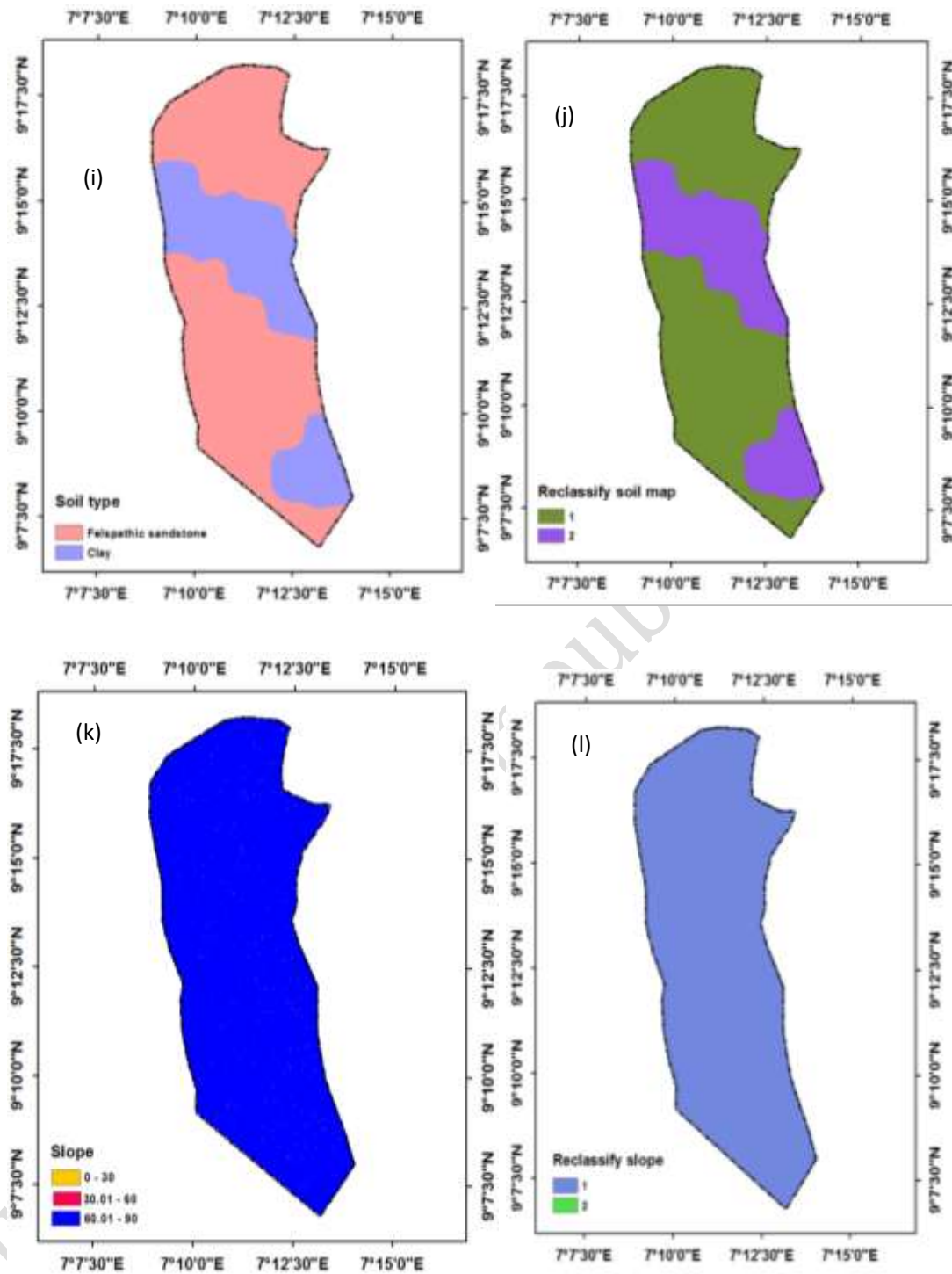
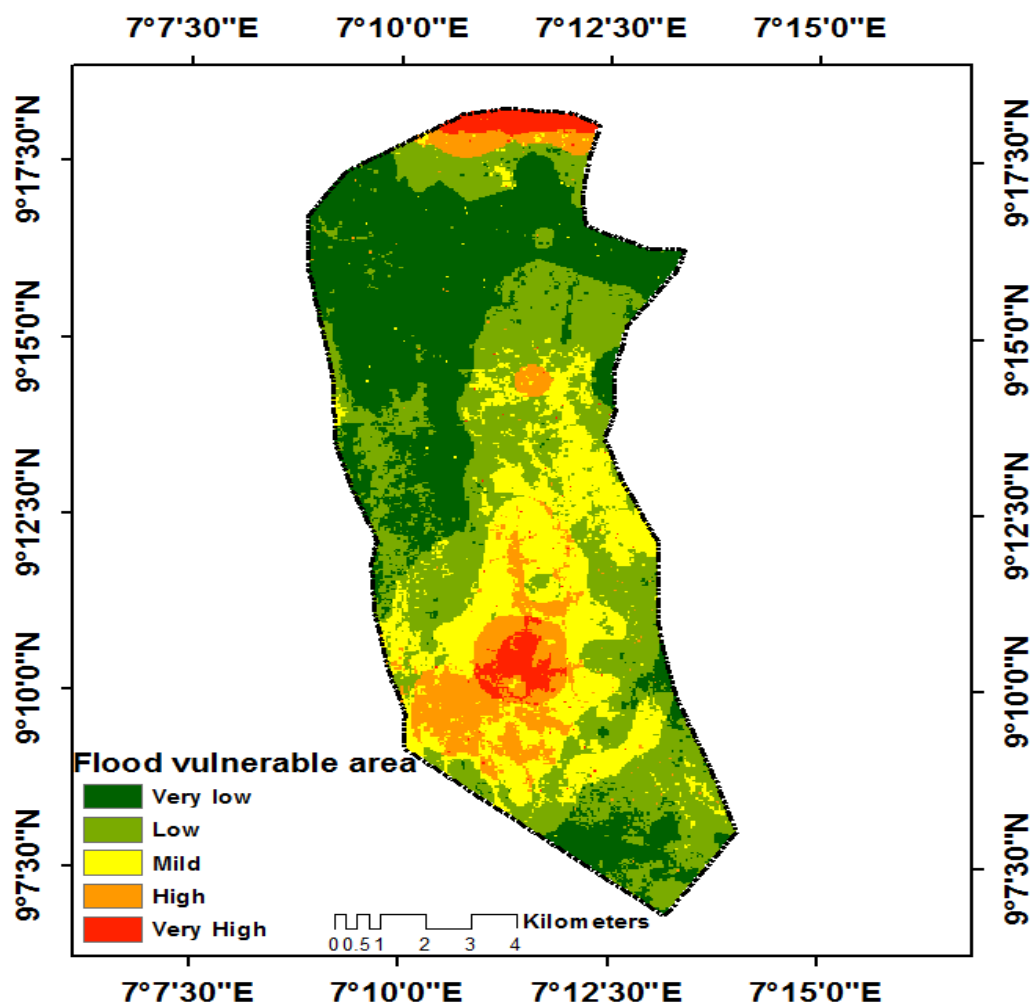


figure 5(a) rainfall map, (b)Reclassified rainfall, (c) LULCT Map, (d)Reclassified LULCT, (e)Elevation map, (f)Reclassified Elevation, (g)Drainage densitymap, (h)Reclassified drainage density, (i)soil map, (j) reclassified soil map,(k) slopemap (l)Reclassified slope map

## Results and discussion



**Figure 6. FLOOD VULNERABLE MAP OF SULEJA**

Figure 6 is the composite map showing the flood vulnerable areas that was created using multicriteria evaluation methods with GIS. From the pairwise comparison rainfall is the highest in term of weight with 0.36 follow by drainage density indicating rainfall as the highest initiating factor amongst selected criteria.

The criterion maps were combined using raster calculator to multiply each criterion by the weight gotten from pairwise comparison in order to delineate different prone zones to flood occurrences. The weight of each criteria is been multiply by the reclassified map figure 6 in raster calculator and all add



together by logical operation to depict the flood vulnerability map that show area highly liable, medium and low liable to flood.

In GIS environment, the range numbers are designated as very high, high, Medium and Low and very low on the output map depicting the level of flood vulnerability of the area. Figure 5 (h) and (a) depict the rainfall distribution in the study area when compared with figure 6 shows clearly that the areas of very high prone zone corresponded to area of high rainfall especially extreme northern part of suleja moving close to Abuja, therefore, indicating how influential rainfall is as an initiating factor to flood occurrence. Drainage density as one of the criteria considered has high influential power as an initiating factor of flood occurrence in the study area with proof comparing figure 5(d) with figure 6 showing the area with high drainage density to be very high flood prone zone, This means that the higher the density, the higher the catchment area is susceptible to flood, resulting in concentration of flood water at the lower grounds.

Considering LULCT as flood initiating factor and how much the land use and land cover type influences flood occurrences because it play a key role in relation to soil stability and infiltration of water into the soil and at a time ability of soil to act as a water store, runoff of rain water is much more likely on bare surface than those with vegetation cover, from figure5(b) and (c) it is noticed that presence of thick vegetative cover slow down water movement into the soil and reduce amount of runoff. On the other hand impermeable surfaces such as concrete, road, buildings, rock outcrop generate more runoff making developed areas of suleja liable to flood as depicted in figure 6

## CONCLUSION AND RECOMMENDATION

### Conclusion

The results of this study confirm that the integration of AHP and GIS techniques provides a powerful tool for decision making procedures in flood hazard mapping, as it allows a coherent and efficient use of spatial data. The use of multi-criteria evaluation for different factors is also demonstrated to be useful in the definition of the risk areas for the flood mapping and possible prediction. In overall, the case study results show that the GIS-AHP based category model is effective in flood risk zonation..

### Recommendation

Since flood is inevitable in as far as the initiating factors remain constant, there is need for mitigating the effect of flood both on life, properties and

immediate environments. From the study the following recommendation are made to reduce the advance effect of future occurrences and for further studies: Afforestation should be encouraged on areas highly prone to flood; this is a measure to reduce the risk. More studies should be undertaken to discover new techniques for evaluating more initiating factors of flood. Developmental projects on flood prone areas should be critically analyzed based on the effective factor causing flood in order to mitigate the effect of occurrences.

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