Eco. Env. & Cons. 30 (October Suppl. Issue) : 2024; pp. (S70-S74)
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ISSN 0971–765X

DOI No. http://doi.org/10.53550/EEC.2024.v30i06s.011

Effects of DEM on Topographic Wetness Index Analyzing at Painganga Wildlife Sanctuary

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(Received 28 February, 2024; Accepted 8 May, 2024)

ABSTRACT

Topographic Wetness Index (TWI) Calculated from digital elevation model (DEM) are datasets plays an important role in Calculation of TWI. DEMs are produced utilizing GPS, satellite images or aerial image, slope, elevation, drainage pattern, stream order, flow of accumulation, flow of direction etc. DEM is as good as the actual ground sampling algorithm potential of where water is likely to accumulate and result showed that waterway obtained from DEM with high spatial resolution so according to results it is suggested that the same model for increasing spatial resolution of DEM in the studies must be used.

Key words: *Topographic wetness index (TWI), Digital elevation model (DEM), Geographic Information System (GIS), Spatialresolution, Slope, Drainage pattern.*

Introduction

"In environmental studies and watershed management, accurate terrain analysis plays a critical role in understanding hydrological processes and landscape dynamics. The Topographic Wetness Index (TWI) is a key parameter used to assess landscape wetness based on terrain characteristics derived from Digital Elevation Models (DEMs). DEMs, which provide digital representations of terrain elevations, are essential for deriving topographic parameters such as slope, aspect, and flow accumulation that form the basis for TWI calculations. A topographic wetness index is based on the idea that a terrain profile controls the distribution of water and areas subject to water accumulation. This index was first developed by Beven and Kirkby (1979). It has lately been accepted as a powerful measure in defining flood preparedness scenarios Buchanan *et al.* (2014), Ballerine, (2017).

TWI analysis is valuable for identifying hydrologically sensitive areas, assessing water availability and quality, and informing land management decisions. However, the quality and characteristics of DEMs can significantly influence TWI outcomes, affecting the accuracy and reliability of hydrological modeling results. Contour lines following the natural formation of the terrain. Contour intervals widens in distance due to subtle elevation differences in flat areas whereas they come tightly together as topography becomes treacherous, accentuating the elevation in their distances Oka *et al*. (2012).

This research paper aims to investigate the consequences of DEM characteristics on TWI analysis. Specifically, the study will evaluate how different DEM resolutions and preprocessing techniques impact TWI calculations and interpretations. Case studies will be analyzed to demonstrate the practical implications of DEM quality on TWI applications in environmental assessments and hydrological modeling. The TWI is a physically based index or indicator of the effect of local topography on runoff flow

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direction and accumulation. The index has applications in specialized rainfall runoff modeling and simulation of the spatial distribution of soil moisture and precision agriculture (Beven and Kirkby, 1979; Qin *et al*., 2011).

Soil moisture patterns in landscapes were a serious challenge in the past so that many notable occurrences cost considerable property damage and death all across the Earth. Niebur *et al*. (2003), Kundzewicz *et al*. (2013), Milly *et al*. (2002), Dutta and Herath, (2004).

The Hydrological indices of topographical wetness index, which determining the places inherently keeping water indicating potential of a comprehensive overview of TWI analysis methods and the influence of DEMs on terrain analysis; the methodology section will detail the approach used to assess DEM effects on TWI calculations; the results and discussion sections will present and analyze findings from case studies and simulations; and finally, the conclusion will summarize key insights and propose recommendations for improving TWI accuracy in future studies."

The Arc-Hydro tool set (Maidment, 2002; ESRI, 2012) uses the sfd algorithm also known as D8 which refers to the eight possible directions that flow may take from a single cell. Besides, three more DEM datasets were produced from vectorized and 1:25000 scaled national quad maps Yilmaz and Erdogan, (2018).

Materials and Methodology

Study Area

The area of protected forests on both sides of the Painganga River which is divides Yavatmal and Nanded District. The it lies between the north latitudes 19°34'20.71"N and east logitudes 78° 1'49.33"E. It has four ranges- Bitargaon, Sondabhi, Kharbi, Korta.

The most of the area occupied by Toposheet No.E43F14, E43F15, E44A2, E44A3. The Study area of the research work is shown in Fig. 1.

The Topographical Map of 1:50000 (E43F14, E43F15, E44A2, E44A3) scale are downloaded from link https://onlinemaps.surveyofindia.gov.in most one of the is freely required which are of change detection of study area.

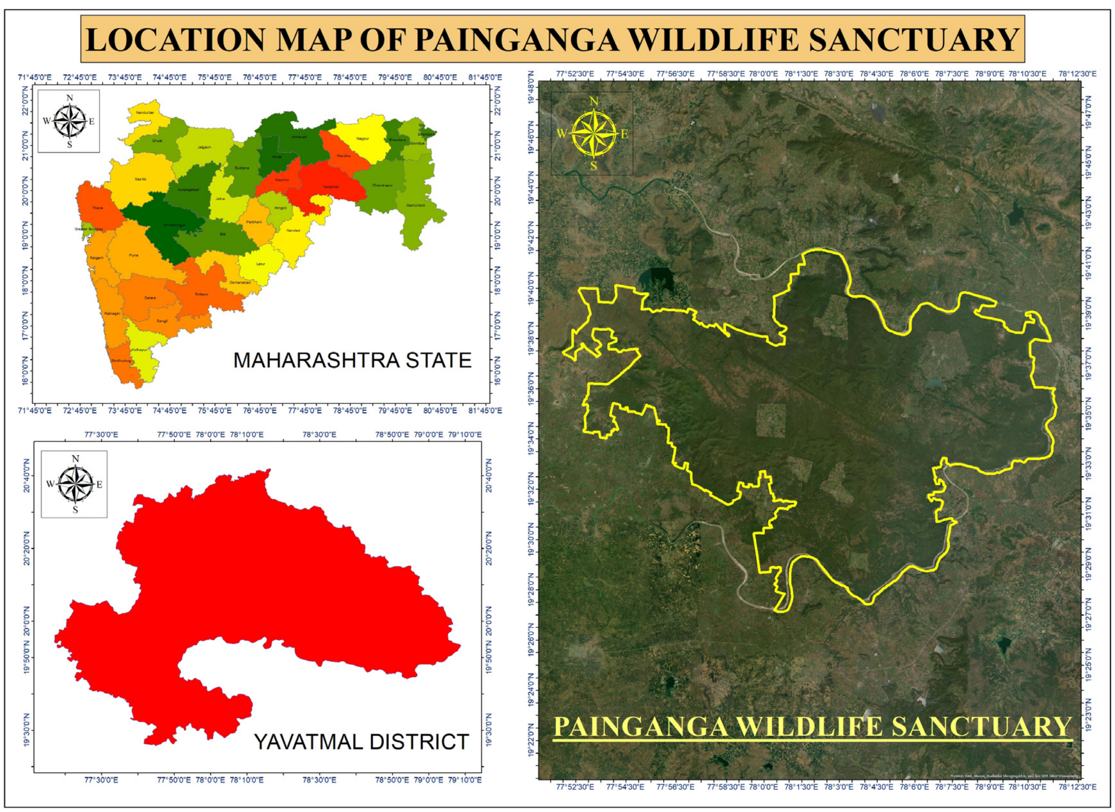

Fig. 1. Location Map of Painganga Wildlife Sanctuary

Table 1. Features of Satellite Data (https://earthexplorer.usgs.gov/)

Projection	Geographic
Horizontal Datum	WGS84
Vertical Datum	EGM96 (Earth Gravitational Model 1996)
Vertical Units	Meters
Spatial Resolution	1 arc-second for global coverage (~30 meters)
Raster Size	1 degree tiles
C-band Wavelength	5.6 cm
Date of Data Acquired	27/10/2023

Compute Topographic Wetness Index (TWI)

Use the derived slope (S) and flow accumulation (A) grids to calculate TWI for each raster cell using the following formula:

The TWI formula used in this study is TWI=ln (a/tanβ)

A = Flow accumulation (number of upstream cells draining into each cell).

β = Slope in radians (converted from degrees if necessary).

Wherea is the upslope contributing area and 5 β is the topographic gradient, and is calculated utilizing a DEM of the study areas. The methodology for the sfd approach and TWI computation presented by Wolock (1995)

TWI is an algorithm which is frequently addressed in hydrology driven studies Pourali *et al.* (2016), Aksoy *et al.* (2016). It can be applied on any DEM no matter what its resolution is because DEM resolution is the driving factor behind the successful generation of TWI.

Results and Discussion

In this study, we conducted a comprehensive analysis of the Topographic Wetness Index (TWI) which shows in Fig. 3 within the Painganga Wildlife Sanctuary using high-resolution Digital Elevation Models (DEMs) and GIS techniques. TWI maps were generated to visualize wetness patterns across the sanctuary and assess the consequences of DEM resolution on TWI calculations. The TWI analysis revealed distinct spatial patterns of wetness, with higher TWI values observed in riparian zones along the Painganga River and low-lying areas within deciduous forests. Present the TWI maps generated for different DEM resolutions (if applicable) or based on specific analyses (e.g., varying slope classes, land cover types). Use color scales or legends to represent TWI values, highlighting areas of high and low wetness across the study area.

Discuss the spatial distribution of TWI values in relation to landscape features (e.g., forests, water bodies) and terrain characteristics (e.g., slope, elevation). Interpret areas of high TWI values as potential wetland habitats or hydrologically sensitive zones within the sanctuary. Areas with high TWI values corresponded to potential wetland habitats and hydrologically active zones critical for supporting biodiversity.

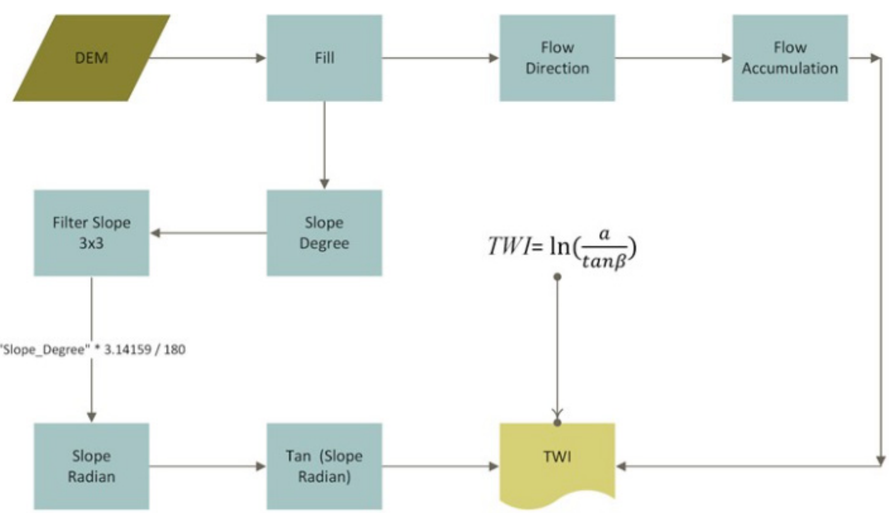

Fig. 2. Flow Chart of Topographic Water Index (https://community.esri.com/t5/spatial-data-science-questions/how-to-deal-with-no-data-)

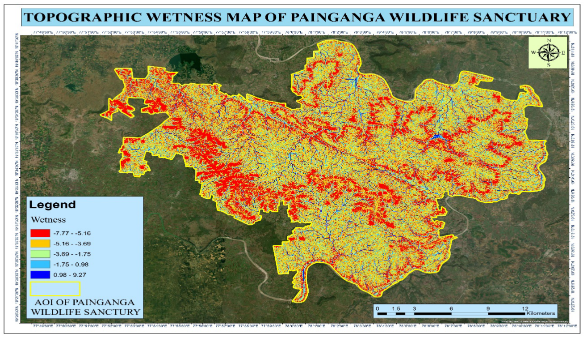

Fig. 3. TWI Map of Study Area

In this study TWI from spatial resolution of Digital Elevation Model 30 m. based on the results obtained, it was determined that Topographic Water Index algorithm calculated over different DEM showed that in Fig. 3-5 Compared with Fig. 3 of study shows in Fig. 5 Slope of area range between 18.16 to 36.46 m of that location has higher Slope in same location in Fig. 3 TWI map shows water scarcity area which have -7.77 to -5.16 range value so it means that higher Slope of area represents higher water scarcity area.

Our results demonstrated that DEM resolution significantly influenced TWI values; with finer-scale terrain features captured more accurately using higher-resolution DEMs. Comparison of TWI maps derived from different DEM resolutions highlighted the importance of spatial resolution in modeling landscape wetness dynamics.

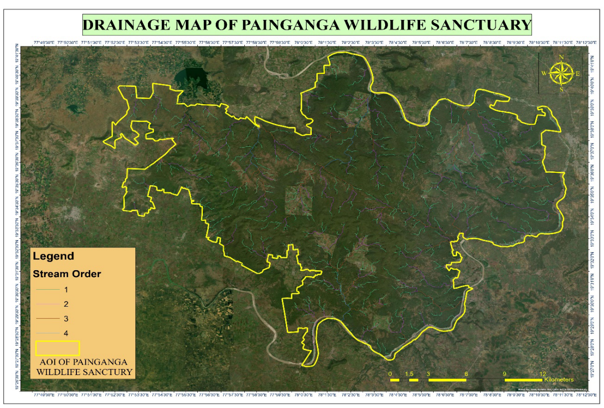

Fig. 4. Drainage Map of Study Area

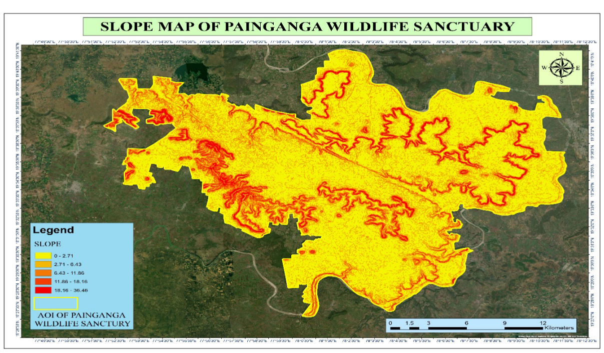

Fig. 5. Slope Map of Study Area

The ecological implications of TWI variations within the sanctuary underscore the role of TWI analysis in ecosystem management and conservation planning. TWI serves as a valuable tool for identifying hydrologically sensitive areas and prioritizing conservation efforts to protect critical habitats and water resources.

While our study provides insights into wetness dynamics within the Painganga Wildlife Sanctuary, limitations such as DEM quality and model assumptions should be considered. Future research directions may include integrating additional environmental variables (e.g., soil properties, climate data) into TWI modeling and applying advanced spatial analysis techniques to enhance hydrological assessments in similar ecosystems.

Conclusion

The observed pattern where higher slope correlates with higher water scarcity underscores the influence of topography on hydrological processes. Steeper slopes often result in faster runoff and reduced water retention, leading to drier conditions and potentially increased water stress in these areas.

The analysis of TWI based on a 30-meter DEM resolution revealed a clear relationship between slope and water scarcity. These findings have implications for water resource management and underscore the value of remote sensing and GIS techniques in studying landscape dynamics. TWI analysis can inform decisions related to watershed management, development, especially in regions characterized by varying topographic features.

Conflict of Interests

The authors declare that they have no conflict of interests.

Acknowledgement

The authors thank the Divisional Forest Office, Wildlife Division, Pandharkawda for the support rendered for this research work.

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