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## Assessment of Hydrological Resource Management Using Remote Sensing (RS) and Geographic Information Systems (GIS); Wadi Sannur Valley, Beni-Suef, Egypt

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Watershed and sub-watershed need quantification analysis for channel network. To understand its hydrological situation. Detailed assessment of the drainage network and its characteristics have been done for Wadi Sannur, east Beni-Suef Governorate, Egypt. To understand its geological variations, topographic information and the tectonic processes for the watershed and sub-watershed. Remote Sensing (RS) and Geographical Information System (GIS) have been the main source for delineation and calculation of morphometric parameters of watershed. Methodology contains a Digital Elevation Model (DEM) was leveraged to visually explore the terrain's intricacies. By harnessing the capabilities of ArcGIS 10.8, a detailed analysis was conducted to quantify linear, areal, and relief properties. This multi-faceted approach allowed for a comprehensive understanding of the landscape's form and function. The Wadi Sannur watershed is spreading over an area of 4313 km2 with dendritic, parallel, and sub-dendritic drainage patterns. All drainage parameters, such as stream order, have been computed. Wadi Sannur basin is divided into 5 sub-watersheds. The mainstream has the highest stream order, the eighth order, with number of streams (Nu) about 206 and total stream length (Lu) about 71 km2. While the first Nu contains about 13717 and Lu 6036 km2. Wadi Sannur basin is about 112 km and has Bifurcation ratio (Rb) 2.06. Rb Values of the 5 sub-watersheds varies from 0.59 to 4.79. SW4 has the lowest Rb value clearly shows a high infiltration rate and rest of sub-watershed has much higher values ranging from 0.59 to 4.79. Drainage density (Dd) value is 2.54 km/km2, fells in the medium class which clearly indicates medium dense vegetation, gentle slope to steep slope morphology, with medium precipitation and less permeable. Drainage texture (Dt) is categorized into one class based on Dd values very fine (>8) so the Wadi Sannur shows very fine textures. Overland flow length (Lg) is 0.197 while all the other sub-watersheds values ranges from 0.19 to 0.20, which indicates the influence of a high structural disturbance, with low permeability, a high surface runoff with steep slopes to very steep slopes. The Wadi Sannur and sub-watersheds showing a well-developed stream network with mature geomorphic stage. Circularity ratio (Rc) is 0.23, whereas in the 5 sub-watersheds, the value ranges between 0.18 and 0.30. This Low Rc value implies an elongated basin shape. Elongation ratio (Re) is 0.60 and values of the 5 sub-watershed varies from 0.48 to 0.72, which indicates elongated basin shape, with high relief, and gentle to steep slope. Gradient ratio (Rg) is 6.92 while the rest of 5 sub-watershed range from 4.35 to 16.23. This study could be applied in any valley to determine the morphometric characteristics, which enables the identification of flood locations and policies for solving them.

**Keywords:** Hydrology and Geomorphometry - Flood Hazard Potential – DEM, GIS and Remote Sensing – Egypt - and ArcGIS.

### 1. Introduction

Determining flash flood, channel avulsion and erosion need well morphometric analysis due to the high reliefs or the moderate slopes (Chakraborty, 2023). Sub-basins prioritization is always essential in any ecosystem management and any planning on the watershed scales. Integration morphometry aspects, remote-sensing (RS), and geographic information system (GIS) help for basin evaluation (Abdo et al., 2023). Morphometrical analysis support planner, engineer, and decision maker for developing zones (Arefin et al., 2023).

For watershed management processing and plans, knowing the hydrological nature of rocks that within watershed is very important which could be led by morphometric analysis (P. Singh et al., 2014).

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The main pillar is the stream networks that show up structural, geological and hydrological setup. Knowing parameters such as topography, stream network, pattern, geology, and the geomorphological setup in watershed allow management planning for the conservation measures which studied by (Sreedevi et al., 2013). Applications of hydrological models solve many hydrology problems. These models could be developed by using geomorphological characteristics of the watershed. Regarding issues of hydrological setup which have a very near relationship with geology could be evaluated by morphometry models (Esper, 2008). Any morphometry study should use the main units considering water management resources. These main units are drainage basins, catchments, and sub-catchments (Moore et al., 1994) and (Rekha et al., 2011). In basin scales the main determinants or running water ecosystem is a morphometric parameters and climatic conditions (Frissel, 1986; Lotspeich & Platts, 1982). The quantitative analysis of watershed morphology helps large utilities in drainage basin evaluation, watershed prioritization for soil and water conservation, and the management of many natural resources. (Malik et al., 2011). Considering the watershed as ideal territorial unit because its morphometric characteristics controls all the surface runoff (Lima et al., 2011). Drainage factors which might be mentioned as; stream order, basin area, perimeter, length of drainage channels, time of concentration stream frequency, bifurcation ratio, drainage density, texture ratio, basin relief, and ruggedness number (Kumar et al., 2000; Nag & Chakraborthy, 2003). Parameters of the shape, size, and configuration of the basin have been analyzed by numerous researchers, who used the traditional approaches. From these scientists are (Agarwal, 1998; Biswas et al., 1999; Horton, 1945; Krishnamurthy & Srinivas, 1995; Narendra & Nageswara Rao, 2006; Smith, 1950; Srivastava & Mitra, 1995; Strahler, 1957). Emerging RS with GIS have overcome all problems found with conventional tools (Banerjee et al., 2015; S. K. Soni et al., 2013; Tripathi et al., 2013). Egypt is subdivided into four regions; each region consists of different geological parameters. Nile Delta, Western Desert, Eastern Desert, and the Sinai Peninsula. The valley of Wadi Sannur valley is located at the Eastern Desert in Egypt and eastern Beni-Suef Governorate as shown in next figure 1.

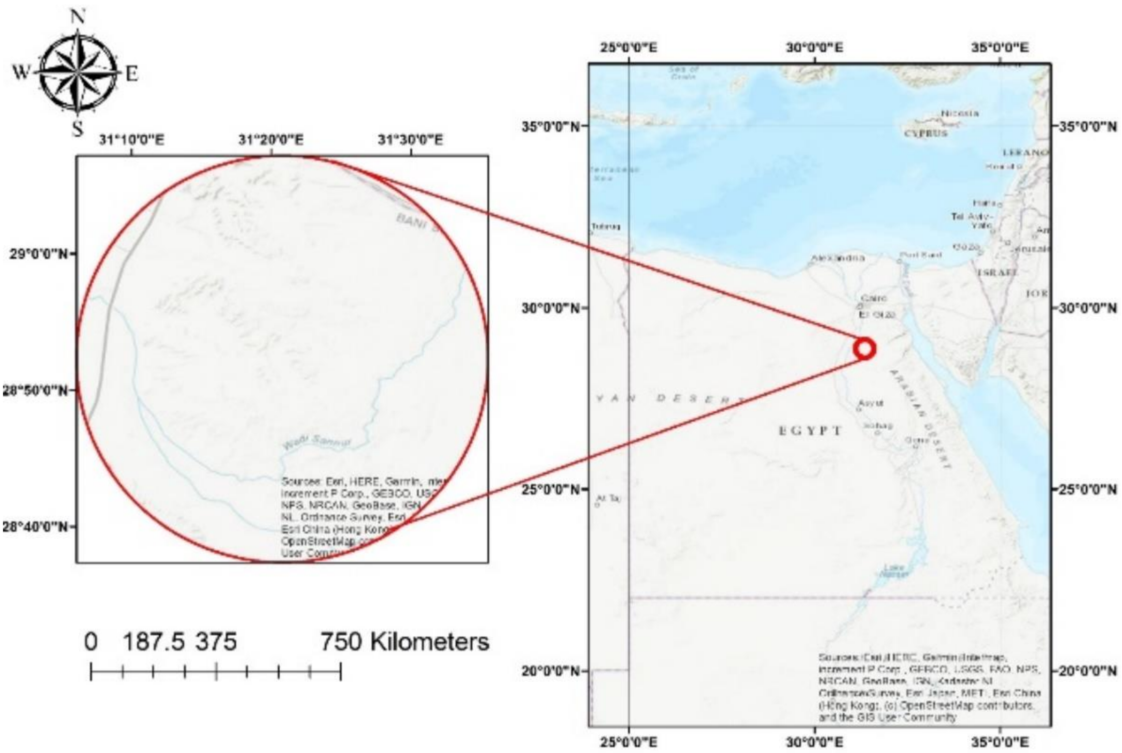



**Fig. 1. Location map of Wadi Sannur valley at the Eastern Desert in Egypt.**

Eastern Desert of Egypt contains limited availability of water. This zone rainfall different seasons, but still intense rainfall is recorded occasionally during winter causing flash floods (Aggour & Sadek MA, 2001). Basins drain towards the Red Sea at the east or the Nile Delta at the west. To make use of these hydrological water there is a must of making runoff controlling systems such like, dykes or dams. The soil temperature regime of the Wadi Sannur is defined as thermic and the soil moisture regime as torrid.

Natural hazards such like various factors, such as land shape, water flow, and human-made structures, influence the risk of flooding. Flood potentiality is determined by rainfall, rainfall aspects, water loss (infiltration and evaporation), drainage orders, drainage basins, drainage characteristics and drainage networks. The topographic attributes of the Wadi Sannur range from 21-763 meters above sea level. This study **aims** to make a quantitative analysis of drainage basins for development and regime that helps in Flood danger evaluation with any future development, using the most up-to-date data sets.

**Main objective** of present study is to detail morphometric parameters of Wadi Sannur watershed and sub-watersheds with identification of the basin geometry. The local economy heavily relies on agriculture, forestry, herbal resources, and basalt mining. Rainfall is the primary water source for agriculture, but groundwater resources are limited due to geological factors. Therefore, this research is crucial for effective watershed management and long-term sustainability. Quantitative analysis for drainage basin reveals hydrogeological behaviour that describes the morphometric analysis, which, determines the shape, size, and water-holding ability of the basin, as well as the rock's ability to allow water to pass through.

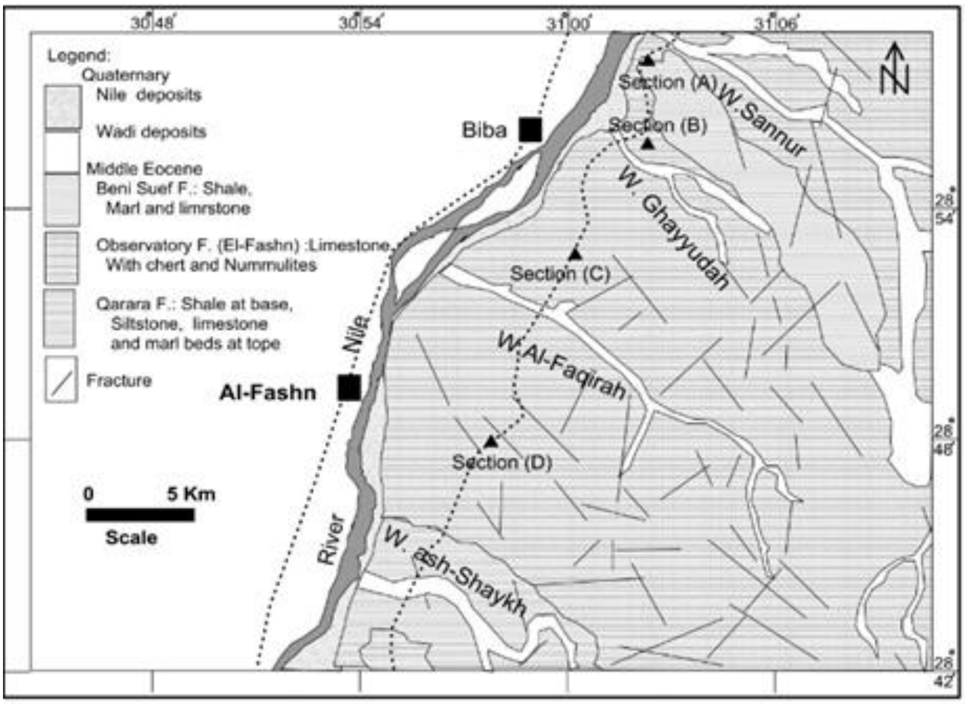



**Fig. 2. Geological map of Wadi Sannur valley at the Eastern Desert in Egypt after (P. Singh et al., 2014).**

## 2. Materials and Methods

Digital Elevation Model (DEM) was downloaded from http://earthexplorer.usgs.gov. All data was used in analysis. Drainage network was extracted from the DEM using ArcGIS 10.8 software. Stream network was extracted from DEM using satellite data. These data give us ability for calculating linear aspects, areal aspect, and relief aspect using suitable software.

The methodology is cited by (AIGR, 2021) and (S. Soni, 2017) for the complete process of morphometric analysis till the production. Download available freely data, and process data in the ArcGIS environment. Final maps were prepared and the tables for publication. Analysis of the morphometry with giving a brief way of the geomorphic attributes and hydrological behaviour of the Wadi Sannur. The absence of weather stations and the inaccessibility of certain areas due to harsh topography have led to remarkable advancements in remote sensing and GIS. Investigate and analysis of morphometric variables. Approaching for the evaluating of the drainage system. That means determining each of number, and length of the streams, drainage density, bifurcation ratio, slope, shape, and relief of the basin. Linear properties of drainage basin; meaning the number of streams (Nμ), Stream order (μ), total stream length (Lμ), mean steam length (Ƭμ), bifurcation ratio (Rb), stream length ratio (Rl), and hydrological storage coefficient (Rho) which have been considered. Areal aspects which contribute to; basin perimeter (P), basin area (A), form factor (F), circularity ratio (Rc), Lemiscate's K, elongation ratio (Re), infiltration number (If), length of overland flow (Lg), compactness coefficient (Cc), Constant of channel maintenance, (CCM), lineament density (LD), drainage density (DD), stream frequency (Fs) and texture ratio (Tu) are the selected parameters of areal aspects analysis of the basin. The relief aspects of the basin, which is related to the hydro-geomorphic behaviour, is being considered. This includes the total basin relief (H)., dissection index (DI), relief ratio (Rh), and average slope (Tan Ɵ) ruggedness number (Rn), Melton ruggedness number (MRn), aspect, and hypsometric integral (HI) (AIGR, 2021).

**Table 1. Illustrating linear aspects for Wadi Sannur Valley with sub-watersheds. Red shading indicates lowest value, while green shading indicates the highest value.**

| | Stream order (u) | Number of Streams for order (Nu) | Stream's length (Lu) | Mean stream's length (Lm) | Stream's length ratio (Rl) | Bifurcation ratio (Rb) | Rho coefficient (q) |
|---|---|---|---|---|---|---|---|
| SW1 | 1 | 978 | 431.2092 | 431.2092 | 1.931028121 | 2.098712446 | 0.920101334 |
| | 2 | 466 | 223.3055 | 111.65275 | 2.28062659 | 2.034934498 | 1.120737101 |
| | 3 | 229 | 97.9141 | 32.63803333 | 1.750360211 | 1.536912752 | 1.138880661 |
| | 4 | 149 | 55.9394 | 13.98485 | 3.310297895 | 2.98 | 1.11083822 |
| | 5 | 50 | 16.8986 | 3.37972 | 0.768866079 | 0.793650794 | 0.968771259 |
| | 6 | 63 | 21.9786 | 3.6631 | | | |
| SW2 | 1 | 782 | 333.8095 | 333.8095 | 2.046202527 | 2.3 | 0.889653272 |
| | 2 | 340 | 163.1361 | 81.56805 | 2.084593268 | 1.674876847 | 1.244624804 |
| | 3 | 203 | 78.258 | 26.086 | 2.089526734 | 1.970873786 | 1.06020322 |
| | 4 | 103 | 37.4525 | 9.363125 | 1.415502593 | 1.450704225 | 0.975734797 |
| | 5 | 71 | 26.4588 | 5.29176 | 1.305472774 | 1.543478261 | 0.845799262 |
| | 6 | 46 | 20.2676 | 3.377933333 | | | |
| SW3 | 1 | 3140 | 1446.7399 | 1446.7399 | 1.747988817 | 2.080848244 | 0.840036664 |
| | 2 | 1509 | 827.6597 | 413.82985 | 1.887905593 | 1.844743276 | 1.023397465 |
| | 3 | 818 | 438.401 | 146.1336667 | 2.160301495 | 1.902325581 | 1.135610811 |
| | 4 | 430 | 202.9351 | 50.733775 | 3.169538646 | 3.257575758 | 0.972974654 |
| | 5 | 132 | 64.0267 | 12.80534 | 1.135003811 | 1.015384615 | 1.117806784 |
| | 6 | 130 | 56.411 | 9.401833333 | 1.901549933 | 1.585365854 | 1.199439188 |
| | 7 | 82 | 29.6658 | 4.237971429 | | | |
| SW4 | 1 | 2141 | 954.3405 | 954.3405 | 1.97443563 | 2.149598394 | 0.918513726 |
| | 2 | 996 | 483.3485 | 241.67425 | 1.868342788 | 1.804347826 | 1.035467087 |
| | 3 | 552 | 258.7044 | 86.2348 | 2.359703122 | 2.147859922 | 1.098629896 |
| | 4 | 257 | 109.6343 | 27.408575 | 2.403249071 | 2.734042553 | 0.879009388 |
| | 5 | 94 | 45.6192 | 9.12384 | 1.130032846 | 1.220779221 | 0.925665204 |
| | 6 | 77 | 40.3698 | 6.7283 | 0.940129062 | 0.592307692 | 1.587230883 |
| | 7 | 130 | 42.9407 | 6.134385714 | | | |
| SW5 | 1 | 5218 | 2214.0477 | 2214.0477 | 2.07073987 | 2.175072947 | 0.952032378 |
| | 2 | 2399 | 1069.2061 | 534.60305 | 2.007360091 | 1.920736589 | 1.045099105 |
| | 3 | 1249 | 532.6429 | 177.5476333 | 1.94535938 | 1.957680251 | 0.993706393 |
| | 4 | 638 | 273.8018 | 68.45045 | 1.592132892 | 1.504716981 | 1.058094586 |
| | 5 | 424 | 171.9717 | 34.39434 | 1.274890968 | 1.228985507 | 1.03735232 |
| | 6 | 345 | 134.8913 | 22.48188333 | 4.129548843 | 4.791666667 | 0.861818889 |
| | 7 | 72 | 32.6649 | 4.666414286 | | | |
| SWmain | 1 | 1458 | 656.7551 | 656.7551 | 1.97982568 | 2.140969163 | 0.924733394 |
| | 2 | 681 | 331.7237 | 165.86185 | 2.056169649 | 1.870879121 | 1.099039284 |
| | 3 | 364 | 161.3309 | 53.77696667 | 2.280585516 | 2.068181818 | 1.102700689 |
| | 4 | 176 | 70.741 | 17.68525 | 19.52714826 | 16 | 1.220446766 |
| | 5 | 11 | 3.6227 | 0.72454 | 4.600253968 | 5.5 | 0.836409812 |
| | 6 | 2 | 0.7875 | 0.13125 | 0.5550074 | 0.666666667 | 0.8325111 |
| | 7 | 3 | 1.4189 | 0.2027 | 0.019825595 | 0.014563107 | 1.361357532 |
| | 8 | 206 | 71.5691 | 8.9461375 | | | |

**Table 2. Areal aspects for Wadi Sannur Valley with sub-watersheds.**

| Sub WaterShed | SW1 | SW2 | SW3 | SW4 | SW5 | Summation | Average |
|---|---|---|---|---|---|---|---|
| Basin Area Km2 (A) | 336.794 | 263.409 | 1144.18 | 762.682 | 1806.54 | 4313.605 | 862.721 |
| Basin Perimeter km (P) | 118.974 | 121.726 | 284.684 | 231.592 | 297.949 | 1054.925 | 210.985 |
| Basin Length km (Lb) | 28.668335 | 31.94935 | 58.63309 | 65.44349 | 83.67074 | 268.365008 | 53.6730016 |
| Basin Width | 11.747944 | 8.24458 | 19.514238 | 11.65406 | 21.59106 | 72.751877 | 14.5503754 |
| Total stream length Km (L) | 847.2454 | 659.3825 | 3065.83923 | 1934.957 | 4429.226 | 10936.65093 | 2187.330186 |
| Drainage density (Dd) | 2.51562 | 2.50326 | 2.67951 | 2.53704 | 2.45177 | 12.6872 | 2.53744 |
| Total number of streams (N) | 1935 | 1545 | 6241 | 4247 | 10345 | 24313 | 4862.6 |
| Stream's frequency (SF) | 5.745352 | 5.865403 | 5.454561 | 5.568507 | 5.726416 | 28.360239 | 5.6720478 |
| Drainage texture (Dt) | 14.453121 | 14.68263 | 14.615552 | 14.12753 | 14.03986 | 71.918683 | 14.3837366 |
| Length of overland flow (Lg) | 0.198758 | 0.19974 | 0.186601 | 0.19708 | 0.203934 | 0.986113 | 0.1972226 |
| Constant of channel maintenance (C) | 0.397516 | 0.399479 | 0.373203 | 0.39416 | 0.407869 | 1.972227 | 0.3944454 |
| Form factor (Ff) | 0.409788 | 0.258052 | 0.33282 | 0.178078 | 0.258048 | 1.436786 | 0.2873572 |
| Circul | 0.298848 | 0.223282 | 0.17732 | 0.178602 | 0.255596 | 1.133648 | 0.2267296 |
| A_by_314 | 107.259238 | 83.88822 | 364.388552 | 242.8924 | 575.3312 | 1373.759587 | 274.7519174 |
| 2rout_A_by | 20.7132 | 18.318 | 38.1779 | 31.1699 | 47.97 | 156.349 | 31.2698 |
| Elongation | 0.722511 | 0.573345 | 0.651132 | 0.476287 | 0.573319 | 2.996594 | 0.5993188 |
| Shape index (Sw) | 2.440285 | 3.875195 | 3.004631 | 5.615512 | 3.875249 | 18.810872 | 3.7621744 |
| Maximum elevation (H) | 298 | 324 | 654 | 740 | 628 | 2644 | 528.8 |
| Minimum elevation (h) | 69 | 185 | 194 | 197 | 118 | 763 | 152.6 |

**Table 3. Relief aspects for Wadi Sannur Valley with sub-watersheds.**

| | SW1 | SW2 | SW3 | SW4 | SW5 | Summation | Average |
|---|---|---|---|---|---|---|---|
| Relief (R) Km | 0.229 | 0.139 | 0.46 | 0.543 | 0.51 | 1.881 | 0.3762 |
| R_Ratio (Rr) | 0.007988 | 0.004350636 | 0.007845399 | 0.008297235 | 0.006095321 | 0.034576498 | 0.0069153 |
| Ruggedness number (Rn) | 0.576077 | 0.347953 | 1.232575 | 1.377613 | 1.250403 | 4.784621 | 0.9569242 |
| Absolute Relief (Ra) | 298 | 324 | 654 | 740 | 628 | 2644 | 528.8 |
| Dissection index (Di) | 0.768456 | 0.429012 | 0.703364 | 0.733784 | 0.812102 | 3.446718 | 0.6893436 |
| Elevation at the source (Es) | 298 | 324 | 654 | 740 | 628 | 2644 | 528.8 |
| Elevation at the Mouse (Em) | 69 | 185 | 194 | 197 | 118 | 763 | 152.6 |
| Gradient ratio (Rg) | 7.987907 | 4.350636 | 7.845399 | 8.297235 | 6.095321 | 34.576498 | 6.9152996 |
| Area power 0.5 | 18.352 | 16.2299 | 33.826 | 27.6167 | 42.5034 | 138.528 | 27.7056 |
| Melton ruggedness number (MRn) | 0.29424 | 0.312601 | 0.648265 | 0.732867 | 0.625224 | 2.613197 | 0.5226394 |

## 3. Results and discussions

### 3.1 Morphological parameters

These parameters included the linear aspects of drainage basin; Stream order (u), Number of Streams order (Nu). Also, Stream length (Lu), Mean stream length (Lm), Stream length ratio (Rl), Bifurcation ratio (Rb), and Rho coefficient (q). Areal aspects parameters such also were determined which includes; Basin Area (A), Basin Perimeter km (P), Basin Length km (Lb), Basin Width, Total stream length Km (L), Drainage density (Dd), Total number of streams (N), Stream frequency (SF), Drainage texture (Dt), Elongation ratio (Re), Length of overland flow (Lg), Form factor (Ff), Constant of channel maintenance (C), Circularity ratio (Rc), Shape index (Sw), Maximum elevation (H), and Minimum elevation (h). Areal aspect is representing the characteristics of the catchment area (S. Soni, 2017). Relief attributes specify the topographic configuration of the watershed and landform features. The relief aspects parameters were also calculated which included Relief (R), Ruggedness number (Rn), Relief Ratio, Absolute Relief (Ra), Dissection index (Di), Elevation at the source (Es), Elevation at the Mouse (Em), Gradient ratio (Rg), and Melton ruggedness number (MRn). The morphometric characteristics of the Wadi Sannur watershed and its sub-watersheds have been analyzed and explained.

### 3.1.1 Drainage pattern

Drainage pattern mainly define slope of drainage basin. It could be defined as the arrangement of the streams in a drainage system. Drainage patterns reflect controlling of structural or lithological factors for rocks beneath surface. Just three types of present drainage patterns that are discovered in Wadi Sannur and they are dendritic, parallel, and Sub-dendritic (as shown in figure 3). SW1 is dendritic. SW2, SW4, SW5, and mainstream are Parallel. SW3 is Sub-dendritic. Dendritic drainage and sub-dendritic patterns show exhibit a uniform soil with rock and homogenous. Parallel drainage pattern exhibits uniform slope, gentle, with less resistant bed rock of the streams in a drainage system. Drainage patterns.

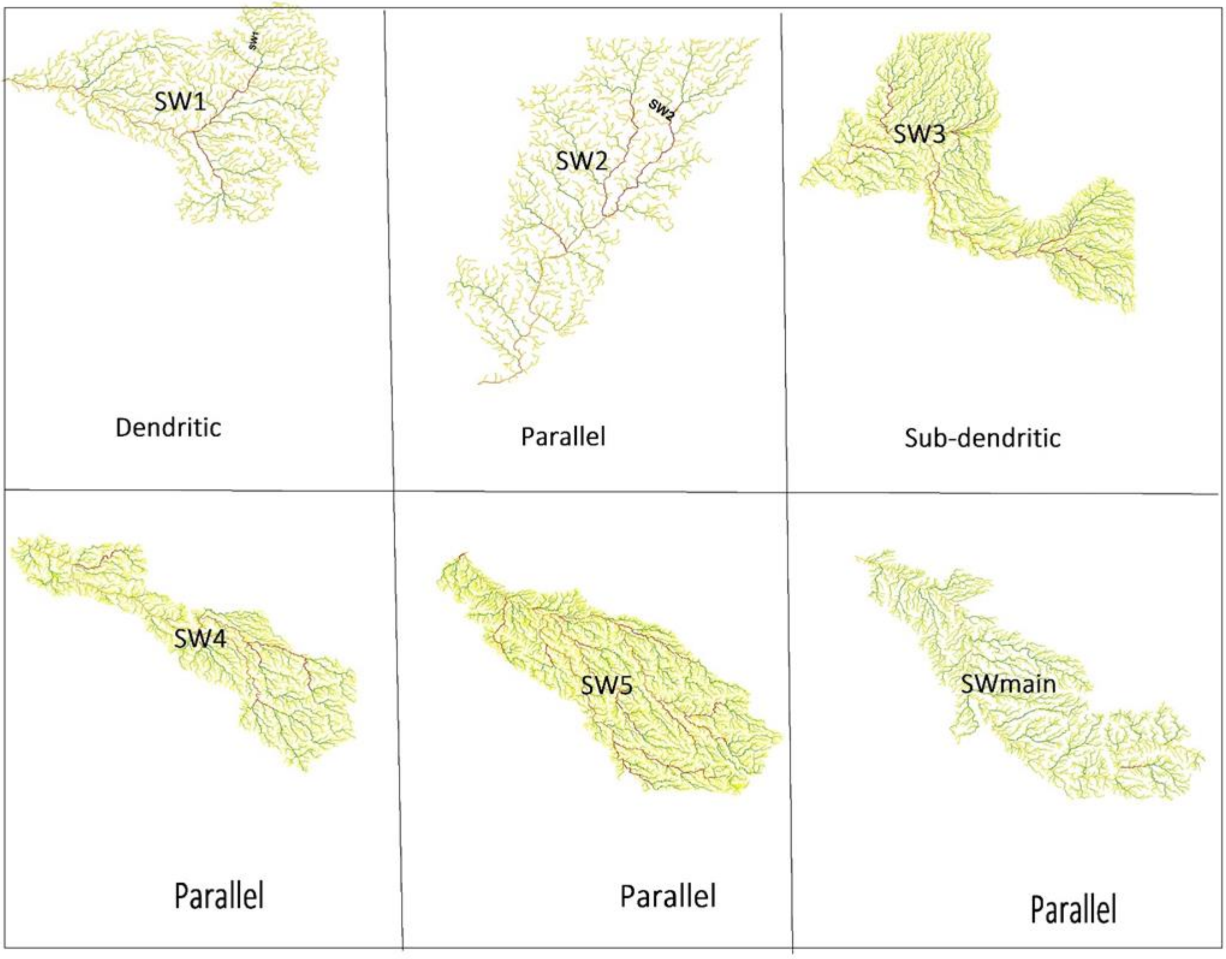



**Fig. 3. Primary drainage patterns determined in Wadi Sannur basin (dendritic, parallel, and Sub-dendritic).**

## 3.2 Linear aspects

### 3.2.1 Perimeter

The overall perimeter of Wadi Sannur Watershed is 1054.925 km while 5 sub-watersheds (SW) is illustrated in table 2, figures 3 and 4. Among the sub-watersheds SW5 with largest 297.949 km that covering the larger basin area of 1806.54 km2 however SW1 with little perimeter of 118.974 km and found in an area of 336.794 km2 of all. The watersheds and sub-watersheds of Wadi Sannur seems to be elongated to semi-circular and that due to perimeter increase as area increase.

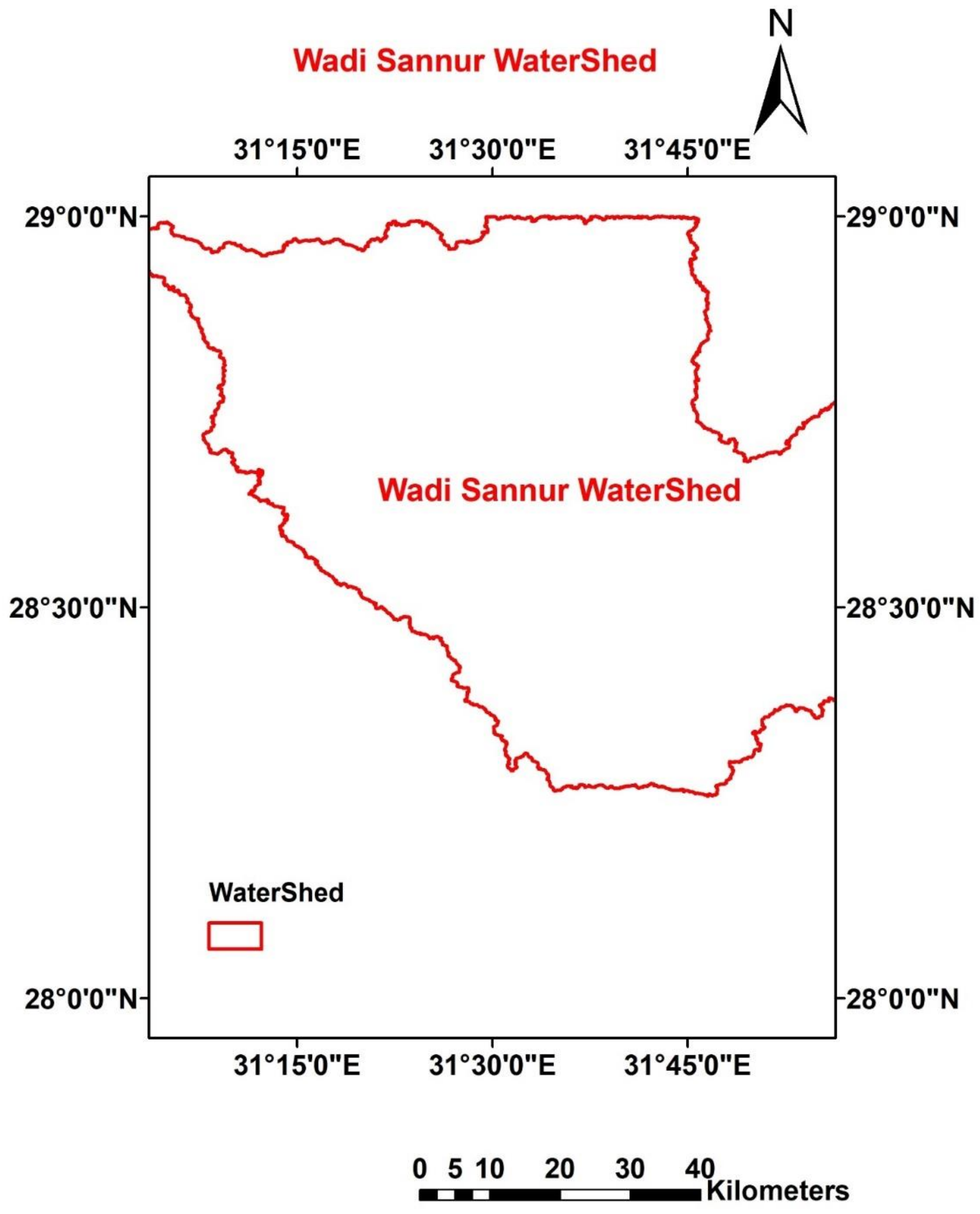



**Fig. 4. Wadi Sannur Watersheds.**

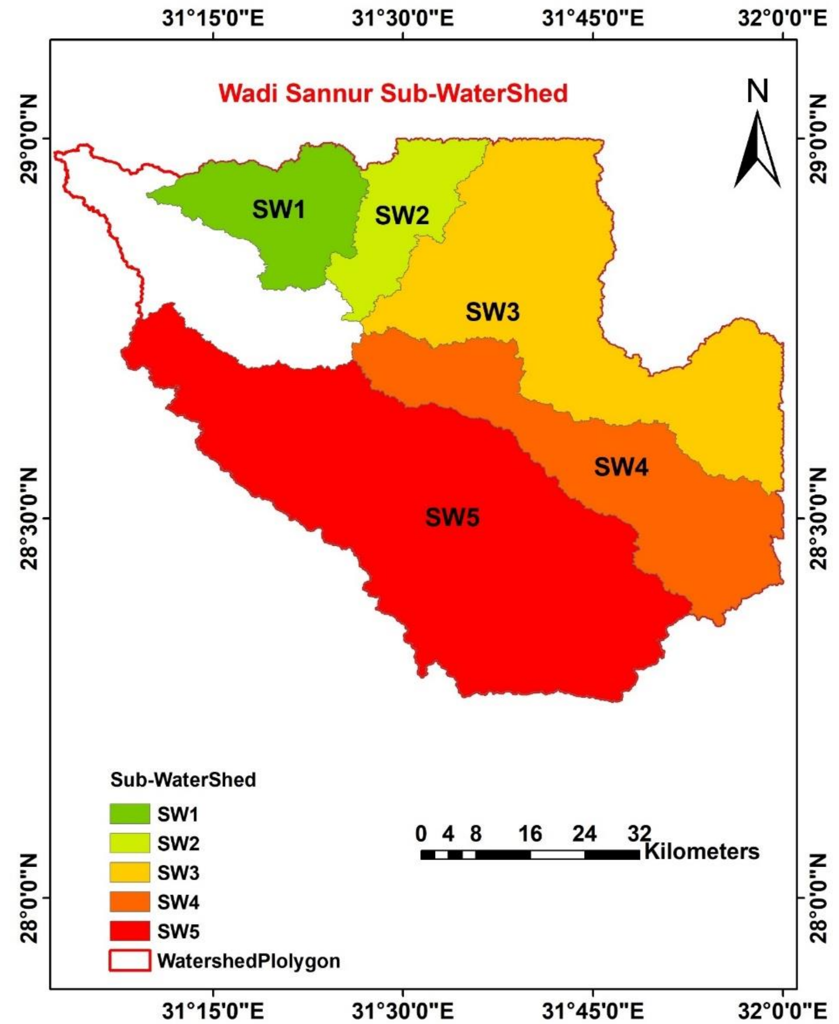



**Fig. 5. Wadi Sannur Sub-Watersheds (SW1, SW2, SW3, SW4, and SW5).**

### 3.2.2 Basin length (Lb)

Basin length could be characterized by being straight-line distance from the basin mouth till the point of outlet as (Horton 1932) illustrated. The basin length of Wadi Sannur is 112.4 km and the 5 SW is illustrated in table 2. All sub-watersheds are longer ones except SW1 (28.67 km). Usually, active correlation with the basin area is tending to head-ward the erosion.

### 3.2.3 Stream order (u)

Stream order plays a significant role in evaluating the drainage dynamics within a basin. We could be defined as the measuring of position for a stream in hierarchy of all other streams. (Horton, 1945; Leopold et al., 1964; Strahler, 1957) illustrated a method for numbering the streams. Smallest fingertip tributaries are defined as order number one or 1st. When two of the first order are met or joining; a channel segment of second order ($2^{nd}$) is formed and so on. Highest order streams are in the mouth. While lower order streams are in the highest points in elevations. Stream order exhibits possibility for runoff and are direct relation for the size of watershed. As shown in table 1 the study area is an eighth ($8^{th}$) order drainage basin having 27209 total number of streams, sprawl over 4313.605 km2 as shown in figure 6.

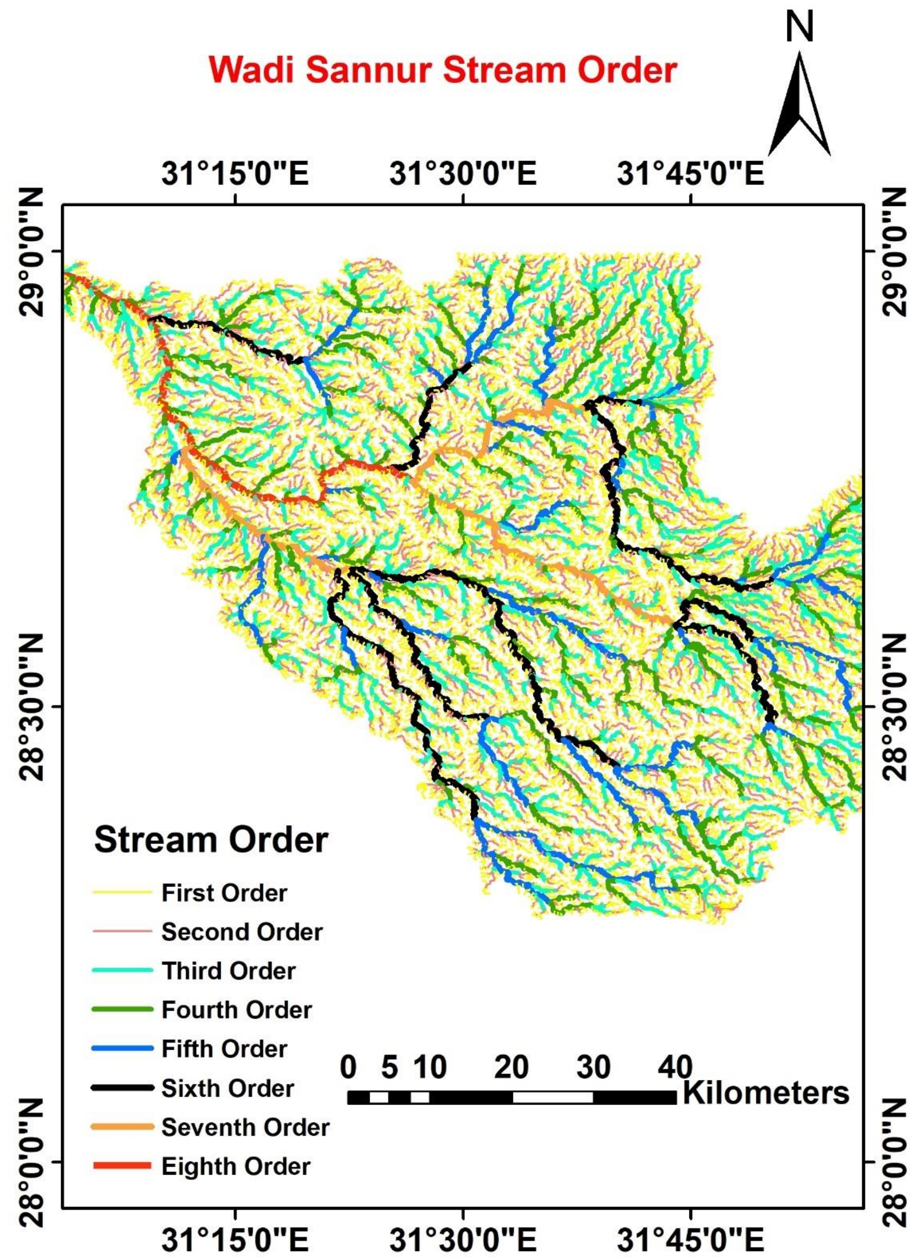



**Fig. 6. Map of Wadi Sannur stream order.**

**3.2.4 Stream number (Nu)**

It is defined as number of streams for each order in each watershed. As Law of streams order discussed by (Horton, 1945); Nu is inverse with geometric sequence against the stream order which describes homogeneous terrain material subjected to weathering (Nag & Lahiri, 2011). The highest stream number is 13717 for 1st stream order, while lowest stream number is 206 for 8st stream order as shown in table 1.

**3.2.5 Stream length (Lu)**

Mean and total stream the length for each order have been measured using GIS techniques and described in the Table 1. Showing enhancement for stream segment and surface runoff parameters. Stream length indicate the situation of the slopes.

So, if having short lengths so the slope usually high and short stream lengths indicate small slopes. Components of stream networs always described by the mean stream lengths according to (Strahler, 1957). Stream lengths maximum usually in the first order then decreases. But unnormal is clearly discovered in SW1 and SW4. This differentiation usually occurs because of the stream flow, slope, and rock types (as shown in figure 7), and topography (*Singh S, Singh MC (1997) Morphometric Analysis of Kanhar River Basin. National Geographical J. of Lndia, (43), 1:31-43*, n.d.; Thomas et al., 2010; Vittala et al., 2004).

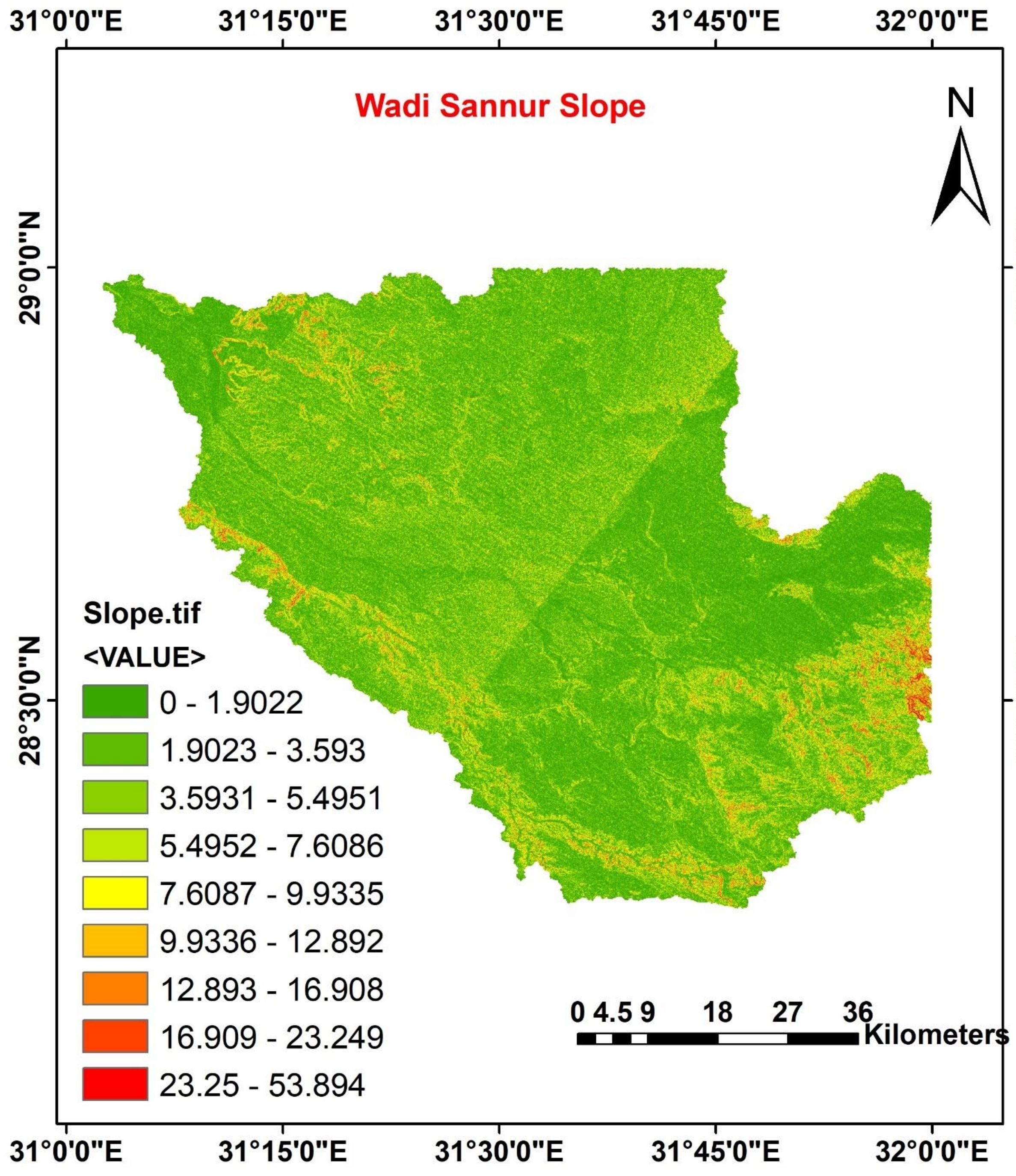



**Fig. 7. Wadi Sannur slope map.**

### 3.2.6. Bifurcation ratio (Rb)

It is defined as ratio of number of streams for given order relative to next higher order (Schumm, 1956). It measures stream network distribution (Mesa, 2006). Homogeneous rocks Rb is from 3.0 to 5.0 (*Morisawa M (1985) Geomorphology Texts Books: Rivers, Forms and Process. Chapter 5, Structural and Lithological Control*, n.d.) negligibly stream network (Nag, 1998; Strahler, 1964; Verstappen, 1995; Vittala et al., 2004). (Nag, 1998; Strahler, 1964; Verstappen, 1995; Vittala et al., 2004). Rb reflects the shape concerning the basin (Ghosh & Chhibber, 1984; Verstappen, 1983). Low Rb values reflects elongated basins, while circular basins have higher Rb values (Vinet & Zhedanov, 2011). Rb value of WADI SANNUR is 2.06 then value of 5 sub-watersheds varies from 0.59 to 4.79. SW4 has lowest Rb that reflects higher infiltration rate, while others of sub-watershed contain higher Rb values and ranging from 0.59 to 4.79 (Table 1).

### 3.2.7 Stream length ratio (Rl)

Stream length ratio measures the relative length of a stream compared to its immediately smaller tributary in a stream network. It can give indication about relative permeability for rock formation. (Horton, 1945) and for Each subsequent stream order within a watershed tends towards a direct geological sequence of increasing stream length as it moves towards higher-order rivers. The mean Rl of WADI SANNUR is 1.95 and varies for 5 SW from 0.77 to 4.13 (Table 1). Slopes' differentiation and topography differ indicate late youth stage for geomorphic.

### 3.2.8 Rho coefficient (Rho)

The Rho coefficient, as described by (Horton, 1945), is a measure of the storage capacity of a drainage network. It's calculated by dividing the ratio of stream lengths by the bifurcation ratio. For WADI SANNUR Rho are 1.03 and others of 5 SW are ranging from 0.84 to 1.59 exhibiting higher hydrologic storage especially in time of floods.

### 3.3. Areal aspects

### 3.3.1 Area

The Wadi Sannur catchment area are 4313.605 km2. SW2 is considered smallest of them with about (263.409 km2) whereas SW5 is the largest one with about (1806.54 km2) among the 5 sub-watersheds.

### 3.3.2. Drainage density (Dd)

Drainage density is the ratio of total stream length of all the orders per unit basin area (Horton, 1945). Dd is A quantitative assessment of terrain-related water flow (Chorley, 1969). Dd indicates infiltration capacity for land and for vegetation which is covering the catchment (Macka, 2001).The Dd depends on the climatic conditions and the vegetation (Moglen et al., 1998). It also depends on landscape properties like the soil and rock (Kelson & Wells, 1989) and relief (Oguchi, 1997). The Dd reflects groundwater potentiality for runoff and permeability. If low Dd results, so the areas of permeable subsoil material, low relief, and dense vegetation, (Nag, 1998). While if high Dd results, so mountainous relief, impermeable subsurface material, and sparse vegetation. Low Dd reflects coarse drainage texture, but high Dd leads to finer drainage texture. The WADI SANNUR is 2.54 km/km2, fells in the medium category which can indicates a gentle to a steep slope terrain, less permeable with medium precipitation, and medium dense vegetation. A table is value for 5 sub-watersheds is listed in Table 2.

### 3.3.3. Stream frequency (Sf)

It is numbers of streams per the unit area (Horton, 1945). The high stream frequency refers to a large surface runoff, A rocky, barren terrain with low water permeability, steeper ground surface, and a higher relief condition. While low Sf reflects a high permeable rock and a low relief. Sf of WADI SANNUR is 5.67 numbers per km2 while Sf of 5 SW vary from 5.87 to 5.45 indicating medium runoff.

### 3.3.4 Drainage texture (Dt)

The Drainage texture is described as product of Sf and Dd and also as a measure for relatively channel spacing in the fluvial-dissected terrain, that affected with infiltration capacity climate, vegetation, rainfall, lithology, soil type and stage of development (Smith, 1950). Vegetation's cover, its density, and its types usually plays serious part in the determination of the drainage texture (Kale & Gupta, 2001). Soft or fine texture is a result from soft weak rocks that is unprotected by vegetations. While coarse textures results from a massive and resistant rocks. As mentioned by (Dornkamp & King, 1971) textures of the rock are a result of climate and vegetation. So as a result, when having numerous drainage lines so we have impermeable areas than permeable areas. Drainage texture (Dt) in Wadi Sannur is categorized into one class which is very fine (>8). The WADI SANNUR displays very fine texture.

### 3.3.5 Length of overland flow (Lg)

It could be described as half of the reciprocal of drainage density. Also, could be described as length of water over the ground before it gets directly concentrated for main streams which effect the hydrologic and the physiographic development of drainage basin (Horton, 1945) and (Schumm, 1956). Study area of WADI SANNUR has Lg value of 0.197 while all the contained sub-watersheds values range between 0.19 to 0.20, as shown in Table 2, which reflects the significance of high steep to very steep slopes, structural disturbance, low permeability, and high surface runoff. The WADI SANNUR and sub-watersheds display a well-developed stream network and maturity of geomorphic stages.

**3.3.6 Constant of the channel maintenance (Cc)**

(Schumm, 1956) has used reverse of drainage density having dimensions of the length as a property termed constant of channel maintenance. Cc value of WADI SANNUR is 0.39 and Cc value of 5 sub-watersheds varies from 0.37 to 0.41. Higher values of Cc reveal a A lithological unit exhibiting strong homogeneity and high permeability, a higher infiltration rates, less dissection, moderate surface runoff, and watershed are away of influencing by structural parameters.

**3.3.7. Basin configuration**

Basin shape mainly contributes in floods intensity. Shape if circular is predicting a dangerous flood while the elongated predict a lower dangerous flood. Floods travel in a more rapidly way in round basins than in an elongated one.

**3.3.7.1 Form factor (Ff)**

It is a dimensionless ratio of area (A) of drainage basin to square of its maximum length (Lb) as mentioned by (Horton 1932). The Ff is a clear indicator for degree of erosion, the flood formation and its move, and transport abilities of the sediment cargo for a watershed. A form factor Ff of WADI SANNUR is 0.29 and that of 5 sub-watersheds as in (Table 2) which varies from 0.18 to 0.41. Ff varies from the 0 (for the highly elongated shapes) to unity 1 (the perfect circular shapes). Primary watershed with sub-watersheds show the lowest value of the Ff which reflects much elongation basin with a lower erosion and a sediment transport capacity, a flatter peak of low flow to the longer duration, and favors also Flooding is reduced as streams merge into the main river more gradually and over larger areas, allowing water to seep into the ground.

**3.3.7.2 Circularity ratio (Rc)**

According to (*Miller VC (1953) A Quantitative Geomorphic Study of Drainage Basin Characteristics in the Clinch Mountain Area, Virginia and Tennessee. Columbia University, New York (3)*, n.d.), it is the ratio of basin area (A) and area of a circle for same perimeter of basin. When it is equal to oneness, so basin shape exhibits a perfected circle. While if it is ranging between 0.4–0.5 so it is elongated and highly permeable homogeneous geologic materials. The WADI SANNUR has a circularity ration value 0.23, whereas in 5 sub-watersheds, the value between 0.18 and 0.30.

**3.3.7.3 Elongation ratio (Re)**

It is described as ratio of diameter of a circle for same area as basin to maximum basin length (Schumm, 1956). It is essential indicator for analyses of basin’s shape. Areas with higher Re have more infiltration cargo and have low runoff. A circular basin is more efficient at draining runoff water than an elongated basin (*Singh S, Singh MC (1997) Morphometric Analysis of Kanhar River Basin. National Geographical J. of Lndia, (43), 1:31-43*, n.d.). (Strahler, 1964) classified Re as: circular (0.9–1.0), oval (0.8–0.9), less elongated (0.7–0.8), elongated (0.5–0.7) and much elongation (<0.5). The Re of Wadi Sannur is 0.60 and values of 5 SW is ranging from 0.48 to 0.72.

**3.3.7.4 Shape index (Sw)**

It is a dimensionless entity and described as a reverse of the form factor. WADI SANNUR has a value of 3.76 and others of 5 sub-watersheds ranging 2.44–5.62. The higher the shape index the more basin elongation and the more the lower flood discharge times.

**3.4. Relief aspects**

**3.4.1 Basin relief (R)**

According to (Rao et al., 2011), calculation of R to exhibits locative variations are very important. Basin relief could be defined as maximum vertical distance between lowest and highest points of the basin. Basin relief is mainly dependable for stream gradient and also influences sediment volume transported and flood pattern (*Hadley RF, Schumm SA (1961) Sediment Sources and Drainage Basin Characteristics in Upper Cheyenne River Basin. US Geological Survey, USGS Water Supply Paper, 1531-B*, n.d.). Basin relief is essential understanding the uncovering characteristics of basin (Sreedevi et al., 2009). To define relief DEM and sub-DEM is shown in figures 7 and 8. The R value of Wadi Sannur is 0.38 km while rest of 5 sub-watersheds is illustrated in Table 3. R is a direct relation with the elevation as shown in figure 8.

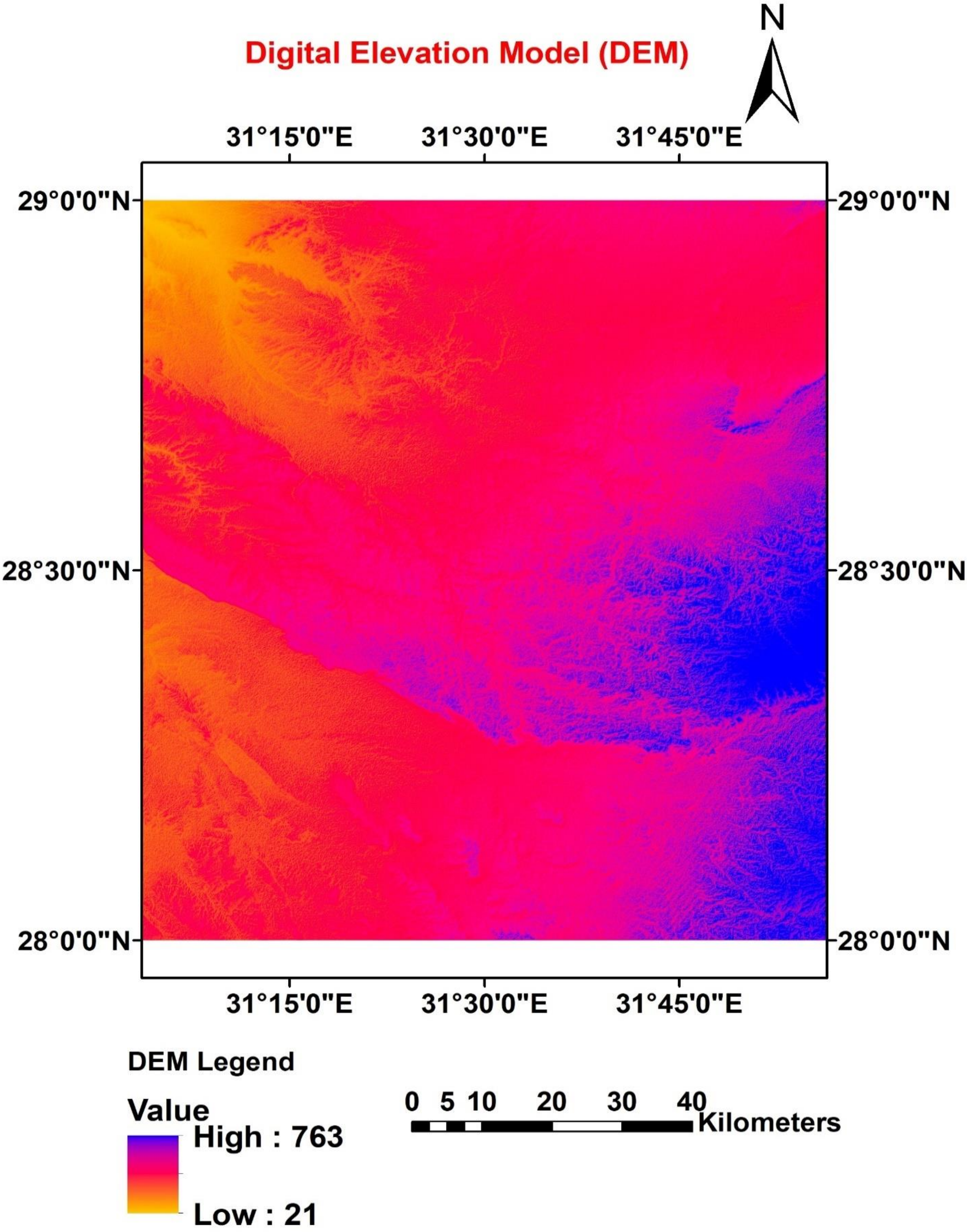



**Fig. 8. Wadi Sannur's DEM (Digital Elevation Model).**

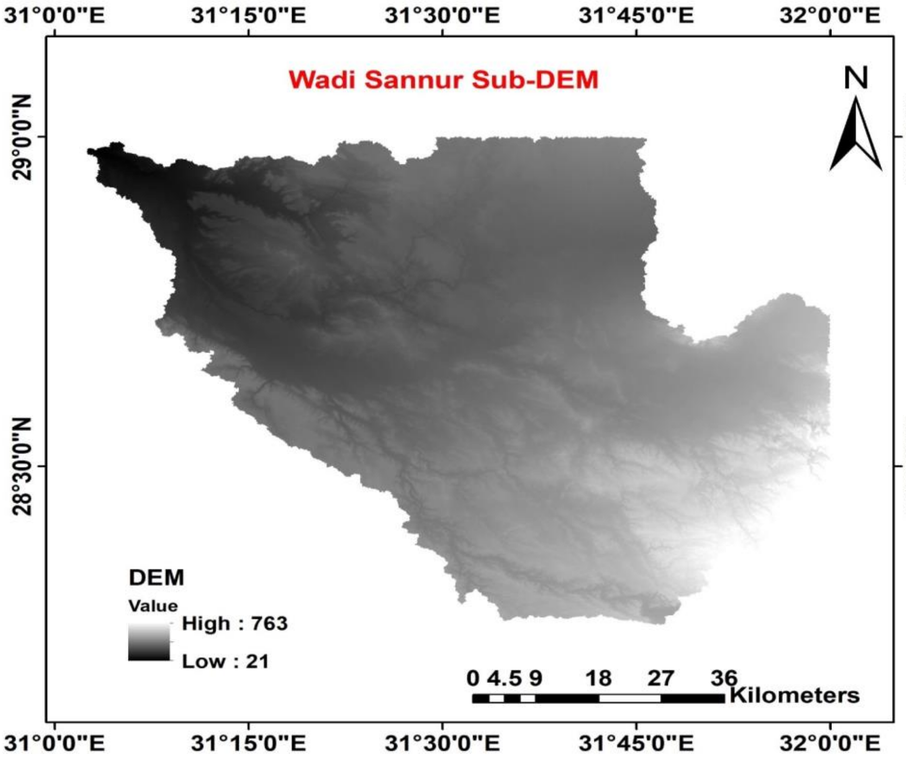



**Fig. 9. Sub-Digital Elevation Model (Sub-DEM) for the Wadi Sannur.**

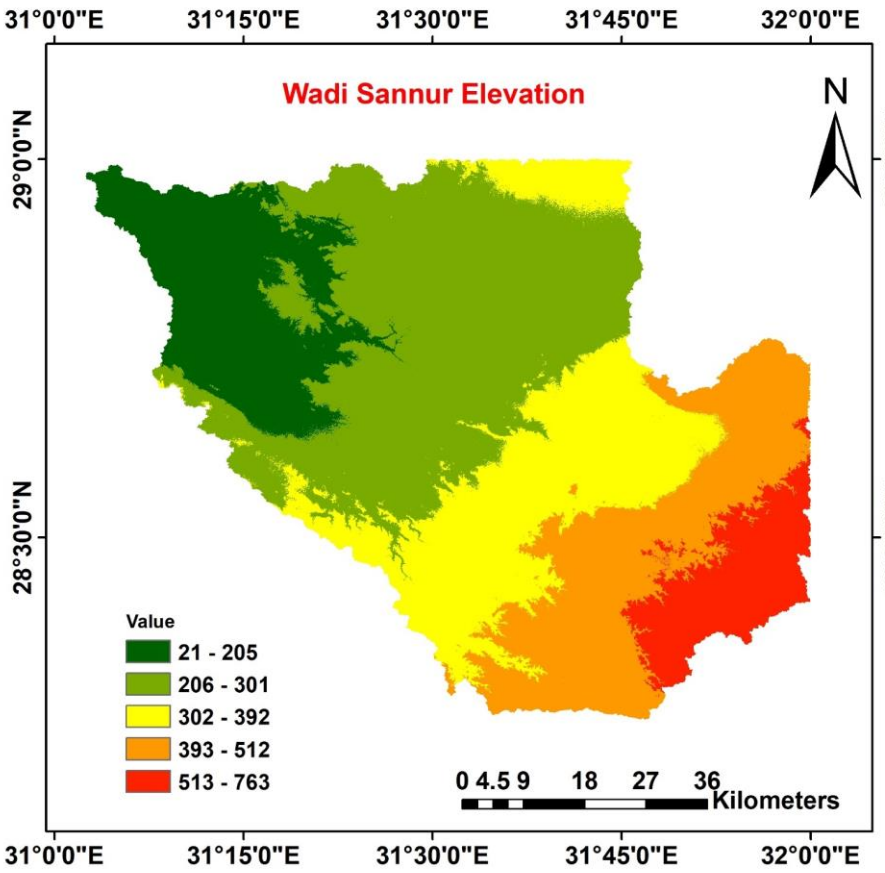



**Fig. 10. Elevation map for the Wadi Sannur.**

### 3.4.2 Relief ratio (Rr)

It is a dimensionless ratio for basin's relief, for the basin length, and active measure for the gradient aspects for watershed (Schumm, 1956). The Wadi Sannur Aspects and Hillshade is shown in figures 10 and 11. The Rr value of Wadi Sannur is 0.007 while values of 5 SW are given in Table 3. Values are in relatively low (<0.1) meaning a moderate slope.

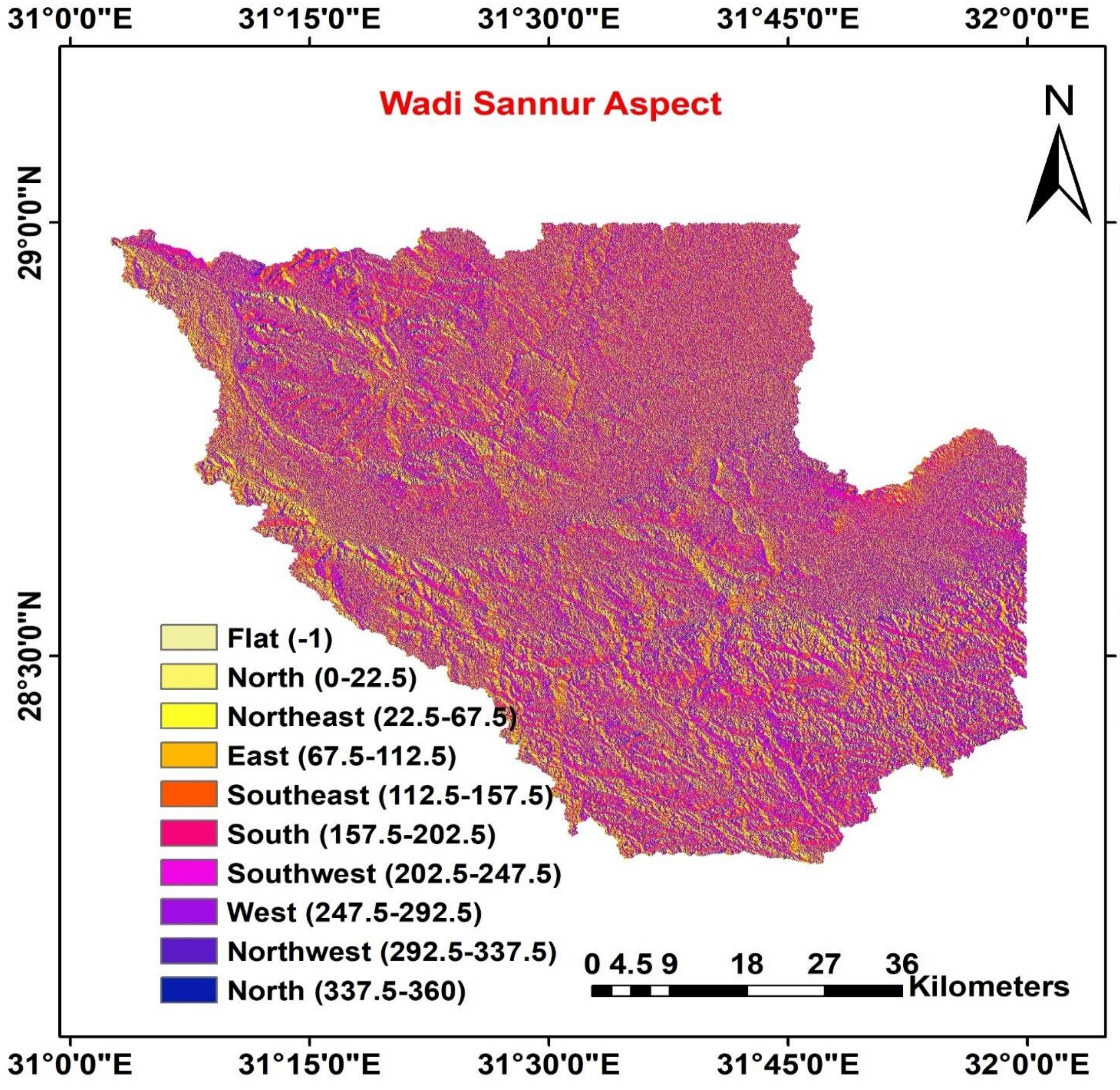
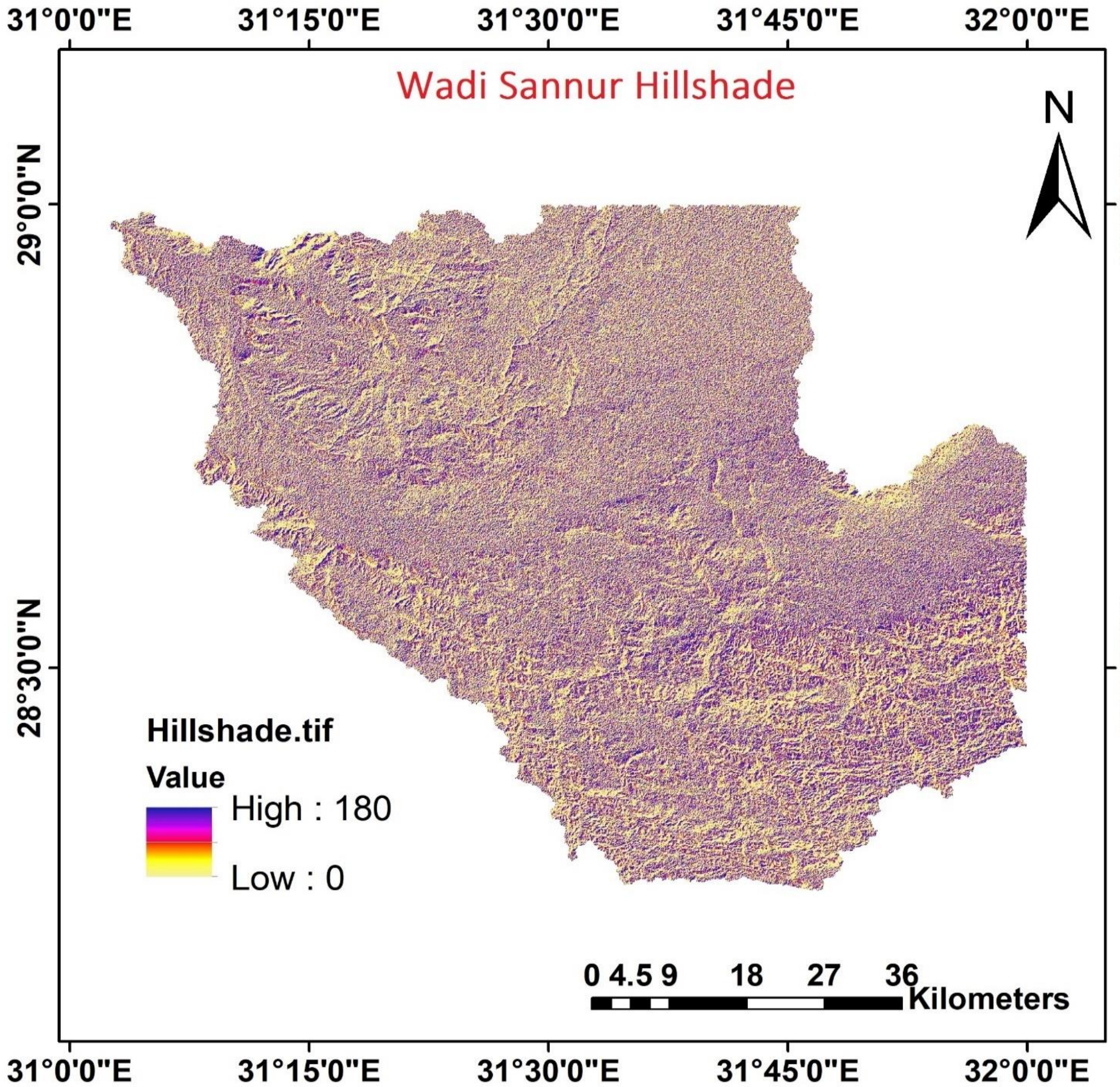



**Fig. 11. Aspect Elevation Model for the Wadi Sannur.**




**12. Hillshade Elevation Model for the Wadi Sannur.**

### 3.4.3 Ruggedness number (Rn)

known as the result of basin relief with drainage density (Strahler, 1958). When Rn value is low that exhibits less prone to the soil erosion and suggests having structural complexity in the companionship with a relief and the drainage density (Paretha & Paretha, 2011). The Rn value of Wadi Sannur is 0.96 and rest of 5 sub-watersheds ranges between 0.34 to 1.38.

### 3.4.4 Dissection index (Di)

Used for understanding the magnitude of dissection of terrain, morphometry, and physiographic attribute (Schumm, 1956; S. Singh & Dubey, 1994; Singh S (2000) Geomorphology. Ed. Allahabad: Prayag Pustak Bhawan, Pp 642, n.d.). value of Wadi Sannur is 0.69 while 5 sub-watersheds exhibit values 0.43–0.81. Lower value of Di implies old stage (*Deen M (1982) Geomorphology and Land Use: A Case Study of Mewat. Thesis (PhD). JNU, New Delhi*, n.d.) of basin and less degree of dissection.

### 3.4.5 Gradient ratio (Rg)

It affects channel slope from which the runoff volume could be evaluated (Sreedevi et al., 2009). Rg values are described in Table 3. Average Rg in Wadi Sannur is 6.92. The rest of 5 sub-watershed is ranging from 4.35 to 16.23. Low Rg values exhibits moderately relief terrain and mainstream flow through plateau.

### 3.4.6 Melton ruggedness number (MRn)

Depending on (Melton, 1965), Melton's Ruggedness numbers are a slope index which provides specialized illustration for relief ruggedness within watershed. The Wadi Sannur has MRn value 0.52 and 5 sub-watersheds range 0.29–0.73 which is a lower values indicating a normal flow in mainstream without more debris flow.

## 4. Conclusion

Channel network is done by quantitative analysis for watershed and sub-watershed. For understanding the hydrological behaviour, the detailed assessment of the drainage network and its parameters have been done for the Wadi Sannur valley, east Beni-Suef governorate, Egypt. Importance of GIS technique by providing high accuracy during mapping and the measurement of morphometric analysis is clearly presented. The study was done to understand its geological variations, topographic information and the structural processes of the watershed and sub-watershed. Remote Sensing (RS) and the Geographical Information System (GIS) have been the main source for delineation and calculation of morphometric parameters of watershed. RS and GIS have been used in all calculations. The Wadi Sannur watershed is spreading over an area of 4313 km2 with dendritic, parallel, and sub-dendritic drainage patterns. All drainage parameters, such as, stream order, have been computed. Wadi Sannur basin is divided into five sub-watersheds. All morphometric parameters have been computed using the Digital Elevation Model (DEM) and ArcGIS software including linear, areal, and relief parameters. There are about three different types of the drainage patterns that are found. They are dendritic, parallel, and Sub-dendritic. Dendritic drainage and sub-dendritic patterns show homogenous and a uniform w and rocks. The parallel drainage pattern is indicating gentle slope to uniform slope and less resistant bed rock. The overall perimeter of Wadi Sannur Watershed is 1054.925 km. SW5 exhibits the largest value 297.949 km that is covering largest basin area of 1806.54 km2 and SW1 is reflecting the smallest perimeter of 118.974 km and an area of 336.794 km2. The sub-watersheds are an elongated to a semi-circular basin. Basin length for Wadi Sannur is 112.4 km. The highest stream order results in eighth order, number of streams (Nu) is about 206, and total stream length (Lu) about 71 km2. While the first stream order (Nu) contains about 13717 and Lu about 6036 km2. Bifurcation ratio (Rb) value of Wadi Sannur is 2.06 and value of 5 sub-watersheds varies from 0.59 to 4.79. SW4 has the lower mean Rb values which is showing a high infiltration rates and other sub-watershed also has higher Rb which ranges from 0.59 to 4.79. Drainage density (Dd) value is about 2.54 km/km2, fells in medium classification which indicates a gentle to a steep slope terrain, less permeable with medium precipitation, and medium dense vegetation. Drainage texture (Dt) is categorized into one class based on the Dd values very fine (>8) so the Wadi Sannur shows very fine texture. The length of overland flow (Lg) is 0.197 while all the other sub-watersheds value ranges from 0.19 to 0.20, which indicates structural disturbance, with steep to very steep slopes and high surface of runoff, with low permeability. The Wadi Sannur and sub-watersheds show a well-developed kind of stream network and a mature geomorphic stage. Circularity ratio (Rc) is 0.23, whereas in the 5 sub-watersheds, the value ranges between 0.18 and 0.30. This Low Rc values exhibits an elongated basin shape. Elongation ratio (Re) is 0.60 and values of the 5 sub-watershed varies from 0.48 to 0.72, which indicates elongated basin with a high relief and a gentle to steep slope. Gradient ratio (Rg) is 6.92 while the rest of 5 sub-watershed range from 4.35 to 16.23. This Low Rg value exhibiting moderate relief terrain and mainstream flow through plateau. Wadi Sannur basin is an essential geomorphological unit which exhibits topographic and hydrological unit. Wadi Sannur basin characterization of watershed and its sub-watershed exhibits the main importance of the morphometric analysis in terrain depiction and any basin evolution. This study indicates that morphometric parameters provide amazing information about terrain characteristics and the hydrological behaviour of the watersheds. Integration between morphometric analysis in GIS and RS is beneficial in watershed management plan.

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# تقييم إدارة الموارد الهيدرولوجية باستخدام الاستشعار عن بعد ونظم المعلومات الجغرافية؛ وادي سنور، بني سويف، مصر

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تتطلب أحواض الصرف الفرعية والرئيسة تحليلًا كميًا لشبكة القنوات لفهم الوضع الهيدرولوجي. تم إجراء تقييم مفصل لشبكة الصرف ومميزاتها لوادي سنور، شرق محافظة بني سويف، مصر. لفهم التغيرات الجيولوجية، تم دراسة المعلومات الطبوغرافية والعمليات التكتونية للحوض الفرعي والرئيسي. اعتمدت الدراسة على تقنيات الاستشعار عن بعد ونظم المعلومات الجغرافية لتحديد حدود الحوض وحساب المعاملات الشكلية. تم استخدام نموذج ارتفاع رقمي (DEM) لتحليل تضاريس المنطقة بدقة باستخدام برنامج ArcGIS 10.8. تم تحديد الخصائص الخطية والمساحية والإرتفاعية للحوض. يمتد حوض وادي سنور على مساحة 4313 كم² بنمط صرف دندريتي ومتوازي وشبه دندريتي. تم حساب جميع معاملات الصرف، مثل رتبة المجاري المائية. ينقسم حوض وادي سنور إلى 5 أحواض فرعية. يمتلك المجرى الرئيسي أعلى رتبة، وهي الرتبة الثامنة، مع عدد مجاري مائية (Nu) حوالي 206 وطول مجاري مائية إجمالي (Lu) حوالي 71 كم². بينما يحتوي الرتبة الأولى على حوالي 13717 و 6036 كم². يبلغ طول حوض وادي سنور حوالي 112 كم ونسبة التفرع 2.06 (Rb). تتنوع قيم Rb للأحواض الفرعية الخمسة من 0.59 إلى 4.79. يظهر الحوض الفرعي الرابع (SW4) أقل قيمة لـ Rb، مما يشير إلى معدل تسرب مرتفع، بينما تظهر بقية الأحواض الفرعية قيمًا أعلى تتراوح من 0.59 إلى 4.79. تبلغ قيمة كثافة الصرف 2.54 (Dd) كم/كم²، مما يشير إلى كثافة نباتية متوسطة، وميل أرضي معتدل إلى شديد، وهطول أمطار متوسط ونفاذية منخفضة. يتم تصنيف نسيج الصرف (Dt) إلى فئة واحدة بناءً على قيم Dd، وهي دقيقة جدًا (>8)، مما يدل على أن وادي سنور يتميز بنسيج دقيق جدًا. يبلغ طول التدفق السطحي 0.197 (Lg)، بينما تتراوح قيم الأحواض الفرعية الأخرى من 0.19 إلى 0.20، مما يشير إلى تأثير اضطراب هيكلي عالٍ، ونفاذية منخفضة، وتدفق سطحي مرتفع، وميل أرضي شديد إلى شديد جدًا. يظهر وادي سنور والأحواض الفرعية شبكة مجاري مائية متطورة مع مرحلة جيومورفية ناضجة. تبلغ نسبة الدائرية 0.23 (Rc)، بينما تتراوح القيمة في الأحواض الفرعية الخمسة بين 0.18 و 0.30. تشير قيمة Rc المنخفضة إلى شكل حوض ممدود. تبلغ نسبة الاستطالة 0.60 (Re) وتتراوح قيم الأحواض الفرعية الخمسة من 0.48 إلى 0.72، مما يشير إلى شكل حوض ممدود، مع ارتياح مرتفع، وميل أرضي معتدل إلى شديد. تبلغ نسبة الانحدار 6.92 (Rg) بينما تتراوح بقية الأحواض الفرعية الخمسة من 4.35 إلى 16.23. يمكن تطبيق هذه الدراسة على أي وادي لتحديد الخصائص الشكلية، مما يمكّن من تحديد مواقع الفيضانات ووضع سياسات لحله.