Geo-Morphometric Comparison of Global Digital Elevation Models: Nasadem, Copernicus and Alos World 3D

Chukwuma Okolie, Caleb Ogbeta, Adedayo Adeleke, Julian Smit and Jon Mills

November 23, 2023

GEO-MORPHOMETRIC COMPARISON OF GLOBAL DIGITAL ELEVATION MODELS: NASADEM, COPERNICUS AND ALOS WORLD 3D

KEY WORDS: Digital elevation model, NASADEM, Copernicus, ALOS World 3D, Geo-morphometry.

1. INTRODUCTION

Morphometry encompasses the fundamental measurements and computational modeling of the soil's surface configuration, form, and landform features (Nwilo et. al. 2021). It plays a pivotal role in hydrological and hydro-geological studies, enhancing our grasp of hydrological traits (Nwilo et. al. 2021). Morphometric analysis is an important factor for studying and understanding the development of any river basin. Morphometric parameters give clear evidence for the evolution of the basins, including the denudation, surface runoff, and subsurface infiltration, as well as the impact of geological formations and structures on the basin evolution. Several factors control the accuracy of morphometric analysis, including the method of data collection, source of data, digital elevation model (DEM) characteristics, and measurement technique.

The origin, nature, and quality of digital elevation models (DEMs) are known to significantly impact hydrological patterns, making the study of DEM effects on hydrological tasks a central topic in the hydrological domain (Xiong et al. 2022). DEMs play a pivotal role in understanding and analysing the topographical features of the Earth's surface. With the advent of satellite technology, several open-access global DEMs have been introduced, each with its unique characteristics.

This paper presents a geo-morphometric analysis and comparison of three prominent 30-metre global DEMs: NASADEM, Copernicus GLO-30, and ALOS World 3D. By leveraging geographic information system (GIS) techniques, various terrain and morphometric parameters of a selected drainage basin in Cape Town (South Africa) were assessed. Cape Town offers diverse geomorphological contexts suitable for this research.

2. METHODOLOGY

A script developed by Beg (2015) (employed in ArcGIS) was used to calculate the main morphometric parameters including the stream order, basin area, basin length, channel length, basin width, drainage texture, drainage density, stream frequency, drainage intensity, length of overland flow, height of basin outlet, and basin relief. These were then compared to compare the suitability of the DEMs for geomorphometric analysis.

A reference LiDAR DEM was downsampled from 2 m to a lower resolution of 30 m. This provides a good approximation of the original ground surface while enabling a fair comparison with the satellite DEMs. After some pre-processing to fill sinks in the DEMs, several geo-morphometric parameters were generated for comparison.

3. RESULTS AND DISCUSSION

Table 1 presents the analysis of geo-morphometric parameters for the selected sub-basin. The highest stream frequency, drainage density and drainage intensity are from the LiDAR dataset. With a drainage density of 29.521 km/km^2, Copernicus DEM is closest to the LiDAR estimate while NASADEM is furthest with a drainage density of 26.37 km/km^2. This corresponds with a previous DEM vertical accuracy assessment by Okolie et al. (2023) in which Copernicus emerged with the least vertical error among four global DEMs. As the coarseness of a DEM increases, its vertical accuracy decreases, and the vertical difference between adjacent pixels increases. This greatly increases the flow distance between adjacent pixels. Expectedly, coarser grid DEMs are less applicable for hydrological modelling in urban areas where the areas prone to flooding must be delineated more precisely. In the comparison, Copernicus DEM was comparable to the resampled LiDAR DEM in the average length of overland flow. This suggests it is a better option for wide-area hydrological modelling in regions with mixed land uses. However, it is not always possible to determine if the differences in the drainage network are caused by the DEM or other factors such as the drainage network algorithm (Polidori & El Hage, 2020). This analysis provides a perspective on the hydrological conditioning of the global DEMs, including their suitability for hydrological operations (e.g., flood modelling and watershed delineation). Figure 1 shows the drainage network in the 6th – 9th stream order range for the selected sub-basin.

4. CONCLUSION

Morphometric analysis plays a pivotal role in understanding the hydrological behaviours and characteristics of a region. In this study, various DEMs were evaluated for their accuracy and reliability in representing the geomorphological features of Cape Town. The results revealed that while each DEM has its unique strengths and limitations, the Copernicus 30m DEM emerged as the most reliable, showcasing values closest to the resampled (reference) LiDAR 30 m DEM. This suggests that the Copernicus 30m DEM could serve as a valuable tool for geomorphometric analysis, especially in regions with diverse landscapes like Cape Town.

Future research could delve into the integration of these DEMs to create a composite model that leverages the strengths of each while mitigating their limitations. Additionally, as technology advances, periodic re-evaluation of these models is recommended to ensure their continued relevance in geomorphological studies.

ACKNOWLEDGEMENTS

The authors are grateful to the University of Cape Town Postgraduate Funding Office and the Commonwealth Scholarship Commission for funding this research.

	LiDAR 30 m (resampled)	NASADEM 30 m	Copernicus 30 m	AW3D 30 m
Drainage network parameters				
Total no. of stream order	151353.0	195754.0	159253.0	171364.0
Total length of streams (m)	20373996.6	17679004.3	19790459.6	17842469.7
Geometry parameters				
Total Basin Area (km^2)	673.3	670.4	670.4	670.4
Basin Length (km)	40.5	39.1	40.5	39.3
Main Channel Length (km)	79.8	72.0	74.2	70.3
Mean Basin Width	16.6	17.1	16.6	17.1
Drainage Texture	728.1	941.7	766.1	824.4
Drainage texture analysis				
Drainage Density (km/km^2)	30.3	26.4	29.5	26.6
Stream Frequency (number/km^2)	224.8	292.0	237.6	255.6
Drainage Intensity	7.4	11.1	8.0	9.6
Average Length of Overland Flow (km)	0.0	0.0	0.0	0.0
Basin relief				
Maximum Height of Basin(m)	456.0	460.0	457.0	461.0
Total Basin Relief (H) m	457.0	460.0	457.0	461.0

Table 1. Analysis of geo-morphometric parameters for the selected sub-basin in Cape Town, South Africa

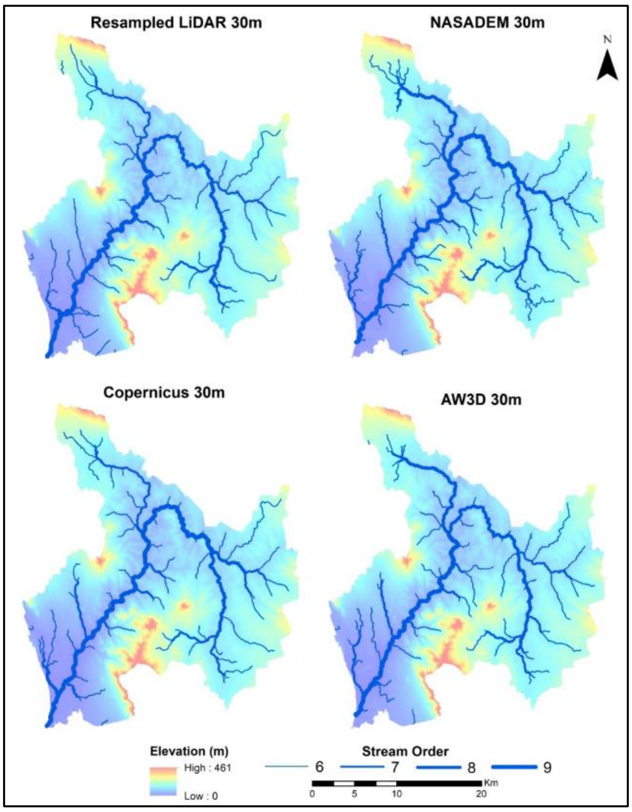

Figure 1. Drainage network in the 6th – 9th stream order range for the selected sub-basin in Cape Town, South Africa

REFERENCES

Beg, A. A. F. 2015. Morphometric Toolbox: A New Technique in Basin Morphometric Analysis Using ArcGIS. *Global Journal of Earth Science and Engineering*, 2(2), 21–30.

Nwilo, P. C., Ogbeta, C. O., Daramola, O. E., Okolie, C. J., Orji, M.J. 2021. Soil Erosion Susceptibility Mapping of Imo River Basin Using Modified Geomorphometric Prioritisation Method. *Quaestiones Geographicae*, 40(3), 143–162.

Okolie, C.J., Mills, J.P., Adeleke, A.K., Smit, J.L.., Peppa, M.V., Altunel, A.O. Arungwa, I.D. 2023. Assessment of the global Copernicus, NASADEM, ASTER and AW3D digital elevation models in Central and Southern Africa. Manuscript in review.

Polidori, L., Hage, M. El. 2020. Digital Elevation Model Quality Assessment Methods: A Critical Review. *Remote Sensing*, 12(21), 3522.

Xiong, L., Li, S., Tang, G., Strobl, J. 2022. Geomorphometry and terrain analysis: data, methods, platforms and applications. *Earth-Science Reviews*, 233, 104191.