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Research Article

The Contribution of GIS to Analyzing Hydrological, Topographical, and Geomorphological Features in the Tidili-Tiouine Basin, Draa, Morocco

Kaouthar Majdouli*, Ahmad Algouti[1], Abdellah Algouti[1], Khadija Lamrani[1], Mohamed Lakhlili[1], Yahia Laadimi[1], Naji Jdaba[2] and Imane El Kihal[1]

[1] *Laboratory: Geosciences, Geotourism, Natural Hazards and Remote Sensing. /Faculty of sciences Semlalia/ University Cadi Ayyad, Morocco*

[2] *Laboratory: Geosciences, Environnement, And Geomatic / Faculty of sciences Ibno Zohr Agadir / Morocco*

**k.majdouli;ced@uca.ac.ma*

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Abstract – It is not paradoxical that a country like Morocco, characterized by its semi-arid climate, experiences periodic exposure to significant flood damage. This phenomenon, increasingly conspicuous over the past two decades, arises, on one hand, from population growth, economic development, and the expansion of urban, agricultural, industrial, and tourist activities, resulting in an augmented occupation of vulnerable areas. On the other hand, it is a consequence of the intensification of extreme events, including droughts and floods, stemming from climate change that induces intense storms, leading to swift and devastating floods.

The Draa basin, particularly its mountainous section, is notably susceptible to flooding. Hence, this thorough examination of the Tidili-Tiouine watershed becomes imperative. The objective is to ascertain the physical characteristics of the basin, an indispensable prerequisite for comprehending the mechanisms of flow and a fundamental component in the execution of projects aimed at safeguarding against the risk of overflow.

Geographic Information System (GIS) provides an efficient method for monitoring and tracking changes in the watershed over time, contributing to a more proactive approach in the management of natural resources. In essence, the role of GIS in the topographic and geomorphological study of a watershed introduces fresh perspectives for the sustainable management of hydrological ecosystems. The spatial visualization of data, accomplished through thematic maps, facilitates the communication of results in an accessible manner. These maps allow for the visual presentation of crucial watershed characteristics, which is essential for informed decision-making by researchers, decision-makers, and stakeholders.

Keywords – Watershed, GIS, Mapping, Geomorphology, Hydrology

I. INTRODUCTION

The climate change has played a significant role in intensifying extreme weather events, such as droughts and floods. The resulting alteration in precipitation patterns and the occurrence of more frequent and severe storms contribute to rapid and destructive floods. This impact is particularly noticeable in regions like the Draa basin, where the mountainous terrain further amplifies the susceptibility to flooding.

In this context, the Tidili-Tiouine watershed assumes critical importance. Conducting a thorough examination of this watershed is essential for understanding the physical characteristics that influence the flow mechanisms. This knowledge is crucial for the successful implementation of projects aimed at mitigating the risk of overflow and ensuring the sustainable management of water resources in the region.

In southern Morocco, along the Lower Draa, the In southern Morocco, along the Lower Draa, the studied basin spans four rural communes – Tidili, Khouzama, Amerzgane, and Siroua – situated in the province of Ouarzazate, approximately forty kilometers from Route Nationale No. 10.

From a climatic standpoint, the Tidili-Tiouine region showcases a temperate Mediterranean climate with hot, dry summers (Csa) according to the Köppen-Geiger classification. The annual average temperature in Tidili is 19.2°C, complemented by an average rainfall of 353.8mm and the average temperature in Tiouine is 19.5°C, with an accompanying average rainfall of 161.9mm. (meteobleu,2023)

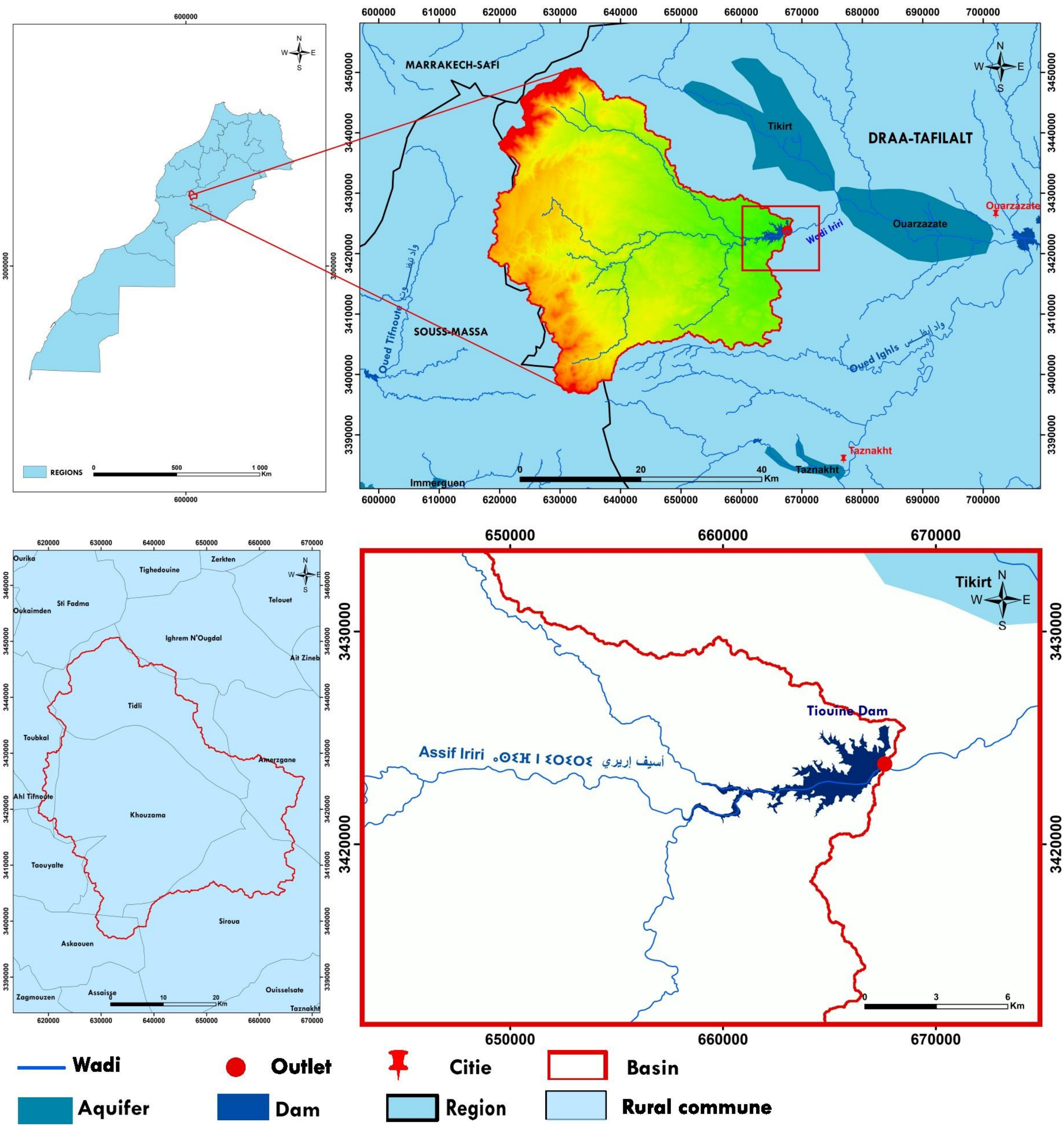


Figure 1 : Localisation of study area

Geologically, Iriri is a south-bank tributary of the Assif Imini. Along the wadi, channelized conglomerates are present within a red-tinged sandstone-conglomerate series, enriched with volcanic rock debris such as andesites and rhyolites. This facies is characteristic of the "Base Series" of the informal Adoudounian stage, corresponding to the end of the Ediacaran period. Moving westward, the Iriri valley expands into the red volcano-sedimentary strata of the late Ouarzazate Group, shaping an anticlinal dome carved out by erosion known as the Tiouine dome.

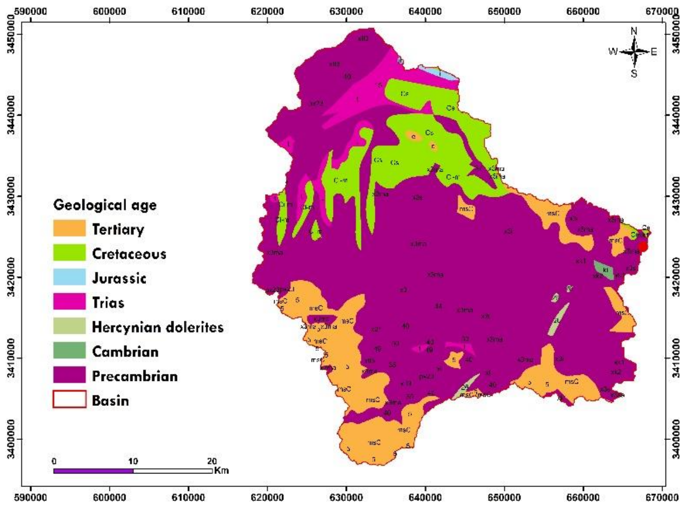


Figure 2 : Geological map of Tidili-Tiouine basin

II. Materials and Method

The utilization of a Geographic Information System (GIS) holds significant importance in the examination of the physical and morphometric characteristics of a watershed. GIS provides an integrated approach to analyze and visualize complex geographical data, thereby aiding in the comprehension of topographical, hydrological, and environmental aspects of a given area.

Regarding physical features, GIS enables detailed mapping of relief, land use, watercourses, slopes, and other essential geographic elements. This geospatial information establishes a robust foundation for assessing the geomorphology of the watershed, pinpointing flood-prone areas, erosion-prone terrain, and other aspects of landscape dynamics. In morphometric terms, GIS facilitates the analysis of parameters such as watershed area, stream length, drainage network density, slopes, and other geometric measurements. These data are pivotal for quantifying the shape of the watershed, evaluating its hydrological response to precipitation, and understanding its specific morphological characteristics.

Employing the SAGAGIS GIS software, we successfully demarcated the boundaries of the watershed under examination and pinpointed its outlet. Subsequently, we conducted an analysis to

1- Physical parameters:

determine various physical parameters characterizing the watershed. These parameters encompassed key metrics such as surface area, perimeter, elevation, KG shape index, orographic index, and emissivity. Through the application of the SAGAGIS GIS software, we not only defined the geographical extent of the watershed but also delved into its morphological and topographical features, extracting essential data to comprehend the overall characteristics of this specific hydrological system.

By combining the functionalities of ArcGIS and SAGA GIS, we identified and analyzed the morphological and topographical parameters that play a role in shaping the geomorphological style of the watershed. This integrated approach allowed for a detailed exploration of landform characteristics, flow patterns, and other crucial geographical aspects that contribute to defining the distinctive morphology of the study area. The synergy of these two GIS software packages provided us with an in-depth perspective on the geomorphological processes occurring in the watershed, establishing the groundwork for a comprehensive understanding of its physical environment.

III. Results

The findings of this study are manifested through a series of maps that offer visual insights into the essential parameters necessary for comprehending the flow mechanisms within the examined watershed. These maps, crafted utilizing detailed data gathered with GIS tools, present a lucid visual depiction of the morphological, topographical, and hydrological traits of the watershed.

Table 1 : Physical parameters

Outlet X	667593.481
Outlet Y	3423766.695
Perimeter (Km)	287.096 Outlet
Area (Km^2)	1552.446
Centroid X	640796.111
Centroid Y	3422821.079
Mean Elevation	1989.362
Gravelius index	2.1
Basin type	rectangular
Orographic	25.492
Missivity	1.8493

These indicators are of major importance as they collectively influence the mechanisms of surface runoff, playing a crucial role in shaping its hydrological response, especially in determining the flow regime during flood periods.

2- Topographical parameters : Slope, hypsometry, slope length, TPI, VRM and MRVBF index

The impact of relief on runoff is easily comprehensible, as numerous hydrometeorological parameters (such as precipitation, temperature, humidity, etc.) and the morphology of the basin vary with altitude. The slope of the basin also influences flow velocity. Relief is further characterized by various indices or characteristics, including hypsometry, slope map, TPI (Topographic Position Index), profile curvature, plan curvature, and roughness slope index...

Based on the variation of these parameters in our study area, we have generated the following maps.

3- Geomorphological parameters : Landform

The geomorphological history and lithological nature of the terrain are the factors that shape the organization of a watershed's hydrographic network. Hence, it is essential to scrutinize the geomorphological aspect of our watershed.

4- Hydrological parameters : the channel network classified ans the drainning density

In a watershed, channels are organized and hierarchized into a network that directs stormwater from streets into streams, stream water into rivers, and river water into larger rivers. These channels are classified according to their capacity for storage and drainage.

The obtained maps represent, respectively, the hydrographic network map classified according to the Strahler classification and the drainage density map indicating the degree of susceptibility to water erosion.

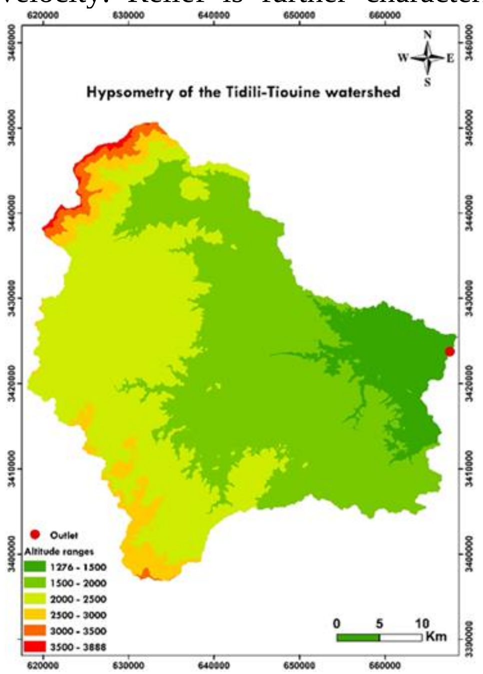


Figure 3 : Slope map of Tidili-Tiouine basin

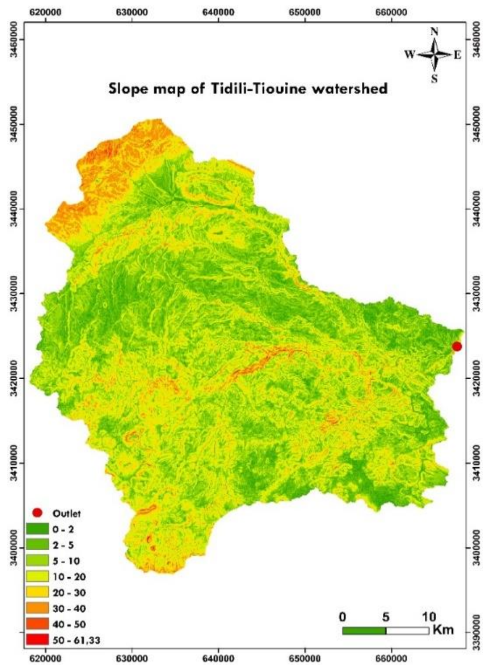


Figure 4 : Hypsometry of Tidili-Tiouine basin

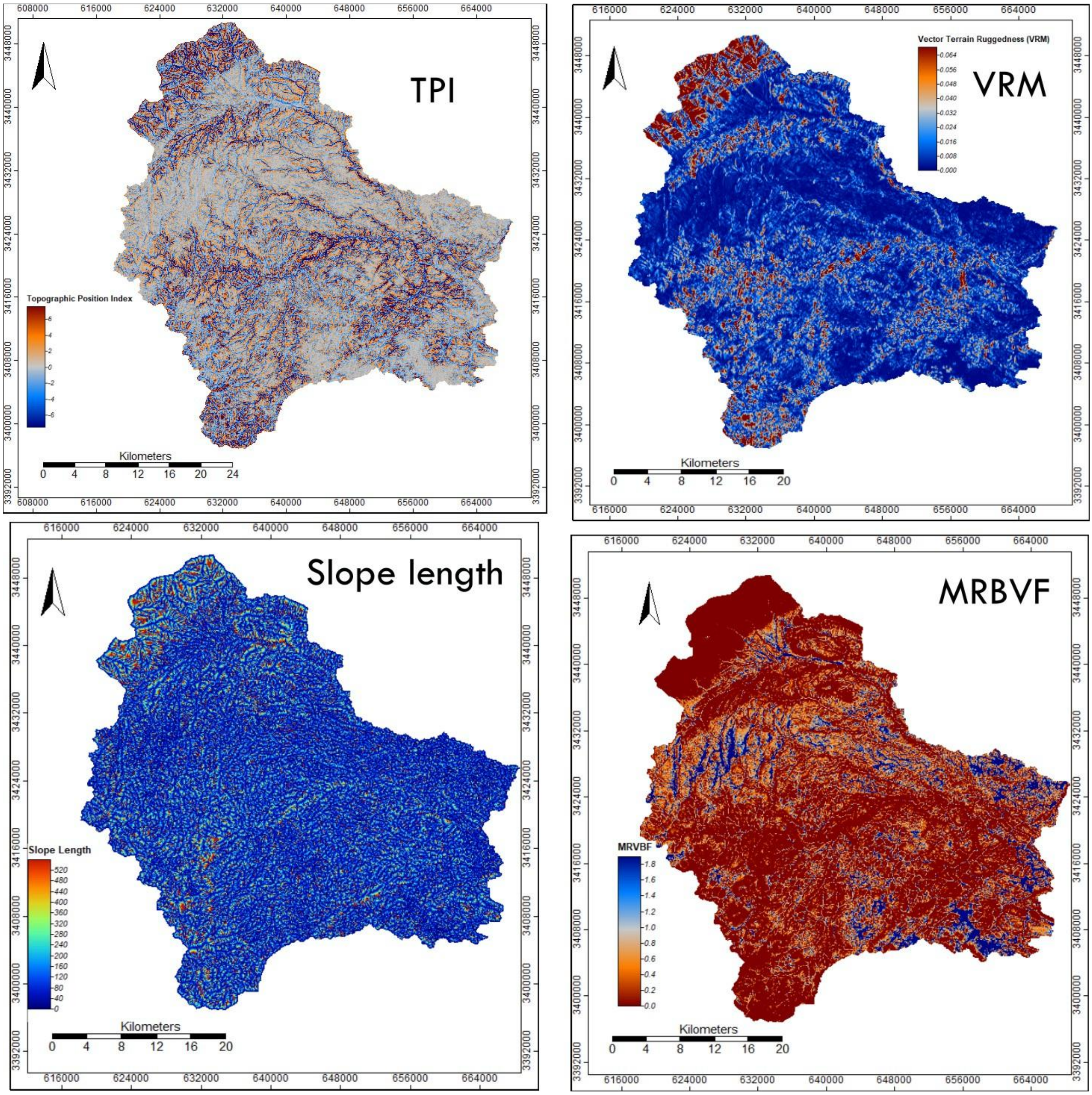
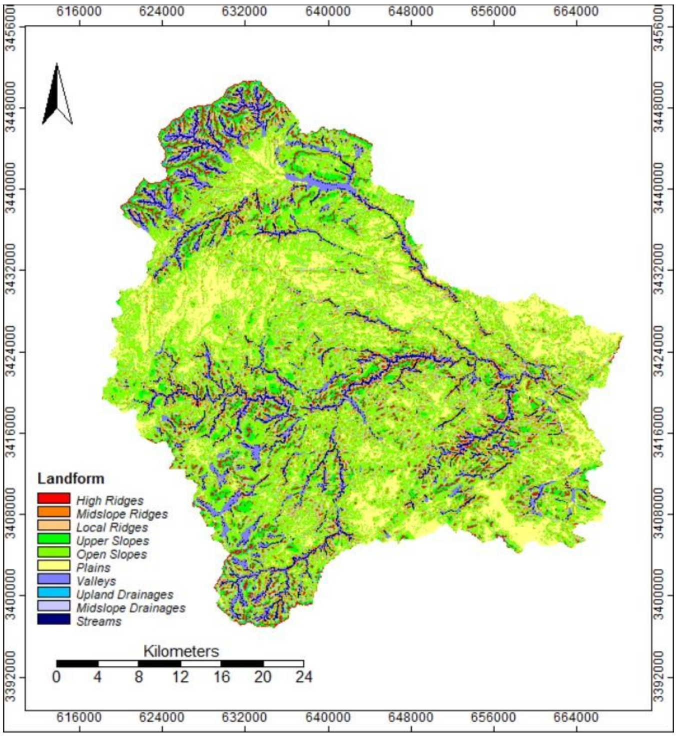


Figure 5 : Topographical parameters



Figur 6 : Geomorphplogical map of the Tidili-Tiouine Watershed

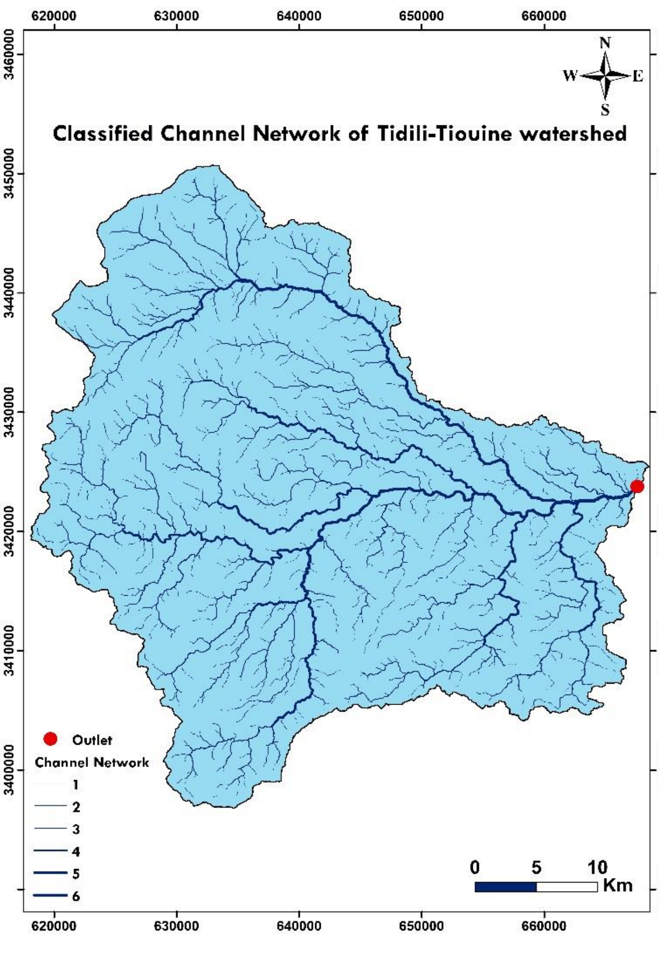


Figure 7 : Channel network of Tidili-Tiouine Watershed

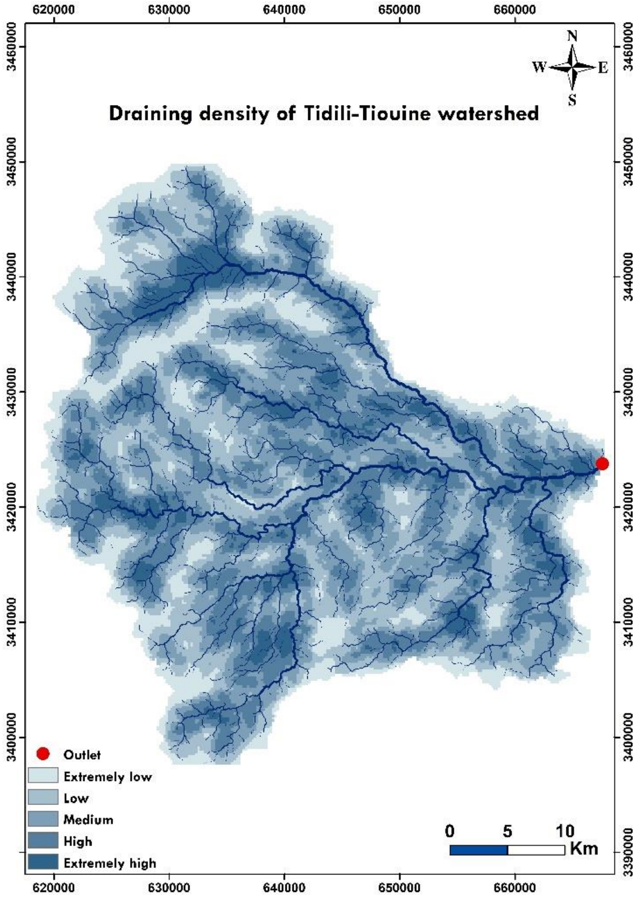


Figure 8 : Draining density of Tidili-Tiouine basin

IV. DISCUSSION

1- Physical parameters:

Surface area and perimeter play a crucial role in the morphological characterization of the study basin and significantly influence the nature of the relationship between flow and time; a large basin reacts more gradually to a downpour. According to the results obtained, the Tidili Tiouine watershed has a perimeter of 287.09 km and a surface area of 1552.44 km².

There are several indices available to characterize runoff and compare watersheds, one of which is the Gravelius KG shape index. This index is a compactness measure defined as the relationship between the perimeter of a watershed and the perimeter of a circle with the same area. The Gravelius index for our watershed has a value of 2.08, indicating an elongated basin shape.

2- Topographical parameters :

The Tidili-Tiouine basin reaches a maximum altitude of 3888 m and a minimum altitude of 1276 m, resulting in an elevation difference of approximately 2612 m and an average altitude of

1989 m. The predominant portion of the basin's terrain lies within altitudes ranging from 1500m to 2000 m.

The slope of the watercourse determines the speed at which water reaches the watershed outlet and, consequently, the time of concentration. It also impacts the condition of stream flow within the watershed. On low slopes, slope can lead to water infiltration, while on high slopes, it may result in runoff, and on steep slopes, it can cause torrential runoff.

The Topographic Position Index, or TPI, is an algorithm used to assess the relative topographic position of an object or point in relation to a relief feature. TPI operates by comparing the value of each DTM cell with the average value of its surrounding neighborhood. Positive values denote areas of relatively high elevation, such as ridges, while negative values indicate areas of relatively low elevation, such as valleys. Values near zero suggest areas with a constant slope.

Variation indices in terrain reggudness and slope length are crucial parameters in the study of water erosion. They indicate the direct relationship between slope or terrain roughness and the risk of soil displacement, contributing to the deformation of basin morphology. The greater the slope value, the higher the frequency of the associated risk.

3- Geomorphological parameters

MrVBF or Module Multiresolution Index of Valley Bottom Flatness, is a topographical index designed to identify areas of material deposition in flat valley bottoms. It is based on the observation of the flatness of valley bottoms in relation to their surroundings, considering that larger valley bottoms tend to be flatter than smaller ones. Zero values indicate eroding terrain, while values of 1 and above indicate increasingly larger areas of deposition. It appears that MrVBF values correlate with the depth of deposited material.

- **Geomorphological map :**

Following the analysis and interpretation of the map, the basin can be categorized into three primary morphological units:

High-Valley Sectors and Gorges : In these areas, the river does not interact significantly with alluvium, and the terrain features high valleys and gorges. The river exhibits a steep gradient in these sections.

Middle Sectors with Alluvial Interaction : These sectors are characterized by the river interacting with alluvial deposits and maintaining a regular gradient.

Naturally Rising Areas : These areas encompass locations where rivers have a very low gradient, including depressions and flat terrain, which are conducive to sediment deposition

Table 2 : Geomorphological classes

Classes	Area (Km^2)
Streams	78,32
Midslope Drainages	110,12
Upland Drainages	7,80
Valleys	87,86
Plains	298,22
Open Slopes	681,21
Upper Slopes	93,73
Local Ridges	7,38
Midslope Ridges	121,40
High Ridges	66,41

4- Hydrological parameters

Strahler's (1957) classification is facilitated by a numbering system for river sections, main rivers, and tributaries. The order of the watercourses, therefore, serves as a classification reflecting the branching pattern of the river network. This classification unambiguously delineates the evolution of the drainage network from upstream to downstream. It adheres to the following rules:

- Any watercourse with no tributaries is designated as order 1.
- The watercourse resulting from the confluence of two watercourses of different orders assumes the order of the higher of the two.
- The watercourse formed by the confluence of two watercourses of the same order is increased by 1.

Drainage density is influenced by various factors, including lithology, tectonics, exposure, vegetation cover, slopes, and climate. Creating and interpreting a drainage density map provides substance to the concept of "chevelu" – whether it is dense or sparse. In general, regions characterized by highly resistant or permeable soil and subsoil, dense vegetation cover, and low relief exhibit low drainage densities. Conversely, under conditions of the opposite nature, very high drainage densities are typically observed. Drainage density, as introduced by Horton, refers to the overall length of the drainage network per unit area of the watershed. The drainage density in the Tidili Tiouine basin is approximately 1 km/km². This suggests that the basin, as a whole, features a permeable geological formation, leading to limited and centralized drainage, while infiltration is enhanced. The basin concludes at one of the most significant water supply dams in the Tiouine Ouarzazate region, serving as the primary water collection point for our basin. Boasting a storage capacity of 270 million cubic meters, the dam is also designed to regulate a volume of 30 million m³/year, with two-thirds of this volume earmarked for providing drinking water to the towns and centers of the provinces of Ouarzazate and Zagora.

V. CONCLUSION

The This study delves into a hydrological characterization of the parameters influencing water flow in the Tidili-Tiouine basin. The assessment reveals that the Tidili-Tiouine wadi features a vast, elongated watershed, with estimated perimeter and surface area of 287.09 and 1552.44 square kilometers, respectively. Examination of hypsometric and slope maps indicates that the flow along the Oued Tidili-Tiouine valley is directed towards the north of the basin. Regarding the basin's morphological parameters, they were instrumental in forming an understanding of flow and sedimentation patterns: areas of depression or concavity reduce flow velocity, thereby favoring deposition. Conversely, open slopes act as catalysts for water erosion. The outcomes of this characterization can be employed in hydrological modeling, aiding decision-makers in choosing interventions and actions for the development of flood-prone and erosion-prone areas. They provide a comprehensive overview of the Tidili-Tiouine wadi's behavior when peak flows, relative to given return periods, are exceeded.

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