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Original Article

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Study of Extent and Characteristic of Badland Areas Using Visualization Techniques on DEM for the Lower Reaches of Chambal-Yamuna and its Tributaries

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Abstract

When discussing land use, the badland topography isn't of much use to humans. The Chambal River serves as the main river for Yamuna and other tributaries. Ravine tracts have developed along the Chambal and its tributaries in the alluvial landscape, covering a large area. However, there is a lack of information about the exact extent of genetically related badlands in this region. To tackle this issue, Digital Elevation Models can be used to map this large area in the GIS platform. This paper attempts to delineate these badlands by using visualization techniques such as shaded relief maps and the Terrain Ruggedness Index on CartoDEM in the QGIS environment. The paper concludes that ravine tracts have been developed along the lower reaches of the incised river channels of Chambal, its tributaries such as Yamuna, Kunwari, and Sindh, and the intensity of these badlands increases downstream up to the Yamuna-Chambal Confluence.

Keywords: CartoDEM, QGIS, Chambal, Yamuna, Badlands.

Introduction

The Chambal River is known for its badlands, which start from the Janapaw hill on the Vindhyan plateau in Madhya Pradesh and flow northwards until they reach the Jhalawar Scarps in Rajasthan. Here, the river debouches into an alluvial landscape and turns towards the northeast, where its tributaries Parvati and Kalisindh join it. The valley then incises deep and flows towards the northeast along the Madhya Pradesh-Rajasthan border before turning towards the southeast, where it meets the Yamuna and Sindh rivers. The study area encompasses the lower reaches of the Chambal and its tributaries, passing through the states of Madhya Pradesh, Rajasthan and Uttar Pradesh.

Historically, the Chambal was considered to be a subsidiary stream of the Yamuna River, but topographic expressions and river discharge suggest that the Yamuna is actually the tributary of the Chambal, not the other way around. This fact is also supported by earlier researchers like Valdiya (2017), Mishra and Vishwakarma (1999). Fig. 2 shows that topographically, the Chambal River is larger than the Yamuna. Therefore, the Chambal joins the Ganga River, not the Yamuna, and makes the Ganga Chambal Axial River. This fact shows that the ravines are related to the trunk stream Chambal, which is why the paper adopts a holistic approach to studying these badlands.

The advent of remote sensing technologies has made it possible to map larger areas with fewer people and in less time. It is now common to map landforms using computer visualizations of DEMs. A CartoDEM with a 30m spatial resolution was used to define the morphological properties of the badlands. We derived slope and aspect maps to characterize the eroded areas from a morphological perspective, taking into account their high potential in landform mapping.

The geographic software package QGIS can visualize 3D landscapes using several different techniques, including Terrain Ruggedness Index, color shading and relief shading.

Visualization Techniques such as ShadedRelief Map and Ruggedness Number have been used to mapping of ravine zones (Smith & Clark 2005) along rivers and then digitization tool have been used to generation of map in QGIS 3.34.3 Version. Field verification have been carried out after map generation through many traverse across Chambal, Yamuna, Chambal- Yamuna Confluence, Kalisindh, Parvati Riveretc.

Data: Digital Elevation Model- Orthorectified tiles of CartoDEM of the study area 30 meter spatial resolution downloaded from the https://bhuvan.nrsc.gov.in/, this DEM is developed by NRSC Hyderabad using CartoSat-1 stereo imagery of 2.5 meter spatial resolution. Downloaded DEM tiles then Merged in QGIS using Raster-Merge tool then area of interest DEM clipped for further use. For Identification of Badland these two techniques have been used.

Ruggedness Index Map: This algorithm calculates the quantitative measurement of terrain heterogeneity (Riley et al. 1999).). It is calculated for every location, by summarizing the change in elevation within the 3x3 pixel grid. Each pixel contains the difference in elevation from a center cell and the 8 cells surrounding it. Ruggedness Index Map (Fig.4) Prepared by Ruggedness Tool of Grass in QGIS. In Ruggedness Index Map badland areas represented by the anomalous higher values of RI compared to plain area, thus Badland has been identified.

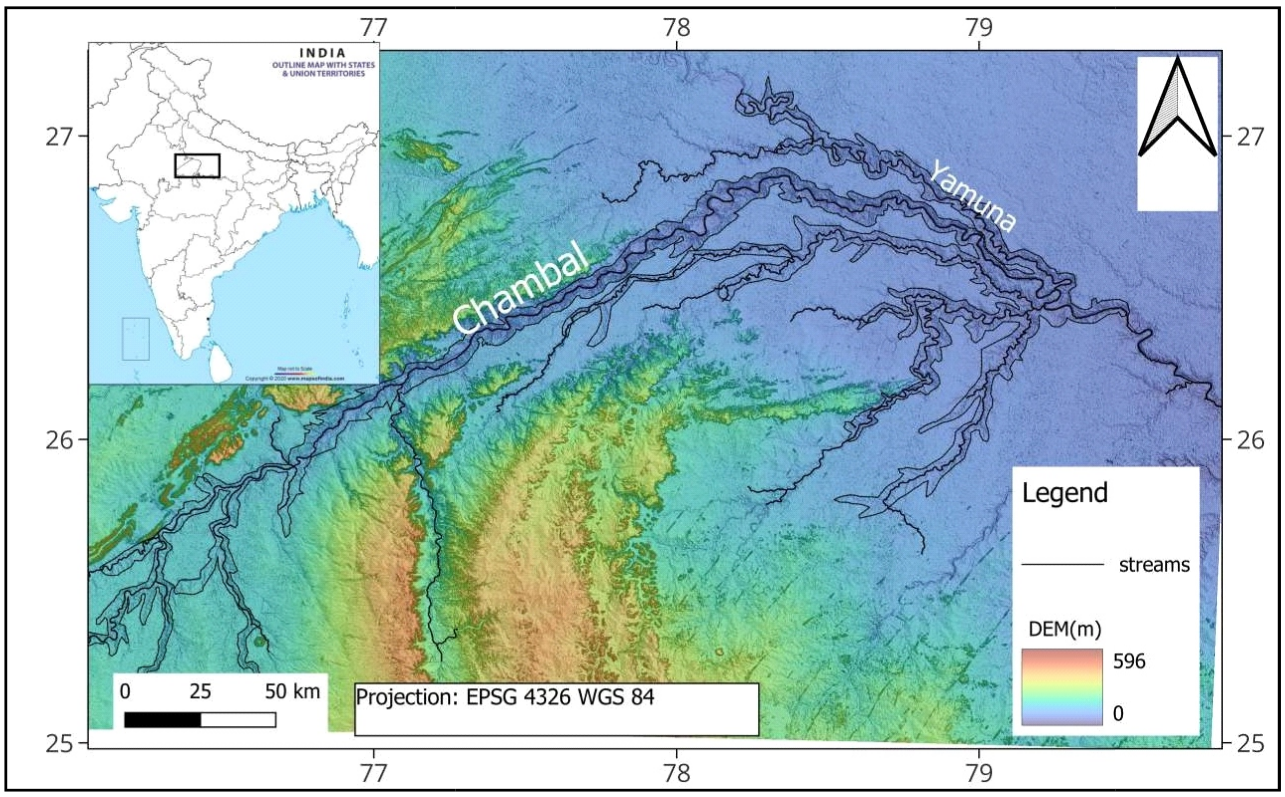


Figure 1: Map show study area on DEM background.

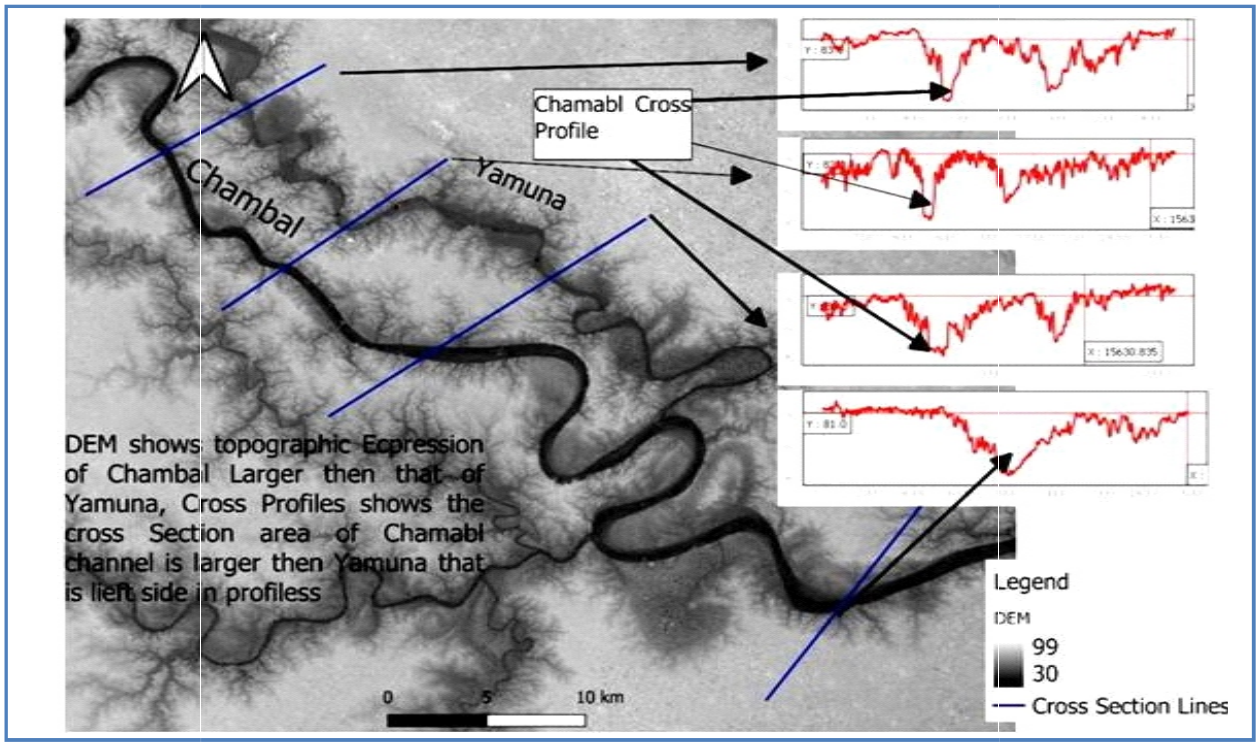
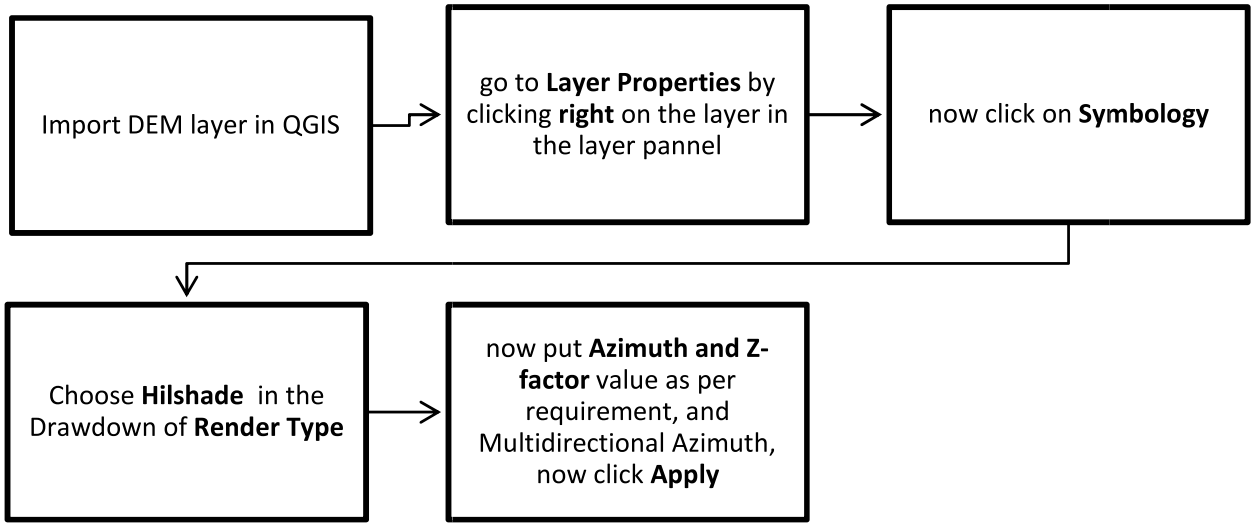


Figure 2: DEM of the Chambal-Yamuna Confluence, Cross Elevation Profiles showsHigher Topographic Expression of Chambalthan Yamuna



Figure 3 Badland Topography Photo of Left bank of the River Chambal Near Dh lpur Rajasthan

Hillshade Map: Multidirectional azimuth Shaded Relief map is useful to map landforms (Smith and Clarck, 2005). A Shaded Relief map (Fig. 5) prepared in QGIS using Orthorectified CartoDEM and used to visually identify badland area, badland area along rivers marked by the highly rough topography due to presence of intense ravines. This is the workflow used for preparation of Shaded Relief map.



Digitization of Identified Badland: Badland area represented by High Ruggedness and with dense network of Ravines and Gullies identified on Shaded Relief Map and on Ruggedness Index Map. High contrast colour Ruggedness Map (Fig.7) Layer with increased Transparency overlapped over Shaded Relief Map(fig.6) with 30 Z exaggeration A Polygon Shapefile Layer has been created. then *Toggle Editing* tool used to map the identified badland zones. After complete digitization of badland area Layer has been saved and final Badland Map (fig.8) have been produced through New Print Layout Tool.

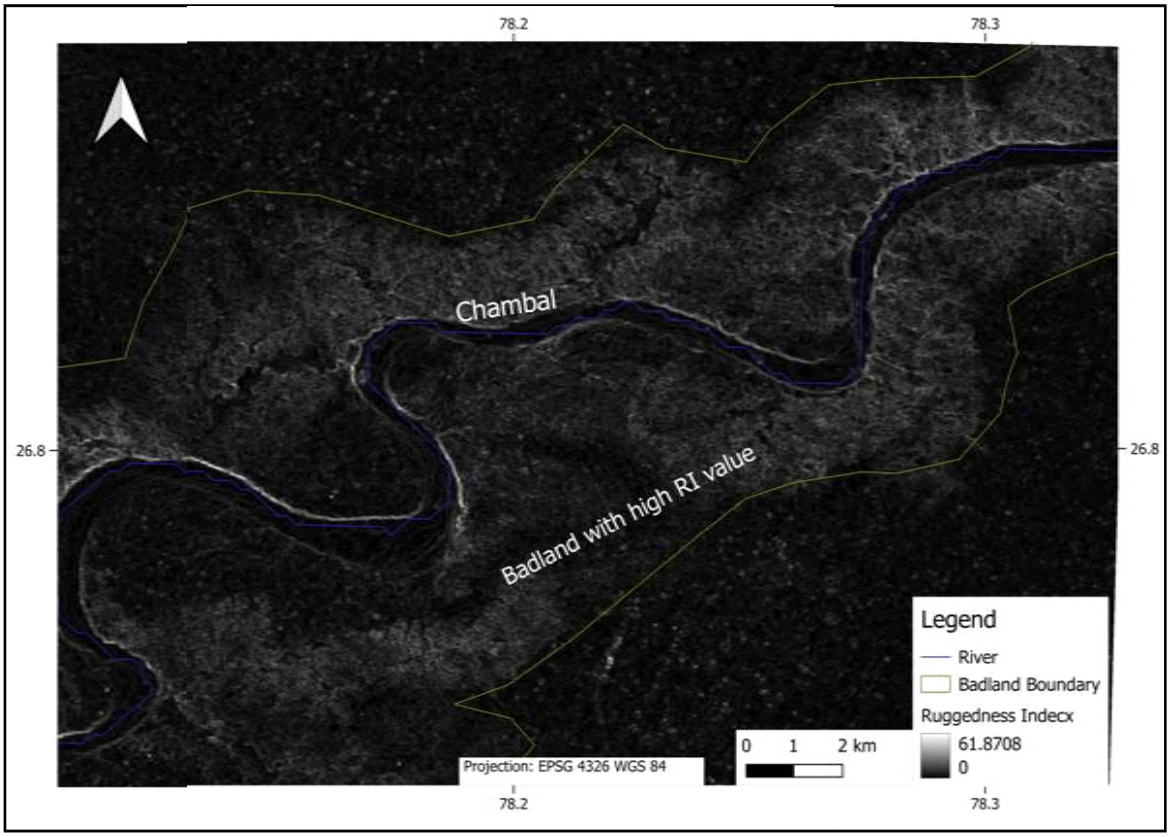


Figure 4. The map represent badland zones of High Ruggedness Value along the river Chambal, flood plain area showing low Ruggedness value

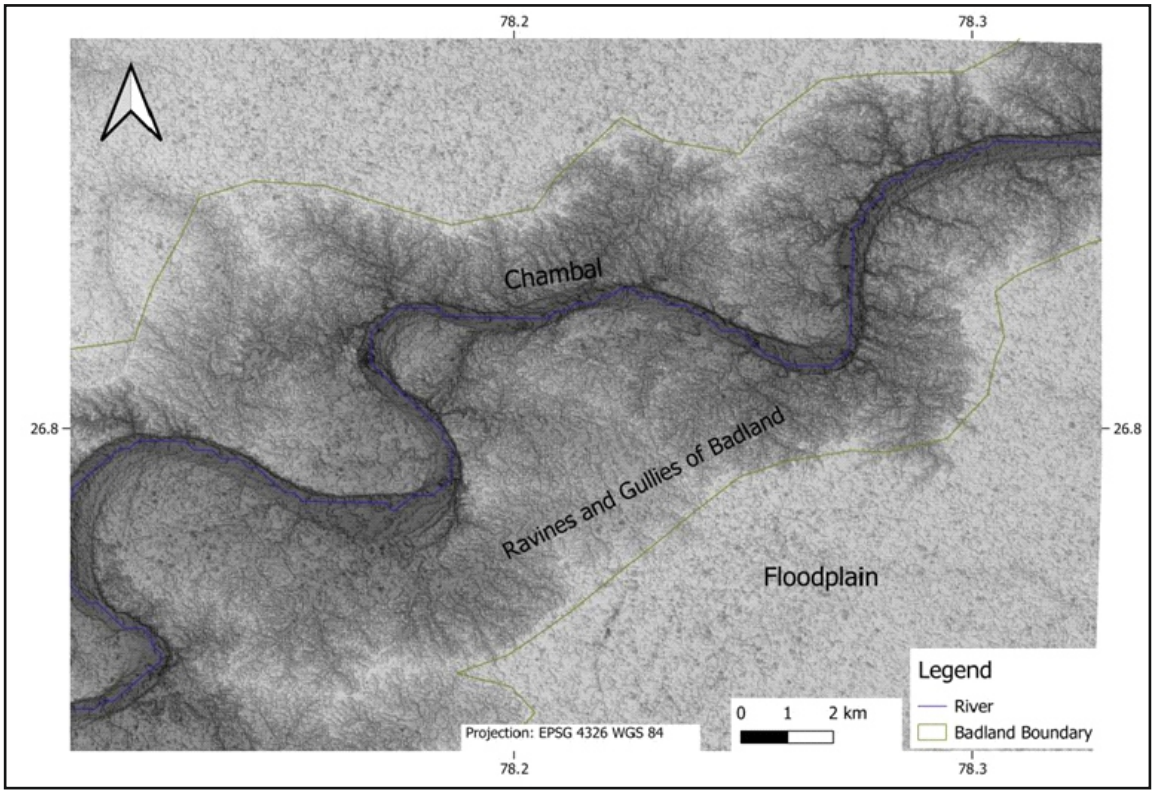


Figure 5 :Hill shade Map represent network of ravines and gullies ting smooth floodplain surface and badland area of dense

Result and Discussion

According to my study, badlands cover an area of 6,900 square kilometers (Fig.8) along the Chambal-Yamuna and its tributaries. These areas are characterized by steep slopes where inter-rills, rills, gullies, and ravines form, with some ravines exceeding a depth of 30 meters (Fig.9). The development of badlands starts after Kota Rajasthan along the Chambal River and increases in intensity downstream towards the Yamuna-Chambal Confluence. Similarly, the intensity of ravine erosion along the Yamuna River increases downstream after Agra. Although other tributaries such as the Kunwari and Sindh rivers also have badland areas along both of their banks near confluence with the Chambal River, the Kalisindh and Parvati rivers joined the Chambal River earlier and have less badland. The formation of these badlands is due to an effect of Himalayan orogeny (Ahmad, 1968; Sharma, 1968; Agarwal et al., 2002). Due to Himalayan orogeny, the fore-bulge of Himalayan foreland basin (Gibling et al., 2005; DeCelles, 2011) experienced an uplift (Agarwal et al., 2002) that forced the Chambal River to attain a new equilibrium, which led to the incision of deposited sediments and the formation of badlands on both sides of the Chambal River and its tributaries (Sharma, 1979; Pani and Mohapatra, 2001, Poesen et al., 2016, Panday,2023). Gibling et al., (2005) suggest badland formation is due to intensification of southwest monsoon between 15–5 ka ago. Unfortunately, these badlands have adverse effects on agriculture, leading to a gradual decline in crop yield and the engulfment of agricultural land by ravines (Pani and Mohapatra, 2001b). As a result, India suffers significant economic losses due to badlands(Ranga et al., 2015b).

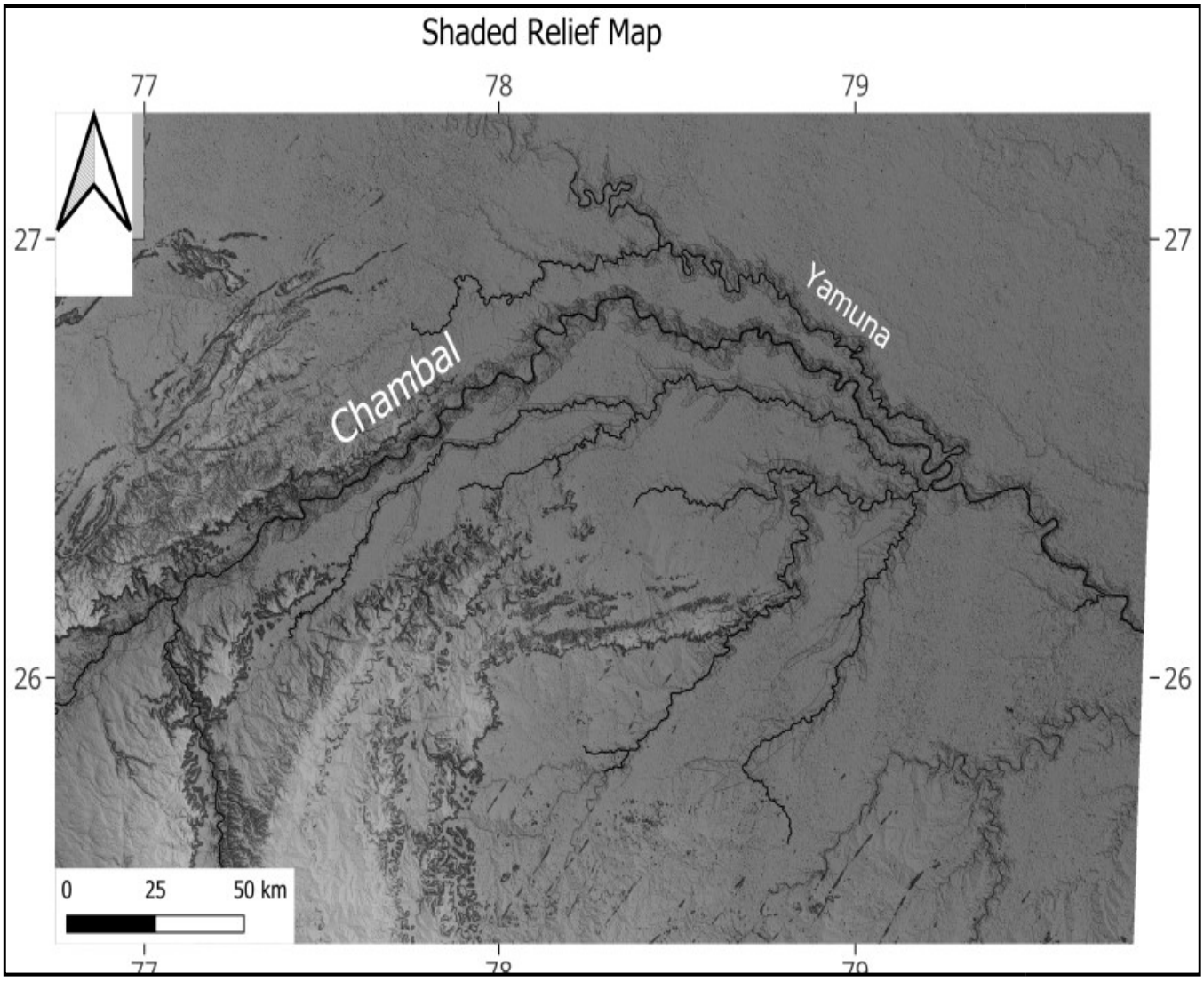


Figure 6: Shaded Relief Map of the area, badlands along rivers represented by rugged topography against smooth flood plains away from river.

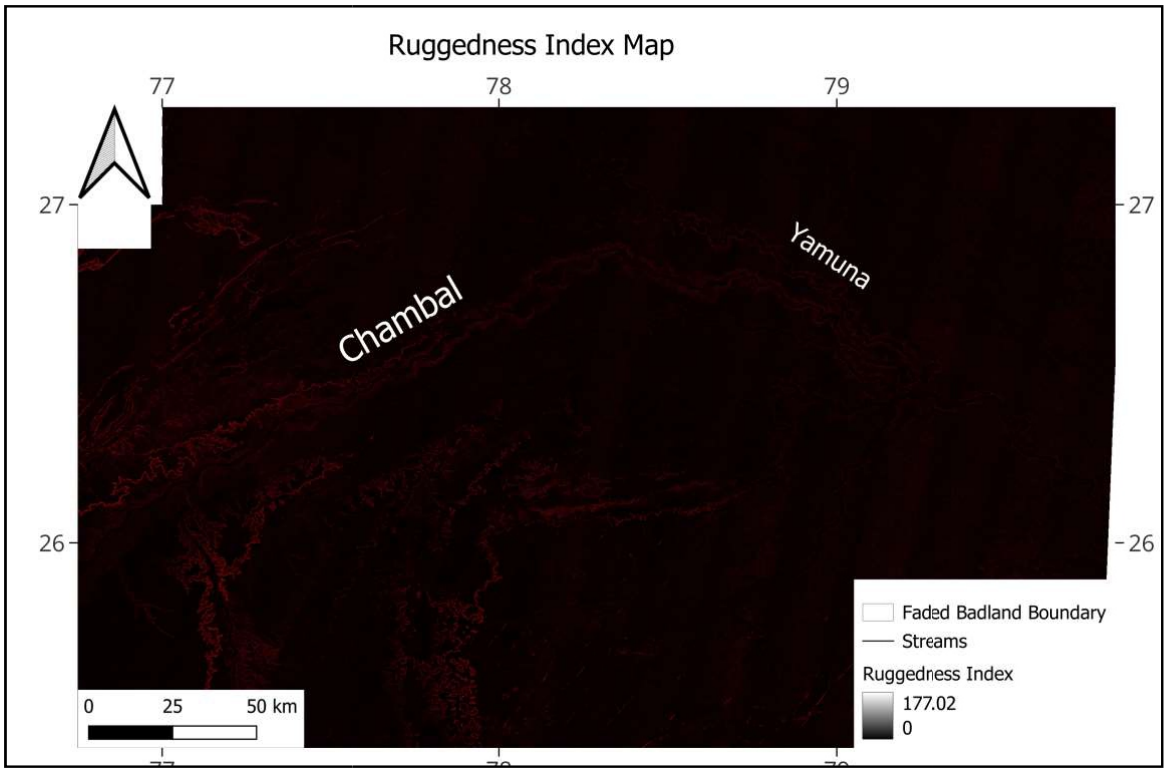


Figure 7: Badland along the rivers represented by the Ruggedness Index Values, other High value areas are curvilinear escarpments / linear of Vindhyan Group Rocks in SW part of the Map

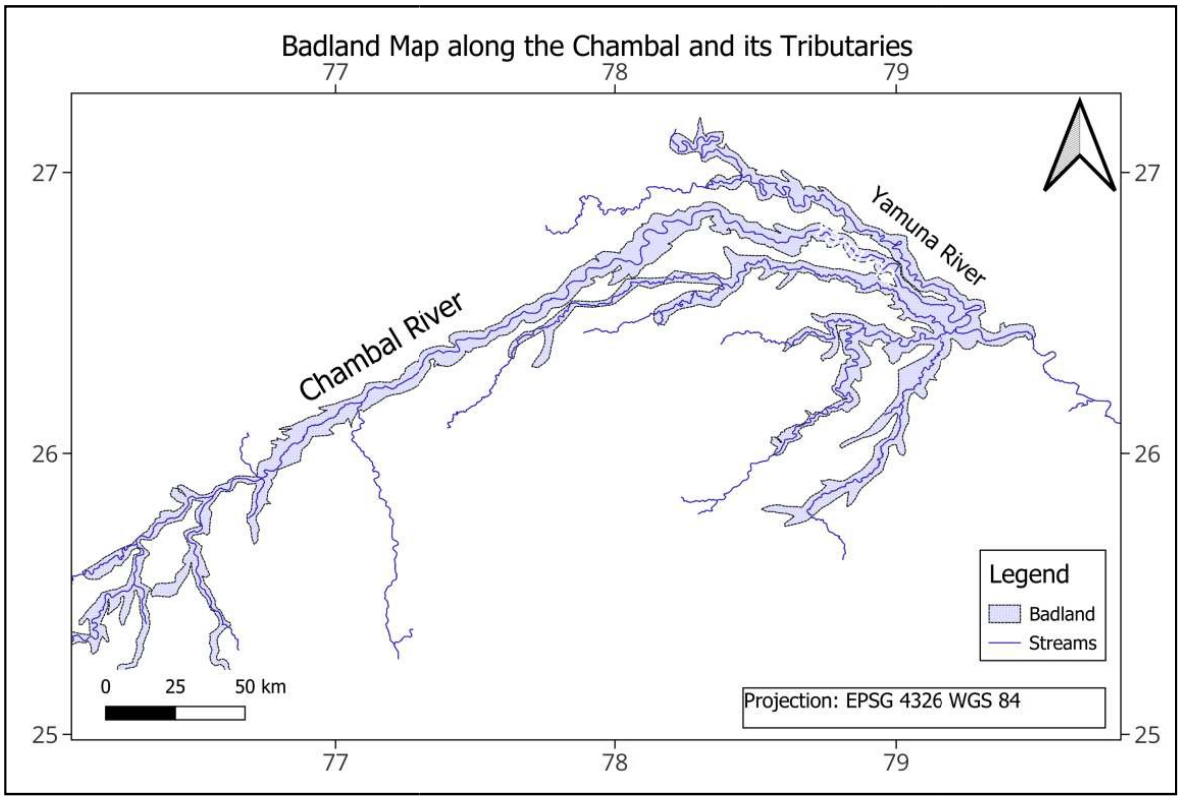


Figure 8: Badland Map along the Chambal and its tributary, total badland area calculated is 69000 sq km. Badland Extracted from the CartoDEM using QGIS

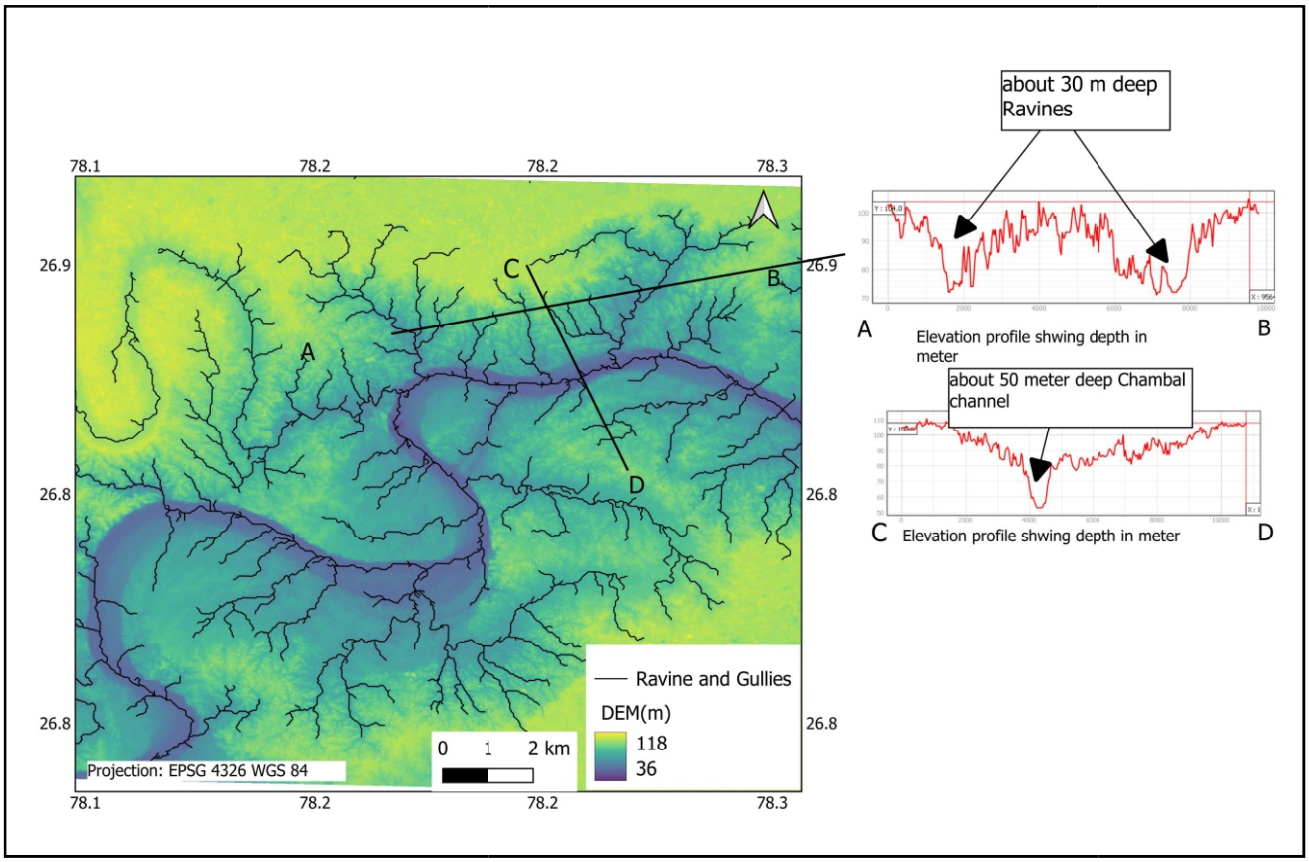


Figure 9: Dense network of Ravines and Gullies makes badland along Chambal, these about 30 meter deep ravines developed due to headword erosion caused by 50 m deep river incision

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