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Topographical Ruggedness Analysis of Jabal Sanam Using Remote Sensing and Geographic Information Systems

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Abstract

This study investigates evidence to determine the topographical roughness of Jabal Sanam in southern Iraq using geographic information system (GIS) remote sensing methods. Jabal Sanam represents one of the most diverse geological features in the undeniably flat sediment of southern Iraq, making it an important location for terrain analysis. Look at the reliability statistics of the Digital Elevation Model (DEM) to obtain terrain characteristics and compare the spatial variant across the mountain range. Several spatial estimation methods have been used as a way to be aware of morphological complexity and version in elevation models, such as slope, mountain shadow, terrain roughness indices. The highest roughness has been focused while the reduction values are calculated within the surrounding surface areas. The findings suggested that the rugged pattern in Jabal Sanam is strongly associated with geological structure and tectonic origin, contributing to complex topographic work despite the generally flat nature of the surrounding environment. This study presents an important empirical foundation for future geological, geological and environmental research in southern Iraq and highlights the value of modern geospatial techniques in studying individual landforms and geodynamics.

Keywords: TRI, Jabal Sanam, GIS, Basrah, Iraq.

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1. Introduction

Rugged terrain is an important geomorphological feature that reflects the complexity of the Earth's surface and directly affects natural processes and human activities, especially in the mountainous and semi-arid regions (Zhang & Guo, 2025; Shams et al.,2026). Topographical ruggedness analysis is a modern method in GIS and remote sensing research (Yang et al.,2026). The method enables quantitative and accurate estimation of elevation and slope change using digital elevation models (DEMs) and a suite of geospatial techniques (Tsutsui et al., 2007; Mesa & Ariza, 2020). Sanam is one of the most prominent topographical features in southern Iraq, representing a unique geological formation within a relatively flat plain, which gives it special geomorphological and environmental importance (Sissakian et al.,2017; Soltan, 2021). The mountain is characterised by its relative height and convex shape resulting from salt formations and tectonic processes, which have made it the subject of interest for many geographical and geological studies (Fouad and Sissakian, 2011; Soltan, 2020). The analysis of the topographical ruggedness of Jabal Sanam is important for various reasons. It facilitates the examination of slope patterns and surface relief, improves our comprehension of the mountain's morphometric attributes, and assists in pinpointing areas with the most intricate topography. This investigation also evaluates the extent to which natural factors affect the mountain's surface. It underscores the significance of contemporary digital technologies in

generating precise topographical roughness maps, applicable in environmental, geology, and planning research.This study utilizes Geographic Information System (GIS) techniques and remote sensing data to analyze the topographic ruggedness of Mount Sanam utilizing appropriate spatial indicators and deriving topographic features from a digital elevation model. The purpose is to achieve a more accurate knowledge of the topographical structure of the mountain and to provide the spatial variation of ruggedness levels in the study area.

2. Study area

Sanam is situated on the Iraqi-Kuwait border in the southwest of Basrah at latitude 30° 08′ 00" - 30° 06′ 55" N and longitude 47° 37′ 00" - 47° 38′ 05" E (Fig. 1). The principal geological structure of the southern alluvium in Iraq is Jabal Sanam, situated approximately 50 km southwest of Basrah and 8 km west of Safwan district (Sissakian et al., 2017). The mountain is distinguished by salt deposition resulting from previous tectonic salt activity (Al-Kaabi, 2023; Al-Rahim, 2017).

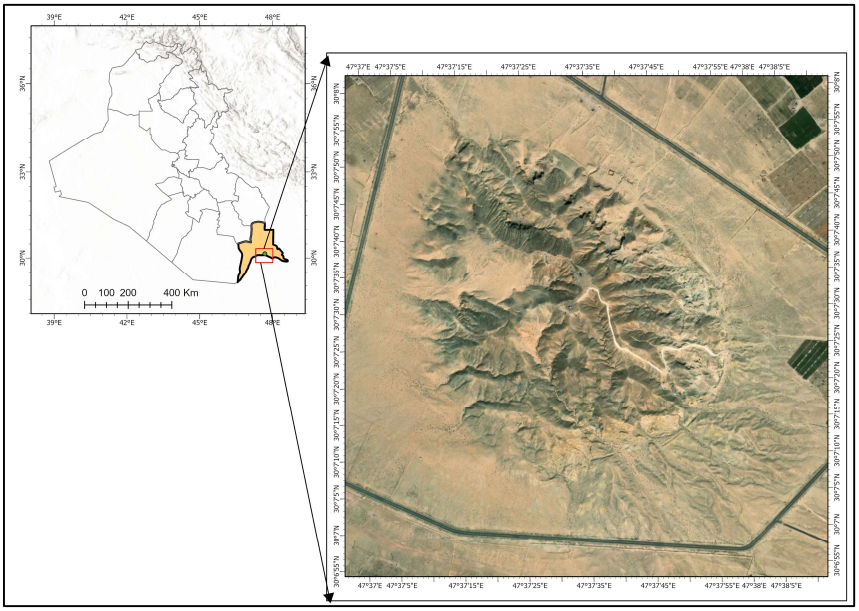

Fig. 1. The study area Location

3. Methodology

In this experiment, geographic information systems (GIS) and 30m of digital elevation models (DEM) from SRTM were used in ArcGIS Pro to assess the topographic roughness of the Jabal Sanam vicinity. The clipped DEM was then used to collapse topographic depressions using the Fill tool as part of the initial data processing. To improve spatial estimation accuracy, the records were transformed and then reprojected to the WGS 84 UTM Zone 38N coordinate tool. The topographic roughness index (TRI) of the Jabal Sanam was calculated using a digital elevation model (DEM) using the equation developed by Riley et al. (1999). This index is entirely based on calculating 'the square root of the sum of the squared elevation differences between the center cell and its eight surrounding cells (3×3 window), and provides high accuracy in identifying regions of sharp spatial variation,

$$\mathrm{TRI} = \sqrt{\Sigma\,(Xij - x00)^2}$$

When TRI is summed over the 8 neighbours, (x_ij) is the neighbour elevation and (x00) is the centre-cell elevation.

4. Result and discussion

Digital elevation model (DEM) results showed that Jabal Sanam represents an isolated landform within the southern

alluvial plain of Iraq (Fig 2). The hillshade has helped to highlight the morphological details of Jabal Sanam and to clarify the areas of slope and ruggedness more accurately and clearly (Fig 3). It was derived from a DEM with a resolution of 30m using 90° of solar azimuth. The topographic ruggedness assessment of Jabal Sanam revealed a clear spatial version of ruggedness in the study area. The TRI values ranged from 0.001 to 11. 987 m. To highlight the widespread local geographic variation in this individual dome, the large square layers of Riley et al. (1999) were replaced by a modified relative category (Natural Breaks-Jenks), divided into five categories (Table 1), the 'very difficult' category (6.112–11.987 m) was concentrated on mountain peaks and ridges, even as the 'flat' category (0.001–0.423 m) represented minimal topography in areas around the mountain, especially on the southwestern slopes (Fig 4).

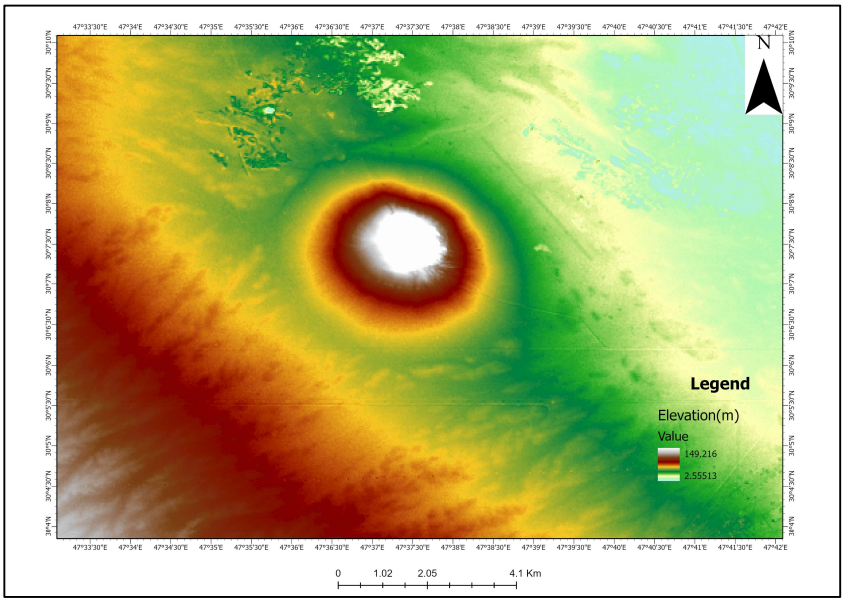

Fig 2. Digital Elevation Models (DEMs) of study area.

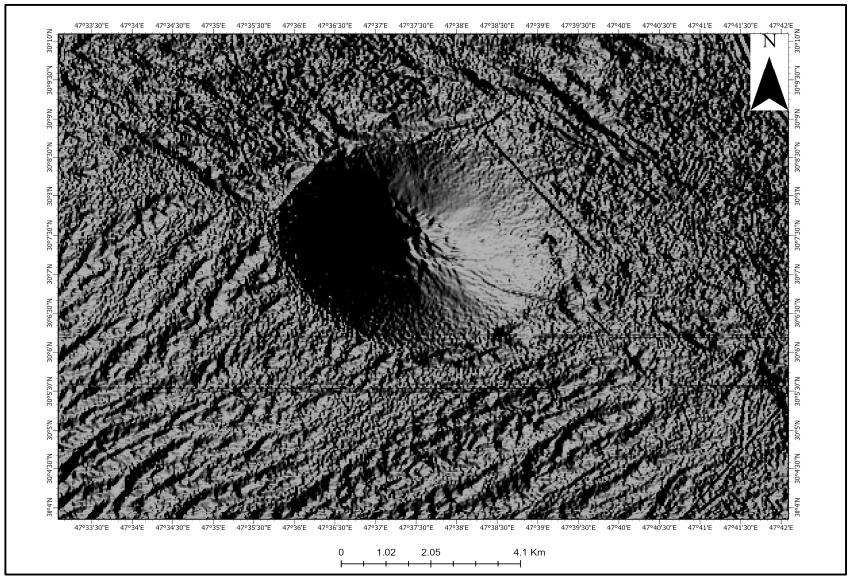

Fig 3. The light azimuths 90◦ of Hillshade images with 45◦ a constant solar elevation

The results of spatial analysis using Geographic Information System (GIS) technology confirmed that the rugged values are immediately related to the geological formation and structural structure of the mountain. Areas of high roughness were also determined to be more susceptible to erosion and surface runoff compared to areas of low roughness. These findings are consistent with those of Sissakian et al. (2017) on the nature of the complex geology of Jabal Sanam and its relationship with ancient tectonic and salt regimes.

Table 1. Classification of Topographical Ruggedness Analysis

Category	Range of TRI (m)	Description
1	0.001 - 0.423	Nearly Level
2	0.424 - 1.457	Slightly Rugged
3	1.458 - 3.479	Intermediately Rugged
4	3.480 - 6.111	Moderately Rugged
5	6.112 - 11.987	Highly Rugged

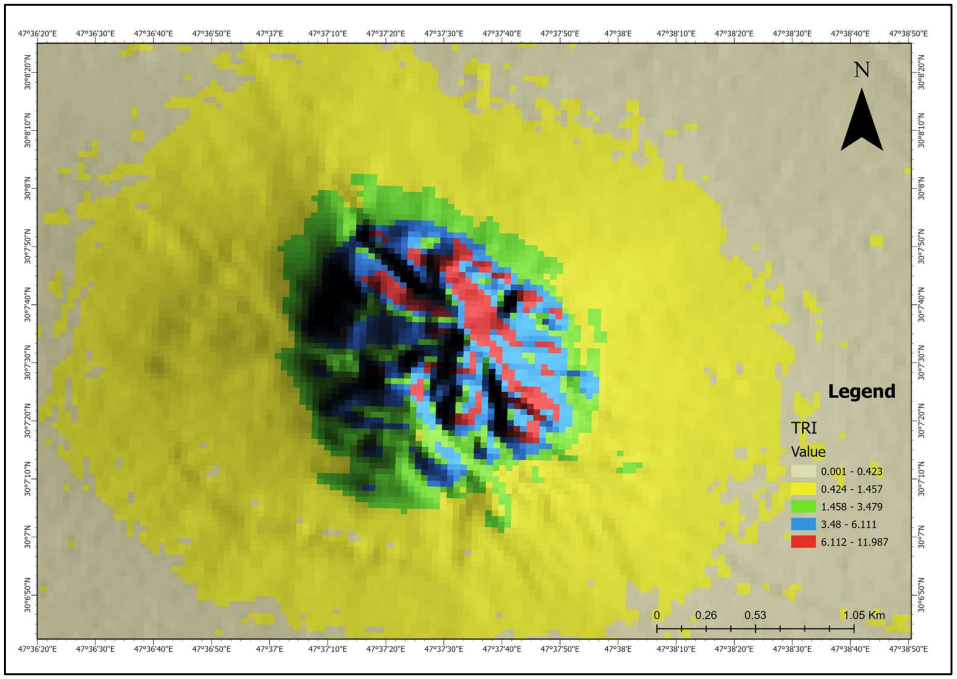

Fig 4. Jabal Sanam topographic ruggedness maps.

5.Conclusion

This study intends to investigate the topographical ruggedness of Jabalsanam using a digital elevation model (DEM) to elucidate the spatial variations in ruggedness and slopes at the observation site through remote sensing methods and geographic information systems (GIS). The findings revealed an extreme pattern of topographic roughness values, with the greatest concentrations within the central and eastern areas of the mountain, demonstrating the influence of geological features and tectonic regimes on the morphological potential of the area. The research revealed that a close chronological sequence is established between the geological framework and the tectonic structure of the topographic rugged pattern, with the salt dome and tectonic movements

contributing to the formation of the present topography .Numerical elevation model and spatial estimation results confirmed high efficiency in representing topographic features and revealing floor information with appropriate spatial accuracy. Remote sensing techniques and geographic data structures have proven powerful in analyzing geological works and producing accurate topographic rough maps that can be relied upon in fate research.

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