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Vallu Tejaswini
Assistant Professor, Department of Agricultural Engineering, Aditya University, Surampalem, Andhra Pradesh, India

Sathian KK
Department of Land and Water Resources Engineering, Kerala Agricultural University, Kerala, India

Corresponding Author:
Vallu Tejaswini
Assistant Professor, Department of Agricultural Engineering, Aditya University, Surampalem, Andhra Pradesh, India

Comparison of digital elevation models for hydrological modeling

Vallu Tejaswini and Sathian KK

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Abstract
Topography represented in the form of DEM has major applications in watershed modeling. Hence, choosing a correct DEM with reasonable accuracy for hydrological modeling is prerequisite. In this study, TOPO DEM, SRTM DEM, ASTER DEM and BHUVAN DEM were taken for comparison in terms of catchment delineation which is a vital information for hydrological modeling. It is observed that there is no considerable difference in the delineation of the watershed with and without the burning of drainage lines. However, between the DEMs, ASTER showed different pattern of delineation, and all other DEMs behaved in similar lines. The percentage variation of area delineated by SRTM, Bhuvan, ASTER with respect to toposheet DEM was 1.50%, 1.86% and 20.09% respectively.

Keywords: Digital elevation model, delineation, watershed, toposheet, interpolation

Introduction

For sustainable productivity, proper management of irrigation is crucial (Yonbawi *et al.*, 2022) [9]. An integrated approach of RS and GIS data can be useful for resource managers, policy makers and planners for sustainable use of resources (Lakshmi *et al.*, 2022) [4]. The available spatial database systems can be tailored for suitability and can be used for any other areas (Rao *et al.*, 2016) [6]. Precise representation of terrain is important as it influences the estimation of runoff, direction of flow and watershed delineation in hydrological modeling. The fundamental data sources for the terrain representation are digital elevation models which provides three-dimensional view of the earths surface. As remote sensing and geospatial techniques are in more advancement level, variety of DEMs are available now, each differs in vertical accuracy, spatial resolution and data acquisition methods which will significantly impact the hydrological simulations and thus water resource assessments. Hence, selecting appropriate DEM is very important to make decisions and manage the water resources.

Sharma *et al.* (2014) [7] studied the hydrological behaviours of SRTM DEM and TOPO DEM in terms of catchment response to runoff and sediment yields and found that SRTM DEM can be a valuable data for hydrological analysis/applications. As the water movement in the hydrological studies depends on geomorphological characteristics of watershed, it is important to conduct DEM based hydrological studies to estimate areas of high hydrological risk (Harnandez *et al.*, 2022) [2]. However, the selection of DEM has a considerable influence on the stream and catchment delineation (Moges *et al.*, 2023) [5]. An accurate, high resolution and freely available DEM is essential to support mapping of flood and hence flood related researchers, other stakeholders and practitioners has to pay keen attention to the uncertainty which causes by DEM quality (Xu *et al.*, 2021) [8]. Morphometric characterization of watersheds which assists the planning and management of water resources can be done in a GIS environment using ASTER and SRTM data, a viable alternative for hydrological modelling (Guedes and Silva, 2012) [1]. Hence, this study was aimed to compare different DEMS such as TOPO DEM, SRTM DEM, ASTER DEM and BHUVAN DEM in terms of catchment delineation which is a vital information for hydrological modelling.

Materials and Methods

Study area: A small sub catchment of Bharathapuzha river basin (longest river in Kerala) which joins laterally with the main stream of the river has been chosen for the study.

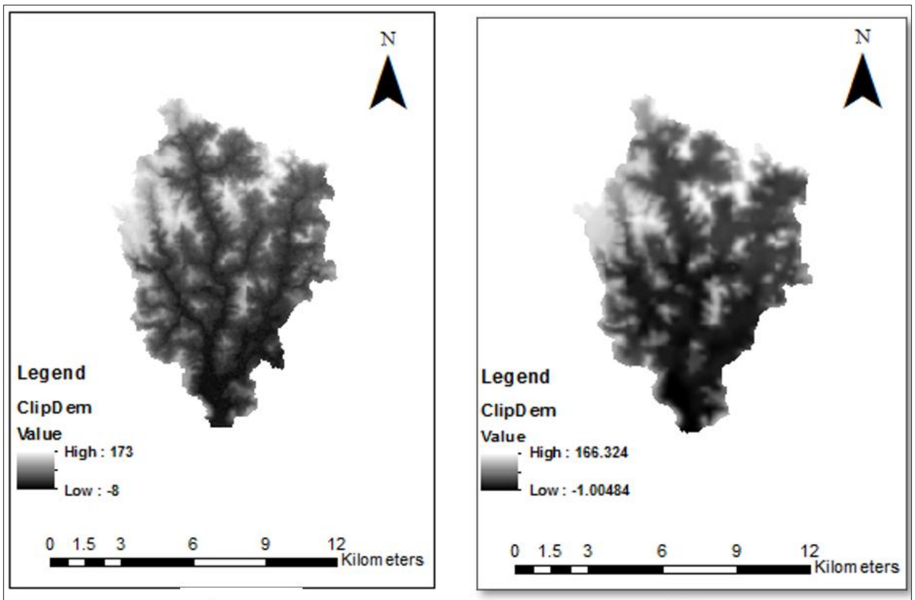
The location map of the catchment is shown in Fig. 3.1. The watershed encompasses one of the important commercial town Valanchery and hence, it is named as Valanchery watershed. The area of the watershed was about 80 Km^2. The small stream from the study area flow towards South and joins about 3 km to the South of Valanchery town. The delineated watershed of the study area lies within the range of 10º47’47.48’’N latitude to 10º58’27.84’’N latitude and 75º58’57.72’’E longitude to 76º11’49.2’’E longitude. The hydrological analysis of the watershed has been done using the SWAT model. Calibration of the model for the study area was not possible as there is no discharge data for the stream originating from the study watershed. Therefore, the neighbouring Kunthipuzha sub basin of Bharathapuzha has been taken for the calibration and validation of the model.

Preparation of DEM

DEM can be generated from contour interpolation and also often derived from satellite imagery such as stereoscopic SPOT images. For comparing different DEM accuracy in hydrological assessment, 4 DEM’s are taken for the study. TOPO DEM, SRTM DEM, ASTER DEM and BHUVAN DEM were taken for comparison in terms of catchment delineation and hydrological modeling whereas TOPO DEM was used for the detailed hydrologic analysis. TOPO DEM was prepared from toposheet by digitizing the contour lines. Georeferencing the toposheet, changing and defining the coordinate systems and digitizing the contour lines were done in ArcGIS 10.2.2. Finally, using spatial analyst tools in ARCGIS, DEM was prepared by using contour shapefile. Shuttle Radar Topographic Mission (SRTM) DEM of 30m resolution was downloaded from earthexplorer.usgs.gov.in website. SRTM DEM was provided by the Consultative Group for International Agriculture Research Consortium for Spatial Information. SRTM 1 Arc-Second Global DEM offers worldwide coverage of void filled data at a 30m resolution. ASTER DEM was also downloaded from the earthexplorer.usgs.gov.in website whereas BHUVAN DEM was downloaded from the Bhuvan website. Drainage network map was prepared for the study area by digitizing the streams from the toposheet. Land use map derived from the LISS (III) imagery of IRS P6 satellite of 2008 was used for the study. The Soil map and the morphological characteristics of the soil collected from the Directorate of Soil Survey & Soil conservation of Kerala State were used for running the model. All the data sets were transformed into WGS_1984_UTM_ZONE_43N coordinate system in ARCGIS before feeding into the model. Both the land use map and soil map were rasterised in ARCGIS 10.2.2 before feeding into SWAT model.

Results and Discussion

An attempt has also been included in this study to identify the best source of DEM to be used in the SWAT model. For this, a contour interpolated DEM was prepared from the topographic data obtained from toposheet which was prepared by Survey of India. Three readily available DEMs *viz*. SRTM and ASTER of USGS and Bhuvan DEM of ISRO were taken for comparison. For each of the DEM, delineation was done with and without burning with stream network. Watersheds delineated by the SWAT corresponding to different DEM inputs by burning with the stream network are shown in the Fig. 4.9. Area of the watershed delineated by different DEMs under the two conditions of with and without burning with the streams is shown in Table 4.5. It is observed that there is no considerable difference in the delineation of the watershed with and without the burning of drainage lines. However, between the DEMs, ASTER showed different pattern of delineation, and all other DEMs behaved in similar lines. The percentage variation of area delineated by SRTM, Bhuvan, ASTER with respect to toposheet DEM was 1.50%, 1.86% and 20.09% respectively. The performance of the SRTM DEM was more close to that of toposheet DEM. Hence, it can be concluded that SRTM DEM is more reliable dataset for hydrological analysis. Huang and Yu (2024) [3] also studied about vertical accuracy assessment of the ASTER, SRTM, GLO-30, and ATLAS in a forested environment and concluded SRTM data provided stable and sufficient vertical accuracy in forested environments.



a) b)

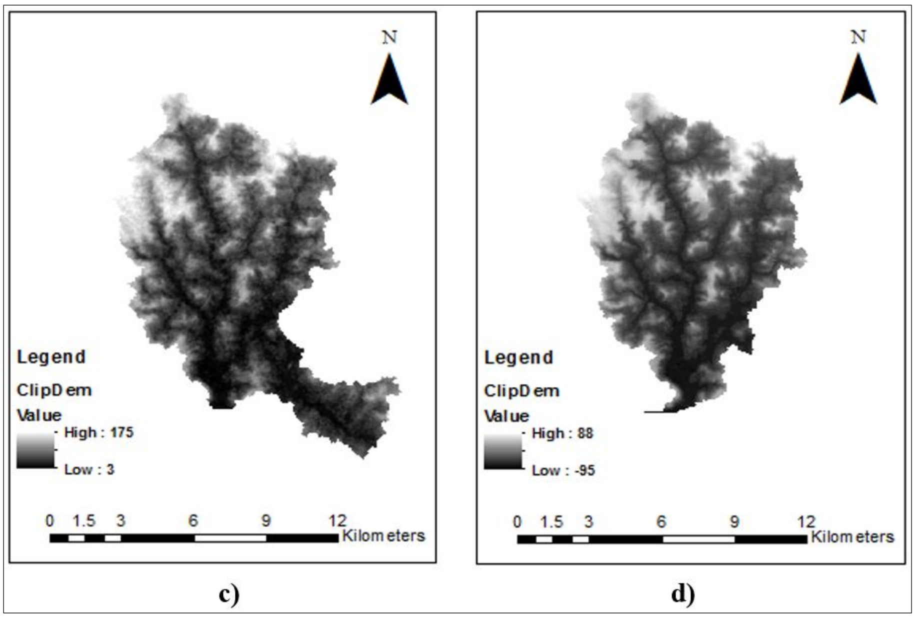


Fig 1: a) SRTM DEM b) TOPO DEM c) ASTER DEM d) BHUVAN DEM

Table 1: Topographical details of watershed using different sources of DEM

DEM	Minimum elevation (m)	Maximum elevation (m)	Mean elevation (m)	S.D (m)	No. of sub basins	Area (Ha)
Aster with drainage map	3	175	54.21	34.80	17	9512.44
Aster without drainage map	3	171	53.75	34.29	15	9463.02
Bhuvan with drainage map	-95	88	-31.98	36.35	13	8068.18
Bhuvan without drainage map	-95	74	-33.01	35.31	9	7971.03
SRTM with drainage map	-8	173	56.97	36.72	13	8039.63
SRTM without drainage map	-8	164	55.82	35.57	11	7931.55
TOPO DEM with drainage map	-1	166	58.71	36.78	13	7920.40
TOPO DEM without drainage map	-1	166	58.19	36.34	9	7865.49

Conclusion

Selecting appropriate DEM is very important to make decisions and manage the water resources. It is observed that there is no considerable difference in the delineation of the watershed with and without the burning of drainage lines. However, between the DEMs, ASTER showed different pattern of delineation, and all other DEMs behaved in similar lines. Hence, it can be concluded that SRTM DEM is more reliable dataset for hydrological analysis.

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