Seismicity and Morphometric Studies In North Sudan

Khalda Yassin Ibrahim

Remote Sensing and Seismology Authority, National Center for Research

INTRODUCTION AND MAIN RESULTS

North Sudan was known as an area of moderate seismic activity. The Nile River is the main stream in the region. The increase of the seismic activity in recent years and the geographic location of the study area motivated the researcher to conduct a seismicity and morphometric study of the area using various types of data.

The final results of this study revealed that the earthquakes in this area are of shallow type, and the aerial distribution of the seismicity illustrated that most of the events are concentrated in the area of moderate and high Normalized difference water index and drainage density

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Introduction

Generally, strong and moderate earthquakes that take place in an active seismic zone produce environmental changes (geophysical, geomorphological, hydrological, and geochemical). Earthquakes cause both static and dynamic (shaking) changes in stress and strain, which alter fluid pressure and rock/sediment hydrologic properties, as well as causing fluid flow, depending on the distance from the epicenter. Changes in the volume, direction, and rate of water flow in streams and fluid pressure in the subsurface are all examples of earthquake-related hydrologic responses.

Changes in permeability caused by seismic waves are also reflected in hydrologic responses to earthquakes. Many anomalous behaviors have been observed before, during, and after a seismic event, such as water level in wells, stream flow rate, and unexpected increase or decrease of stream flow level. The increase of the water level in wells and the variations in the flow can be used as earthquake precursors and to elucidate the mechanisms of the seismic source because they are noticeably influenced by the deformation field related to the earthquake.. Different studies were performed to display the relation between earthquakes and hydrology (Roeloffs 1988, Rojstaczer *et al* 1992 Brodsky *et al* 2003, Jonsson *et al* 2003 and Claesson *et al* 2004). North Sudan was known as an area of moderate seismic activity. .

Geologically, North Sudan mainly consists of two types of rocks, which are basement and sediments. The study area is located in northern Sudan. Numerous earthquakes have been reported in the study area around the Nile River. Fig. 1 displays the topographic map of the study area..

Various research studies in the field of seismology were conducted in Sudan and South Sudan, including works by Ambraseys and Adam (1986), Mula (1983, 1990), and Khalda et al. (2015, 2018).

The increase in seismic activity in recent years, and the location of the study area between Aswan High Dam in the north and Merowe Dam in the south, motivated the researcher to conduct a seismicity and morphometric study of the area using various types of data..

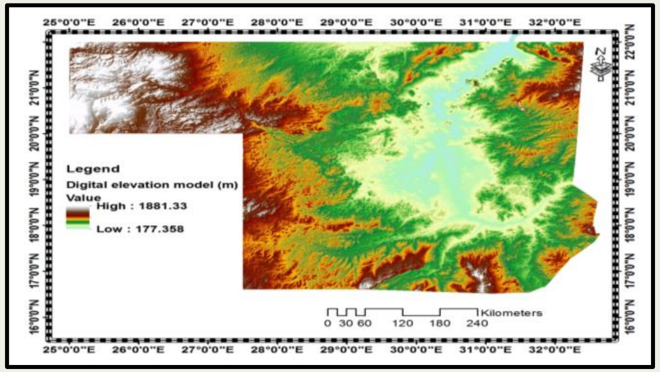

Fig 1. Topographic map of the study Area

Objectives/ Methods and Data

● The main objective of this research is to study the seismic activity and estimate the morphometric aspect of the North locality .

This study has five secondary objectives.

● Create a seismicity map of the study area.
● Delineate the stream network and stream order.
● Construct a surface drainage density map.
● Quantitatively assess the morphometric parameters (linear, relief, and areal).
● Create a normalized difference water index map.

This research was performed using multiple types of data, such as digital elevation model, seismicity data (Mw magnitude) for the period between 1906 and 2016. Babiker (2010) equation (1) was used to convert duration magnitude to the moment magnitude (Mw) to unify the magnitude of the seismicity in the study area. Also, Landsat 8 OLI data 2013 path and row (174/45, 174/46, 175/45, 175/46 band 3and 5) was used to calculate The normalized difference water index (NDWI) based on equation (2).

$$Mw = 1.198Md - 0.841 \quad \text{Equation (1)}$$

$$NDWI = (\text{band 3} - \text{band 5}) / (\text{band 3} + \text{band 5}) \quad \text{Equation (2)}$$

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Table.1 Method of Calculating Morphometric Parameters

Morphometric Parameters	Equation/Definition	References
Stream Order (Su)	Hierarchical order	Strahler,1964
Stream Length (Lu)	Length of the stream	Horton, 1945
Drainage Density (Dd)	$Dd = \frac{Total\ lu}{A}$ Where, Lu=Total length of stream, A= Area of basin.	Horton, 1945
Bifurcation Ratio (Rb)	$Rb = \frac{Nu}{Nu+1}$ Where, Nu=Number of stream segments present in the given order and Nu+1= Number of segments of the next higher order	Schumn,1956
Basin Relief (m)	$H = Z - z$ Where Z is the highest point and z is the lowest point	Schumn,1956
Relief Ratio (Rh)	$Rb = \frac{H}{Lb}$ Where, H=Basin relief, Lb=Basin length.	Schumn,1956
Drainage Texture (Dt)	$Dt = \frac{Total\ Nu}{P}$ Where, Nu= number of stream, P=Perimeter of basin	Horton, 1945
Form Factor (Rf)	$Rf = \frac{A}{(Lb)2}$ Where, A=Area of basin, Lb=Basin length.	Horton, 1945
Ruggedness Number (Rn)	$Rn = Ddx(\frac{H}{1000})$ Where H= Basin relief, Dd=Drainage density.	Schumn,1956
Stream Frequency (Fs)	$Fs = \frac{Total\ Nu}{A}$ Where, Nu= number of stream, A=Area of basin	Horton, 1945
Circularity ratio (Rc)	$Rc = \frac{4\pi A}{P2}$ Where A= Area of basin,π=3.14, P= Perimeter of basin.	Miller,1953

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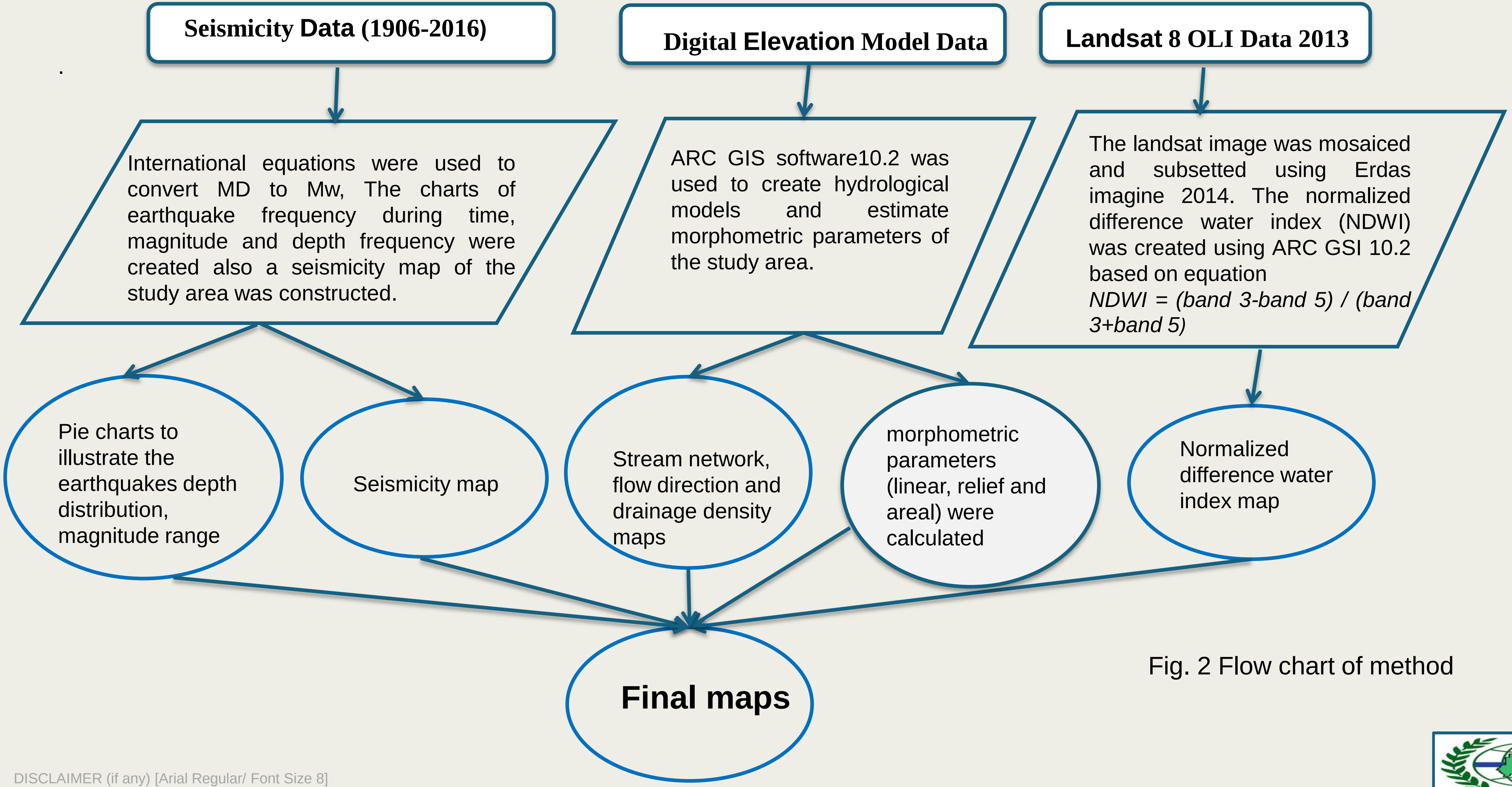

Fig. 2 Flow chart of method

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Results

To understand the seismic activity and the surface hydrological properties of the study area, the results of all data analyses were integrated. The histogram of earthquake frequency during time (figure 3) reveals the increase of seismic activity in recent years from 2010 to 2016. A pie chart of earthquake depth frequency (figure 4) illustrates that earthquakes are of shallow type and more than 71% of the events have a depth between 2.1 km and 13 km. Figure (5) clarifies that earthquake magnitude (Mw) in the study area ranges between 1 and 5.75, and most of the events have a magnitude (Mw) between 2.1 and 4.

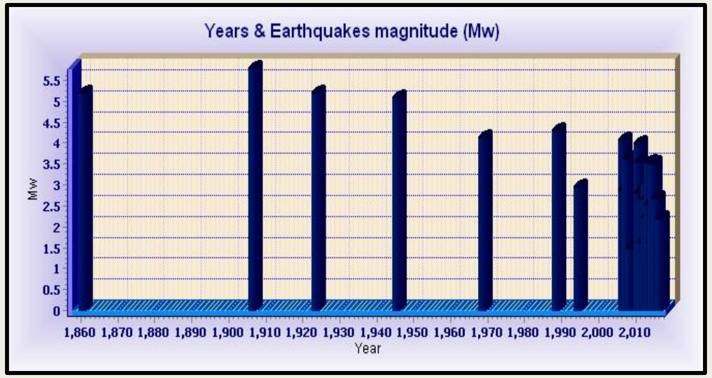

Fig 3. Histogram of time (year) and earthquakes magnitude

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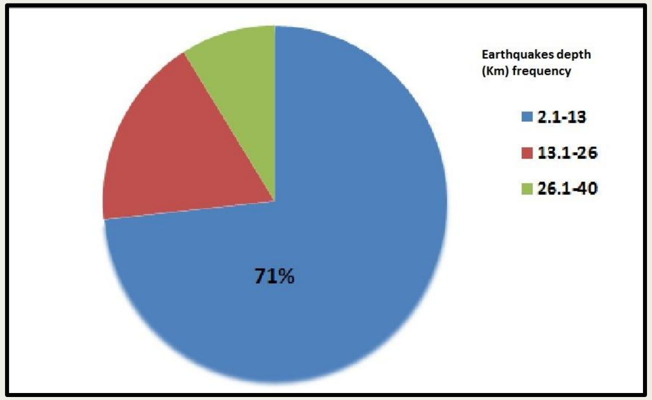

Fig 4. Pie chart of earthquakes depth frequency

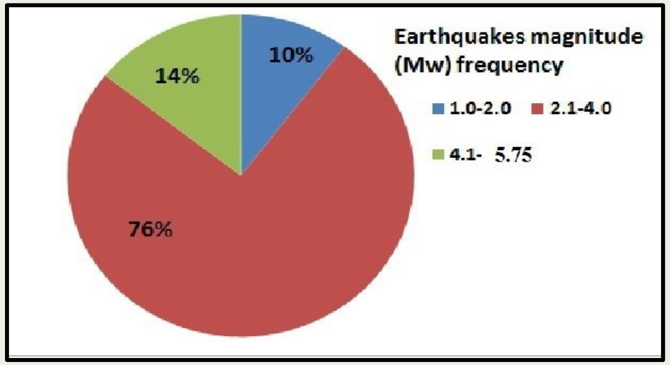

Fig 5. Pie chart of earthquake magnitude frequency

The seismicity map of the study area is constructed in figure (6), shows the concentration of the earthquakes in the northern and eastern parts of the study area.

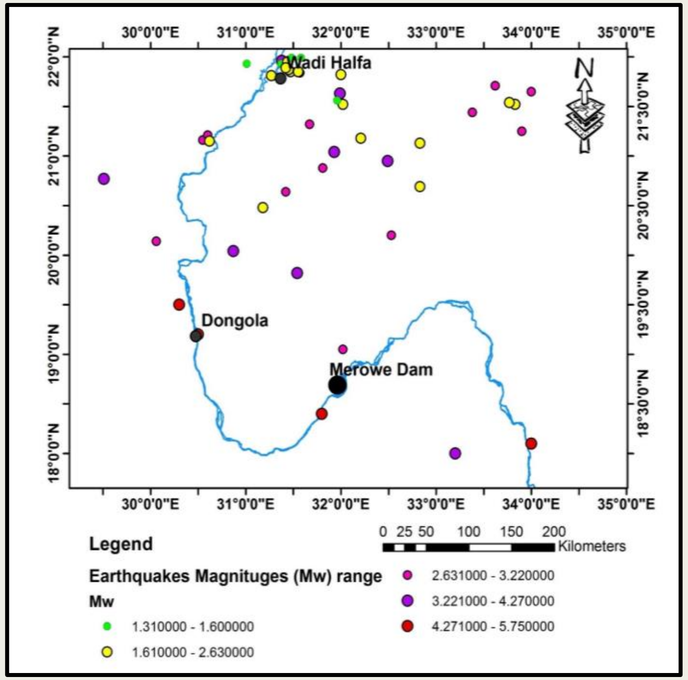

Fig 6. *Seismicity map of the stud area*

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Figure (7) displays the stream order, and figure (8) the seismic event superimposed on the stream network revealed that most of the earthquakes are associated with the stream network.

Figure (9) elucidates the relation between the drainage density and seismicity, where most of the events are located in the area of moderate and high drainage density. Also, the normalized difference water index (NDWI) was calculated and presented in a map overlaid by earthquake epicenters (figure 10) to elucidate that the majority of the events are located in the area of moderate to high NDWI.

The final results of the morphometric characteristics are presented in Table 2. The results would help to understand the relationship between hydrological variables and geomorphological parameters for better decision-making.

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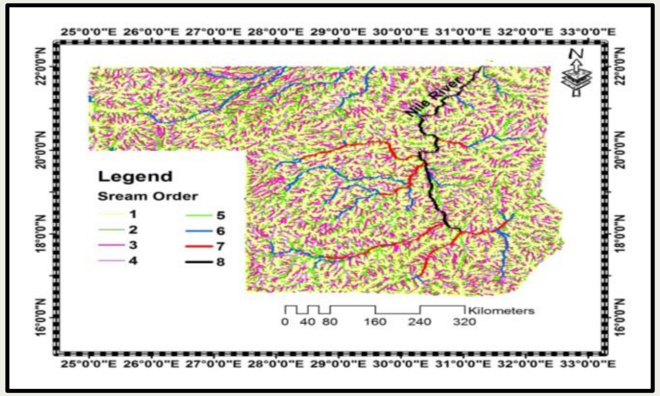

Fig 7. Shows the stream order

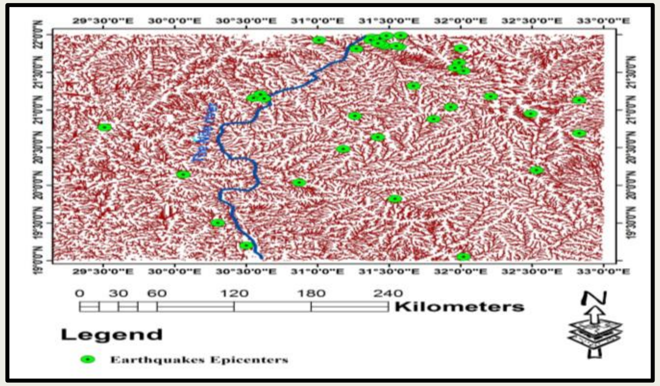

Fig 8. Represents the seismic event superimposed on the stream net work

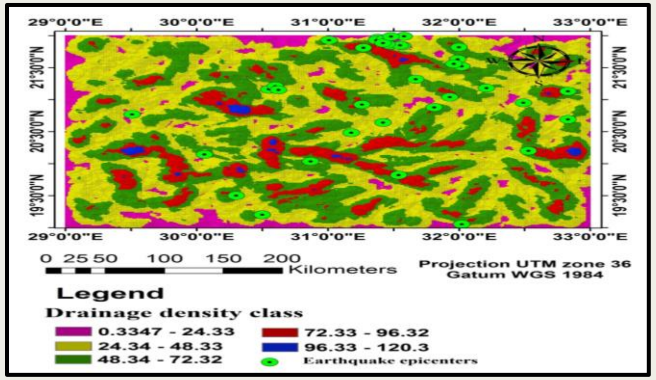

Fig 9. Shows the earthquakes superimposed on the drainage density

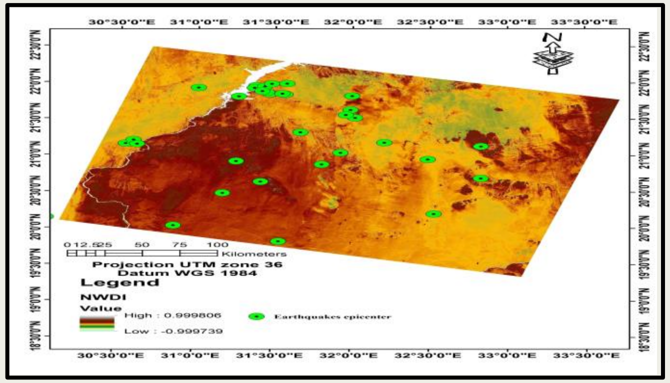

Fig 10. Reveals the earthquakes superimposed on the Normalized difference water index of the study area

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Table 2. Results of Morphometric analysis

Parameters	**Value**
Area (km2)	364752.71624
Perimeter(km)	2792.687868
Total Stream Number (Nu)	81354
Total Stream Length (Lu) (Km)	199107.012759
Drainage Density (Dd)	0.546
Bifurcation Ratio (Rb)	2.122
Zone Relief (m)	1709.203
Relief Ratio (Rh) (degree)	2.16
Drainage Texture (Dt)	29.131
Form Factor Ratio (Rf)	0.584
Ruggedness Number (Rn)	0.9332232
Stream Frequency (Fs)	0.223
Circularity ratio (Rc)	0.587

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Conclusion

The current study estimated the morphological characteristics of the North locality to determine the hydrological behavior. The highest stream order of the study area is eight-order; the variance in the stream order is primarily due to the watershed region's topographic/physiographic factors. According to Ritter et al. [83], lower-order streams are a stronger flood predictor and a fast accumulator of rainwater. Thus, in the current catchment, the first-order stream-distributed area can be used to assign recharge points, and there is a high risk of water overflow in higher-order streams. In the present study, the value of the Bifurcation Ratio (Rb) is 2.122 (<5); hence, the area has probably suffered any structural disturbances. The drainage density (Dd) of the area is 0.546, indicating that the region has low texture.
Minimum values of stream frequency (Fs) (0.223) show that the stream is restricted by the fractures. The form factor (Rf) plays a key role in explaining the drainage characteristics. The Rf value reached 0.584, with the low value of the form factor indicating a narrow and long basin (Chandrashekar, H. et al. 2015, Dubey, S.K. et al. 2015, Dahiphale, P. et al. 2014). The circulatory ratio (Rc) is principally concerned with the length and frequency of streams, the geological structure of the basin, the land use and cover of the basin, the climate, relief, and slope of the basin.

The circularity ratio can be used as a useful tool to assess flood risk. An increasing value of the circularity ratio means a higher degree of flooding and vulnerability to flood hazards at the outlet of the catchment. The Rc value of the North locality is 0.587. A low value (< 1) means that it is an almost elongated basin (Aher, P.D. et al. 2014), which is less likely to be flooded.

The increase of seismic activity in recent years and the location of the study area between Aswan High Dam in the north and Merowe Dam in the south motivated the researcher to conduct this research to determine the vulnerable zones to earthquakes based on the hydrological properties and morphometric parameters.

The seismic risk is probable to increase around the streams of higher order. Also, the region of saturated soil is probably subjected to high seismic risk. Finally, it can be concluded that the integration of seismic study, hydrological characteristics, and morphometric aspects was useful for the determination of weak zones in terms of floods, earthquakes, and other topographic and climatic hazards.

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Website
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