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RESEARCH ARTICLE

Appraisal of Digital Elevation Models for Hydrological Modeling in Port Harcourt Metropolis, Nigeria

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Abstract
Digital Elevation Models (DEMs) are essential geospatial datasets for hydrological studies, representing terrain morphology critical for simulating surface runoff, delineating watersheds, and extracting drainage networks. In flood-prone urban areas like Port Harcourt Metropolis, accurate elevation data directly influences water flow patterns and inundation dynamics. However, Nigeria's lack of high-quality local elevation data forces reliance on global DEMs—Copernicus, ALOS, and SRTM—which vary in spatial resolution and vertical accuracy but are often used interchangeably without evaluation.

This study assessed these DEMs' suitability for hydrological applications in Port Harcourt Metropolis. Watershed boundaries and stream networks were extracted using standard GIS tools, overlaid for spatial comparison, and evaluated via hydrological indicators: drainage density, stream frequency, watershed area, and perimeter consistency.

Results showed significant variability. Copernicus DEM yielded the largest watershed extent, highest stream density (0.809 km/km²), and stream frequency (0.805 streams/km²), demonstrating superior sensitivity to subtle elevation changes. SRTM performed moderately, while ALOS underestimated perimeter by 25.34% and area by 4.36% due to terrain smoothing. Despite minor built-up area deviations, Copernicus DEM offers the most reliable representation for detailed hydrological analysis in Port Harcourt Metropolis

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1. INTRODUCTION

Floods are the most pervasive and disastrous natural disasters globally, accounting for significant economic losses, social disruption, and environmental degradation. They threaten lives, property, and infrastructure, with their impacts increasing due to rapid urbanization, population growth, and climate variability (Xu *et al*, 2024). This has created a pressing need to develop comprehensive strategies for flood mapping, monitoring, and risk management. In this regard, geospatial technologies have become indispensable, particularly in flood inundation mapping, which is typically performed using remote sensing datasets (Raheel *et al*, 2025).

Digital Elevation Models (DEMs) constitute a fundamental geospatial dataset in hydrology as they provide a digital representation of the Earth's surface morphology, which is critical for simulating water flow, predicting inundation patterns, and understanding terrain characteristics. In hydrologic and hydraulic modelling, the accuracy of a bare-earth Digital Terrain Model (DTM) is essential to reliably simulate water movement across a floodplain and to predict the extent of flooding under different scenarios (McGrath *et al*, 2025).

Global spaceborne DEMs, such as the Shuttle Radar Topography Mission (SRTM), Advanced Land Observing Satellite World 3D (ALOS AW3D), TerraSAR-X add-on for Digital Elevation Measurement (TanDEM-X), and the Advanced Spaceborne Thermal Emission and Reflection Radiometer Global DEM (ASTER GDEM), have become essential tools in hydrological studies because they provide near-global coverage at resolutions finer than 100 m. These DEMs have been widely adopted in applications ranging from flood susceptibility mapping to the derivation of seamless river networks at continental scales (Raheel *et al*, 2025).

However, the major challenge with these global DEMs lies in their limitations. They often do not represent the true bare-earth elevation because of vegetation and built-up features that distort vertical accuracy. This issue results in the overestimation of terrain heights, which poses a significant problem for hydrological applications such as river network delineation and floodplain modelling (Aaron &, Venkatesh, 2009). Although LiDAR-derived DEMs are widely recognized as the most accurate sources of elevation data due to their ability to penetrate vegetation and filter out surface obstructions, they remain largely inaccessible in many developing nations due to cost, limited technical capacity, and the unavailability of nationwide airborne laser scanning (ALS) campaigns. As such, global DEMs continue to serve as alternatives, even though their accuracy varies considerably across land cover types and topographic settings (Maresova *et al*, 2024).

The accuracy of DEMs is especially crucial in low-lying, flood-prone regions where even minor vertical errors can significantly alter hydrological modelling outputs. Studies have shown that inundation depth and extent are highly sensitive to small elevation inaccuracies, particularly in low-gradient floodplains, thereby making DEM quality a critical factor in flood risk assessments (Zandsalimi *et al*, 2024). To improve the applicability of DEMs for hydrological purposes, additional processing methods such as vegetation bias removal and hydrological conditioning have been developed, resulting in enhanced products like MERIT DEM and FABDEM. Nevertheless, discrepancies remain, and uncertainties in DEMs can undermine the reliability of flood hazard models, particularly in regions without access to high-quality LiDAR DTMs.

In Nigeria, flooding has emerged as one of the most recurrent and destructive natural disasters, affecting both rural and urban communities. Major cities, including Port Harcourt, face increasing flood vulnerability due to a combination of poor urban planning, inadequate drainage infrastructure, high population density, and the encroachment of settlements into floodplains (Echendu & Georgeou, 2021). Port Harcourt, located within the Niger Delta, is particularly at risk given its low-lying terrain, rapid urbanization, and proximity to tidal rivers and creeks. In recent years, several devastating floods have led to the displacement of communities, damage to infrastructure, and disruption of economic activities. The situation highlights the urgent need for reliable topographic information and improved hydrological models to support flood risk management in the city (Nzelibe, Mogaji & Tata, 2024).

Moreover, the global development agenda requires accurate DEMs for hydrological applications, which are central to achieving the United Nations Sustainable Development Goals (SDGs). Specifically, Goal 11 (Sustainable Cities and Communities) and Goal 13 (Climate Action) call for resilient infrastructure, sustainable urban planning, and proactive climate adaptation strategies. Without precise elevation data, flood risk assessments and resilience planning in rapidly growing cities like Port Harcourt remain compromised, leaving communities vulnerable to recurrent disasters and hindering sustainable development.

Therefore, the appraisal of DEMs for hydrological applications in Port Harcourt Metropolis is both timely and necessary. By assessing the accuracy and suitability of available DEMs for flood risk analysis, the study will provide a scientific basis for selecting the most reliable elevation data to support hydrological modelling and disaster risk reduction strategies. This will not only contribute to improved flood management in Port Harcourt but also provide insights applicable to other Nigerian cities and flood-prone regions of sub-Saharan Africa. Ultimately, the research seeks to bridge the gap between global DEM availability and localized hydrological needs, thereby justifying its importance in addressing both national and global challenges in flood resilience and sustainable urban development.

Hydrological applications such as flood modelling, watershed delineation, and streamflow analysis require accurate, high-resolution Digital Elevation Models (DEMs) that represent bare-earth terrain without distortions from vegetation, buildings, or other surface obstructions (Konadu & Fosu,2009; Courty, *et al*, 2019). In many developed countries, this is achieved through LiDAR-derived Digital Terrain Models (DTMs), which provide exceptional vertical accuracy and allow for precise simulation of water flow across floodplains. Such accurate DEMs form the backbone of effective flood risk management, urban planning, and disaster preparedness, supporting the development of resilient cities in line with global best practices.

However, in Nigeria and similar developing regions, access to nationwide, high-resolution LiDAR-derived DEMs remains extremely limited, leading researchers, engineers, and urban planners to rely heavily on freely available global DEM products such as SRTM, ALOS, and Copernicus DEM. While these models are widely used, they differ significantly in terms of spatial resolution, vertical accuracy, and sensitivity to vegetation and urban features. Unfortunately, in most cases, users adopt these DEMs interchangeably without adequate appraisal of their accuracy or suitability for hydrological applications.

This practice has serious implications. When DEM inconsistencies are overlooked, the resulting hydrological models may misrepresent drainage networks, over- or under-estimate runoff volumes, or produce unreliable flood risk maps. In flood-prone urban areas like Port Harcourt, such inaccuracies can lead to poor planning decisions, inadequate flood mitigation measures, and continued vulnerability of communities to flooding hazards.

Therefore, this study aims to appraise selected Digital Elevation Models (DEMs) for hydrological applications in Port Harcourt Metropolis, Nigeria. Specifically, it extracts watershed boundaries and stream networks from DEMs, overlays these features for spatial comparison, and assesses their performance using key hydrological indicators to determine suitability and reliability for urban flood modeling and watershed analysis.

2.0 MATERIALS AND METHODS

2.1 The Study Area

The study area is Port Harcourt metropolis, comprising the two Local Government Areas (LGA) that make up the Port Harcourt metropolitan area in Rivers State, Nigeria, along the Bonny River, an eastern tributary of the Niger River. The City of Port Harcourt is a significant urban hub in Southern Nigeria. The research area encompasses the coastal zones and water bodies that house several jetties that are essential to the region's marine infrastructure. This location was chosen because of its economic importance, vibrant marine life, and extensive network of jetties that facilitate trade, transit, and industrial activity. Its shoreline is dotted with several jetties, creating a complicated urban landscape. These jetties enable industrial activity as well as facilitate the import and export of goods, among other uses. Because the study area serves as a major hub for maritime operations in the area, it is crucial to conduct a thorough geospatial evaluation to improve knowledge and guide sustainable development practices (Collins & Gbenekanu, 2020).

Port Harcourt metropolis is geographically bounded by coordinates Latitude 4°56'42.59"N and Longitude 6°53'7.10"E at the top, and Latitude 4°44'11.07"N and Longitude 6°53'15.34"E at the bottom, forming a polygonal area that defines the study region. The city borders the Local Government Areas (LGAs) of Degema, Emuoha, Ikwerre, Etche, Oyigbo, Eleme, & Okrika. Strategically located at the mouth of the Bonny River in Rivers State, it is approximately 25 km from the Atlantic Ocean, situated between the Dockyard Creek/Bonny River and Amadi Creek. The city's average elevation is around 12 meters above sea level (Akukwe, 2014). Port Harcourt metropolis spans across two LGAs: Port Harcourt and Obio/Akpor, as depicted in Figure 1.

Figure 1: Map of Port Harcourt Metropolis (Obio/Akpor LGA and Port Harcourt City Local Government Area. (Source: Author, 2026)

2.1.1 Data Acquisition

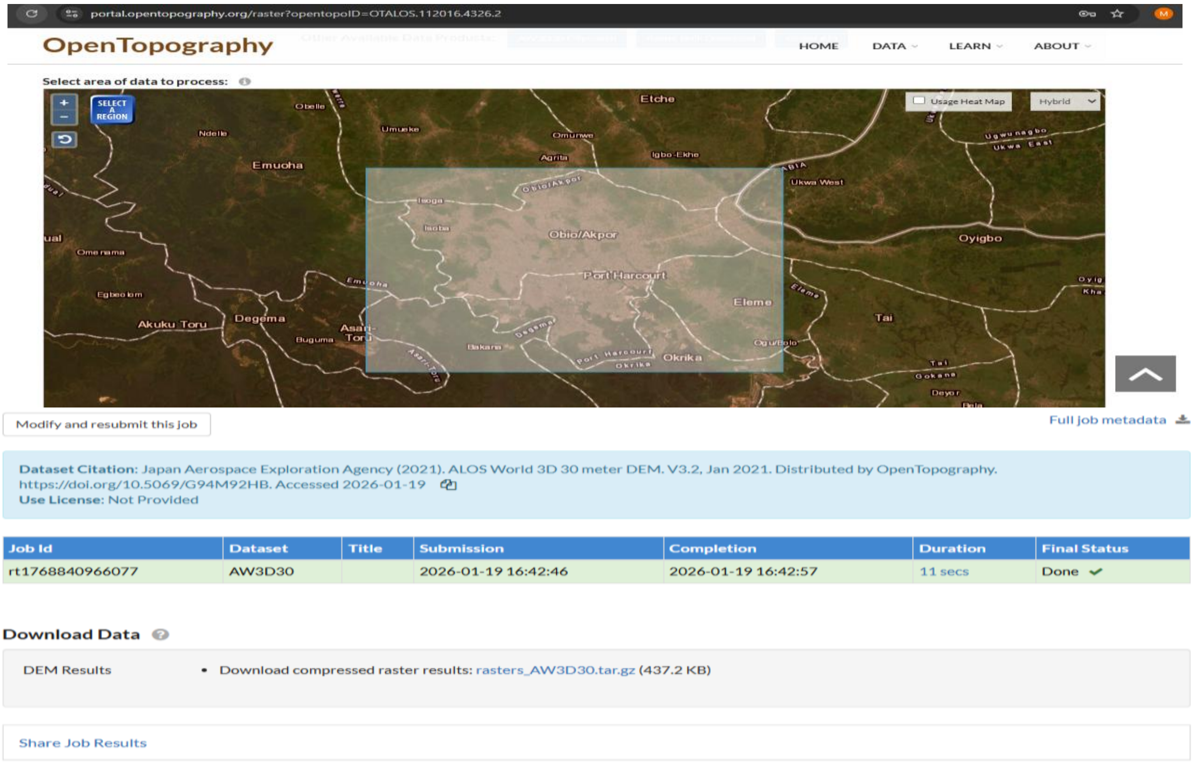
The study relied mainly on Secondary data, which formed the core datasets used for the analysis. The study utilized three Digital Elevation Models: Copernicus GDEM, ALOS DEM, and SRTM DEM, which were downloaded from their respective official repositories via OpenTopography, as shown in Figure 2. These DEMs provided the elevation information required for watershed delineation, flow direction, flow accumulation, and stream network extraction.

In addition, ESRI World Imagery was used as a base map for overlay analysis to visually assess the alignment of extracted stream networks with real-world surface features. Administrative boundary data of Port Harcourt Metropolis were also obtained from relevant geospatial sources to define the study extent.

The combination of primary validation data and secondary elevation datasets ensured a comprehensive and objective appraisal of the selected DEMs for hydrological applications in the study area.

Table 1. Secondary Dataset utilized for the Study

S/N	DEM	Spatial Resolution (m)	Area Covered	Source
1.	Copernicus GDEM	30	Obalga and Phalga	Open Topography
2.	ALOS DEM	30	Obalga and Phalga	Open Topography
3.	SRTM DEM	30	Obalga and Phalga	Open Topography
4.	LGA Shapefile		Obalga and Phalga	Geofabrik



Dataset Citation: Japan Aerospace Exploration Agency (2021). ALOS World 3D 30 meter DEM. V3.2, Jan 2021. Distributed by OpenTopography. https://doi.org/10.5069/G94M92HB. Accessed 2026-01-19
Use License: Not Provided

Job Id	Dataset	Title	Submission	Completion	Duration	Final Status
rt1768840966077	AW3D30		2026-01-19 16:42:46	2026-01-19 16:42:57	11 secs	Done ✓

Download Data

DEM Results
- Download compressed raster results: rasters_AW3D30.tar.gz (437.2 KB)

Share Job Results

Figure 2. A Sample of Digital Elevation Models Spanning Obio/Akpor and Port Harcourt LGA Downloaded from Open Topography

2.1.2 Data Processing

The data processing stage involved a series of systematic procedures carried out using the ArcGIS environment to prepare the Digital Elevation Models (DEMs) for hydrological analysis and comparison. Hydrological processing of the SRTM, ASTER, and ALOS DEMs was carried out independently using ArcGIS 10.7.1. Each DEM was projected to WGS 1984 UTM Zone 32N and corrected for surface depressions using the Fill algorithm. Flow direction and flow accumulation rasters were generated to model drainage patterns. Stream networks were extracted using a comparable flow accumulation threshold, while watershed outlets were defined at identical real-world locations but snapped independently to each DEM. Watershed boundaries were delineated and converted into vector format for morphometric analysis and comparative appraisal.

2.1.3 DEM Clipping

Each DEM was clipped to the administrative boundary of Port Harcourt Metropolis using the Extract by Mask tool in ArcGIS, as shown in Figure 3. This process restricted the datasets to the defined study area and eliminated unnecessary surrounding data. Clipping improved processing efficiency and ensured that all subsequent analyses were confined strictly within the study boundary.

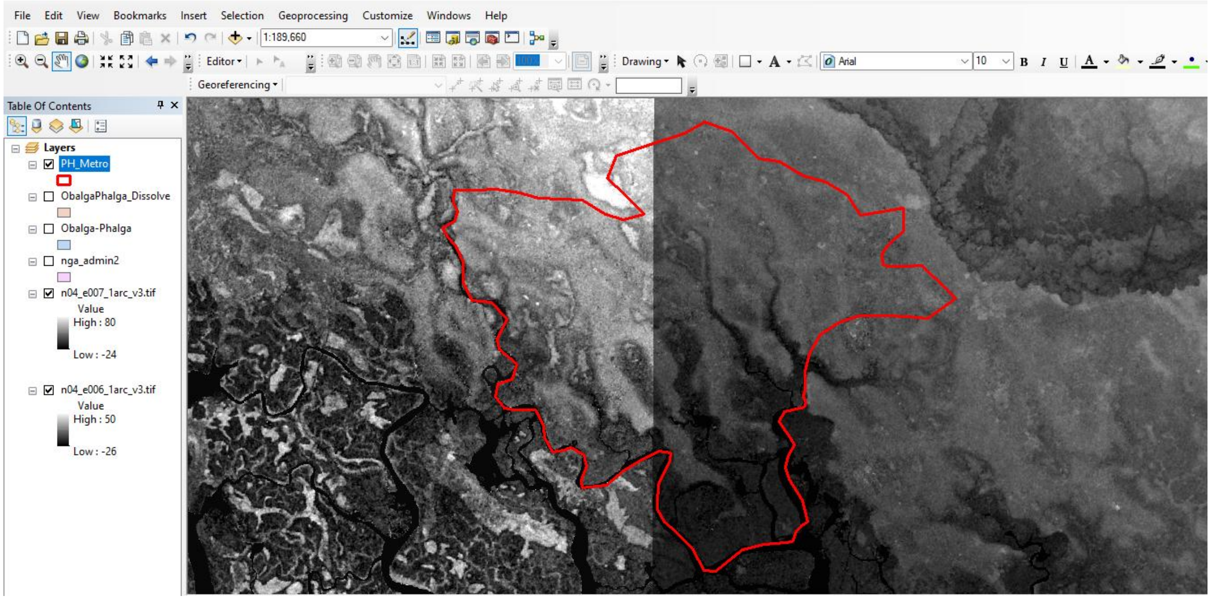


Figure 3. A Sample of the DEM and Port Harcourt Metropolis in the ArcGIS Environment

2.1.4 DEM Preprocessing/Sink Filling

Raw DEMs often contain depressions or sinks caused by data errors or resolution limitations. These depressions can interrupt natural flow modelling. Therefore, the Fill tool was applied to remove spurious sinks and create a hydrologically correct surface. This step ensured continuous water flow across the terrain surface. This process is shown in Figure 4.

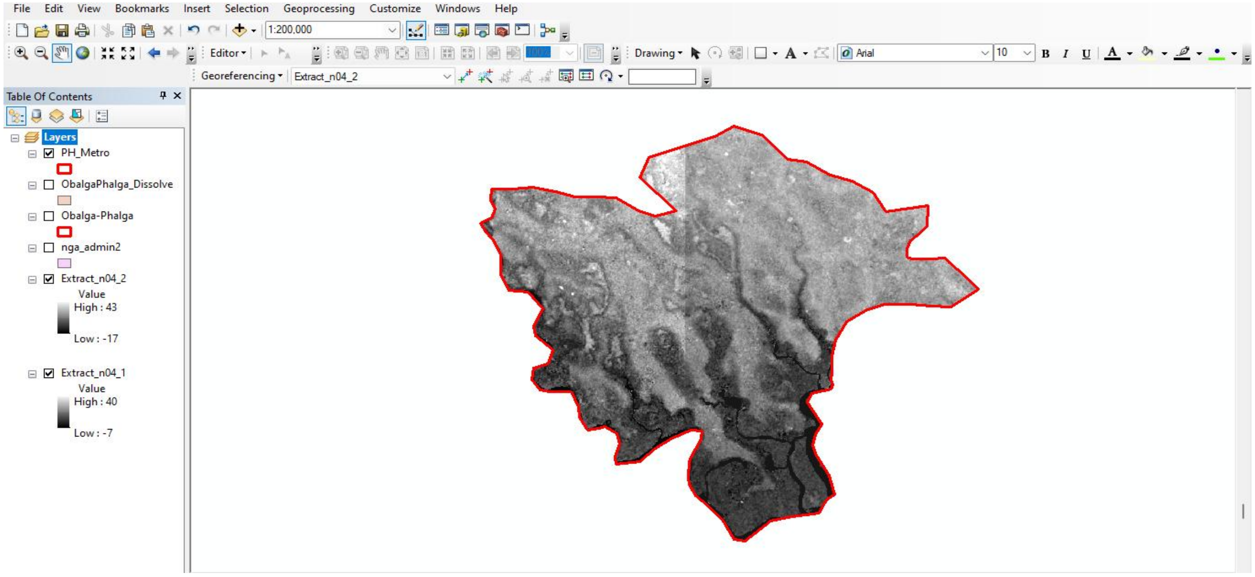


Figure 4. A Sample of DEM Clipped into the Study Area using the Extract by Mask Tool in the ArcGIS Environment

2.1.5 Flow Direction

The flow direction operation was performed on each preprocessed DEM as shown in figures 5 to 7 as shown below, this is after (Zhang *et al*,2017). This determined the direction of water flow from each raster cell based on the steepest descent principle. The output raster indicated how surface runoff would move across the terrain and served as the basis for further hydrological modelling.

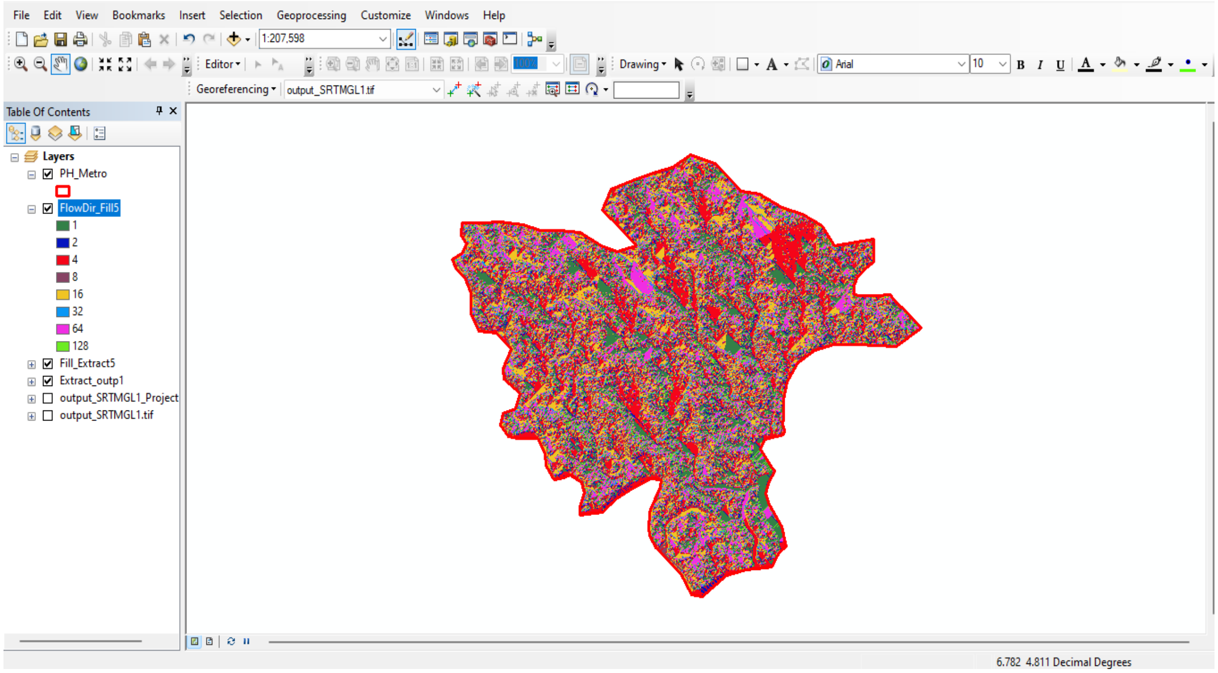


Figure 5. Flow Direction of SRTM DEM in ArcGIS Environment

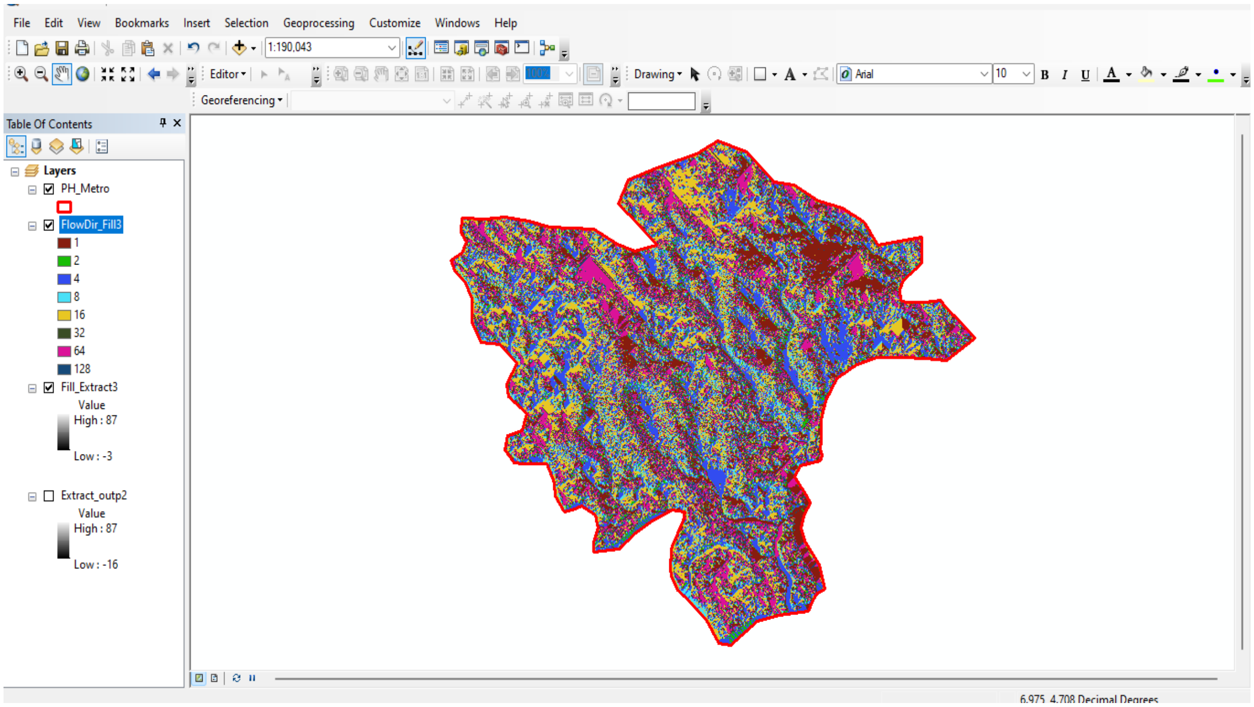


Figure 6. Flow Direction of ALOS DEM in ArcGIS Environment

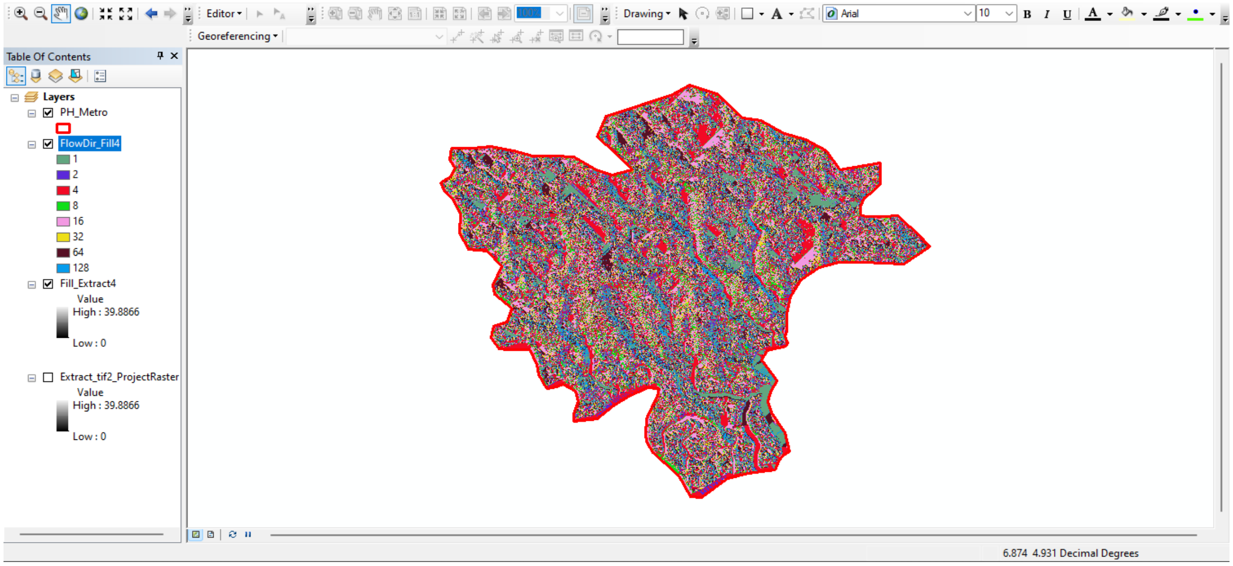


Figure 7. Flow Direction of ALOS DEM in ArcGIS Environment

2.1.6 Flow Accumulation and Stream Extraction

Using the flow direction output, flow accumulation was computed to determine the number of upstream cells contributing flow into each cell. Cells with high accumulation values indicated potential stream channels. A defined threshold value was applied to extract the stream network from the accumulation raster. To ensure comparability across DEMs of varying resolutions, flow accumulation and stream networks as shown in figures 8 and 9 were extracted. A threshold defined as a fixed percentage (3%) of the maximum flow accumulation for each DEM after (Ozulu, & Gökgöz, 2018). This approach accounts for differences in grid structure while maintaining consistent hydrological logic suitable for the low-relief coastal environment of Port Harcourt Metropolis.

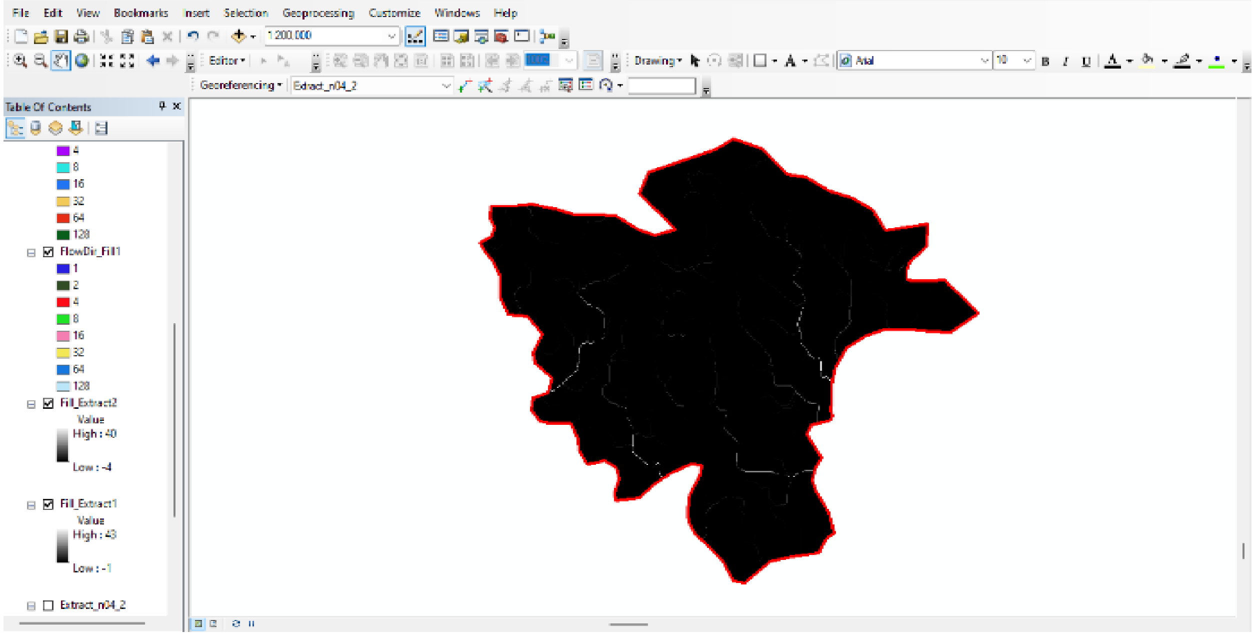


Figure 8. A Sample of Flow Accumulation of DEM in ArcGIS Environment

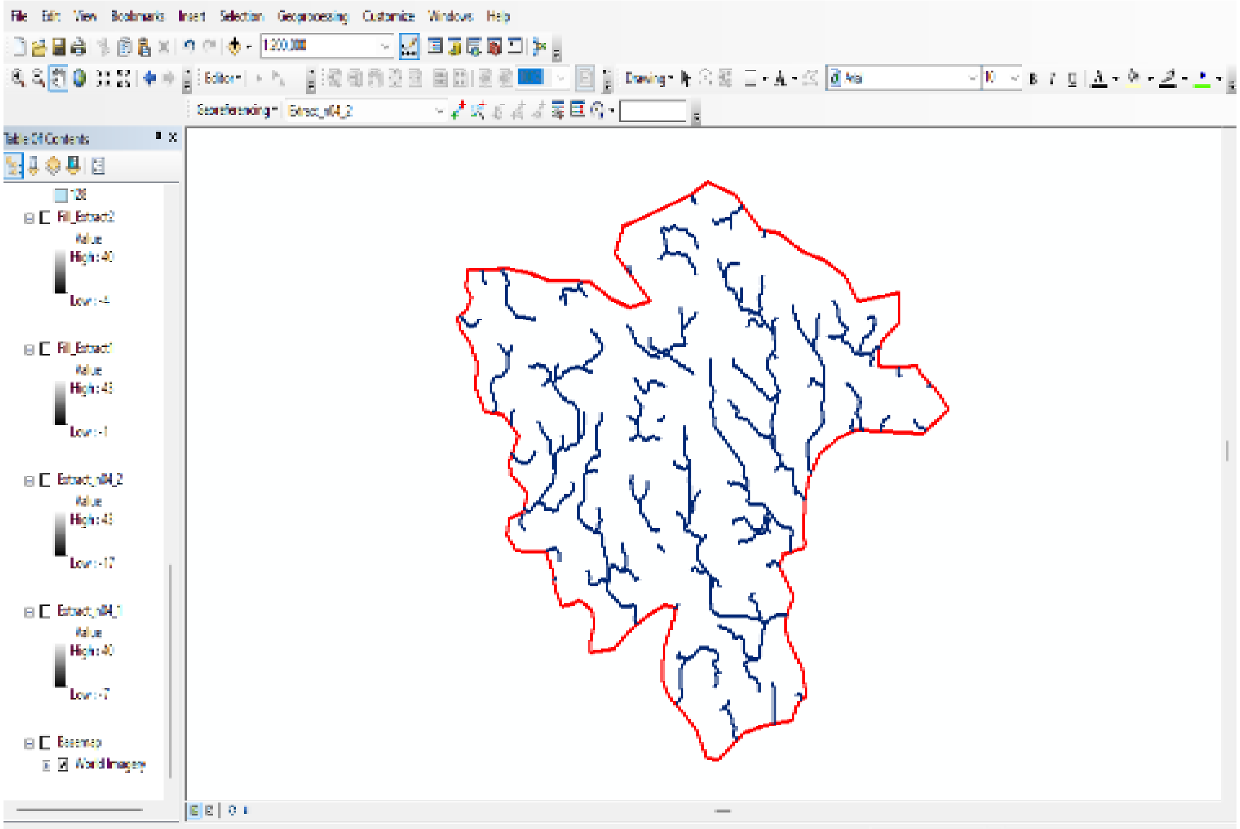


Figure 9. A Sample of Flow Accumulation of DEM in the ArcGIS Environment

2.1.7 Watershed Delineation

Watershed boundaries were delineated using the flow direction raster and selected outlet points within the study area. This process defined the drainage basin contributing runoff to each outlet. The extracted watershed boundaries were also converted to vector format to enable calculation of basin area and perimeter. Watershed delineation was carried out using the Hydrology tools in ArcGIS. The DEM was projected and corrected for surface depressions using the Fill algorithm. Flow direction and flow accumulation rasters were generated to model runoff pathways. A pour point (Ashvath et' al, 2024) was defined at the major drainage outlet and snapped to the highest flow accumulation cell. The watershed tool was then applied to delineate the contributing catchment, which was subsequently converted to vector format for analysis.

2.2 METHODS

This study employed hydrological methodology using the principle Remote Sensing and Geographic Information System (GIS). The flowchart in figure 10 describes the process involved:

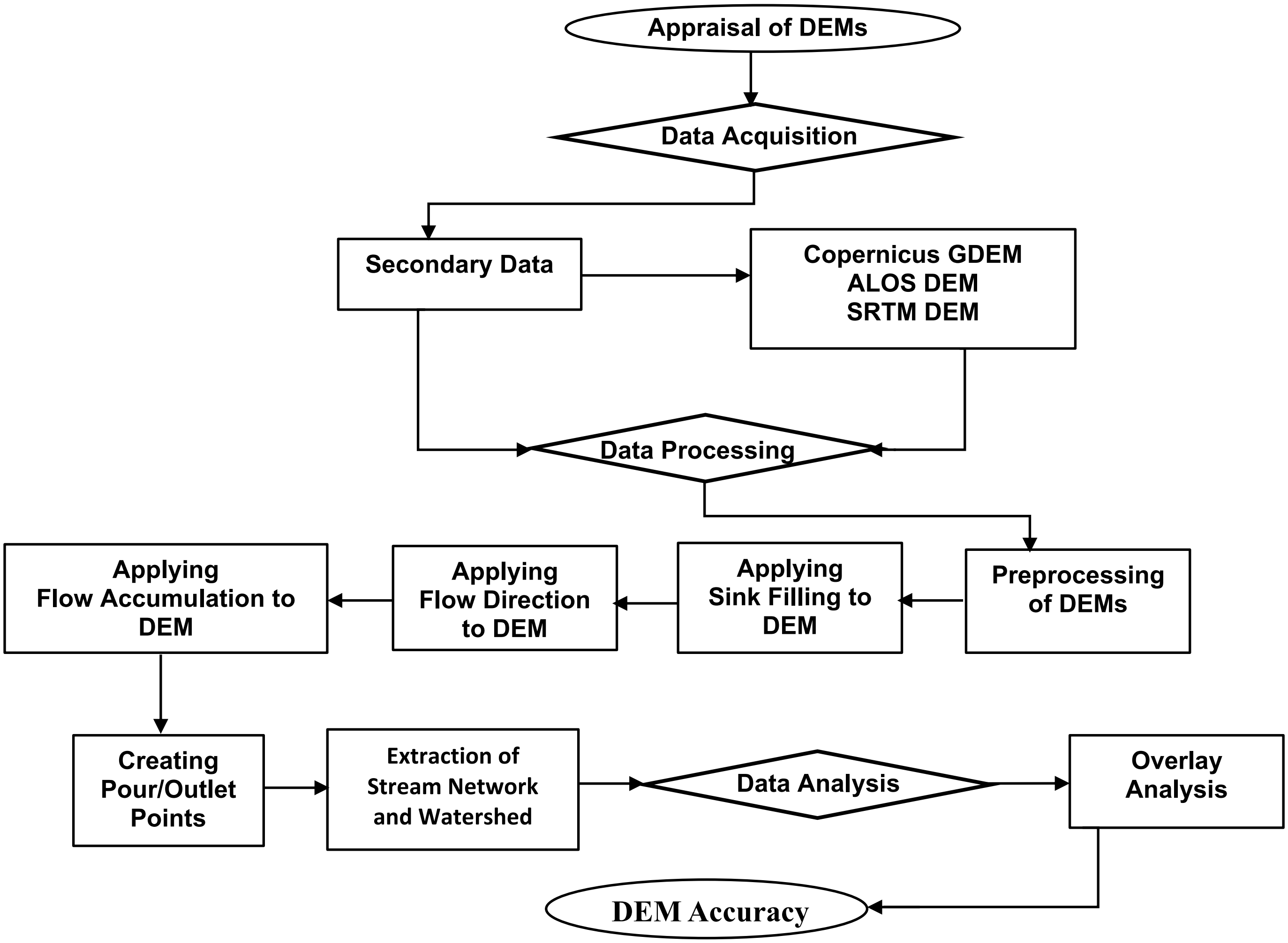


Figure 10: Flow chart of Research Design (Author's Concept, 2026)

2.2.1 Data Analysis

From the extracted stream networks and watershed boundaries, hydrological parameters were computed. These included total stream length, stream count, drainage density, and stream frequency. Drainage density was calculated as the ratio of total stream length to basin area, while stream frequency was calculated as the ratio of stream count to basin area. These parameters were used to assess and compare the performance of the selected DEMs for hydrological applications.

2.2.2 Stream Network Parameters

Total Stream Length (L_{total}): Defined as the sum of the lengths of all streams within a watershed or catchment. It represents the overall extent of the drainage network captured by a DEM.

A longer total stream length often indicates finer resolution of terrain and better detection of small tributaries.

Stream Count (N): The total number of stream segments within the watershed and provides information on the complexity and density of the drainage network.

Drainage Density (Dd):

Drainage density is the ratio of the total length of streams to the area of the basin as given in equation (1):

$$D_d = \frac{L_{TOTAL}}{A} \quad (1)$$

Where:

D_d is the drainage density (km/km²)

L_{TOTAL} is the total stream length in the watershed (km)

A is the Area of the watershed (km²)

Importance to the Study: DEMs with higher spatial resolution typically capture more streams, resulting in higher drainage density, which better represents real hydrological behavior.

Drainage density influences flood prediction, watershed management, and erosion assessment, making it a critical parameter for hydrological applications.

Stream Frequency (F_S)

Stream frequency is the ratio of the number of stream segments to the area of the basin. It reflects the number of streams per unit area, indicating the potential for runoff generation and drainage network complexity as given in equation (2).

$$F_S = \frac{N}{A} \tag{2}$$

Where:

Fs is the Stream frequency (number/km²)

N is the Total number of stream segments

A is the Area of the watershed (km²)

Importance to the Study: Stream frequency is useful in assessing the resolution of DEMs, as higher-resolution models tend to detect more streams. It helps in identifying areas prone to flooding and in evaluating the accuracy of watershed delineation.

3.0 RESULTS AND DISCUSSIONS

Results of Objective I

The watershed boundaries were extracted from all the selected Digital Elevation as shown in figure 11.

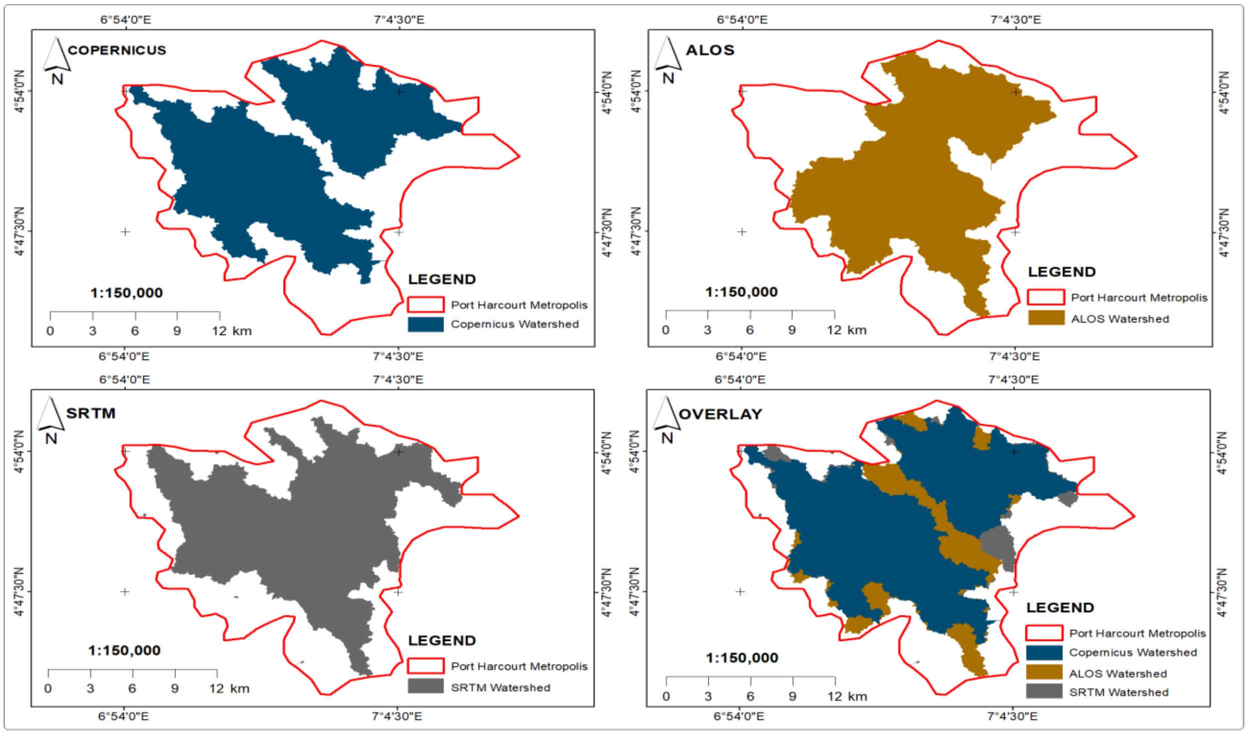


Figure 11. Watershed Extracted from Selected DEM covering Port Harcourt Metropolis

Table 2. Spatial Extent of Extracted Watershed for Selected DEMs

S/N	DEM	Perimeter (km)	Area (km^2)
1	Copernicus	161.917	202.474
2	ALOS	120.892	193.641
3	SRTM	145.651	205.477

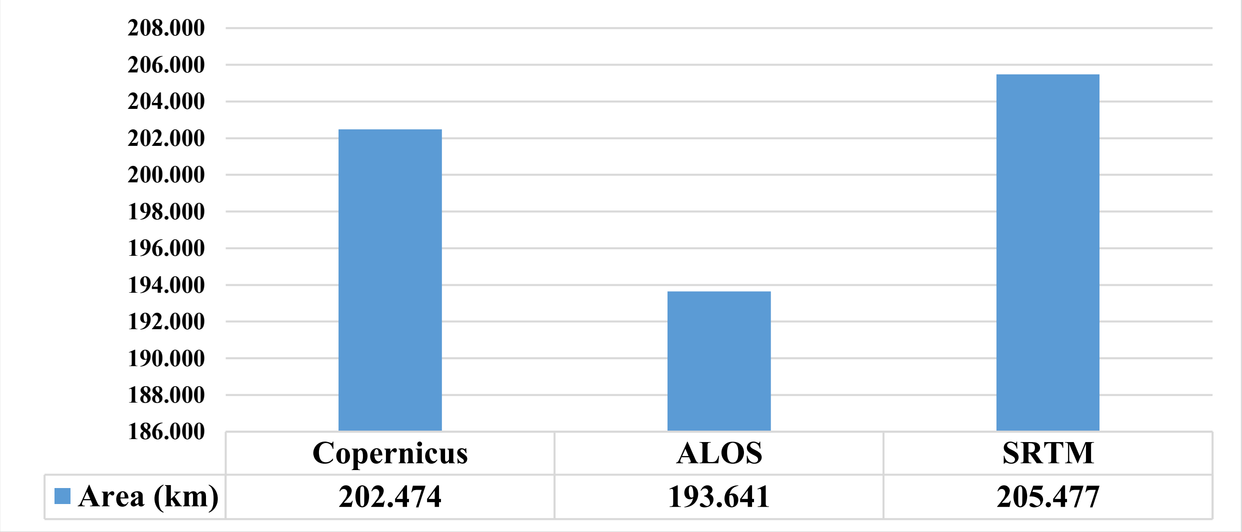


Figure 12. Chart illustrating the Spatial Coverage of Watershed Extracted from Selected DEMs within Port Harcourt Metropolis

Table 3: The Sum of Distances of Stream Network Extracted from Selected DEMs in Port Harcourt Metropolis

Copernicus (km)	ALOS (km)	SRTM (km)
163.746	145.347	152.633

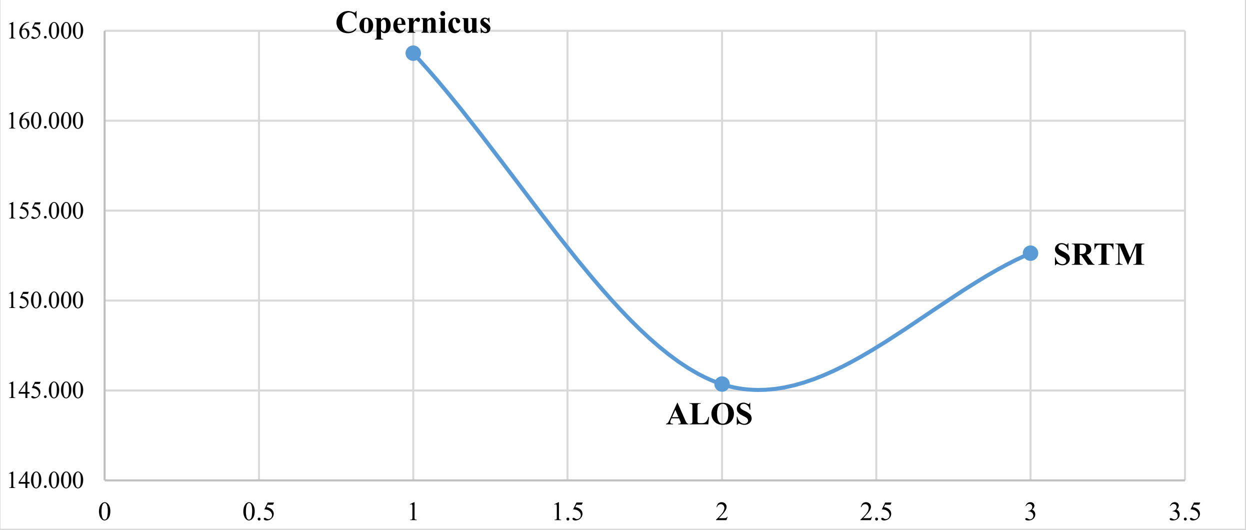


Figure 13. Chart illustrating the Total Stream Lengths Derived from Selected Digital Elevation Models in Port Harcourt Metropolis

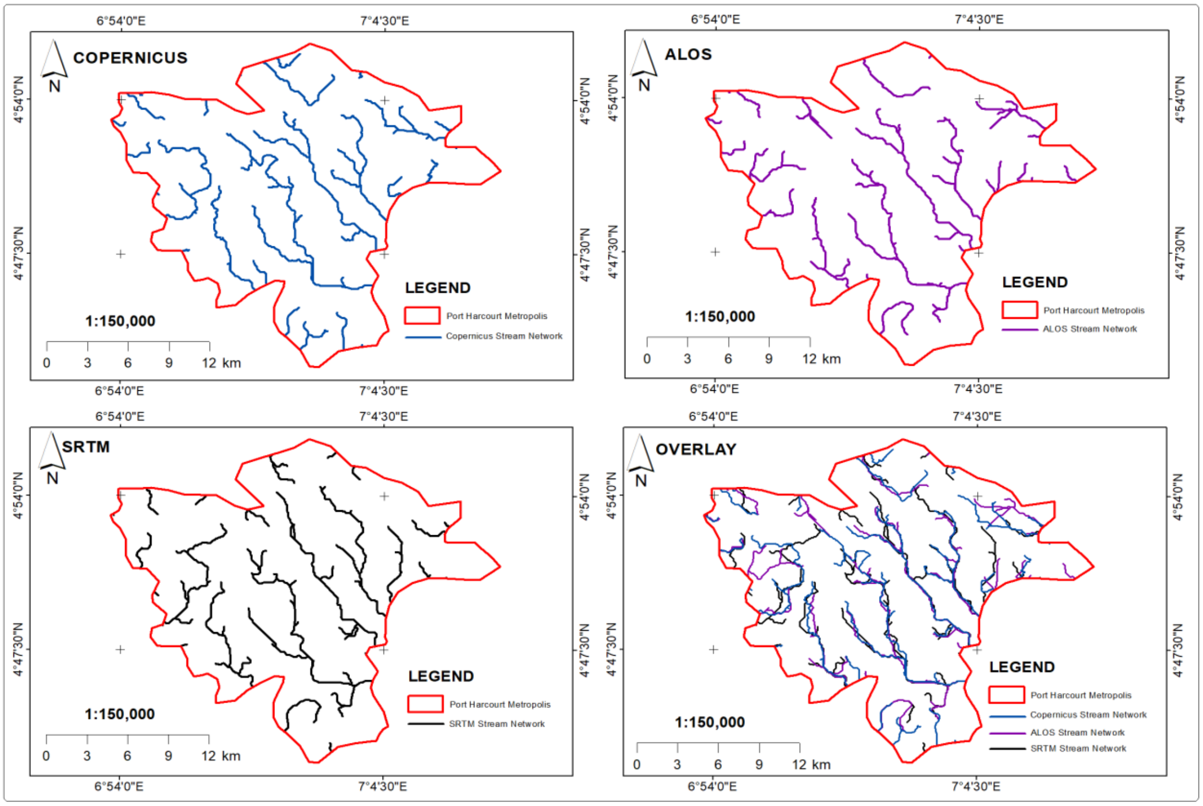


Figure 14. Stream Network Extracted from Selected DEM covering Port Harcourt Metropolis

Models (DEM), namely Copernicus DEM, ALOS DEM, and SRTM DEM, within Port Harcourt Metropolis. However, noticeable variations existed in the extent and spatial definition of the extracted watersheds as evident in Figure 14. The Copernicus DEM produced the largest watershed area, indicating a more detailed surface representation, while the ALOS DEM generated a comparatively smaller watershed extent. The SRTM DEM produced a watershed extent that fell between those of Copernicus and ALOS, suggesting moderate performance. In Figure 12, the stream network extraction revealed that all the DEMs successfully generated drainage patterns consistent with the natural hydrological setting of Port Harcourt Metropolis. The Copernicus DEM produced the highest number of stream segments and the most detailed drainage network, indicating better sensitivity to subtle elevation changes. The ALOS DEM generated fewer stream segments, resulting in a simpler drainage pattern, while the SRTM DEM produced a moderately dense stream network, as shown in Table 3 and Figure 13.

Analysis of the stream length values showed that the total stream length extracted from the Copernicus DEM was the highest, followed by the SRTM DEM, while the ALOS DEM recorded the lowest total stream length, as visibly shown in the chart in Figure 13. This indicates that higher-resolution DEMs were more effective in capturing minor channels and tributaries that are important for hydrological analysis. The spatial pattern of the extracted streams showed that the Copernicus and SRTM DEMs produced drainage networks that closely followed known river paths and low-lying areas within the study area. In contrast, the ALOS DEM exhibited some generalized stream alignments, which may affect precision in detailed hydrological modeling. Overall, the results demonstrated that DEM resolution significantly influenced watershed and stream network extraction. The Copernicus DEM showed superior performance in terms of watershed size, stream density, and total stream length, making it more suitable for detailed hydrological applications in Port Harcourt Metropolis. The SRTM DEM showed moderate reliability and consistency, while the ALOS DEM was less detailed but still useful for generalized hydrological assessments.

Results of Objective II

Table 4 shows the discrepancies in the spatial extent of extracted watershed boundaries for selected DEMs.

Table 3. Digital Elevation Models in Port Harcourt Metropolis

S/N	DEM	Perimeter (km)	Area (km2)	Diff. in Perimeter (km)	Diff. Area (km2)
1.	Copernicus	161.917	202.474		
2.	ALOS	120.892	193.641	-41.025	-8.833
3.	SRTM	145.651	205.477	-16.266	3.002

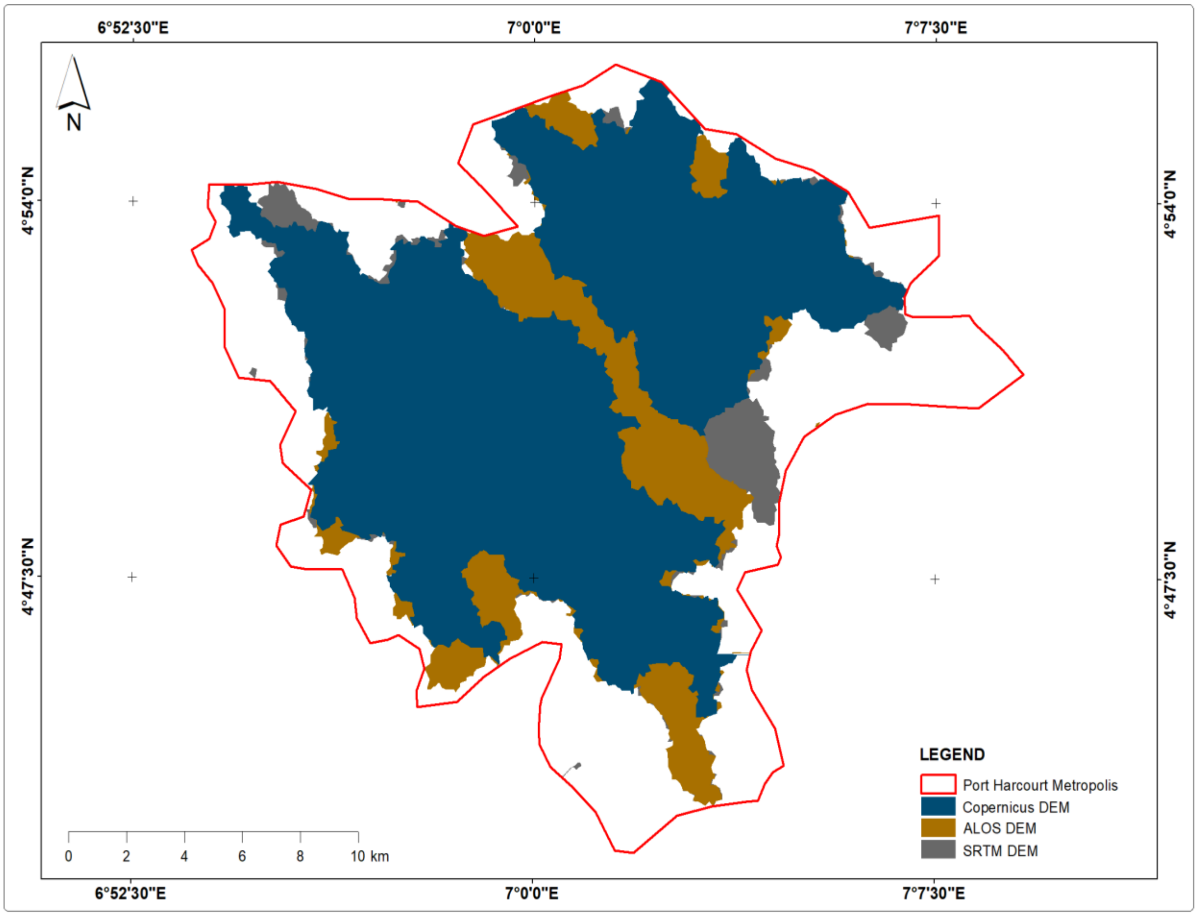


Figure 15. Overlay of the Extracted Watershed Boundaries for Selected Digital Elevation Models in Port Harcourt Metropolis

Table 5. Discrepancies in the DEMs Derived Stream Network in Port Harcourt Metropolis

Copernicus CP (km)	ALOS AL (km)	SRTM SR (km)	Difference (km)	
			CP-AL	CP-SR
163.746	145.347	152.633	18.399	11.113

The overlay of the extracted watershed boundaries from the selected Digital Elevation Models showed that all the DEMs were able to delineate a coherent watershed for Port Harcourt Metropolis figure 15. The Copernicus DEM produced a watershed boundary that was more spatially continuous and well-defined, with smooth and consistent boundary alignment. The SRTM DEM generated a watershed boundary that generally followed the same spatial configuration as that of the Copernicus DEM, although minor boundary irregularities were observed in some sections. In contrast, the ALOS DEM produced a watershed boundary with more noticeable deviations, particularly along the peripheral areas, indicating differences in how drainage divides were represented. These variations revealed that while all DEMs delineated the watershed, the level of spatial consistency differed across the datasets.

The overlay of the extracted stream networks revealed clear differences in stream distribution and continuity among the DEMs. The Copernicus DEM produced a dense and well-connected stream network that was evenly distributed within the watershed area. The SRTM DEM also generated a logical stream network, but with fewer minor tributaries and occasional discontinuities in stream segments. The ALOS DEM produced the least dense stream network, with several areas showing sparse or missing tributaries. In some locations, stream segments derived from the ALOS and SRTM DEMs were observed to approach or slightly diverge from the watershed boundary, indicating spatial mismatches between stream paths and watershed limits. These discrepancies highlighted variations in the ability of the DEMs to represent internal drainage connectivity.

Results of Objective III

Table 6 shows the discrepancies in the spatial extent of the watershed boundary within Port Harcourt Metropolis; Table 6 reveals the percentage differences of the selected DEMs-derived watershed boundaries, comparing it with the Copernicus DEM and overlaying it on ESRI World imagery from the ArcGIS environment. Hence, this satisfies the third objective of the study.

Table 6. Percentage Differences in the Spatial Extent of Extracted Watershed Boundaries for Selected Digital Elevation Models in Port Harcourt Metropolis

S/N	DEM	Difference		% Difference	
		Perimeter (km)	Area (km^2)	Perimeter (km)	Area (km^2)
1.	Copernicus				
2.	ALOS	-41.025	-8.833	−25.34%	−4.36%
3.	SRTM	-16.266	3.002	−10.04%	1.48%

ALOS DEM underestimated the watershed perimeter by 25.34% and the area by 4.36%, showing significant smoothing of terrain and loss of minor drainage features. SRTM DEM slightly underestimated the perimeter by 10.04% but overestimated the area by 1.48%, indicating boundary expansion and possible inclusion of extra terrain features.

This confirms that DEM choice significantly affects hydrological outputs, with Copernicus providing a more balanced representation for Port Harcourt Metropolis. Although the Copernicus DEM generally showed better performance in watershed delineation, slight deviations were observed in the extracted stream network when overlaid on ESRI World Imagery, as some stream segments traversed built-up areas rather than strictly following natural drainage channels, as shown in plates 1 to 3. However, this deviation was relatively minimal compared to those observed by the ALOS and SRTM DEMs, as evident in plate 2.

The stream networks derived from ALOS and SRTM exhibited more pronounced misalignment, with several extracted channels running extensively across buildings and developed areas instead of aligning with identifiable stream paths as evident through plate 1 to 3. This suggests that while Copernicus DEM is not completely free from errors in complex urban terrain, it provides a more realistic representation of drainage patterns in Port Harcourt Metropolis. In contrast, ALOS and SRTM DEMs show reduced suitability for detailed hydrological applications in built-up environments due to greater spatial distortion of stream networks.

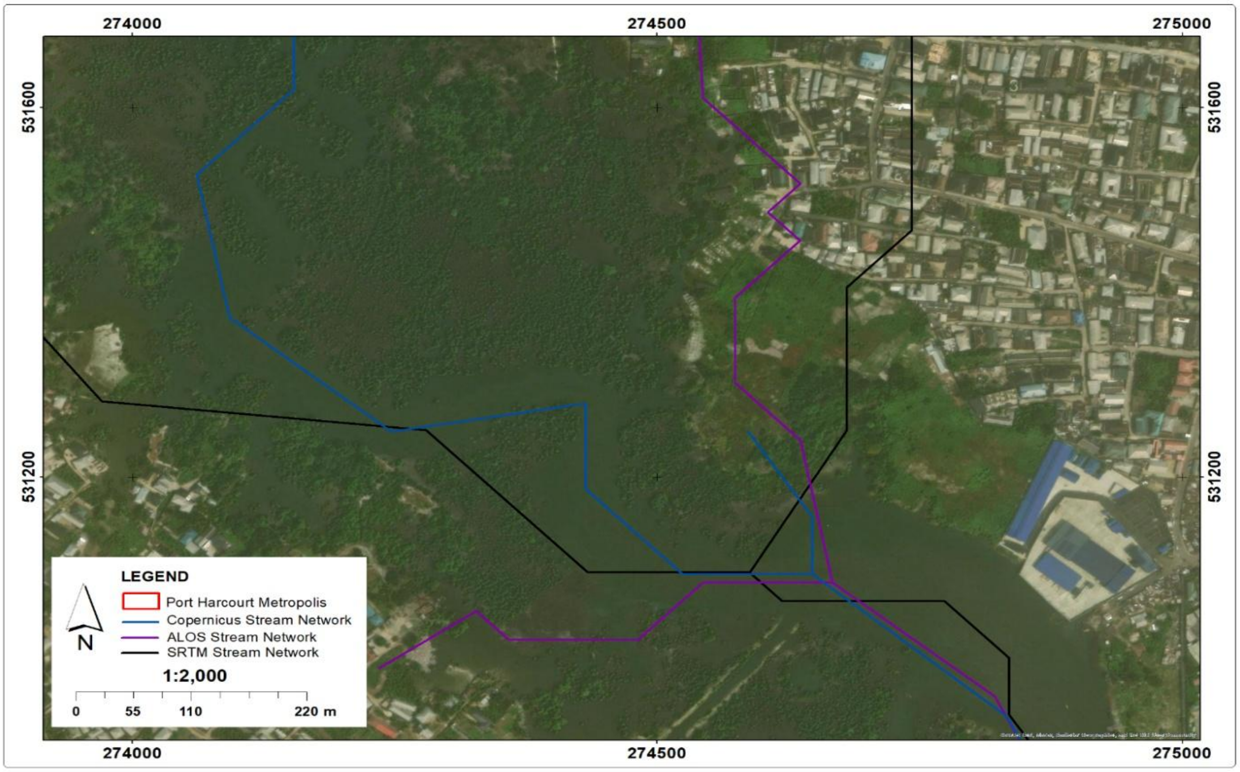


Plate 1. Overlay Analysis of Selected DEM-Derived Stream Networks on ESRI World Imagery in Port Harcourt Metropolis

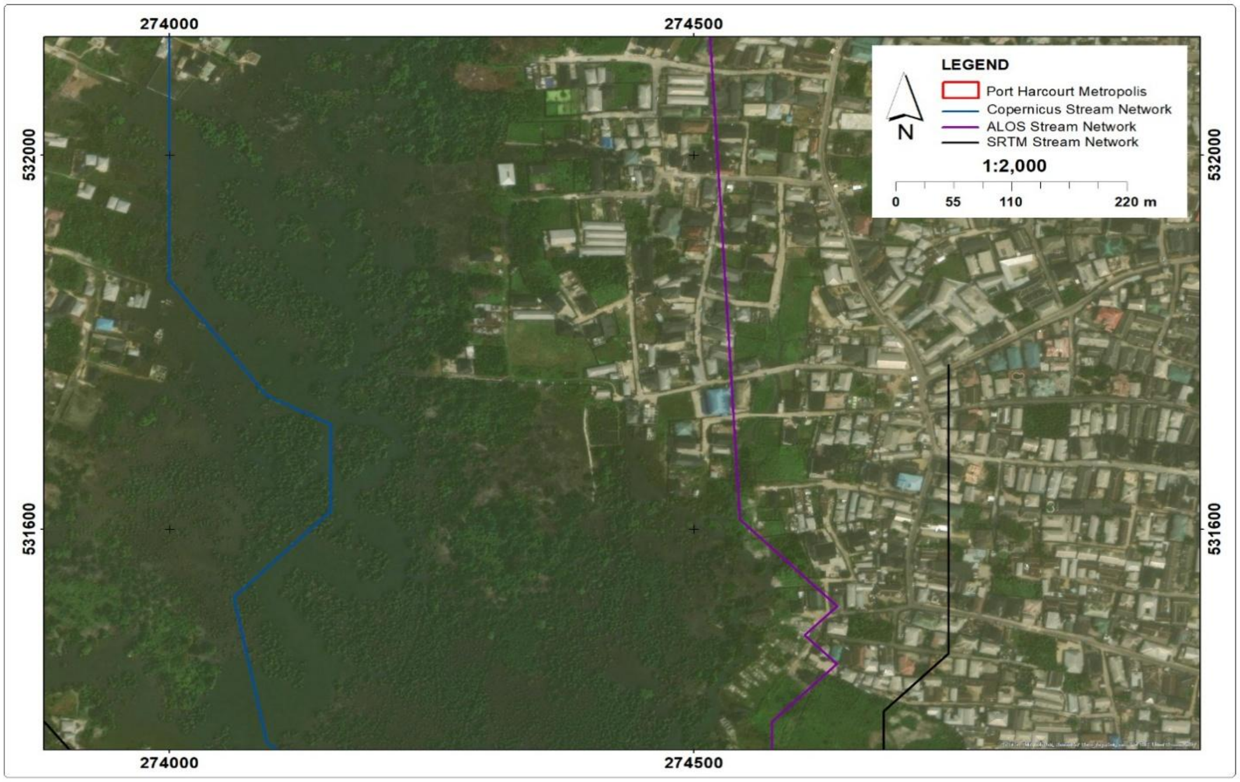


Plate 2. Validation of DEM-Derived Stream Networks Using ESRI World Imagery in Port Harcourt Metropolis

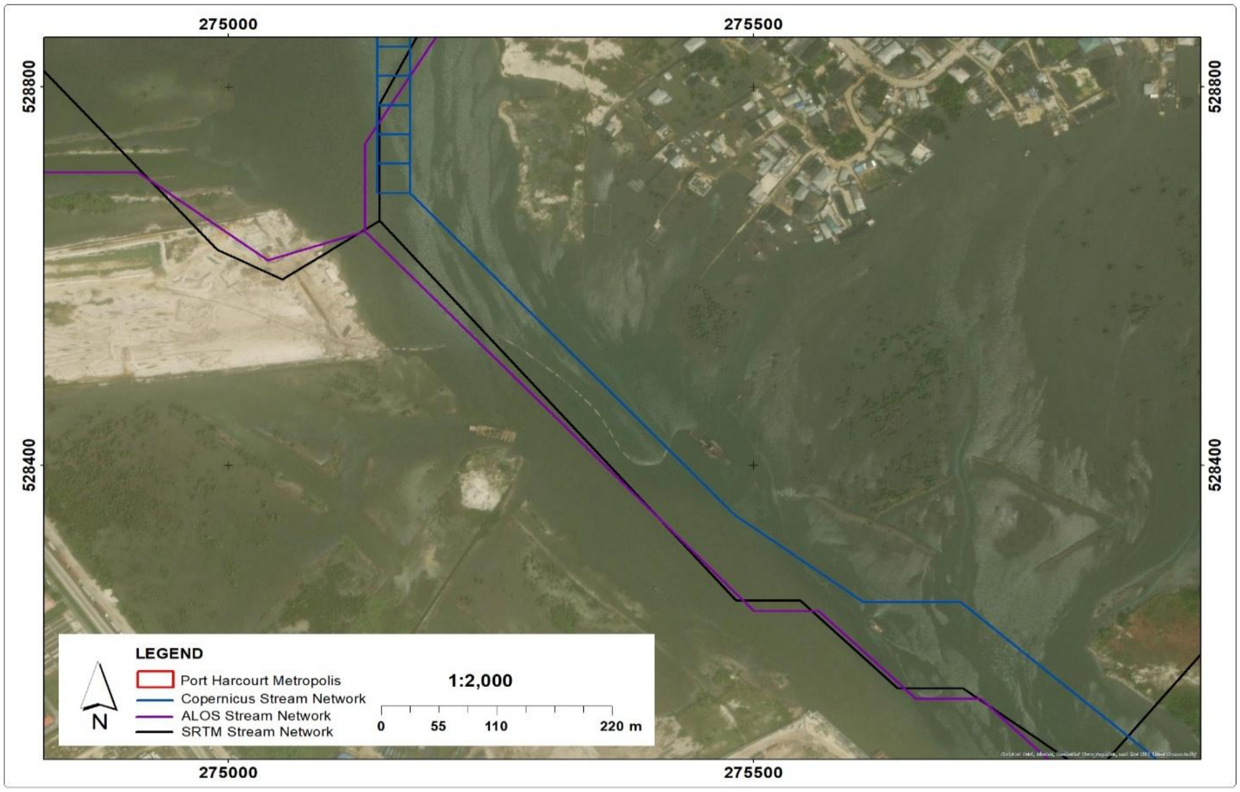


Plate 3. Comparison of DEM-Derived Stream Networks with ESRI World Imagery in Port Harcourt Metropolis

Table 7: Evaluation of Selected DEM Performance for Hydrological Applications in Port Harcourt Metropolis

S/N	DEM	Basin Area (km)	Total Stream Length (km)	Stream Count	Drainage Density (km/km^2)	Stream Frequency
1	Copernicus	202.474	163.746	163	0.809	0.805
2	ALOS	193.641	145.347	146	0.751	0.754
3	SRTM	205.477	152.633	150	0.743	0.730

The drainage density and stream frequency computed for the selected DEMs further revealed variations in their performance for hydrological applications in Port Harcourt Metropolis. The Copernicus DEM recorded the highest drainage density (0.809 km/km^2) and stream frequency (0.805 streams/km^2), indicating its ability to capture a relatively higher number of drainage channels and a more detailed stream network within the basin area. This suggests that Copernicus DEM provides a more comprehensive representation of surface drainage characteristics. The ALOS DEM produced moderate values of drainage density (0.751 km/km^2) and stream frequency (0.754 streams/km^2), reflecting a reduced level of drainage detail when compared with Copernicus. This implies that ALOS DEM tends to smooth terrain features, leading to the omission of some minor stream channels and a less dense drainage network, as shown in Table 7.

The SRTM DEM recorded the lowest stream frequency (0.730 streams/km^2) and a relatively low drainage density (0.743 km/km^2), indicating fewer extracted stream segments per unit area. Although SRTM captured a reasonable extent of drainage features, the lower values suggest potential generalization or distortion of drainage patterns, particularly in built-up areas, as evident through plates 1 to 3. Overall, the results demonstrate that Copernicus DEM exhibits superior performance in representing drainage characteristics, while ALOS and SRTM show comparatively lower effectiveness for detailed hydrological analysis in Port Harcourt Metropolis. These findings confirm that drainage density and stream frequency are useful indicators for evaluating DEM suitability in urban hydrological studies. These observations align with the findings of Laurent and Mhamad (2020), who reported that the quality of DEMs is context-dependent, varying according to the intended application, terrain characteristics, and required resolution.

4.0 CONCLUSION

The appraisal of selected Digital Elevation Models (DEMs) for hydrological applications in Port Harcourt Metropolis has demonstrated that the choice of DEM source has a significant influence on the accuracy and reliability of derived hydrological features, including watershed boundaries, stream networks, and associated drainage characteristics. Among the DEMs evaluated, the Copernicus DEM emerged as the most suitable for urban hydrological analyses. Watershed boundaries derived from Copernicus closely matched expected terrain extents, exhibiting perimeter and area values that provided a balanced representation of the landscape. The stream network extracted from this DEM displayed higher alignment with observable channels when overlaid on ESRI World Imagery, capturing both major and minor tributaries with minimal deviations. Although some stream segments slightly traversed built-up areas, the deviations were minor compared to those observed in the ALOS and SRTM DEMs, suggesting that Copernicus is capable of representing realistic hydrological patterns even in a complex urban environment.

The ALOS DEM consistently underestimated watershed parameters, producing smaller area and perimeter values relative to the baseline Copernicus DEM. Correspondingly, its derived stream network exhibited lower density and frequency, indicating a tendency to smooth the terrain and omit smaller channels. This underestimation may limit its suitability for detailed urban hydrological modeling, particularly in areas where accurate drainage mapping is essential for flood risk assessment, stormwater planning, and watershed management. On the other hand, the SRTM DEM generally overestimated drainage features, producing stream paths that frequently crossed buildings and other non-drainage zones. While it captured a substantial number of streams, the excessive density and misalignment of its network suggest the presence of topographic noise or generalization errors, which could result in misleading interpretations if used without corrective measures.

Quantitative indicators such as drainage density and stream frequency further confirmed these observations. Copernicus exhibited the highest drainage density and stream frequency, reflecting its superior capacity to represent drainage complexity accurately. ALOS recorded moderately lower values, consistent with its smoothing effect, while SRTM displayed the lowest stream frequency despite reasonable drainage density, indicating inconsistencies in channel representation. These metrics reinforce the conclusion that DEM selection directly affects the quality of hydrological analyses and the reliability of derived outputs for urban water management. Overall, the study underscores that while all DEMs can provide baseline hydrological information, their performance varies depending on resolution, source, and terrain complexity. Copernicus DEM stands out as the most balanced and reliable for Port Harcourt's urban environment, offering high spatial fidelity of watershed and stream features. ALOS may be suitable for broader regional assessments where minor stream details are less critical, and SRTM may require preprocessing to reduce overestimation and alignment errors in densely built-up areas. These findings highlight the necessity for careful DEM selection, validation against high-resolution imagery or surveyed data, and consideration of urban land cover when conducting hydrological modeling in complex metropolitan landscapes. The findings of this study would help in flood risk mapping, Urban planning and zoning, design of levees and drainage systems, climate change impact assessment, and emergency response planning, which supports "SDG 13" for Climate Action.

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