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Abstract: The recurrence in the event and seriousness of floods has rapidly increased worldwide. In any case, numerous areas around the world, particularly in developing nations, come up short on the essential field observing information to portray flood hazard risk. Flash floods are hazardously quick-moving floods brought about by a lot of overwhelming precipitation in a restricted zone. These sorts of floods happen for an assortment of reasons, including concentrated precipitation, and enormously affect the nature and social structure of the zone. They pulverize drainage frameworks in urban areas; structures can be altogether harmed and even wrecked. Many developing nations are confronted with fast and uncontrolled urbanization, particularly settlements that were fabricated near riverbeds. Urbanization along these lines would cause impermeable surfaces where percolation of water can't happen and the impact of flood likewise increments. This study focused on the assessment of flood hazard areas of Juba city using remote sensing, geographic information system and analytic hierarchy process. It is a city where flash flooding is very common whenever it rains heavily either due to the blocking of water channels by buildings constructed on waterways or due to lack of drainage channels. It’s of this view that flash flood mapping to recognize locales in high hazard flood zones is one of the integral assets that will be advantageous to urban and infrastructure organizers, hazard administrators, and calamity response or crisis administrations during extraordinary and extreme precipitation occasions. To achieve the above objective, thematic layers such as slope, rainfall, geology, drainage density, distance from the drainage network, soil texture, topographic wetness index, land use land cover, flow accumulation, elevation were prepared and geocoded to WGS-1984 (UTM zone 36N) and weights were assigned using analytic hierarchy process and then raster calculator in ArcGIS was used to generate the final flood hazard map. The flood hazard zone map was generated with four classes namely; very safe, safe, high and very high with 1.19%, 59.52%, 38.69% and 0.60% respectively. The flood hazard zones map was not validated due to lack of ground data, however, as being the resident of the city and having knowledge of frequently flooded areas, visual inspection of safe and risky areas was done on google earth by converting the map into KML format and verifying, it was found that most risk areas fall in recently flooded areas. This study would fill the gap and provide a vital database of susceptible zones to flash flooding of the city to come up with early management mitigation measures.

Index Terms: Flood hazard, remote sensing, GIS, analytic hierarchy process. Juba city

I. INTRODUCTION

Flooding is characterized as a transitory covering of land by water because of surface water getting away from their ordinary limits or because of overwhelming precipitation floods. There are several forms of floods such as storm floods which normally happen along the shorelines of oceans and huge lakes, river floods are the result of intense and/or persistent rain for several days or even weeks over large areas sometimes combined with snowmelt and Flash floods that imprint the start of river flood, yet for the most part, they are neighbourhood occasions generally free of one another and dissipated in existence. They are generated by exceptional precipitation over a little region [1]. Floods are one of the most far-reaching and savage of cataclysmic events. They can be characterized as overfloods by the water of the typical limits of a stream or other waterway, or the gathering of water by drainage over regions that are not typically submerged [2]. Flood hazard can be characterised as compromising characteristic occasion of flood including its likelihood of event[1]. It contains numerous viewpoints that incorporate basic and disintegration and washing away of properties causing harm, contamination of food and water, interruption of routine activities including transport and just as the death toll and property [3]. Flash floods happen given the quick aggregation and arrival of overflow waters from upstream to downstream, which can be brought about by exceptionally substantial precipitation. Discharges rapidly arrive at the most extreme and reduce nearly as quickly particularly in populated regions, they are more damaging than different kinds of flooding due to their eccentric nature and strangely vivid flows which convey enormous centralizations of residue, giving practically zero time for residents living in its way to get ready, and making significant obliteration infrastructure, the nearby the population and whatever else holds them up. Urban zones specifically experience the ill effects of a relatively high flood because of their high population density. Notwithstanding population development and the continuous collection of significant worth resources, both the recurrence and size of stream floods because of environmental change are required to increment later on, in this way disturbing the current flood hazard. Little streams in urban zones can likewise rise rapidly after overwhelming precipitation because of higher produced overflow and less resident time [4]. Nearly one-fifth of South Sudan is engaging the outrageous downpour of water. In other parts of the nation, entire communities, including health centres, nutrition centres, and schools are submerged in water and up to 90 per cent of the fundamental administrations have been suspended in certain zones. Most water sources in the influenced regions are
contaminated by the floodwater, representing a colossal wellbeing hazard for kids[5]. Juba city, in particular, is not exceptional, the occurrence of flash flood during heavy precipitation is becoming increasingly common nowadays, this could partly be due to lack of drainage channels or buildings constructed in water path hence leading to flash flooding during heavy downpour hence there is need for a robust technique for assessing areas that are susceptible to flash flooding to come up with early management mitigation measures as flood forecasting and hazard planning are one part of coordinated flood the management[6]. Therefore, the integration of remote sensing and GIS has proven to be very vital in such a case due to availability of spatial, temporal data especially for areas that lack ground data. GIS apparatuses give a decent stage to consolidate, control, and break down the data for the assurance of potential flood territories rapidly and more productively[7] and also the integration of GIS with remote sensing (RS) procedures are productive apparatus for investigation of flood risk zones and flood impacts on the immersed region[8][9][10], playing a progressively significant part in drought checking and flooding crisis responses[11], when making hydrological models to examine flood dangers in catchments, Digital Elevation Models (DEMs) are utilized in a GIS to obtain fundamental topographical factors[8]. Many researchers around the globe have integrated remote sensing and GIS to assess the flood hazards, flood vulnerability and flood risks, for instance, use of GIS-based support vector machine model[12], incorporated flood management inside the system of ArcGIS[13], Weakness evaluation of urban roads from urban flood[14], assessment of the possibility of using satellite remote sensing and GIS apparatuses in flooding, spatial forecast of flood susceptible regions utilizing rule-based decision tree[15] etc.

Assigning of weights to the thematic layers was done using the analytic hierarchy process (AHP). It is a multi-criteria decision-making strategy, which gives an efficient way to deal with surveying and coordinating the effects of different variables, including a few degrees of dependent or independent, qualitative just as quantitative data[16]. It likewise endeavours to determine conflicts and break down decisions through a procedure of deciding the overall significance of a lot of exercises or measures by pairwise correlation of these rules on a 9-point scale. To do this, an intricate issue is first isolated into various less difficult issues as a choice a decision hierarchy[17]. It is frequently used to analyse the general inclinations of few choices concerning a general objective. AHP is getting well known in decision-making investigations where clashing goals are included[16]

II. THE STUDY AREA AND FRESH FLOODS PROBLEMS

The investigation region covers Juba city the capital city of South Sudan that turned into a capital city after the marking of the exhaustive harmony understanding between South Sudan and Sudan in 2009. It lies on latitude 4° 51’ 50.68” and 4° 53’ 00.33” N, Longitude 31° 28’ 15.96” and 31° 37’ 51.97” E, around covering a territory of 168 km². Authoritatively, it covers the fundamental payams (a subdivision of a city) of Juba county viz. Munuki Payam, Kator Payam, Juba Payam, and some neighbouring payams. The city is situated on the western bank of the White Nile in an alluvial plain that inclines in the South West to North-East towards the White Nile (Bahr-el-Jebel) in the East. As indicated by the fifth Sudan Population and housing enumeration that occurred in April/May 2008 expressed that the number of inhabitants in juba region was 372,413, which later was dismissed by the administration of South Sudan, from that point forward, there hasn't been population evaluation, the majority of the population figures are being assessed by non-governmental organizations[18] The investigation territory is found in beautiful landforms, from the high ground, for example, mountain (Jebel) Kujur in South West piece of the examination zone; extending from an elevation of 643 – 733 meters above mean sea level to fields in the North East along banks of White Nile (Bahr-al-Jebel) going from a height of 451 – 481 meters above mean sea level. It is overwhelmingly covered by sandy loamy soil and loam and secured by quaternary, Precambrian geology[19][20] and the drainage pattern is dendritic with streams, for example, Khor Rumula, Khor William and so on stream in various ways concerning their origin lastly draining into the White Nile. The majority of these streams are occasional streams where water stream can be found in the wet season and during the dry season they dry. Its atmosphere is delegated as a tropical atmosphere with two seasons; Rainy season and Dry season. The stormy season begins from April to October with normal yearly precipitation of 941 mm and the dry season begins from November with a little measure of precipitation and heightens from December to March. The normal yearly temperature of Juba is 27.5°C with the most reduced precipitation in January adding up to a normal of 4mm and in August, the precipitation arrives at its top with a normal of 147 mm. March is the most sizzling month of the year with a normal temperature of 29.9°C and August is the coldest month of the year with a normal temperature of 25.5°C. Fig1 shows the locale of the study area. The primary drivers of the flooding marvels in Juba city “Figure1” are distinctive because of the unplanned urban growth, infringement of marshes, stream floods, drainage blocking, precipitation, soil disintegration and man-made causes
III. MATERIALS AND METHODOLOGY

Data used

In flood hazard mapping perspective, the quality of the data is always very important. Therefore, most of the data were downloaded from websites, for example, DEM and land sat 8 were downloaded from USGS, rainfall data from climate research unit website, soil data from FAO soil website, geology from https://catalog.data.gov/dataset/surfacial-geology-of-africa which were then projected to Universal Transverse Mercator (UTM) projection-WGS (World Geodetic System) 1984 zone 36N in ArcGIS 10.2 and further processed to get the thematic layers needed for flood hazard mapping.

Selection of factors that could be favouring flash flood

The selection of the flood causative variables is a critically important step to consider in flood hazard appraisal. The chosen components ought to envelop the properties of the given area. The factors were selected after broad literature review [21],[22],[3],[23],[24],[25],[10],[16],[26],[15],[27],[28],[29],[11],[12],[30],[31] and the following were considered the factors that could be influencing flash flood in the study area: digital elevation model, soil texture, rainfall, geology, land use land cover, flow accumulation, drainage density, distance from the drainage, topographic wetness index, slope.

Slope: High slope can speed up overflow water, while low slope declines the speed of runoff water. Subsequently, level zones will in general flood more effectively and quicker than steep slants. The incline of the land in the watershed is a main consideration in deciding the water speed. The threat from flash flood increments as the surface incline increments. It is a strong pointer for flood vulnerability [32],[27].

Rainfall: The probability of flood increments as the measure of a downpour at area increments. Higher rain intensity can bring about more overflow in light of the fact that the ground can’t assimilate the water rapidly enough [32],[27].

Soil type: Soil is a significant factor in deciding the water holding and percolation properties of territory and thus influence flood susceptibility. Other kinds of soil can cause fast overflow even in dry conditions. Overflow from heavy precipitation is probably going to be quicker and more noteworthy with clay soil than with sand [33].

Drainage density: Drainage density is the ratio of the length of all channels inside the basin or watershed to the total area of the drainage basin [34]. Drainage density controls the risks as its densities signify the idea of the soil and its geotechnical characteristics. This implies that the higher the density, the higher the catchment region vulnerability to disintegration, bringing about sedimentation at the lower grounds [25].

Distance from drainage network: Zones found near the channels and streamflow accumulation way are bound to get flooded. Following precipitation occasions, residue gathering happens when discharge increments, with conceivable flooding of the encompassing zones [30]. Aside from zones of concentrated surface water, waterway floods are significant for the commencement of a flood occasion and frequently the immersion exudes from riverbeds and grows in the environmental factors [21].
Land use/land cover: This portrays the physical and recreational features on the landscape and is commonly characterized by the sum and kind of vegetation, a settlement which is an impression of its utilization, condition, and development. Land use impacts the infiltration rate, the interrelationship between surface and groundwater. Along these lines, while vegetation favours infiltration, urban and encourages runoff. The land cover and land use are other fundamental effects on runoff [21].

Geology: The geology of flood risk territories is a significant measure, in light of the fact that it might enhance/mitigate the magnitude of flood occasions. Porous formations favour water penetration, through flow, and groundwater flow. On the opposite impermeable rocks, for example, crystalline stone, favours surface overflow. Karst can likewise altogether influence the flash flood[35]. The geology of a region containing soil type, and bedrock developments may enhance the size of flood occasions. Soil type decides the water holding and percolation qualities of a zone and thus influences flood vulnerability[25].

Topographic Wetness Index: The TWI is a physical trait of flood-immersion territories, is viewed as a significant factor of a catchment, and incorporates two delegate estimations: hydrographic position and level land. It is utilized to portray the spatial soil dampness patterns and disintegration, and high TWI values emphatically correspond with floodplain formation[30].

Elevation: elevation likewise impacts flood guideline capacities, as there is a tendency of high precipitation and stream discharge with increasing elevation[30].

Flow accumulation: The gathered entireties of water streaming down-slope demonstrate regions with concentrated stream flow and accordingly proportionate the relative flood danger potential[10].

Methodology

The procedure of the investigation is as, in “figure 3”, the base map for the study region was digitized from Google Earth and the various thematic layers were subset as indicated by the base map limit. The info information comprises of two classes viz., remote sensing information, and conventional maps. From the remote sensing information, a digital elevation model of a 30-meter resolution was downloaded from USGS whereby slope, elevation, and topographic wetness index were created from it, the drainage system was digitized from Google Earth in which drainage density was set up from it in ArcGIS 10.2. land use/land cover was produced from Landsat-8 (OLI/TIR C1 level1 information dated fifth/8/2018 path 172 and row 57) downloaded from the USGS webpage. The conventional maps were downloaded from dependable sources. At long last, soil type, precipitation, and geology were set up in ArcGIS. All the thematic maps were then projected to WGS-1984 UTM zone 36N and later changed over to raster and weights. The standards of the AHP strategy were applied to get the last weights for each factor. The initial phase in the AHP is the calculation of the pair-wise correlation grid, where every section represents the overall noteworthiness of a factor to the others. The relative significance between two variables is estimated by a numerical scale from 1 to 9 the connection between the numerical qualities and the force of significance is the accompanying: 1 = equivalent significance, 2 = frail or slight, 3 = moderate significance, 4 = moderate plus, 5 = strong significance, 6 = strong plus, 7 = Very strong, 8 = amazingly strong, 9 = of outrageous significance. Contrarily, less significant factors were evaluated somewhere in the range of 1 and 1/9 [17]. The strategy requires standardization of all factor weights by the accompanying condition:

$$\sum_{i=1}^{n} Ri = 1$$

equation (1)

Where R refers to weights

It is imperative to check the consistency of each table matrix after the count of the weight esteems. Thus, the ramification of each is to be checked with the consistency proportion (ratio)

$$CR = \frac{CI}{RI}$$

equation (2)

where RI is the arbitrary list which was created by Saaty (1977) and it is a steady which relies upon the order of matrix and the CI is determined by the condition:

$$CI= \frac{\lambda_{\text{max}}-n}{n-1}$$

equation (3)

where $\lambda_{\text{max}}$ is the biggest eigenvalue of the network, and n is the order of the matrix. This proportion is utilized to keep away from the formation of any coincidental judgment in the framework and when CR is 0.1 a satisfactory degree of consistency has been accomplished [23]. Finally, the flood hazard zones map was created in ArcGIS 10.2 utilizing the raster calculator function in ArcGIS 10.2. weights were allocated using the AHP method.
IV. RESULTS AND DISCUSSIONS.

Generation of the influencing flash flood factors.

**Elevation map:** A digital elevation model of a 30-metre resolution was downloaded from [https://earthexplorer.usgs.gov](https://earthexplorer.usgs.gov) and processed in ArcGIS 10.2. The elevation of the study area varies from 451 to 733 metres above mean sea level (AMSL) with 51.8% of the area falling under low land areas (451 to 481 metres above mean sea level) and 0.6% falls under highland (642 to 733 metres above mean sea level) as shown in “figure4A”. In terms of flash flood hazard mapping, areas of high elevation such as mountains and hills with steep slopes are considered to be of low vulnerability due to the tendency of more runoff facilitated by the high slopes whereas areas of low elevation and flat are considered to be of high vulnerability to flooding due to their ability to increase the residence time of surface water.

**Slope map:** The study area slope map was prepared from processed DEM of 30 m resolution using spatial Analyst tool in ArcGIS. The study area slope varies from 0-44.5 degrees in which 79.89% of the area falls under slope that ranges from 0-5.0 degrees and 0.65% falls under >20.6 degrees as shown in “figure4B”. In terms of flash flooding areas of low slope or flat areas are considered susceptible to flooding.

**Drainage density map:** Drainage density is an indirect measure of porosity and permeability of a terrain. It also indicates the closeness of spacing of channels which provides a quantitative analysis of average length of stream channels stretching the entire part of the study area. The streams of the study area were digitised from Google Earth in keyhole makeup language (kml) format and later converted from kml to polyline layer in ArcGIS 10.2 in which drainage density map was later on processed from it using line density function of spatial analyst tool in ArcGIS. The drainage density of the study area ranges from 0 - 2.68 km/km² in which 34 km² of the area falls under 0-0.5km/km² and 10km² falls under 2.1-2.68km/km² as shown in “figure4C”. In flash flood perspective, areas of high drainage density area considered as highly vulnerable to floods.

**Rainfall map:** The probability of flood increments as the measure of a downpour at area increments. Therefore, precipitation dissemination alongside the inclination legitimately influences the percolation rate and runoff water. The rainfall data was downloaded from Climate Research Unit ([www.cru.uea.ac.uk/data](http://www.cru.uea.ac.uk/data)) in “Netcdf format” which was later converted into a useable format and interpolated using kriging in spatial analyst tool in ArcGIS 10.2 to generate the annual rainfall of the study area. The annual rainfall of the Juba city is fairly distributed running from 972 mm to 1012mm, 41.67% of the study area receives annual rainfall ranging from 1003mm to 1012mm and 35.12% receives annual rainfall ranging from 972mm to 989mm as shown in “figure4D”.

**Geology map:** The infiltration-runoff relationship is controlled prevalently by porousness, which thusly is an element of rock type and cracking of the bedrocks or bed surface hence geology is a very important parameter in the perspective of flesh flood hazard mapping. The geology map was downloaded from the website [https://catalog.data.gov/dataset/surficial-geology-of-africa](https://catalog.data.gov/dataset/surficial-geology-of-africa) (scale 1:500,000) that shows geology provinces of Africa meant to provide the geological information [36]. The geology map of the study area was generated from it in ArcGIS. in which 74.78 km² of the study area falls in quaternary (undivided) and 93.78 km² falls under Precambrian (undivided) as shown in “figure5H”
Soil map: Soil texture plays a significant part in the measure of percolating water into the soil. Therefore, infiltration rate relies upon the soil texture and related hydraulic characteristic of the soil. The soil map was downloaded from the FAO soil website (http://www.fao.org/geonetwork/srv/en/metadata) and the study area map was generated from it in ArcGIS 10.2. Therefore, the study area has two types of soil texture namely; loam soil and sandy loam soil. 0.05 km² of the study area falls under loam soil while 167.95 km² falls under sandy loam soil as shown in “figure5J”.

Land use/Land cover map: Landsat 8 data was downloaded from https://earthexplorer.usgs.gov and supervised classification in ArcGIS 10.2 was used to classify the study area into seven categories namely; water body, settlement, Artificial forest (plantation), grassland, agriculture, wetland and bare land as shown in “figure5G”

Topographic Wetness Index: The TWI is a physical trait of flood-immersion territories, is viewed as a significant factor of a catchment, and incorporates two delegate estimations: hydrographic position and level land. It is utilized to portray the spatial soil dampness patterns and disintegration, and high TWI values emphatically correspond with floodplain formation as shown in “figure5E”. It was generated from a digital elevation model using the formula [12] as below:

\[ TWI = \ln \left( \frac{\beta}{\tan \theta} \right) \]  

Where \( \beta \) = bottom-up cumulative area through a point, \( \theta \) = slope angle at that point

Distance from drainage network: Zones found near the channels and streamflow accumulation way are bound to get flooded. Following precipitation occasions, residue gathering happens when discharge increments, with conceivable flooding of the encompassing zones as shown in “figure5E” below. It was generated from the drainage network in ArcGIS 10.2.

Flow accumulation: The gathered entireties of water streaming down-slope demonstrate regions with concentrated stream flow and accordingly proportionate the relative flood danger potential. It was created from a digital elevation model downloaded from USGS site as shown in “figure5F”.
Figure 4
Figure 5
Assigning of weights to the thematic layers: Analytic hierarchy process (AHP strategy was applied to get the last weights for each factor. The initial phase in the AHP is the calculation of the pair-wise correlation grid, where every section represents the overall noteworthiness of a factor to the others. The relative significance between two variables is estimated by a numerical scale from 1 to 9 the connection between the numerical qualities and the force of significance is the accompanying: 1 = equivalent significance, 2 = frail or slight, 3 = moderate significance, 4 = moderate plus, 5 = strong significance, 6 = strong plus, 7 = Very strong, 8 = amazingly strong, 9 = of outrageous significance. Contrarily, less significant factors were evaluated somewhere in the range of 1 and 1/9. The strategy requires standardization of all factor weights. The results are as shown in Table1 below.

Table1: Pairwise matrix using AHP

<table>
<thead>
<tr>
<th>FACTORS</th>
<th>Slope</th>
<th>Elevation</th>
<th>D. density</th>
<th>TWI</th>
<th>Soil</th>
<th>Rainfall</th>
<th>Geology</th>
<th>LULC</th>
<th>Flow acc</th>
<th>Dist. drain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope</td>
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<td>0.947</td>
<td>4.851</td>
<td>0.102</td>
<td>0.211</td>
<td>1.381</td>
<td>2.254</td>
<td>1.543</td>
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<td>0.670</td>
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<td>1.000</td>
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<td>2.333</td>
<td>1.598</td>
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<td>1.500</td>
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<td>0.667</td>
<td>0.457</td>
<td>0.101</td>
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<td>0.286</td>
<td>1.000</td>
<td>1.000</td>
<td>0.667</td>
<td>0.457</td>
<td>0.101</td>
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<td>3.286</td>
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<td>Dist. drain</td>
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Table2: Normalised weights

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<th>TWI</th>
<th>Soil</th>
<th>Rainfall</th>
<th>Geo.</th>
<th>LULC</th>
<th>Flow acc</th>
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<td>0.024</td>
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<td>0.078</td>
<td>0.078</td>
<td>0.078</td>
<td>0.078</td>
<td>0.078</td>
<td>0.078</td>
<td>0.124</td>
<td>0.078</td>
</tr>
<tr>
<td>Flow acc</td>
<td>0.350</td>
<td>0.350</td>
<td>0.350</td>
<td>0.350</td>
<td>0.350</td>
<td>0.350</td>
<td>0.350</td>
<td>0.350</td>
<td>0.350</td>
<td>0.350</td>
<td>1.000</td>
<td>0.350</td>
</tr>
<tr>
<td>Dist. d</td>
<td>0.179</td>
<td>0.179</td>
<td>0.179</td>
<td>0.179</td>
<td>0.179</td>
<td>0.179</td>
<td>0.179</td>
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<td>0.179</td>
<td>0.179</td>
<td>1.000</td>
<td>0.179</td>
</tr>
<tr>
<td>sum</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
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<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Table3: Final assigned weights using AHP

<table>
<thead>
<tr>
<th>Factors</th>
<th>weights</th>
<th>percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope</td>
<td>0.12</td>
<td>11.96</td>
</tr>
<tr>
<td>Elevation</td>
<td>0.1</td>
<td>1.26</td>
</tr>
<tr>
<td>Drainage density</td>
<td>0.03</td>
<td>2.61</td>
</tr>
<tr>
<td>TWI</td>
<td>0.12</td>
<td>12.38</td>
</tr>
<tr>
<td>Soil</td>
<td>0.02</td>
<td>2.36</td>
</tr>
<tr>
<td>Rainfall</td>
<td>0.04</td>
<td>3.54</td>
</tr>
<tr>
<td>Geology</td>
<td>0.05</td>
<td>5.31</td>
</tr>
<tr>
<td>LULC</td>
<td>0.08</td>
<td>7.75</td>
</tr>
<tr>
<td>Flow accumulation</td>
<td>0.35</td>
<td>34.96</td>
</tr>
<tr>
<td>Distance from drainage</td>
<td>0.18</td>
<td>17.86</td>
</tr>
</tbody>
</table>

(CI=0.00, RI=1.490 and it was consistent, therefore the weights were used for generating the flood hazard map)
Generation of the flood hazard zones map: The flood hazard zone map was obtained by summing the product of the flood influencing thematic layers and their weights using raster calculator in ArcGIS 10.2, utilizing the equation (5) and generated as in “figure6” below with four classes namely, very safe, safe, high and very high flood hazard zones.

\[ \text{FHZ} = \sum (F_i \times W_i) \]  

equation (5)

Where FHZ is the flood hazard zone, \( F_i \) is the flood influencing factor and \( W_i \) is the flood influencing factor weight.

Analysis of the generated flood hazard zones map: The generated flood hazard zone map shows that 60.7% of the area falls in safe flood hazard zones and about 39.3% falls in risk flash flood zones as shown graphically in “figure7”

V. CONCLUSION

This study focused on the assessment of flash flood hazard areas of Juba city using remote sensing, geographic information system and analytic hierarchy process. It is a city where flash flooding is very common whenever it rains heavily either due to blockage of water channels by buildings constructed on waterways or due to lack of drainage channels. GIS gives incredible assets to the appraisal of hazard and the general administration of common hazards. It also helps in deciding regions influenced by floods or anticipating territories prone to be overwhelmed dependent on the examination of the drainage basin. To achieve the above objective, thematic layers such as slope, rainfall, geology, drainage density, distance from the drainage network, soil texture,
topographic wetness index, land use land cover, flow accumulation, the elevation of the study area were prepared in ArcGIS and weights to this thematic layers were assigned based on analytic hierarchy process technique and then raster calculator in ArcGIS was used to generate the final flood hazard map. The flood hazard zone map was generated with four classes namely; very safe, safe, high and very high with 1.19%, 59.52%, 38.69% and 0.60% respectively. In general, 60.7% of the area falls in safe flood hazard zones and about 39.3% falls in risk flood hazard zones. The flood hazard zones map was not validated due to lack of ground data, however, visual inspection of safe and risky areas was done on google earth. It is worth concluding that the primary drivers of the flooding marvels in Juba city are distinctive because of the unplanned urban growth, infringement of marshes, stream floods, drainage channels blocking, high precipitation, and man-made causes. As found out in this study, about 39.3% of the study area falls in risky flash flood hazard zones and vast area falls in safe zones hence the major cause of this flash flood could be blocking of the runoff water by structures that were constructed in waterways, not only that, the lack of well-designed open drainage network in the city plays a major part in causing flash floods in the city. Subsequently, prudent steps can be recommended in a convenient way so as to limit unfriendly flood impacts, this could be by at least constructing the main drainage channels.

The main focus of this project was to assess the flash flood hazard zones of Juba city using remote sensing and GIS and AHP techniques, however, due to lack of ground data, the study mostly used secondary data, therefore the following could be the future scope; the present study was based on logical conditions and reasoning, therefore, the same method can be used with appropriate modifications for other similar studies, there is need to validate the generated map using ground data in future, the flash flood hazard map along with other thematic maps serve as resource information database which can be updated from time to time by adding new information, there is also need for future study of river flooding to assess the high-risk areas that are close to the White Nile.

The outcomes that appeared in this paper can support the designers, organizers, and specialists to successfully concoct flash flood alleviation measures for high flood danger zones.

VI. ACKNOWLEDGEMENT

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REFERENCES


