

International Symposium on Applied Geoinformatics (ISAG2021)

COMPARING THE BASIN MORPHOMETRIC PARAMETERS DERIVED FROM FREELY AVAILABLE DEMS AND TOPOGRAPHIC DATASET: A CASE STUDY OF SAZ-ÇAYIROVA BASIN, TURKEY

Batuhan Kilic [1], Fatih Gulgen [1], Meltem Celen [2], Mehmet Salim Oncel [3], Halil Nurullah Oruc [2], Sinem Vural [3]

[1] Yildiz Technical University, Faculty of Civil Engineering, Department of Geomatic, Istanbul, Turkey
(batuhank/fgulgen@yildiz.edu.tr); **ORCID 0000-0002-0529-8569, ORCID 0000-0002-8754-9017**
[2] Gebze Technical University, Earth and Marine Sciences Institute, Kocaeli, Turkey
(mkocal/horuc@gtu.edu.tr); **ORCID 0000-0001-9487-497x, ORCID 0000-0002-6386-0046**
[3] Gebze Technical University, Department of Environmental Engineering, Kocaeli, Turkey
(soncel/s.vural@gtu.edu.tr); **ORCID 0000-0002-1945-2336, ORCID 0000-0001-8842-0226**

ABSTRACT

Drainage basin/watershed analysis based on morphometric parameters has a vital role in watershed management and planning. In this study, five different datasets with the similar resolution, such as ASTER GDEM (Advanced Spaceborne Thermal Emission and Reflection Radiometer), SRTM DEM (Shuttle Radar Topography Mission), ALOS DSM (Advanced Land Observing Satellite), NASA DEM (National Aeronautics and Space Administration) and TOPO DEM (1:25K scaled topographic maps), were investigated based on morphometric parameters. Except for TOPO DEM, DEM data used in the study were chosen as data that can be obtained from open access sources. The morphometric parameters' result of TOPO DEM was used as the reference data for comparing the results of the other DEMs sources. In addition, percentage error was used to compute the accuracy between the freely available DEMs and the TOPO DEM for every morphometric parameter. The outcomes of this study reveal that the most consistent results with the TOPO DEM are provided by SRTM DEM, following the NASA DEM.

Introduction

Water is a fundamental necessity for human beings to survive and fulfill environmental functions. With the development of technology, the pressures on soil and water resources have started to increase with the growth of the ways and rates of water use, the distribution of water resources for many purposes such as drinking utilization, energy production, irrigation water. Therefore, river basins and drainage networks constitute the fundamental input data for a wide range of water and land resources management applications such as flood prediction, contaminant transport, and streamflow hydraulics (Thomas and Prasannakumar, 2015).

Drainage networks and watershed analyses based on morphometric parameters are crucial for hydromorphological processes and integrated watershed management. It gives an idea about the basin characteristics regarding basin geometry, slope, topography, soil condition, runoff characteristics, and surface water potential. (Sukristiyanti et al., 2018). Morphometric analyzes provide descriptive information about drainage networks and watersheds (Karabulut and Ozdemir, 2019). Several data sources which are produced from different techniques can be used in the morphometric analysis. Theoretically, they are manually delineated from topographic maps with field surveys. The derived information always depends on the scale factor and contour intervals. The generation of reliable data often sets costly and labor-intensive efforts (Thomas and Prasannakumar, 2015). Therefore, the laborious production process of DEMs obtained from topographic maps directs researchers to easily accessible data sources. This study aims to test the usability of freely accessible DEM sources in terms of morphometric parameters. The morphometric features of the Saz-Çayırova basin

were examined using four different DEM sources; ASTER GDEM, SRTM DEM, ALOS DSM, and NASA DEM. The morphometric parameters' result of TOPO DEM was used as the benchmark data for comparing the results of the other DEMs sources. For a more accurate comparison, a DEM resolution of 30 meters was chosen for all data sources.

Study Area and Methodology

The Saz-Cayirova basin, which lies within a sub-basin of the Marmara Basin in the northwest part of Turkey, was chosen as the study area. Saz and Cayirova are two neighboring streams that share an industrialized small-scale catchment. The sub-basin areas of the Saz and Cayirova streams are approximately 20 and 30 km^2, respectively (Oruc et al., 2020).

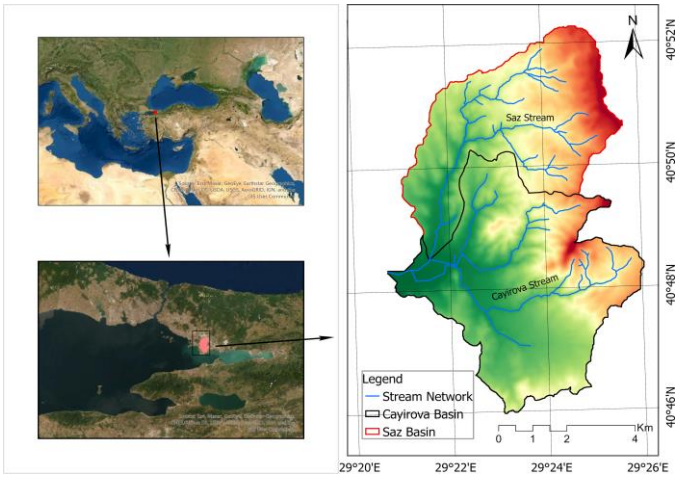

Figure 1 The study area

Four different DEM datasets, such as ASTER GDEM (ASTER GDEM Validation Team, 2011), SRTM DEM, ALOS DSM, and NASA DEM (NASA JPL, 2021), gathered from different sources were used. ASTER, SRTM, NASA, and ALOS DEMs can be downloaded from the Earth Explorer of USGS, the NASA EOSDIS Land Processes Distributed Active Archive Center and the Earth Observation Research Centre (EORC) of JAXA websites. TOPO DEM was created using 1:25K scale topographical maps. The elevation (contours and elevation points) and hydrography (streams, channels, lakes, and coastline) data of the current topographic databases produced by the Turkey General Directorate of Mapping (TGDM) in the Geographic Coordinate System (WGS 1984) were used to generate 30-meter resolution DEM. For further analysis, the four DEMs excluding TOPO30 DEMs were reprojected into Universal Transverse Mercator (zone 35) Projection to have the same measurement units for x, y, and z directions. Before the morphometric analysis, each DEM was hydrologically corrected using fill sinks and stream burning processes. After extracting drainage lines and watershed boundaries from each DEM, basic descriptors and selected morphometric parameters were calculated. Last but not least, Mean Absolute Percentage Error (MAPE) was computed using Equation 1 to evaluate the accuracy of different DEM sources based on morphometric analysis. Finally, their parameters' results and percentage errors were compared with the results of TOPO DEM (Figure 2).

$$\mathbf{MAPE} = \frac{\mathbf{100}}{\mathbf{n}} \sum_{\mathbf{i=1}}^{\mathbf{n}} \left| \frac{(\mathbf{TOPO\ DEM})_i - (\mathbf{Other\ DEM})_i}{(\mathbf{TOPO\ DEM})_i} \right| \quad (1)$$

where n is the number of morphometric parameter.

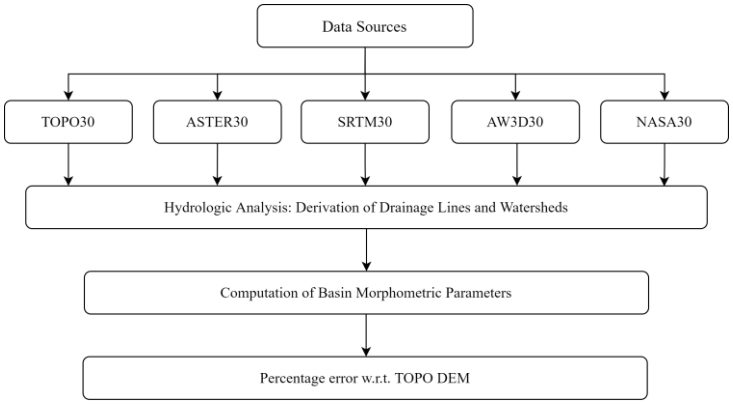

Figure 2 Flowchart of the methodology

Results and Discussion

The linear, areal, and relief characteristics of measures were used in basin morphometric analysis. These parameters are Bifurcation ratio (R_b), length of overland flow (l_o), texture ratio (T), drainage density (D_d), drainage frequency (F_d), Gravelius index (K_g), time of concentration (T_c), ruggedness number (R_n) and basin relief (B_h). The results of the morphometric parameter values and basic descriptors such as area (A) and perimeter (P) derived from each DEM source are shown in Table 1.

Table 1 The results of morphometric parameters derived from five different DEM sources

Methods	Indicator	TOPO30	ASTER30	SRTM30	AW3D30	NASA30
Basic Descriptors	Area (A)	51.85	50.11	50.33	50.30	50.45
	Perimeter (P)	48.84	52.24	51.30	52.56	49.14
Linear Characteristics	Bifurcation ratio (R_b)	2.81	1.78	2.59	1.71	2.16
	Length of overland flow (l_o)	0.51	0.46	0.46	0.45	0.51
	Texture ratio (T)	0.63	0.54	0.55	0.63	0.53
Areal Characteristics	Drainage density (D_d)	0.98	1.09	1.08	1.10	0.98
	Drainage frequency (F_d)	1.18	1.08	1.09	1.29	1.01
	Gravelius index (K_g)	1.90	2.06	2.02	2.06	1.94
Relief Characteristics	Time of concentration (T_c)	224	236	228	239	224
	Ruggedness number (R_n)	0.31	0.34	0.34	0.35	0.31
	Basin relief (R)	311.59	311	312	314	314

The physical features and stream networks such as area and perimeter have significance on the basin hydrology. While the area delineated from TOPO30 DEM was significantly higher than the other DEM sources, the perimeter derived from NASA30 DEM was close to the TOPO30 result comparing with other DEMs.

Depending on the Strahler stream order method, the Bifurcation ratio is expressed as the ratio of the number of streams of any order to the number of streams of the next higher-order (Horton, 1932; Strahler, 1957). R_b value derived from TOPO30 is significantly higher than that of ASTER30, AW3D30, and NASA30. However, the R_b value (R_b = 2.59) obtained from SRTM30 is close to the R_b value of TOPO30. Length of overland flow (l_o) reveals the relationship between the factors controlling surface erosions, depending on the drainage density of the basins. The results derived from TOPO30 and NASA30 are identical. The l_o values obtained from the other three DEM data other than NASA30 differ from the reference level but are significantly close. Texture ratio (T) is the ratio of the total tributaries in the first order to the basin perimeter. The obtained T values from ASTER30, SRTM30, and NASA30 reveal that the number of tributaries in the first order that flows water to the mainstream is low. However, the T value generated from the AW3D30 is precisely the same as the reference value.

Drainage density (D_d) is obtained by dividing the total drainage length in the basin by the catchment area. It provides essential information regarding the infiltration capacity of the land, climate and runoff potential, and vegetation cover of the basin (Thomas and Prasannakumar, 2015). While the results derived from TOPO30 and NASA30 are identical, all DEM sources reveal that surface water seeps into the underground and a basin with resistant rocks. Drainage frequency (F_d) is defined as the total number of stream segments per unit area. The F_d results derived from all DEM sources show considerable variability. Therefore, the low results for all DEMs can also be attributed to relatively lower relief, higher infiltration capacity, and dense vegetation cover. Gravelius Index (K_g) is an index that contributes to explain basin shapes. This index value is 1 for an ideally circular watershed. Index values derived from all sources reveal that it indicates more deviation from the circular nature of the basin and produces similar results.

Time of concentration (T_c) is the longest time required for a particle to travel from the watershed divide to the watershed outlet. The T_c value derived from NASA30 (224 minutes) is significantly closer to that of TOPO30 (224 minutes), while SRTM30 has a comparatively higher value (229 minutes). Ruggedness number (R_n) is obtained by multiplying the basin relief and the drainage density. While the results derived from TOPO30 and NASA30 are identical, the other DEM sources have similar results compared to TOPO30. Basin relief (R) is the vertical distance between the outlet and the point with the highest elevation of the watershed. The R values derived from all DEM sources have similar results, and the difference between them is mainly due to the varying vertical accuracy of the data. For most of the parameters, the NASA DEM has performed better than other DEMs. However, a few parameters also exhibited consistent performance in ASTER DEM, ALOS DSM and SRTM DEM (Table 1). Due to such conditions, MAPE has been used to provide better analysis and statistically identify the best performing DEM in the morphometric analysis (Table 2). When the percentage error values in Table 2 are examined, NASA DEM is the best-suited method for the morphometric analysis of the Saz-Çayırova Basin. On the other hand, ASTER DEM and ALOS DSM were not provided suitable results compared to

TOPO DEM. Apart from the NASA DEM, the SRTM DEM was also performed well.

Table 2 MAPE results of different DEM sources with respect to TOPO30

Error	ASTER30	SRTM30	AW3D30	NASA30
MAPE (%)	10.40	6.73	10.17	5.42

Conclusion

This study investigates the usability of different DEMs in terms of morphometric parameters in an industrialized and urbanized small-scale watershed. The outputs of this study reveal that the most consistent results with the TOPO30 DEM are provided by SRTM30 DEM, following the NASA30 DEM for this study area. The reason for the production of different parameter values from other DEM sources may be due to the inability to fully reflect the surface topography characteristics of the region due to intense urbanization and industrialization. Further studies can be performed on different basins with similar characteristics to a more precise comparison of morphometric parameters.

Keywords: *Basin Morphometric Analysis, ASTER GDEM, SRTM DEM, ALOS DSM, NASA DEM, Topographic Maps*

Acknowledgments

This study has been financially supported by the Scientific and Technological Research Council of Turkey (TUBITAK) Project number 119Y032.

References

ASTER GDEM Validation Team (2011). ASTER global digital elevation model version 2-Summary of validation results. NASA Land Processes Distributed Active Archive Center and Joint Japan-US ASTER Science Team.

Horton, R.E. (1932). Drainage basin characteristics. American Geophysics Union, 13(1), 350–361.

Karabulut, M. S. and Özdemir, H. (2019). Comparison of basin morphometry analyses derived from different DEMs on two drainage basins in Turkey. Environmental Earth Sciences, 78(18), 1-14.

NASA JPL (2021). NASADEM Merged DEM Global 1 arc second V001. Distributed by OpenTopography. https://doi.org/10.5069/G93T9FD9 (accessed on 20 September 2021).

Oruç, H. N., Çelen, M., Gülgen, F., Öncel, M. S., Vural, S. and Kilic, B. (2020). Sensitivity of the SWAT Model to Soil Data Parameterization; Case Study in Saz-Çayırova Stream, Tur-key. In: 5th EurAsia Waste Management Symposium, Istanbul-Turkey, pp.503-513.

Strahler, A. (1952). Dynamic basis of geomorphology. Geological Society of America Bulletin, 63, 923–938.

Sukristiyanti, S., Maria, R. and Lestiana, H. (2018). Watershed-based morphometric analysis: a review. In IOP conference series: earth and environmental science (Vol. 118, No. 1, p. 012028). IOP Publishing.

Thomas, J. and Prasannakumar, V. (2015). Comparison of basin morphometry derived from topographic maps, ASTER and SRTM DEMs: an example from Kerala, India. Geocarto International, 30(3), 346-364.