



## Digital Terrain Characterization of Nilona Micro Watershed of Darwha Block of Maharashtra

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### Authors' contributions

*This work was carried out in collaboration among all authors. Author RR designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors AD and SC managed the analyses of the study and the literature searches. All authors read and approved the final manuscript.*

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### ABSTRACT

Watershed characterization is the first step in the sustainable management of watershed resources. Morphometric analysis of a watershed using Digital Elevation Model (DEM) provides a quantitative description of the drainage system which is an important aspect of the characterization of watersheds. The study was conducted in Nilona micro-watershed covering an area of 1297.35 ha in Darwha tehsil of Yavatmal district, Maharashtra. The terrain attributes and drainage configuration were derived from the Cartosat-1 data, 10m resolution Digital Terrain Model (DTM) using ArcGIS. Surface soil samples of 118 locations were collected from grid points located at regular interval of 325 m. The digital terrain analysis showed that slope varies from 0 to 45.9 percent, with a mean value of 4.5%. Most of the area of Nilona micro-watershed was classified as gentle sloping. Profile curvature varies from -5.1 to 4.6 m m<sup>-1</sup>, respectively indicating the coexistence of erosive as well

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as depositional landforms. Overall, the study documents the utility of site-specific modeling and geo-statistical interpolation based predictive mapping for watershed planning.

*Keywords: Morphometric; nilona micro-watershed; geo-statistical; digital terrain model.*

## 1. INTRODUCTION

The watersheds are natural hydrological entities that cover a specific aerial expanse of land surface from which the rainfall runoff flows to a defined drain, channel, stream or river at any particular point. The terms region, basin, catchment, watershed, etc. are widely used to denote hydrological units. In the last two decades, watershed management has gained the top most priority in water resources sector. Implementation of any water management measure requires a suitable hydrological unit.

Watershed delineation is one of the most commonly performed activities in hydrologic and environmental analyses. Digital elevation models (DEM) provide good terrain representation from which the watersheds can be derived automatically using GIS technology. The techniques for automated watershed delineation have been available since mid-eighties and have been implemented in various GIS systems and custom applications [1]. In general, the traditional approach in automated watershed delineation required high-end GIS and often resulted in long processing time that varied with respect to the location of the point of interest [2]. Use of digital terrain model has the advantage that the result is independent of human decisions bias and being less time-consuming. The accuracy of the results depends on both quality and type of digital terrain model (DTM) used.

The information generated during the study can be replicated in different watersheds representing similar climate, geology and physiography, landforms and soils. The data is available in spatial and digital format so that the land resources can be monitored on a regular basis. Similarly, this information can be utilized to prepare water management plan for the area. The study carried out for the watershed level, however, cannot be utilized for individual parcel of land due to scale limitation.

## 2. MATERIALS AND METHODS

### 2.1 Location of Study Area

The study area located between 20° 15' 43" to 20° 17' 39" N latitude and 77° 38' 41" to 77° 41'

10" E longitude, covering an area of 1297.35 ha in Darwha tehsil of Yavatmal district, Maharashtra (Fig 1). The elevation of the area ranges from 360 to 467 m above MSL. The study area falls under North Deccan (Maharashtra) Plateau and is agro-climatically placed under hot moist to semi-arid eco-sub-region.

### 2.2 Climate

The climate of the area is subtropical, dry sub-humid with well-expressed summer (March-May), rainy season (June-October) and winter season (November-February). The mean maximum temperature varies from 33 °C to 46 °C in summer season, mean daily minimum temperature is 13 °C to 15 °C with a mean annual temperature of 29 °C. The climate data was obtained from Agrometeorological research station, Nagpur.

### 2.3 Site Delineation and Characteristics

Nilona micro watershed was delineated and 118 surface soil samples was collected from grid points located at regular interval of 325 m. The site characteristics such as landform, location, slope, runoff, drainage, erosion, stoniness, land use and natural vegetation were studied.

### 2.4 Digital Terrain Analysis

#### 2.4.1 Digital elevation model

Cartosat-1 stereo pair data were processed to generate the digital terrain model (DTM) of 10 m spatial resolution using rigorous math model (Toutin's Model) [3] In the model, Ortho Engine of Geomatica version 14.0 was used to generate DTM following the sequence of steps namely, projection setup, sensor data reading, and collection of GCPs (Ground Control Points) and tie points, block adjustment, model computation (Satellite Math Model), epipolar image generation and digital surface model (DSM) extraction. Balancing algorithm was applied to obtain the seamless mosaic DSM height. Filtering was done to convert bare earth model i.e. DSM to DTM (Digital Terrain Model). Editing was done to smooth out the irregularities and

create a quality output. The RMS statistics report (X RMS: 0.98 and Y RMS: 0.93) was also generated to evaluate the accuracy of the DTM output.

DTM so generated, was subjected to a series of hydro-enforcement process including reconditioning, sinks and pit removal, flat and level water bodies, flat and level bank to bank and gradient smoothening by DAT/EM and Arc Hydro tool. This is essentially needed to enrich the quality of the hydrological output such as slope, contour and drainage. The secondary attributes such as Topographic Wetness Index, Stream Power Index and Sediment transport Index. This altogether needed to improve the accuracy of landform mapping. The terrain attributes were derived from the 10m resolution DTM using ArcGIS version 10.2.2. The terrain variables employed in this study are: elevation (m, above mean sea level), slope (percentage), contour (10m interval), profile curvature ( $m\ m^{-1}$ ) and drainage (600 stream cell count).

#### 2.4.2 Terrain characterization: primary attributes and secondary attributes

Primary attributes are derived directly from the DEM. The slope, aspect, plan and profile curvature primary attributes were used to calculate secondary attributes such as Topographic Wetness Index, Stream Power Index and Sediment transport Index.

#### 2.4.3 Formula used for calculating secondary attributes

##### • Stream Power Index (SPI):

Mathematical formula:  $SPI = \ln(DA_i * \tan(G_i))$   
where SPI is the stream power index at gridcell i, DA is the upstream drainage area (flow accumulation at gridcell i multiplied by gridcell area), and G is the slope at a grid cell i in radians  
Formula in GIS:  $SPI = \ln("Flow\ Accumulation" + 0.001) * ("Slope" / 100) + 0.001$

##### • Compound Topographic Index (CTI):

Mathematical formula:  $CTI = \ln[\alpha / \tan \beta]$   
where:  $\alpha$  represents the catchment area per pixel  
 $\beta$  refers to the slope, in degrees  
Formula in GIS :  $CTI = \ln(("Flow\ Accumulation" + 0.001) / ("Slope" / 100) + 0.001)$

##### • Sediment Transport Index (STI):

Mathematical formula:  $STI = (m + 1) * (A_s / 22.13)^m * \sin(B / 0.0896)^n$

Where,  $A_s$  is the specific catchment area (i.e., the upslope contributing area per unit contour length) estimated using one of the available flow accumulation algorithms in the Hydrology toolbox;  $B$  is the local slope gradient in degrees; the contributing area exponent,  $m$ , is usually set to 0.4 and the slope exponent,  $n$ , is usually set to 1.4

Formula in GIS:

Power ("Flow Accumulation"/22.13,0.6) \*Power (Sin("Slope"/0.0896),1.3)

### 3. RESULTS AND DISCUSSION

#### 3.1 Terrain Characterization

Topographic attributes can be divided into primary (Table 1) and secondary (or compound) attributes. Primary attributes are directly calculated from elevation data and include variables such as elevation and slope. Compound attributes involve combinations of the primary attributes and are indices that describe or characterize the spatial variability of specific processes occurring in the landscape such as soil water content distribution or the potential for sheet erosion.

The descriptive statistics of terrain parameters are presented in Table no. 2. The highest elevation in the micro-watershed is 467 m, exists in the southwestern parts of the micro-watershed, which induces highest runoff and thus, less possibility for infiltration of rain water and the lowest elevation is 360 m. Similarly, Patil et al. [4] reported highest elevation showed greater runoff due to summit position of hill slope and shoulder while, foot slope showed lower runoff. (Fig. 2)

The aspect map is a very important parameter for understanding the impact of sun on the area's local climate. In most cases a west-facing slope will be warmer than an east-facing slope, especially in the afternoon. Aspect has major effects on vegetation distribution. The aspect map of the Nilona micro-watershed was derived from Cartosat-1 DEM and represents the compass direction of the aspect (Fig. 3). The result shows a high percentage of east-facing slopes. These slopes have relatively higher soil moisture content and moderate vegetation compared to west facing slope of the micro-watershed. The results are in accordance with Nagalakshmi and Pakrasi [5] and George and Vayia [6] who classified slope characters into

different classes and reported higher moisture content in east facing slopes than west facing slopes.

The slope map of the study micro-watershed was grouped into five classes. 0% - 3% (flat or almost flat), 3% - 8% (gently sloping), 8% - 15% (sloping), 15% - 30% (moderately steep) and 30% - 50% (steep) [7] (Fig. 4). The slope varies from 0 to 45.9 percent, with a mean value of 4.5%. Most of the area of Nilona micro-watershed was classified as gently sloping. Gentle slopes were designated in the “excellent” category for groundwater management as the nearly flat terrain is favorable for more infiltration. Moderate slopes are also considered “good” due to slightly undulating topography which gives maximum percolation or partial runoff. The “steep” areas, which has high surface runoff and least amount of soil infiltration regarded as good locations for construction of check dams for water harvesting or infiltration ponds for groundwater recharge [8].

Slope is a crucial parameter which directly controls the balance between runoff response and infiltration rates of a terrain. High runoff generated in higher slope regions results in less infiltration. This factor significantly controls the development of aquifers. (Fig. 4).

Profile curvature varies from -5.1 to 4.6 m m<sup>-1</sup>, respectively indicates the presence of erosive as well as depositional landforms within the DTM scene (Fig. 5). The mean profile curvature indicates the dominance of erosive features over the depositional one. The other important secondary terrain parameters are also derived to characterize the terrain. The profile curvature of Udhakamandalam also exhibited dominated erosion factors than deposition factors as reported by Nagalakshmi and Pakrasi [5].

The secondary attributes such as topographic wetness index (CTI) ranged from -2.2 to 15.9, as an indicator of the spatial distribution of soil water content and soil water drainage (Fig. 6). The stream power index or its derivatives which ranges from -13.8 to 3.1, could be used to identify places where soil conservation measures can be taken to reduce the erosive effects of surface runoff (Fig. 7) and the ranges of sediment transport index varies from 0.0 to 104.1 was used to identify the spatial pattern of erosion/deposition. Similar attributes are explained by Mutasem et al. [9] in Malaysia; Gabrecht and Martz [1] Florinsky and Kuryakova [10].

**Table 1. Primary topographic attributes**

Sr no	Attribute	Definition	Hydrologic significance
1	Altitude	Elevation	Climate, vegetation type, potential energy
2	Aspect	Slope azimuth	Solar irradiation
3	Slope	Gradient	Overland and subsurface flow velocity and runoff rate
4	Plan	Contour curvature	Converging/ diverging flow, soil water content
5	Profile curvature	Slope profile curvature	Flow acceleration, erosion/ deposition rate

**Table 2. Statistical analysis of terrain attributes**

Terrain parameters						
Primary attributes (m)						
Sr no		Minimum	Maximum	Mean	SD	CV
1	DEM	360.0	467.0	406.7	19.6	4.82
2	Slope	0.0	45.9	4.5	6.2	137.80
3	Aspect	-1.0	358.3	129.9	116.1	89.35
4	Plan	-4.8	4.6	0.0	0.7	-3400
5	Profile Curvature	-5.1	4.5	0.0	0.8	-1000
Secondary attributes						
6	Topographic Wetness Index	-2.2	15.9	5.4	4.3	79.14
7	Stream Power Index	-13.8	3.1	-7.0	4.3	-61.49
8	Sediment transport Index	0.0	104.1	3.7	6.7	179.89

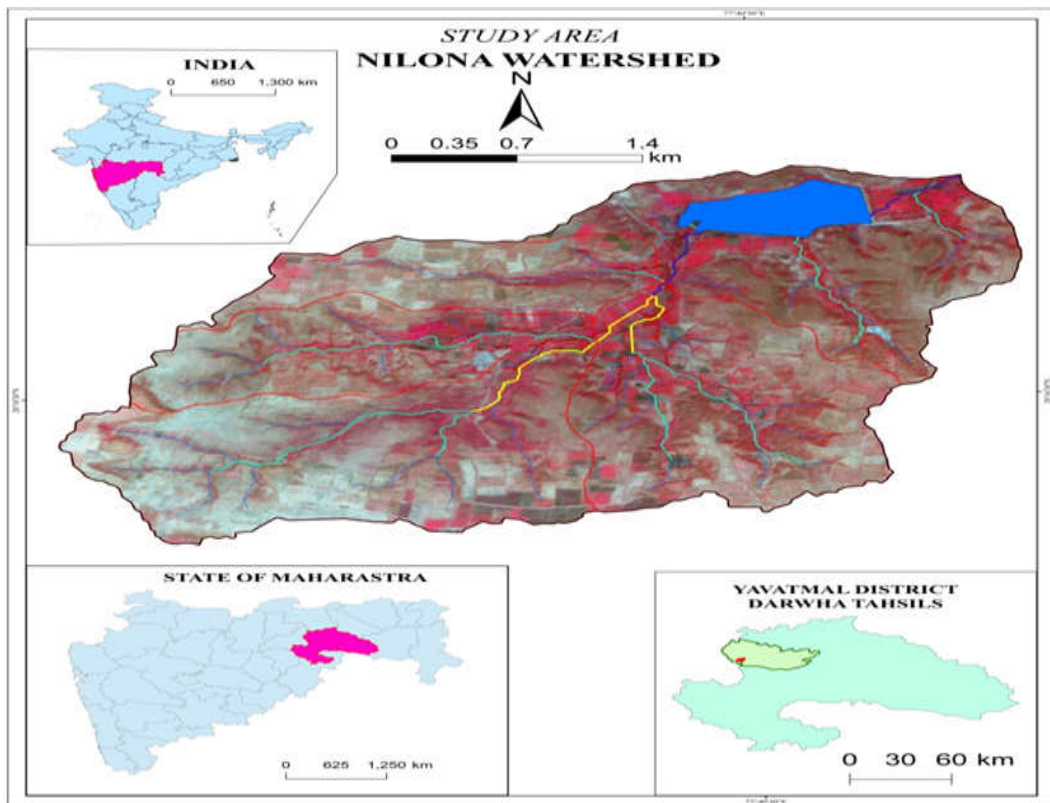


Fig. 1. Location map of Nilona microwatershed, Darwha block, Yavatmal district

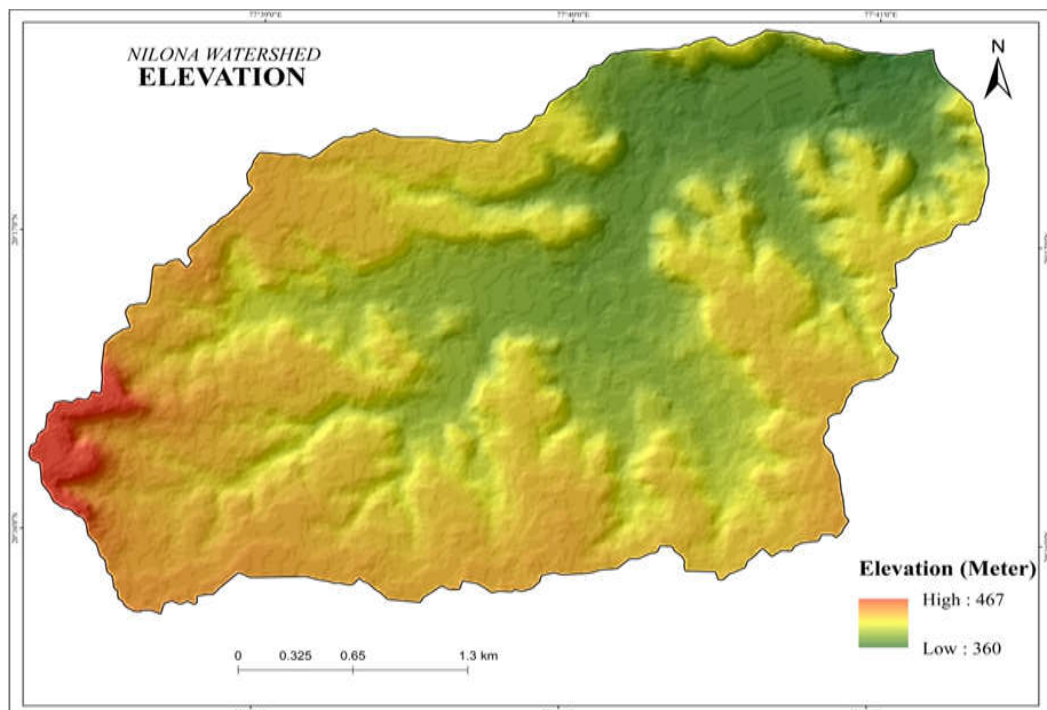


Fig. 2. Elevation map of Nilona microwatershed

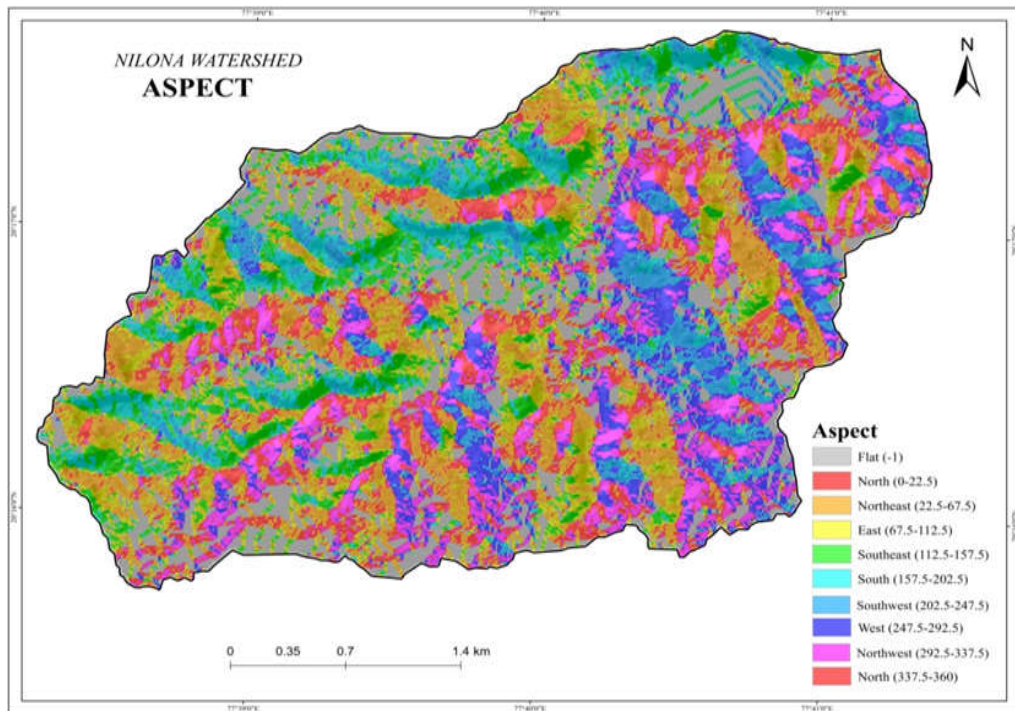


Fig. 3. Aspect map of Nilona microwatershed

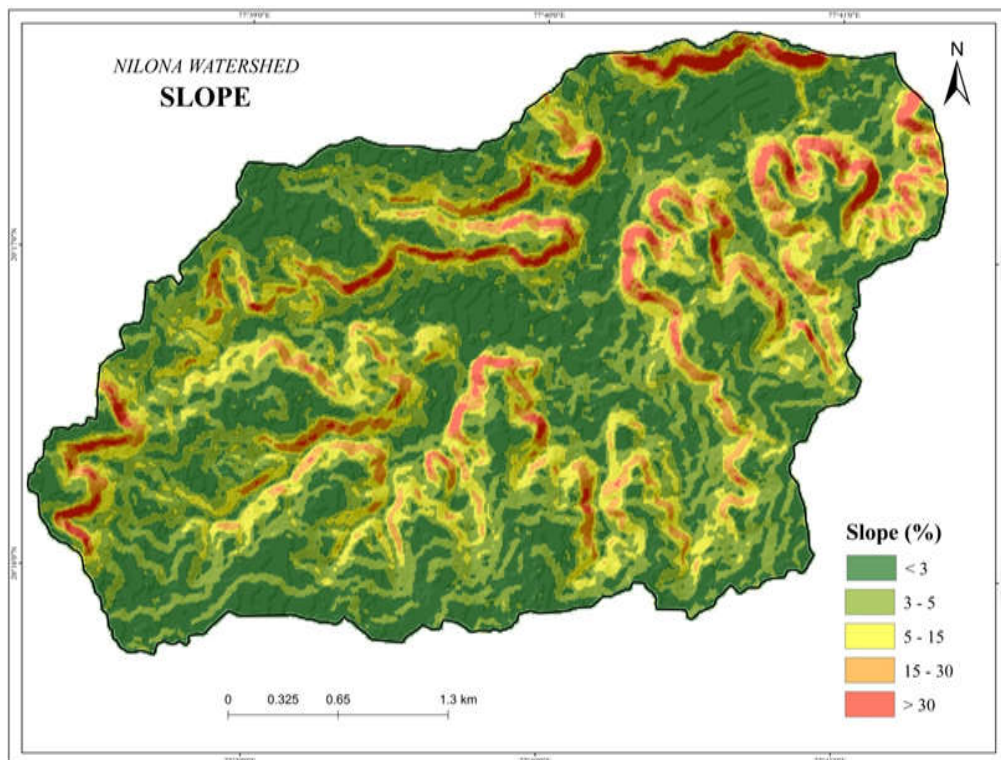


Fig. 4. Slope map of Nilona microwatershed

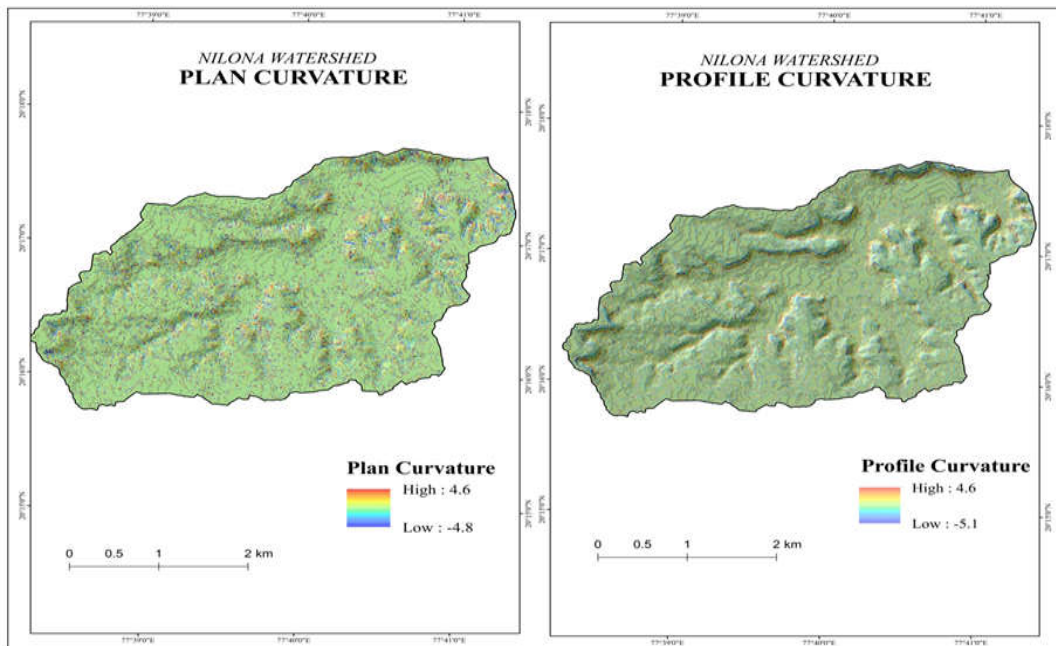


Fig. 5. Plan and Profile Curvature map of Nilona microwatershed

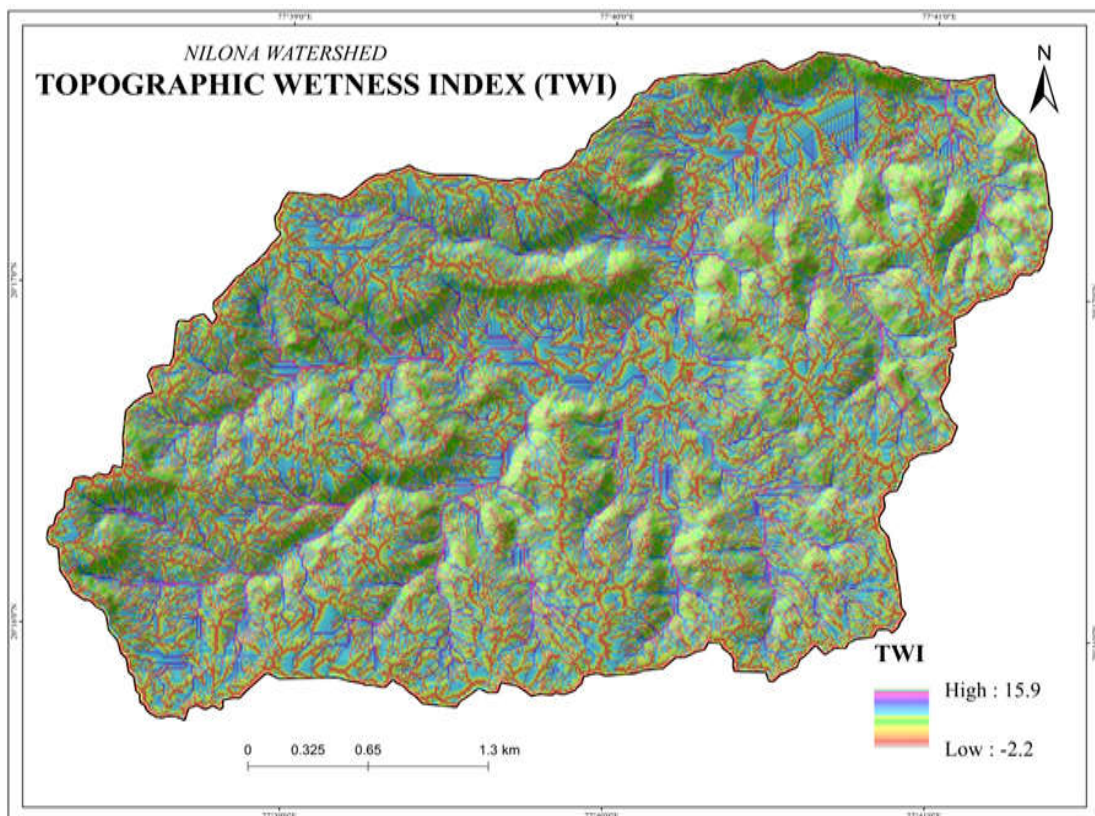


Fig. 6. Topographic Wetness Index map of Nilona microwatershed

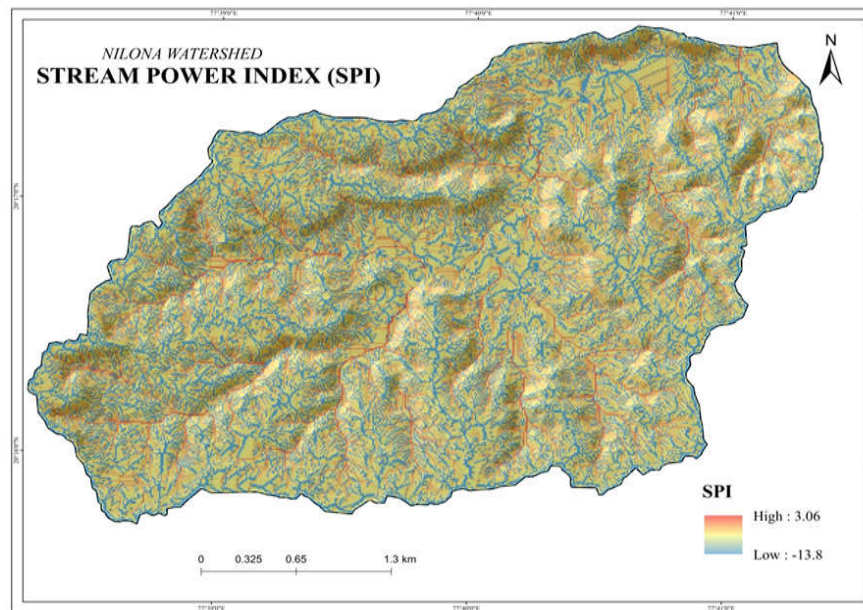


Fig. 7. Stream Power Index map of Nilona microwatershed

#### 4. CONCLUSIONS

The present investigation was carried out in Nilona micro watershed of Darwha block, Yavatmal district, Maharashtra to study the terrain and morphometric characterization of micro watershed. The highest elevation within the micro-watershed is 467 m and the lowest is 360 m. The slope varies from 0 to 45.9 percent, with a mean value of 4.5%. Most of the area of Nilona micro-watershed was classified as gently sloping and sloping. Profile curvature varies from -5.1 to 4.6  $m\ m^{-1}$ , which indicates the presence of erosive as well as depositional landforms within the DTM scene. The topographic wetness index, range from -2.2 to 15.9, as an indicator of the spatial distribution of soil water content and soil water drainage. The digital terrain analysis helps to determine the terrain features of watershed which helps for watershed planning and management which has practical utility in soil and water conservation planning.

#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

#### REFERENCES

1. Grabrecht J, Martz LW. An automated digital landscape analysis tool for

topographic evaluation, drainage identification, watershed segmentation and subcatchment parameterization; TOPAZ Overview. United States Department of Agriculture. 1999;99-(26):26.

2. Perez A. A comparison of watershed delineation methods in ARC/INFO and ArcView, Proceedings of the 19<sup>th</sup> ESRI Users Conference, San Diego, CA; 1999.
3. Beaumont BJ. Combining pedo transfer functions with physical measurements to improve the estimation of soil hydraulic properties. *Geoderma*. 1975;103:133-147.
4. Patil NP, Kadale AP, Mhetre GS. Assessment of morphometric characteristics of Karwadi-Nadapur micro watershed using remote sensing and geographical information system. *International journal of Scientific and technology research*. 2015;4(4):175-179.
5. Nagalakshmi R, Pakrasi D. Comparative analysis of terrain characteristics of Udhagamandalam, Nilgiri district, Tamil nadu. *Ecology, Environment and conservation*. 2017; 23(2);1154-1160.
6. George D, Malpandes and Vayia V. Pangiotidis. The aspects of aspect: Understanding land exposure and its part in geographic information systems analysis. *Energy and environment*. 2018; 1(10):1-16.
7. Chitra C, Alaguraja P, Ganeshkumari K, Yuvaraj D, Manivel M. Watershed Characteristics of Kundah sub basin using



- remote sensing and GIS techniques. International Journal of Geomatics and Geoscience. 2011;2(1);311-335.
8. Tesfaye Gebre, Tigist Kibru, Samuale Tesfaye and Gebeyehu Taye. Analysis of watershed attributes for water resources management using GIS: The case of Chelekot micro watershed, Tigray, Ethiopia. Journal of Geographic Information System. 2015;7: 177-190.
  9. Mutasem S, Tiwary P, Deevu M. Pedotransfer functions. A tool for estimating hydraulic properties of two major soil types of India. Current Science. 2013;107 (9):1431-1439.
  10. Florinsky GA, Kuryakova. Determination of grid size for digital terrain modelling in landscape investigations at micro scale. International Journal of Geographical Informaton Science. 2000;14(8):815-832.

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