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Research Article

Evaluation of Catchment area delineation Methods: Comparison of TOPAZ on WMS with HEC-HMS 4.12

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ABSTRACT

The delineation of catchment areas plays a crucial role in hydrological modeling, influencing water resource management and flood analysis. However, differences in Digital Elevation Model (DEM) resolutions and processing methods can significantly affect the accuracy of delineation results. This study aims to evaluate the differences in catchment area delineation using Hydrologic Engineering Center-Hydrologic Modeling System (HEC-HMS) 4.12 and Watershed Modeling System (WMS) TOPAZ across three DEM resolutions: DEMNAS (8.29 m), ASTER (30 m), and SRTM (90 m). The methodology involves processing DEM data using both software tools, comparing catchment area, main river length, and basin length derived from each resolution. The analysis reveals that higher DEM resolution results in greater similarity between the two methods. At an SRTM resolution of 90 m, the delineated catchment area is 1474.41 km² (WMS) and 1468.03 km² (HEC-HMS), whereas at an 8.29 m DEMNAS resolution, it is 1462.64 km² (WMS) and 1462.91 km² (HEC-HMS). Additionally, significant differences are observed in the main river length, with 44,368.54 m (WMS) and 34,960.17 m (HEC-HMS) at 90 m resolution, and 58,195.71 m (WMS) and 42,537.38 m (HEC-HMS) at 8.29 m resolution. These findings highlight the importance of selecting an appropriate DEM resolution to ensure accurate and consistent hydrological delineation.
Keywords: Delineation; DEM Resolution; TOPAZ; HEC-HMS

INTRODUCTION

A catchment area is the basic unit for describing the hydrological cycle and resource management, catchment area can be determined from widely available topographic data and river flow can be measured at their outlet [1]. Topographic conditions plays an important role in hydrological modeling, geographic representation in a digital environment is a key aspect of modelling. Accurate deliniation of catchment boundaries is essential, as most hydrological modelling requires accuracy in the process of determining these boundaries [2]. In the process of digitally generating topographic data, flow routing algorithms such as Deterministic Eight-node (D8), Rho8, and D8-LTD are widely used in various software such as HEC-HMS and WMS.

These flow routing algorithm process a Digital Elevation Model (DEM), which is a rectangular grid data set containing elevation information at specific location. The D8 algorithm, which is most commonly used, generates the grid-based flow matrix required for catchment area delineation. The D8 algorithm is recognized as one of the most widely used methods for determining flow direction in DEMs in hydrology studies and catchment area delineation. Some studies state that although there are other methods such as D∞ or Multiple Flow Direction (MFD), the D8 algorithm remains popular due to its simplicity and ability to provide fairly accurate results in most applications, especially in areas with clearer topography [3].

Catchment delineation is one of the fundamental steps in water resources management, especially in hydrological modeling, land use planning, flood disaster mitigation, and others. By conducting catchment area delineation, the geographical boundaries of the area that drains water to a certain outlet point can be identified, thus becoming the basis for further hydrological analysis [4]. In recent decades, various methods and tools have been developed to delineate catchment area and calculate hydrological parameters with increasingly high precision. Among these tools, Topographic Parameterization (TOPAZ) integrated with Watershed Modeling System (WMS), and Hydrologic Engineering Center - Hydrologic Modeling System (HEC–HMS) are two frequently used software tools to delineate catchment area [5],[6].

Accurate catchment area delineation is critical in hydrological modeling, as it directly affects water resource management, flood prediction, and watershed planning. Various methodologies have been developed to process Digital Elevation Models (DEM) for delineating watershed boundaries and river networks. One such approach is the TOPAZ technique, which utilizes topographic parameterization to analyze elevation data and address imperfections in DEM. By processing elevation data, TOPAZ can improve the accuracy of watershed delineation by identifying catchment boundaries and mapping river networks. This capability is particularly beneficial for hydrological studies, as it ensures a more precise representation of surface flow, aiding in effective decision-making for water resource management [7].

HEC-HMS version 4.12 has undergone significant development in terms of catchment area delineation. In this version, HEC-HMS no longer requires HEC-GeoHMS to perform the delineation function. By using DEM data in GeoTiff format directly, HEC-HMS can perform catchment areas and river networks with better automation and a simpler interface. The catchment area delineation process in HEC-HMS starts with a DEM input, which is then processed using flow direction and flow accumulation algorithms to determine catchment area boundaries and river flow. These algorithms are equivalent to approaches used in other GIS software, but are fully accessible in the HEC-HMS environment without the need to pre-processing in other software [8]. These advances make HEC-HMS version 4.12 more efficient for users who want an integrated hydrological modeling solution.

In addition to method selection, the selection of the Digital Elevation Model (DEM) data also plays an important role in determining catchment area boundaries. Some commonly used DEM types are the Shuttle Radar Topography Mission (SRTM) 90 m, the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) 30 m, and National Digital Elevation Model (DEMNAS) 8,29 m [9]. However, with the emergence of DEMNAS which has a higher resolution of 8.29 meters, opportunities to increase the accuracy of catchment area delineation are increasingly open. DEMNAS offers finer topographic details and allows the identification of topographic features with more precision compared to SRTM and ASTER [10]

Although both tools and DEM data are used for the same purpose, differences in the approaches, tools, and DEM resolution used can result in different catchment area delineations. Several previous studies have shown significant variations in delineation results between these two methods and different types of DEM, which in turn influences the results of subsequent hydrological analyses [11]. Therefore, this research aims to compare the results of catchment area delineation using TOPAZ in WMS and HEC–HMS 4.12 with various types of DEM, namely SRTM 90 m, ASTER 30 m, and DEMNAS 8.29 m. This research has not only evaluate the differences in delineation results but also explore the factors that cause these differences, which is expected to make a significant contribution in selecting more appropriate delineation methods and DEM data according to application needs

Recent advancements have also integrated remote sensing technologies to enhance delineation accuracy [12]. Higher resolution DEMs can capture more intricate details of stream networks, which play a vital role in defining hydrological features. The location of hydrological sinks within these networks can affect downstream flow values and significant impact on delineation accuracy. Studies have shown that the inclusion of detailed river networks can effectively overcome the variability caused by different DEM resolutions, highlighting the importance of river networks in hydrological modeling [13]. Likewise, variations in DEM resolutions, such as those derived from LiDAR or ALOS data, can lead to subtle inconsistencies, but higher resolutions often reduces potential errors by offering more detailed and reliable hydrological features, even in complex terrains [14]. Innovations in DEM data processing techniques, such as multi-source DEMs, have reduced raw data errors, thereby improving delineation accuracy [15]. Despite these limitations, refined methodologies continue to improve the accuracy and stability of catchment delineation, even in data-limited areas, by adapting DEM-derived indicators for wider applications. [16].

In addition, innovations in DEM data processing techniques and ultra-high-resolution datasets have improved watershed delineation methods, especially by addressing errors and improving spatial accuracy [17][18]. Recent researches has also explored the potential of data assimilation approaches, combining remote observations with DEM-based models to improve hydrological predictions [19]. By combining these advances, tools such as HEC-HMS and TOPAZ can achieve higher accuracy and efficiency in delineating catchments. Future researches are expected to explore further integration of multi-source DEM and remote sensing data to improve real-time monitoring and analysis of watershed characteristics [20][21].

METHODS

Study Area

This research is located in the Jatigede Dam catchment area, which is part of the Cimanuk catchment area within the Cimanuk–Cisanggarung (Cimancis) river basin. Geographically, the location of this study is in Sumedang Regency, West Java Province. The geographical coordinates of the delineation outlet at Jatigede Dam are 6°51'23.86"S, 108°5'52.65"E [22]. Jatigede Dam is a national strategic project that plays an important role in water resources management, both for irrigation, flood control, and raw water supply. The Jatigede Dam catchment area covers a large area with varying topography, from lowlands to mountains. This makes this area an ideal location for catchment area delineation studies, because the topographic variations allow for a comprehensive analysis of the effectiveness of the various methods and DEM data used. Figure 1 shows the study area in this study.

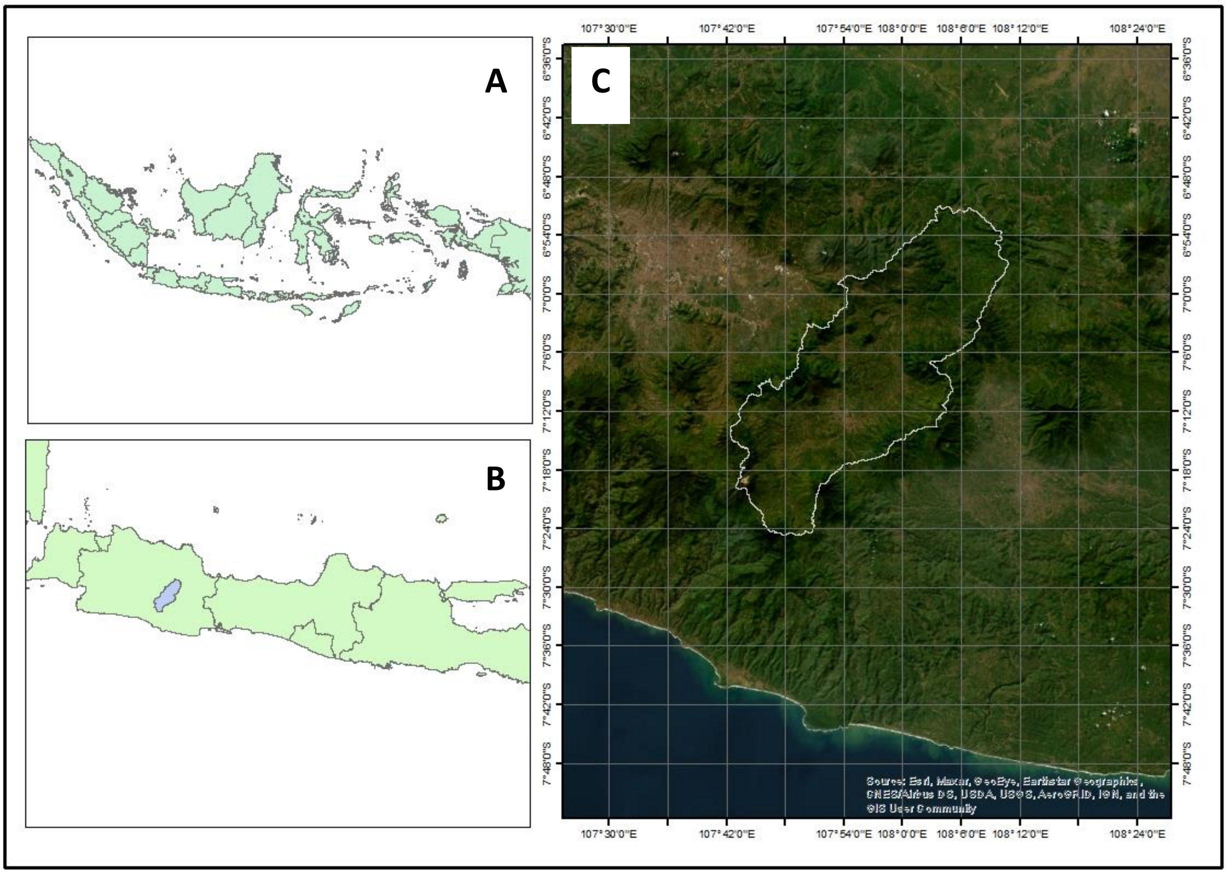

Figure 1 Study Area A) Indonesia, B) West Java Province C) Jatigede Watershed

Data

This study uses three types of Digital Elevation Models (DEM) to form the Jatigede Dam catchment area, namely DEMNAS 8.29 m, SRTM 90 m, and ASTER 30 m. Each DEM data sources has unique characteristics and advantages, resulting in an accurate delineation processes.

1. National Digital Elevation Model (DEMNAS) with 8.29 m Resolution

DEMNAS has a higher resolution of 8.29 meters compared to SRTM and ASTER. DEMNAS is produced by combining data from LIDAR, IFSAR, and stereo spot-6/7 technologies, resulting in a more detailed and accurate elevation model, especially for local studies in Indonesia [10]. DEMNAS can be accessed through the official Badan Informasi Geografis (BIG) website which is very useful for topographic analysis that requires good local details.

2. Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) with 30 m Resolution

ASTER data has a resolution of 30 meters. This ASTER data was developed through a collaboration between National Aeronautics and Space Administration (NASA) and Ministry of Economy, Trade, and Industry of Japan (METI). ASTER GDEM (Global Digital Elevation Model) is produced using active sensing from two different viewpoints, which allows it to provide more accurate elevation information in areas with significant elevation variations [24]. This data is particularly useful in areas with varying topography and elevations. ASTER data can be accessed through the NASA LP DAAC portal, which manages its distribution for research and scientific applications.

3. Shuttle Radar Topography Mission (SRTM) with 90 m Resolution

This SRTM data was developed by NASA. SRTM is one of the most widely used topographic data sources in the world. The resolution of SRTM data is 90 meters, this data was obtained from a radar mission carried out in 2000, which provides consistent global elevation data. SRTM can be accessed through the USGS Earth Explorer portal [25]. The main advantage of SRTM is its global coverage, making it suitable for large-scale studies. However, this 90-meter resolution may not be sufficient for more detailed topographic analysis, such as that required for small catchments or areas with complex elevation terrain.

Research Design

To study the accuracy of the delineation of the Jatigede Dam catchment area, this study used three types of DEM data, namely SRTM 90 m, ASTER 30 m, and DEMNAS 8.29 m. The study compares the delineation results using WMS (TOPAZ) and HEC-HMS 4.12. The analysis focuses on the differences in catchment area size, stream length, and the overall configuration produced by each DEM and software. Both WMS TOPAZ and HEC-HMS 4.12 utilize the same fundamental hydrological algorithms for delineating watersheds, namely: flow direction, flow accumulation, stream definition, flow length, and watershed delineation. Despite the differences in the number of steps required in each software, the underlying processes are essentially the same. Figure 2 illustrates the detailed flowchart of the research process.

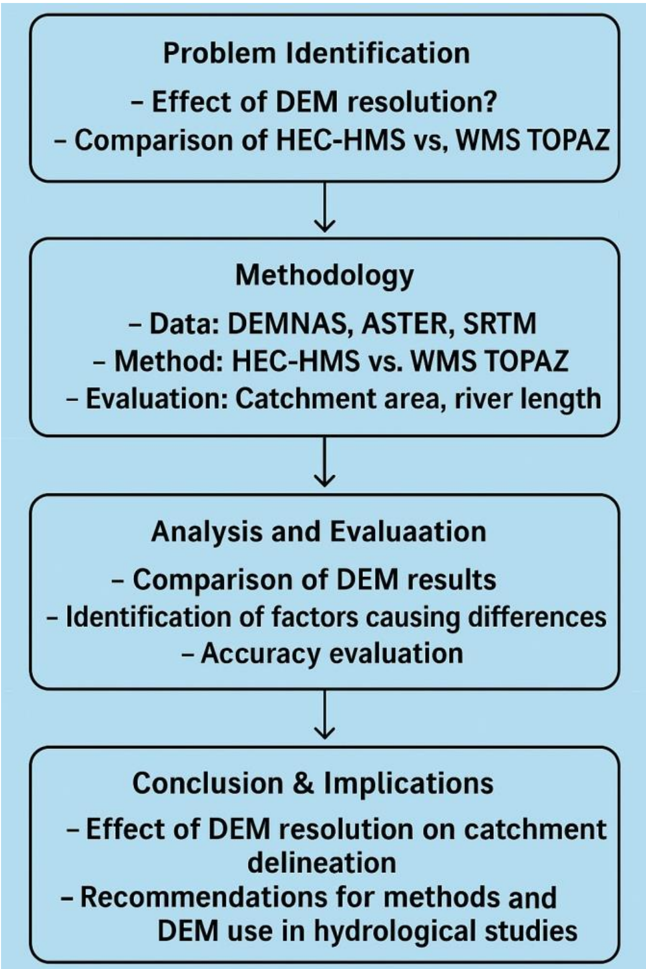

Figure 2 Research Design Flowchart

Hydrologic Modeling System (HEC-HMS)

HEC–HMS version 4.12, developed by the U.S. Army Corps of Engineers, is the most recent iteration of the software used for simulating the complete hydrologic processes of a watershed. One of its key strengths is the ability to delineate watersheds using a combination of DEM and hydrological inputs. With version 4.12, HEC-HMS incorporates enhanced GIS integration, allowing users to directly import DEM for watershed and sub-basin delineation, streamlining the entire modeling process [8]. The software also supports various algorithms to determine flow direction and accumulation, critical for accurate runoff simulations.

HEC-HMS 4.12 is equipped with advanced hydrological analysis tools, including an enhanced rainfall – runoff model, infiltration calculations, and flood routing through river and reservoirs. Its ability to describe cacthments and river network is essential for comprehensive hydrological modelling. The flexibility of the software allows modeling a wide range of hydrological processes, from small-scale cathment to large river basin.

Futhermore, the new version supports better interoperability with other software such as HEC-RAS and ArcGIS, making it more efficient for users to move between different hydrological and hydraulic analyses. HEC-HMS also improves on previous versions by allowing simulation of more complex hydrological systems, including systems with multiple outlets, distributes rainfall, and real-time forecating capabilities. However, it still requires some external GIS preprocessing for tasks such as detailed DEM processing, similar to previous versions.

Watershed Modeling System (WMS)

WMS, developed by Aquaveo, is a GIS-based software designed to simplify watershed delineation and hydrologic modeling. One of its main strengths lies in its ability to automatically delineate watersheds using DEM data, allowing users to quickly extract important hydrologic features such as flow direction, slope, and accumulation. Unlike HEC-HMS, WMS processes DEMs directly without the need for extensive external preprocessing, which saves time and makes the workflow more efficient. This capability, combined with its ability to handle large data sets, makes WMS extremely useful for fast and accurate watershed delineation.

WMS also supports a variety of hydrological models, such as HEC-HMS, HEC-RAS, and TR-55, which allow users to simulate storm-water runoff, infiltration, and drainage networks. Its automated tools for defining river networks, sub-basins, and flow paths are invaluable for tasks such as floodplain management, drainage system design, and erosion control. Furthermore, WMS provides interactive editing options, allowing users to refine watershed boundaries as needed. With its intuitive interface and powerful analysis tools, it is a great option for both academic research and real-world water resources management.

In addition to delineation, WMS has advanced hydrological modeling capabilities, including simulation of rainfall-runoff processes, sediment transport, and hydraulic connectivity within a catchment area. Its seamless integration with topographical data enhances the accuracy of hydrological simulations. Compared to HEC-HMS, WMS offers added flexibility by allowing users to manage spatial data directly and conduct more detailed spatial analyses for hydrological parameter extraction. This combination of efficiency, flexibility, and detailed modeling makes WMS a robust tool for tackling both simple and complex hydrological challenges.

Flow Direction

This study uses TOPAZ and HEC-HMS WMS software. The Flow Direction D8 algorithm (Deterministic 8-neighbor algorithm) is used to determine the direction of water flow in the Digital Elevation Model (DEM). The D8 algorithm functions to determining the direction of flow from each grid cell to one of its eight neighboring cells that has the lowest elevation. Each cell has only one flow direction, which is described by eight possible directions based on the neighbor grid [26].

The D8 algorithm is based on a slope calculation that determines the steepest descent between a cell and its neighboring cells. The formula for the slope is derived from the basic principle of gradient, which calculates the vertical change in elevation relative to the horizontal distance between the cells. Mathematically, the slope (Sij) between the center cell (i,j) and its neighboring cell (k,l) is expressed as:

$$S_{ij} = \frac{z_{ij} - z_{kl}}{d_{ij,kl}} \quad (1)$$

Where:

- Sij represents the slope or gradient between the central cell (i,j) and its neighboring cell (k,l)
- zij and zkl are the elevations of the center cell and the neighboring cell, respectively,
- dij,kl is the horizontal or diagonal distance between the two cells, with d = 1 for horizontal/vertical neighbors and d = $\sqrt{2}$ for diagonal neighbors.

The flow is directed towards the neighboring cell that has the steepest negative slope (the highest descent in elevation). This method allows for an efficient way to simulate water flow across the catchment area (Jones, 2002). Despite its effectiveness, the D8 algorithm has limitations, especially in representing more complex flow patterns in flat or valley areas, where water can flow in multiple directions [27].

In the D8 algorithm, there are eight flow directions that a cell may pass through which are coded with numbers: East (E) = 1, Southeast (SE) = 2, South (S) = 4, Southwest (SW) = 8, West (W) = 16, Northwest (NW) = 32, North (N) = 64, and Northeast (NE) = 128. The flow direction grid numbering convention is shown in Figure 3. If after analyzing the relative slope, the flow of a cell leads to the West, then the flow is coded with the number 16. However, in some cases, some cells do not have a clear flow direction because the elevation of the eight cells around them is higher. In DEM processing, this situation is known as a sink or flow depression area. Water that flows into the sink cell cannot move to the next cell, thereby causing a disruption in the flow network and potentially causing puddles [27].

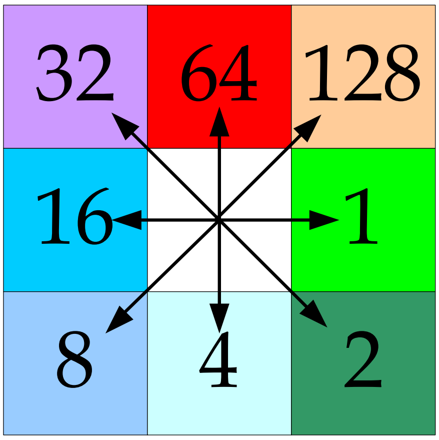

Figure 3 Flow direction grid numbering convention

Flow Accumulation

Flow accumulation can be derived from flow direction maps. Basically, if each cell has a defined flow direction, then when it rains, the accumulated flow from each cell will go to the cell that has the lowest elevation. These cells that have the lowest elevation will form a river network in a stretch of the catchment area. For normal flow accumulation conditions where the cell value is not specifically defined, the value of each grid cell pixel is assumed to be one. Meanwhile, for cells that are defined, the value is the cell which is the result of the sum of each cell which is then accumulated in the cell that is defined as having the lowest elevation value [28].

It is important to note that flow accumulation does not have a single formula, as it is more based on computational algorithms within Geographic Information Systems (GIS). The algorithm traces the flow direction from each cell and calculates the number of neighboring cells that flow into a particular cell. This process results in a flow accumulation map, where cells with higher accumulation values are likely to represent rivers or main flow paths.

As depicted in Figure 4, the image illustrates how flow directions are determined on the left, while the accumulation of flow is shown on the right. The arrows represent the flow direction for each cell, and the black dots indicate the accumulation paths forming a network of streams and rivers.

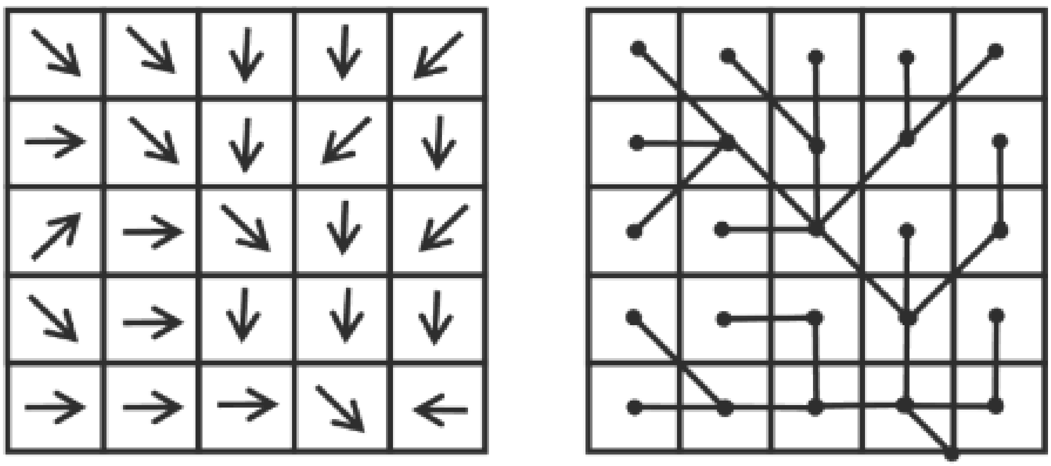

Figure 4 Flow Accumulation

RESULTS

The delineation results from WMS TOPAZ and HEC-HMS 4.12 on each DEM data using the same outlet produce varying sub-basin and river parameters. The results of each parameter can be seen in Table 1.

Table 1 Catchment Area and River Parameters from Simulation Results

Parameter	DEMNAS		ASTER-30m		SRTM-90 m	
	WMS	HEC-HMS	WMS	HEC-HMS	WMS	HEC-HMS
Input Files	DEM	TIFF	DEM	TIFF	DEM	TIFF
Threshold (km²)	100	100	100	100	100	100
Number of Sub-basin	1	3	1	3	1	3
Sample Spacing X & Y Axis	8.29	8.29	30.71	30.71	96.14	96.14
Catchment area (km2)	1462.64	1462.91	1467.88	1465.03	1474.41	1468.03
Basin Slope (m/m)	0.22	0.24	0.21	0.23	0.16	0.19
Basin Length (m)	122738.01	172180	107313	153910	97527.97	145680
Main River Length (m)	58195.707	42537.38	50697.81	36604.97	44368.54	34960.17

Table 1 presents a comparison of catchment area analysis using three types of Digital Elevation Model (DEM) data, namely DEMNAS, ASTER 30 meters, and SRTM 90 meters, with two processing methods: WMS and HEC-HMS. Each DEM is processed with the same parameters for a threshold of 100 km², but the analysis results show significant differences in several aspects.

Comparison of Sub-Basin Area and River Network

The results of sub-basin and river network delineation show significant differences between the use of TOPAZ WMS and HEC-HMS, even though both apply similar hydrological algorithms such as flow direction, flow accumulation, and stream definition. As seen in Figure 5 (Panels A and C), the TOPAZ WMS produces one sub-basin and a relatively simple river network. In contrast, HEC-HMS (Panels B and D) produces multiple sub-basins and a more complex river network. This difference highlights the sensitivity of the parameters used in each software in processing DEM data for hydrological modeling.

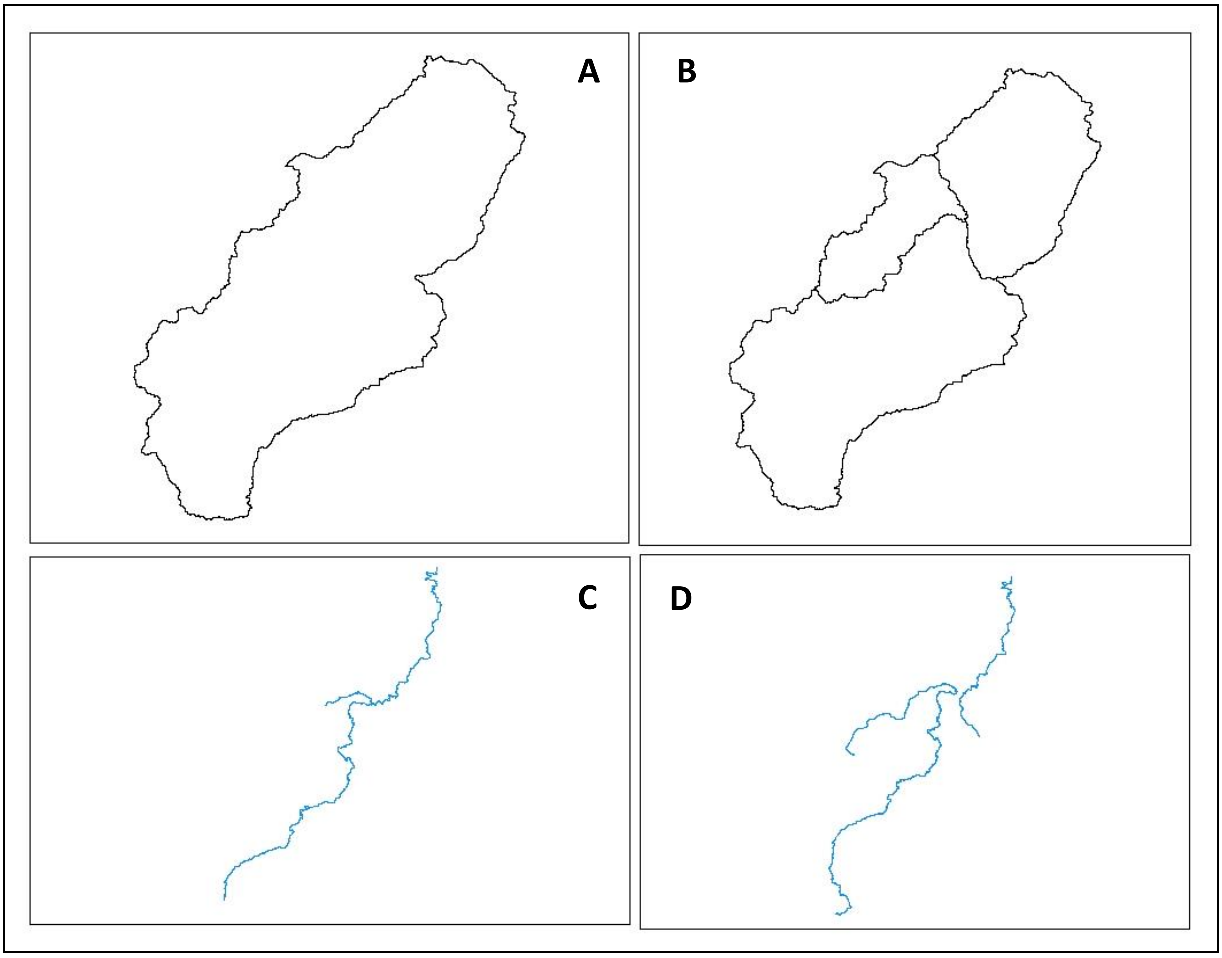

Figure 5 Comparison of Sub-basin Area and River Network A) catchment area of WMS, B) Catchment area of HEC-HMS, C) River Network of WMS, D) River Network of HEC-HMS

In this study, HEC-HMS presented a more detailed river network and sub-basin delineation compared to WMS Topaz. However, it is essential to clarify that this research does not aim to determine which software is superior. The results merely indicate that when using higher-resolution DEMs, such as DEMNAS 8.29 m, both WMS and HEC-HMS yield comparable results, with no significant differences in the delineation process. Therefore, future research opportunities exist to explore which software better represents actual hydrological conditions.

The river networks in panels C and D also highlight this difference. The WMS river network (panel C) appears simpler and less detailed, while HEC-HMS (panel D) offers a more intricate and extensive stream network. This disparity supports findings that the accuracy of DEM-derived hydrological features is heavily influenced by the DEM resolution. Higher-resolution DEMs lead to more detailed watershed delineations, even when two DEMs have similar nominal resolutions, as discussed in previous studies [29]. This suggests that HEC-HMS might apply more refined or sensitive parameters when defining river networks and sub-basins, resulting in a more detailed outcome. Additionally, variations in stream threshold settings between software can result in different interpretations of the river networks and sub-basin boundaries. These differences highlight the nuanced ways in which each software tool processes the same data, which future research should investigate to determine which software most accurately reflects real-world hydrological conditions.

Comparison of Water Catchment area

Table 1 illustrates the comparison of catchment areas, highlighting that differences in delineation results are influenced not only by the DEM resolution but also by the methods and software employed. Despite keeping input files, thresholds, and other parameters constant, the results generated by WMS and HEC-HMS vary depending on the resolution of the DEM used. For instance, with DEMNAS (8.29 meters), the discrepancy between WMS and HEC-HMS is minimal (1462.64 km² vs. 1462.91 km²). However, for SRTM (90 meters), the difference becomes more pronounced (1474.41 km² vs. 1468.03 km²). The trend of these discrepancies is visually depicted in Figure 6.

This shows that the lower the DEM resolution, the greater the possibility of differences in delineation results between these two software. This agrees with [15] which shows that the use of different DEM resolutions can affect the accuracy of catchment area delineation, with SRTM showing better correlation results but ASTER being superior in the mean center distance. Moreover, DEMNAS data has an even higher resolution, so the delineation accuracy is higher. This was also agreed with [31] which explains that the accuracy of water catchment delineation is very dependent on the accuracy and quality of the available Digital Elevation Model (DEM).

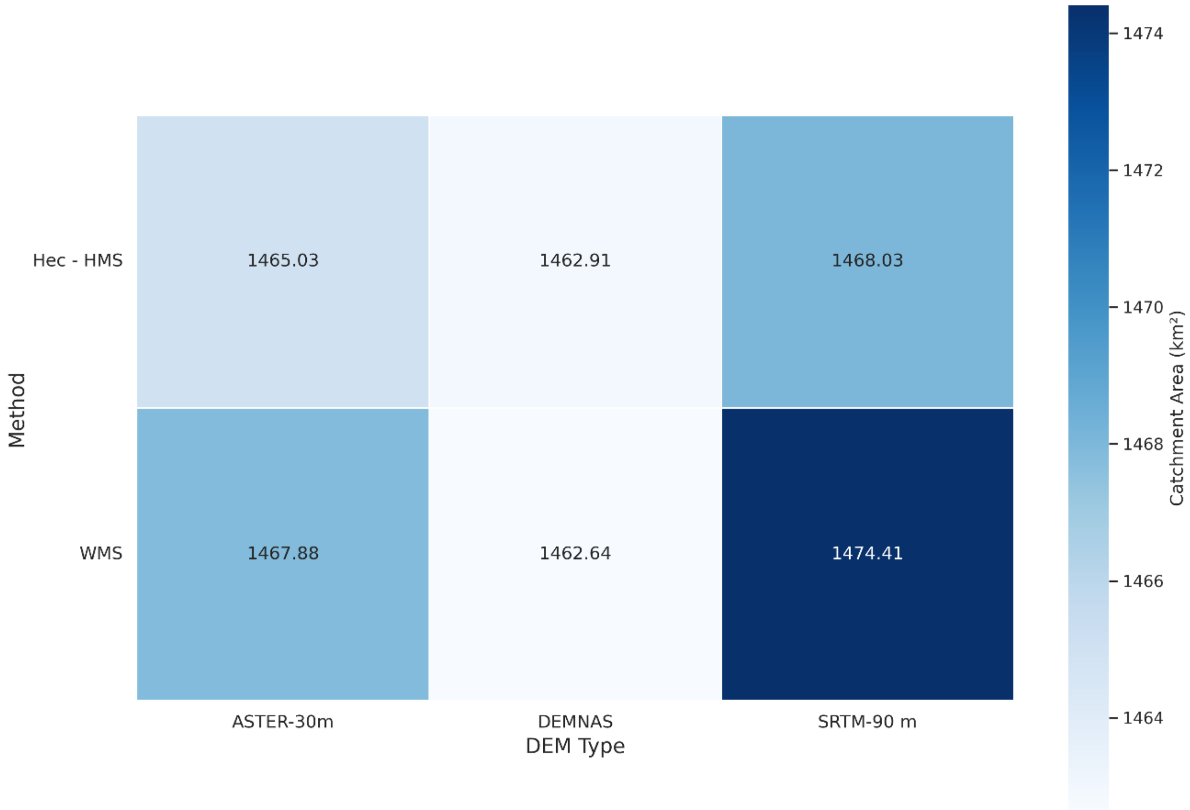

Figure 6 Comparison of Catchment area

Recent studies have further explored the impact of DEM resolution on hydrological modeling. For example, a study conducted by [4], found that higher resolution DEMs improved the accuracy of watershed delination in stratified catchments, resulting in better simulation of river flow. Similarly, research by [17], demonstrated that the use of high-resolution DEMs enhanced the precision of flood simulations, which is crucial for accurate hydrological modeling. Additionally, a study by [18], highlighted that the accuracy of DEMs significantly affects the optimal catchment area threshold, impacting river network extraction.

In Figure 6, the trend of difference between the two software becomes clearer. At lower resolutions, such as SRTM (90 m), WMS consistently produces a larger catchment area compared to HEC-HMS. This suggests that WMS may be more sensitive to topographic distortions inherent in lower-resolution DEMs, whereas HEC-HMS appears more stable across all resolutions. These findings highlight the critical role of DEM resolution in hydrological modeling and underscore the importance of selecting the right software and data sources for accurate delineation.

Comparison of Basin Slope

The catchment slope, as shown in Table 1, is greatly influenced by the quality and resolution of the DEM used. Higher resolution DEMs, such as DEMNAS, provide slope that more accurately reflect the real-world topography. For example, in DEMNAS, the slope calculated by WMS is 0.22 m/m, while HEC-HMS produces a slightly higher slope of 0.24 m/m. This small variation suggests that WMS may be more sensitive in capturing fine topographic details, while HEC-HMS tends to provide more consistent slope calculations at different DEM resolutions.

To explore this further, Figure 7 presents a graphical comparison of baisn slope calculated by WMS and HEC-HMS using different DEMs. This comparison helps to illustrate how the resolution of a particular DEM and spesific software processing methods can affect the interpretation of topographic characteristics. Understanding this variations is critical for hydrological analysis, as catchment slope plays a critical role in determining surface water flow patterns and the basin flood response. Steeper slope, for example, can lead to faster runoff and shorter lag time during flood events, while gentler slopes can slow down water movement. By analyzing differences in slope calculations, researchers and practitioners can gain deeper insights into how catchment topography affects hydrological processes and water management outcomes.

Recent research has emphasized how crucial DEM resolution is in accurately determining basin slope. High-resolution DEMs, like those generated from LiDAR data, offer a much clearer depiction of terrain, capturing subtle variations in slope that often go unnoticed in lower-resolution models. For example, a study by [32], found that using finer DEM resolutions significantly improves the precision of hydrological simulations, underscoring the importance of choosing the right DEM source for accurate basin slope analysis.

In addition, recent advances have shown that combining multiple DEM sources can further improve the accuracy of topographic and hydrological modeling. By integrating data from different resolutions, researchers can minimize errors and gain a better understanding of terrain features. This approach not only improves slope calculations but also strengthens the reliability of hydrological predictions, especially in complex catchments where terrain variations play a critical role in runoff patterns and flood response.

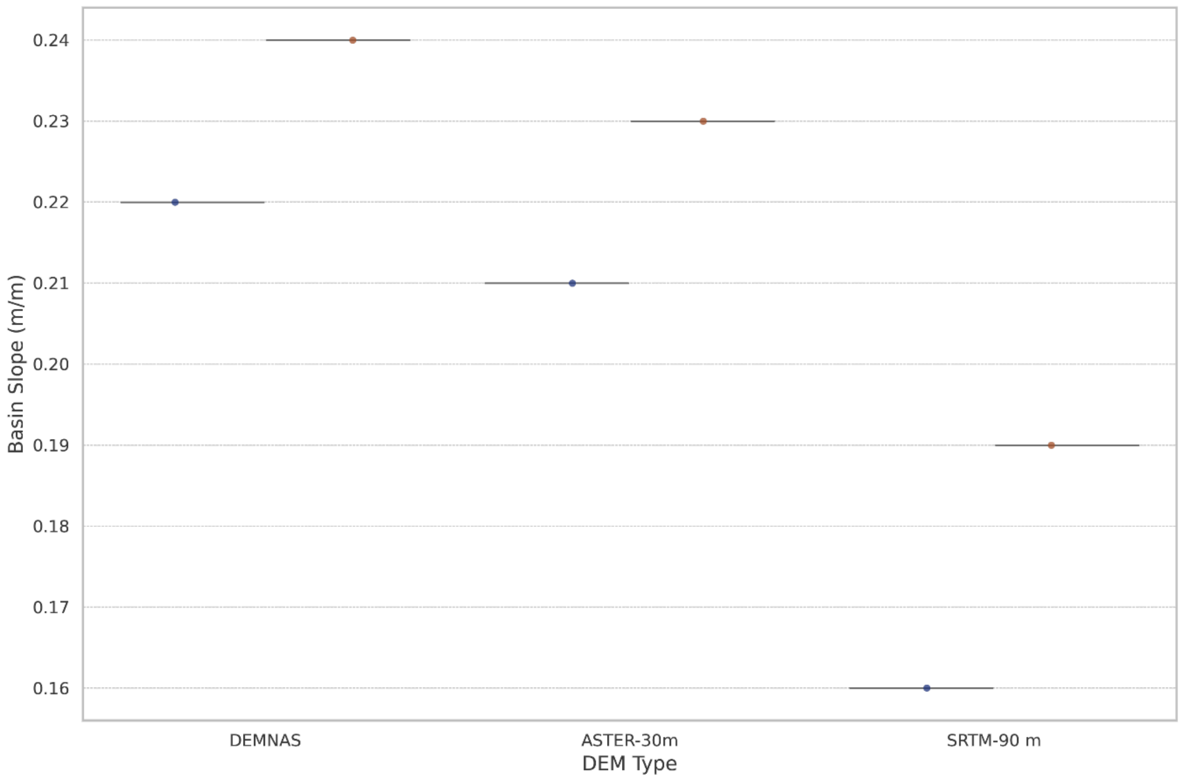

Figure 7 Comparison of Basin Slope

The graph in Figure 7 above explains the variation in results obtained from two software (WMS and HEC-HMS) with three different DEM resolutions, namely DEMNAS (8.29 m), ASTER (30 m), and SRTM (90 m). From this graph, it can be seen that WMS tends to produce higher slopes than HEC-HMS, especially at lower-resolution DEMs such as SRTM-90 m. For example, on SRTM-90 m, WMS produces a slope of 0.16 m/m, while HEC-HMS produces 0.19 m/m. This agrees with [33], which emphasizes that the high quality of the DEM greatly influences the accuracy of delineation, especially in conditions of steep and steep catchment area slopes.

Comparison of River Length

The difference in river length produced by these two software also shows that DEM resolution plays an important role in interpreting river shape and water flow. In DEMNAS, which has a higher resolution, the results from both software tend to be more similar, but there are still striking differences when the DEM resolution decreases as in SRTM-90 m. Overall, WMS provides more detailed results for river length interpretation, especially in DEMs with lower resolution.

To further explore the effect of DEM resolution and delineation methods on the resulting river length, below is a comparison graph of river length between WMS and HEC-HMS with various DEM resolutions. The trend of differences in river lenght can be seen in Figure 8. This graph aims to show how variations in DEM resolution affect the interpretation of river lengths within the catchment area. River length is an important parameter in hydrological analysis, which is closely related to water flow patterns, flow travel time, and flood response in a catchment area.

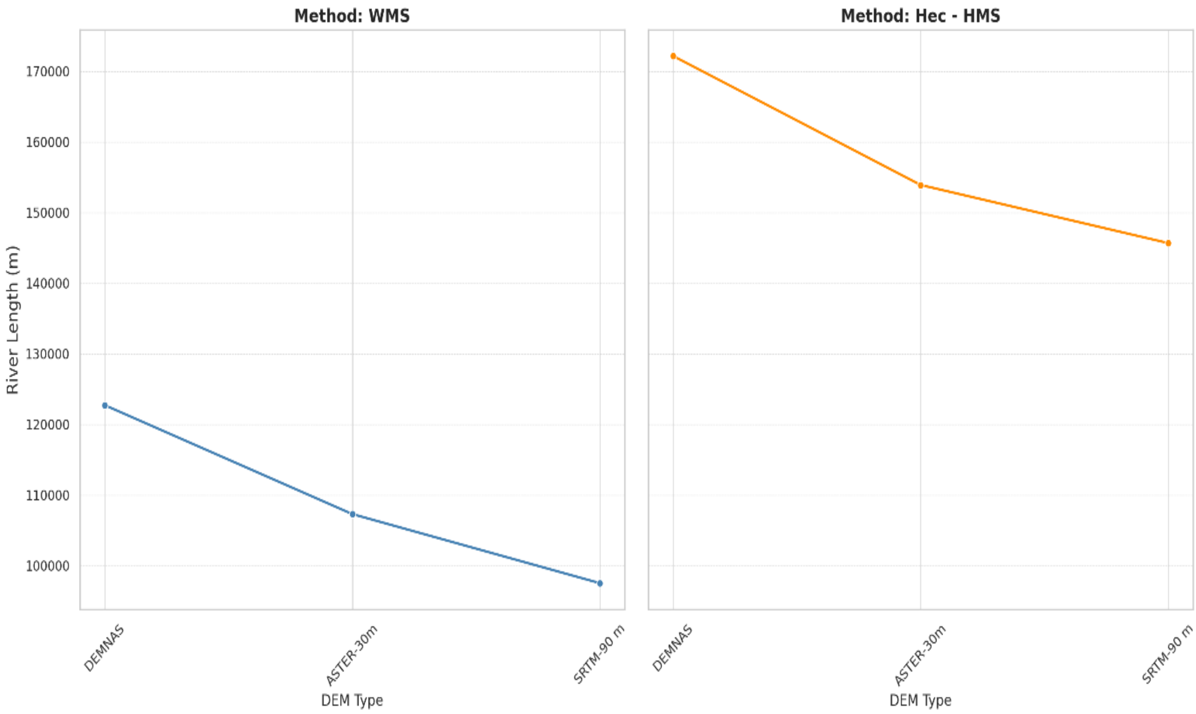

Figure 8 Comparison of River Lenght

The graph in Figure 8 highlights the marked differences in river lengths produced by WMS and HEC-HMS when using a various DEM resolutions, including DEMNAS (8,2 m), ASTER (30 m), and SRTM (90 m). Interestingly, HEC-HMS consistently produces longer river lengths than WMS, especially when working with lower-resolution DEMs. For example, with SRTM-90 m, HEC-HMS computes significantly longer river length, suggesting that it may be more sensitive to detecting river flow details in coarser DEMs, perhaps due to the way it interprets flow directions and channel networks.

On the other hand, WMS tends to produce more consistent river length measurements, regardless of DEM resolution. This suggest that WMS delineation process may be more stable and less affected by changes in DEM resolution, thus offering a more uniform interpretation of river networks. These differences are important because they highlight how software-specific algorithms can affect the way hydrological features are represented, which can impact downstream applications such as flood modeling or water resource management.

These findings align with recent studies emphasizing the importance of DEM resolution in river network extraction and hydrological modeling. For instance, [34], highlighted that higher-resolution DEMs improve the accuracy of river network delineation by reducing topographic distortion. Similarly, [35] found that multi-source DEM fusion techniques enhance river network interpretation, particularly in regions with complex terrain. These results underscore the importance of selecting appropriate DEM resolutions and software methodologies to ensure accurate hydrological analysis and modeling.

Overlapping Area WMS and HEC–HMS 4.12

WMS TOPAZ and HEC-HMS 4.12 are widely used tools in hydrological analysis, especially for mapping catchment area boundaries using Digital Elevation Model (DEM) data. This study compares the outputs from both methods to identify areas of overlap with similar delineation results, as well as areas of disecrepancy. Understanding these overlaps and variations is essential to assess how consistent the two methods are in delineating catchment boundaries and pinpoint any discrepancies that may arise due to differences in their algorithms or the resolution of the DEMs used.

Accurate catchment delineation plays a critical role in hydrological analysis since it directly affects how surface water flow, runoff patterns, and flood responses are modeled within the basin. By exploring the similarities and differences between WMS TOPAZ and HEC-HMS, this analysis aims to provide insights that can help researchers and practitioners choose the most suitable tool and DEM resolution for specific hydrological applications. Overlapping areas are not seen only based on differences in the catchment area from the delineation results but also on differences in the catchment area boundaries. The results of overlapping areas between WMS - TOPAZ and HEC-HMS 4.12 for DEMNAS can be seen in Figure 9, for ASTER - 30 m can be seen in Figure 10, and for SRTM - 90 m can be seen in Figure 11. Deviations from each resolution can be seen in Table 2.

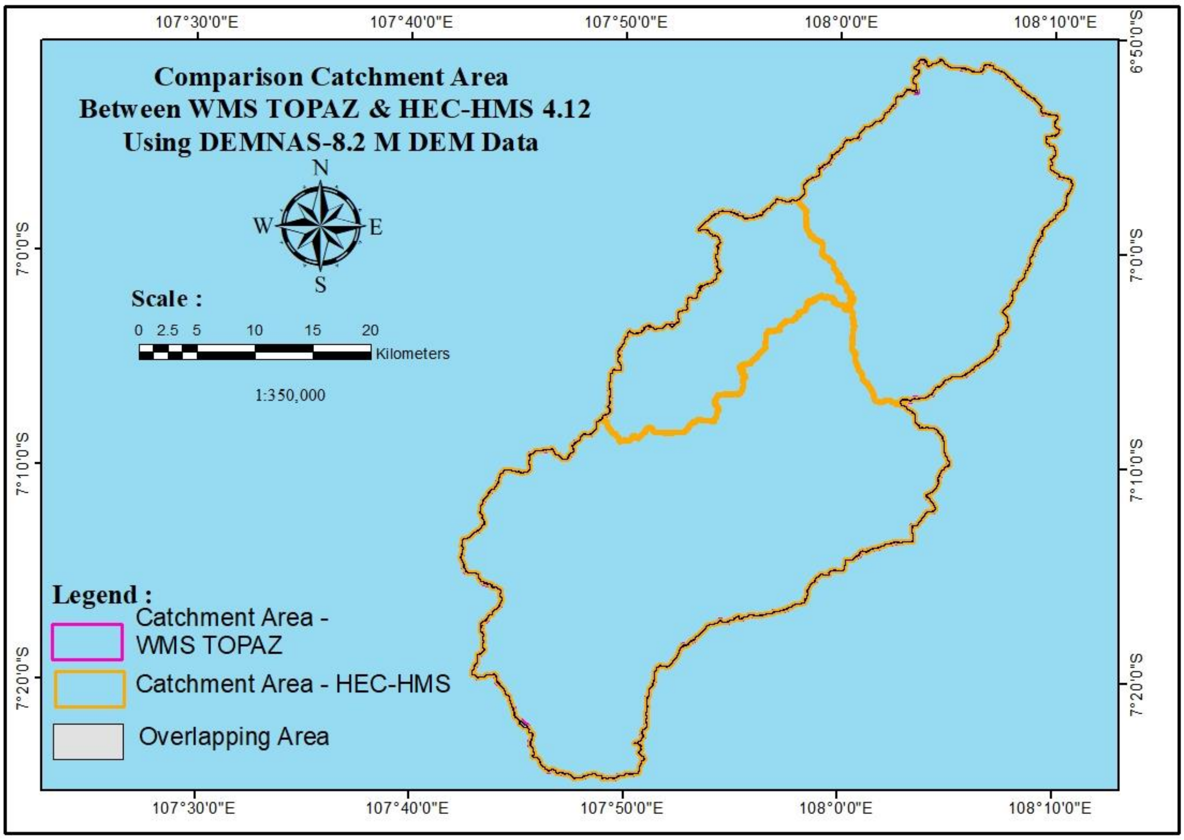

Figure 9 Comparison of Catchment area between WMS TOPAZ & HEC–HMS 4.12 with DEMNAS data

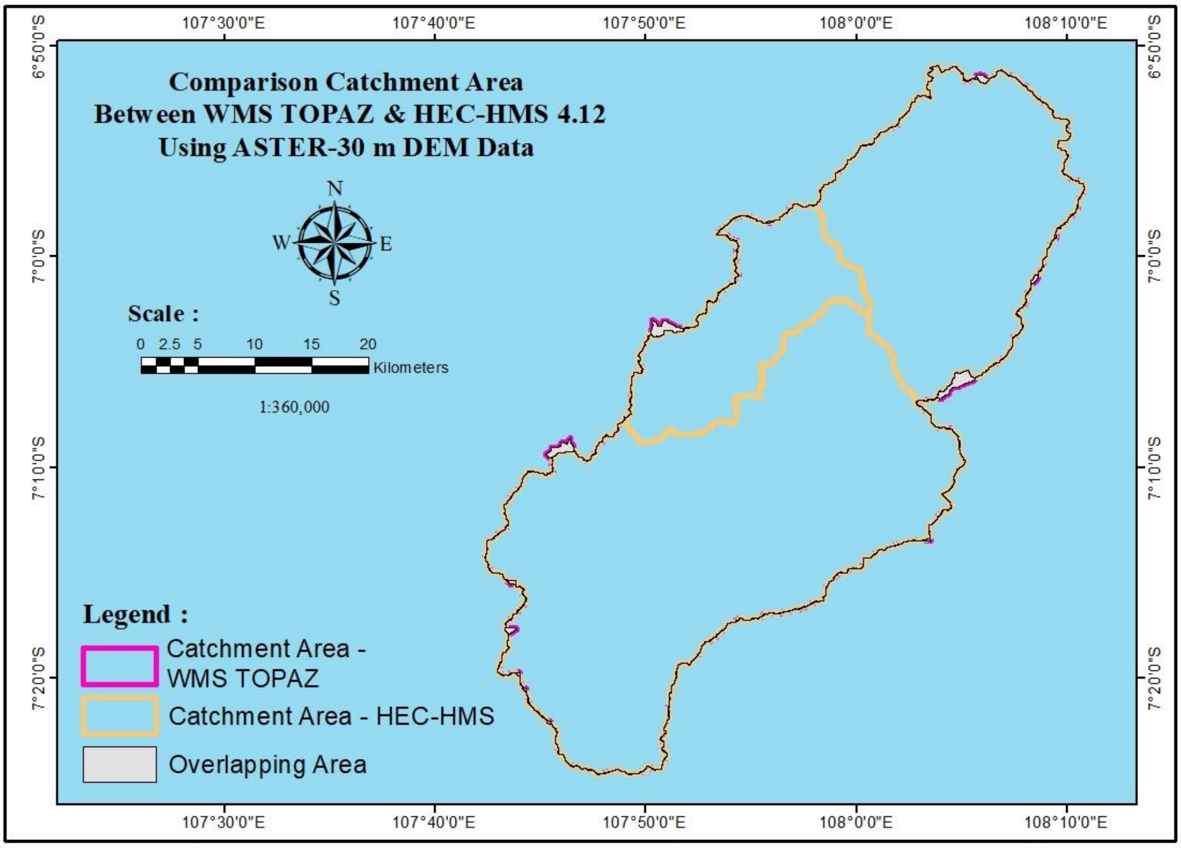

Figure 10 Comparison of WMS TOPAZ & HEC–HMS 4.12 Catchment area with Aster – 30 m data

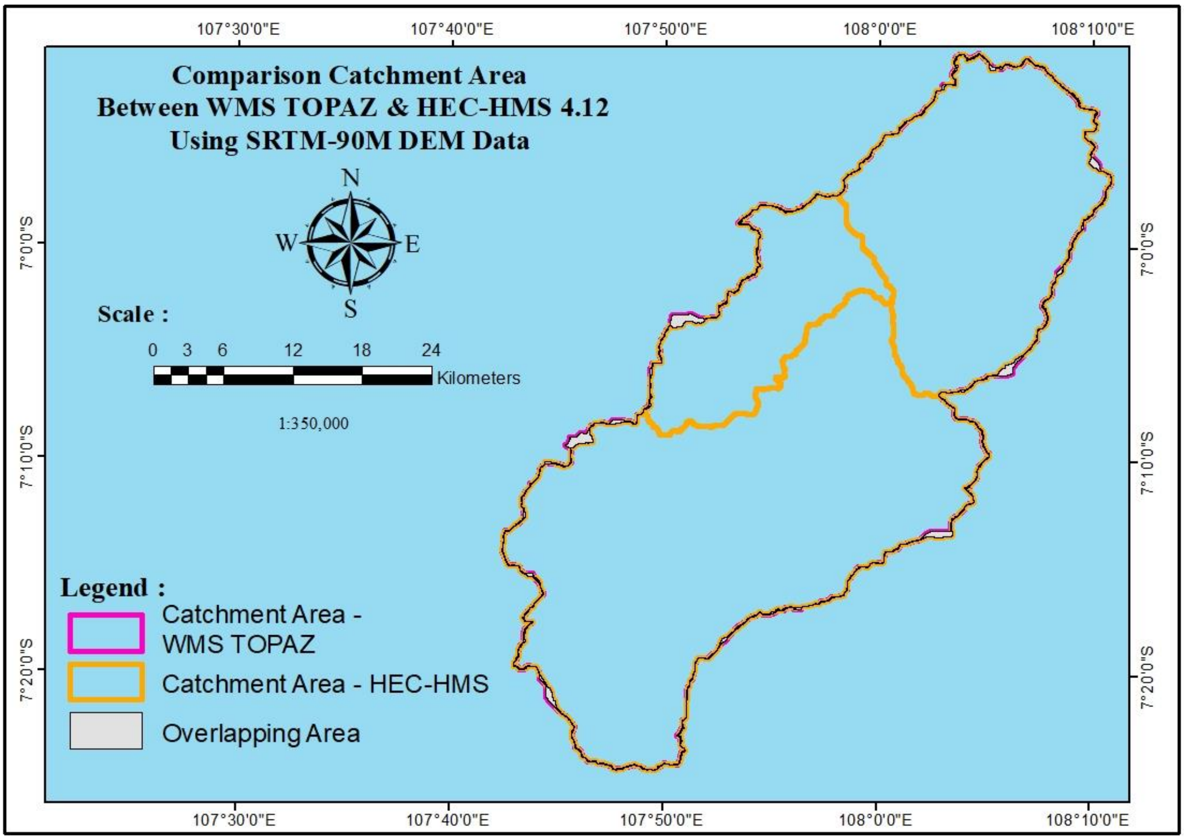

Figure 11 Comparison of Catchment area between WMS TOPAZ & HEC–HMS 4.12 SRTM - 90 m data

Table 2 Overlapping Area

DEM Resolution	Overlaping Area (km2)
DEMNAS - 8.2 m	2.19
ASTER - 30 m	10.39
SRTM - 90 m	17.44

DISCUSSION

In this analysis, it found the effect of Digital Elevation Model (DEM) resolution on the overlapping area of the River catchment area delineation results obtained using two different methods, namely WMS TOPAZ and HEC-HMS 4.12. This analysis was carried out to understand how differences in DEM resolution can affect the delineation results and the level of similarity between the two methods. The results of the analysis can be seen in the graph in Figure 12.

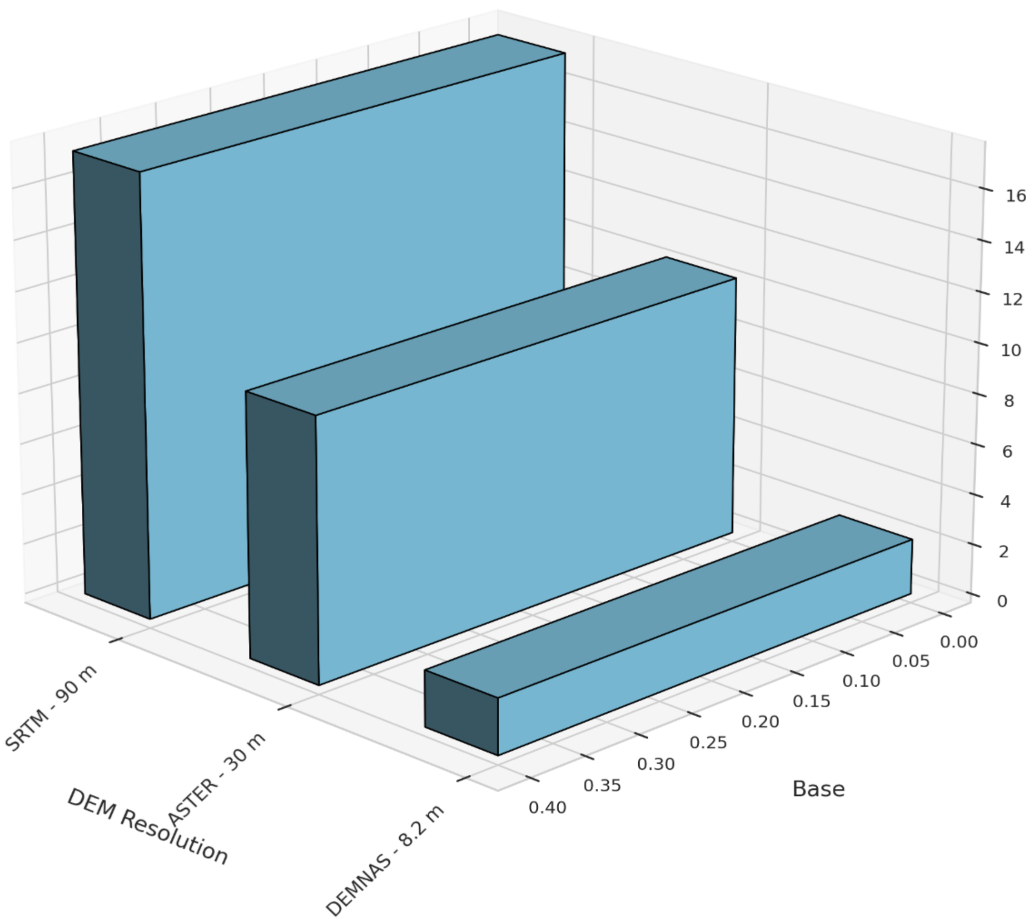

Figure 12 Impact of DEM Resolution on Overlapping Area Size

Figure 12 shows the impact of the Digital Elevation Model (DEM) resolution on the overlapping area, which indicates that there is a positive linear relationship between the two. From this graph, it can be seen that the greater the DEM resolution, the greater the overlap area formed.

The linear regression equation obtained is $y = 7.626x - 5.2457$ where every 1 meter increase in DEM resolution increases the overlapping area by 7.626 km². Additionally, the constant -5.2457 represents a theoretical starting point when the DEM resolution approaches zero; however, this value is derived through extrapolation rather than actual data observation. The R2 value of 0.9981 indicates that the regression model is very good at explaining data variations—around 99.81% of the variation in overlapping areas is explained by changes in DEM resolution.

This trend suggests that DEMs with greater resolution (e.g. 90 meters) tend to produce larger areas of overlap due to coarser topographic detail. In contrast, DEMs with smaller resolutions (e.g. 10 meters) are able to capture finer topographic details, resulting in smaller overlap areas. This provides an understanding that higher DEM resolution (lower resolution in meters) provides more precise results in spatial analysis, especially in area delineation. Thus, the importance of selecting the appropriate DEM resolution in the delineation process is emphasized to ensure accurate and reliable results.

CONCLUSION

In this study, HEC-HMS showed its capability to produce more detailed river network and sub-basin delineation compared to WMS Topaz. However, it is important to clarify that the goal here is not to determine which software is inherently “better.” Rather, the findings suggest that the use of higher resolution DEMs does not result in significant differences in catchment delineation, regardless of the software applied. This opens up interesting opportunities for future research to assess which software more accurately reflects real-world hydrologic conditions. The differences observed between WMS and HEC-HMS, even when using the same DEM resolution and comparable algorithms (e.g., flow direction, flow accumulation, and stream definition), may stem from several factors. One major factor lies in how each software defines stream thresholds, which directly impact the stream network and watershed boundaries. Additionally, while both platforms follow similar hydrologic processing steps, slight variations in how they handle flat, or basin areas may contribute to the differences. Furthermore, differences in default parameters, such as how each handles flow path length may further impact the final results. These findings emphasize the importance of DEM resolution in improving the accuracy of hydrological features while highlighting that software-based algorithmic variations can still produce different results. Therefore, a deeper understanding of how different software programs process hydrological data is essential, especially when working with high-resolution datasets. Future research can investigate these nuances to explore which software is more appropriate to actual field conditions and hydrological behavior.

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DECLARATIONS

Conflict of Interest

We declare no conflict of interest, financial, or otherwise.

Ethical Approval
On behalf of all authors, the corresponding author states that the paper satisfies Ethical Standards conditions, no human participants, or animals are involved in the research.

Informed Consent
On behalf of all authors, the corresponding author states that no human participants are involved in the research and, therefore, informed consent is not required by them.

DATA AVAILABILITY
Data used to support the findings of this study are available from the corresponding author upon request.

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