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Research Article:

Watershed management for soil and water conservation in the Amban Ganga sub-basin of the Mahaweli Basin, Sri Lanka: A morphometric analysis-based approach under a GIS environment

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Abstract

Watershed prioritization using the morphometric analysis method is one of the best ways to ensure proper planning and soil and water resources management in a watershed. Amban Ganga, an 81 km-long tributary of the Mahaweli River, plays a crucial role in nourishing agricultural fields and forest areas in the Central and North Central parts of Sri Lanka. The study aims to prioritize watersheds of this river basin using Geographic Information System (GIS) techniques. By analysing spatial data obtained using Digital Elevation Model (DEM) with a 20 m contour interval, the research assesses the hydrological characteristics and soil erosion potential of this river basin. A study found that the Amban Ganga stream network exhibits a dendritic drainage pattern and extends to Strahler's 7th order, comprising 8,581 streams over 1,555.98 km². Further, 18 micro-watersheds were identified within the sub-basin, and morphometric analysis (considering linear, areal, and relief parameters) was conducted for micro-watersheds. Findings indicated that permeable sub-soil, dense vegetation, and a smoother peak runoff have led to somewhat reduced flood risks within the area. Elongated basin shape and a gradual slope further help to mitigate flooding and soil erosion risks. Additionally, the relief analysis confirmed that lower flood risk is due to the gradual slope of this sub-basin. According to morphometric analysis, micro-watersheds were prioritized into high (4), medium (6), and low (8) categories. Prioritizing watershed areas and understanding their unique features enables stakeholders to develop effective conservation strategies to protect soil and water resources and promote sustainable development within the studied river basin.

Keywords: GIS, Morphometric analysis, Soil and water conservation, Watershed management

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1. Introduction

A watershed, defined as a land area where water on Earth's surface, received from precipitation, collects into a single point, such as a river, lake, or ocean, functions as a dynamic system with inputs from atmospheric processes and outputs through water and sediment flows at the basin's outlet (Adhikari, 2020). According to Schumm (1977), a watershed is a crucial sediment production area of influenced by climate, land use practices, and geological factors, making it essential for understanding how natural processes affect water and soil conservation. Conducting a morphometric analysis requires measuring and mathematically examining a watershed's physical features, which provide essential information on the formation and behaviour of a watershed. This analysis encompasses three primary aspects: linear, areal, and relief. Linear aspects include the study of stream lengths, stream orders, and drainage patterns, which help to describe the watershed's hydrological structure. Areal aspects include evaluating the size, shape, and drainage density of the assessed watershed, which are crucial for understanding water flow and sediment transport. Relief aspects focus on the elevation, slope, and terrain variations within the watershed, which influence soil erosion processes and water movement (Rastogi and Sharma, 1976). Through morphometric analysis, researchers can assess these features to understand how they impact the watershed's hydrological behaviour and identify areas prone to soil erosion and other environmental issues (Shekar and Mathew, 2022) and when determining the response of the watershed to climate change, morphometric analysis acts as a crucial tool (Rais and Javed 2014). This understanding provides a basis for developing effective soil and water conservation strategies within watersheds.

Amban Ganga originates from streams flowing from the Paulu Hills (Dumbara / Knuckles Hills) in Matale and joins another river, the 'Kaluganga', which originates from the 'Kalupahana' Hills 'Thushisgala' of the 'Dumbara' Hills at the border of Wasgamuwa National Park. The main tributary of the Amban Ganga is the 'Kaluganga', after which another tributary, Kirioya', also joins the Amban Ganga. The Amban Ganga, which continues to expand its water capacity, joins the Mahaweli River at 'Tunmodara' in the Manampitiya Flood Plains National Park (Madusanka, 2022). The Amban Ganga sub-basin, which encompasses 1555.98 km², has historically served as a crucial catchment supporting irrigated agriculture in Sri Lanka's Dry Zone, while demonstrating intricate geomorphological features (Ekanayake et al., 2026).

The integration of GIS technology has revolutionized watershed management by providing powerful tools for collecting, analysing, and visualising spatial data. GIS platforms enable storage, manipulation, and display of spatial information, which supports decision-making processes in natural resource management (Merry et al., 2023). Initially, GIS was used for basic natural resource management tasks, but advancements in satellite technology and GIS software have since enabled more detailed analyses of land cover changes, hydrological processes, and environmental conditions (Trivedi et al., 2021). As a result, GIS and Remote Sensing techniques have recently become highly efficient and effective tools for morphometric analysis and watershed management studies.

By combining morphometric analysis with advanced GIS and remote sensing technologies, this study aims to provide a detailed, nuanced understanding of the sub-basin's environmental conditions. This approach will support effective and sustainable management strategies to conserve soil and water resources while benefiting local communities (Moilanen et al., 2011). Therefore, the study's goal is to enhance ecosystem health in the Amban Ganga sub-basin and to provide a plan for conservation efforts, especially in sensitive micro-watersheds facing environmental challenges.

2. Materials and Methods

2.1 Study Area

The Amban Ganga sub-basin of the Mahaweli River Basin in Sri Lanka was the study area of focus in this research. It is in North Central Province, belonging to the Dry Zone of Sri Lanka, at an elevation of 13 m above sea level, between 7°20' 00 " and 7°52' 41" North latitudes and 80°30' 00" and 81°10' 00" East longitudes. (Figure 1).

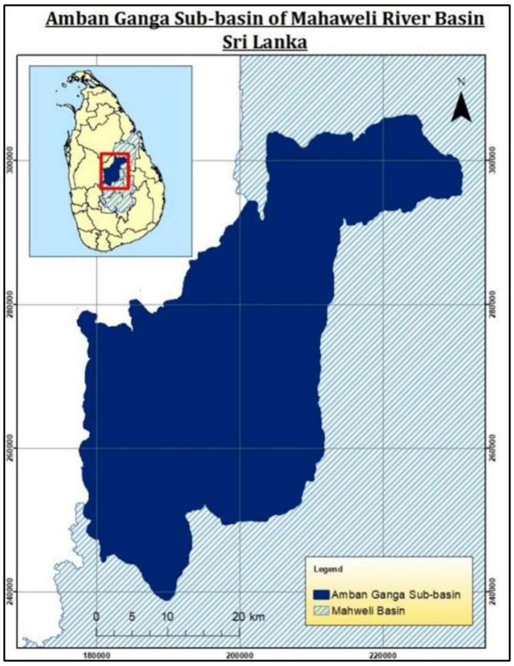

Figure 1: Location map of the Amban Ganga Sub-basin within the Mahaweli River Basin, Sri Lanka. *The map shows the sub-basin boundary (dark blue), and the inset map of Sri Lanka indicating the study area's position (between 7°20'–7°52' N and 80°30'–81°10'*

2.2 Materials

Contour layers of 20 m interval obtained from the Survey Department of Sri Lanka were used to derive the Digital Elevation Model (DEM). Additionally, topographic map sheets, specifically sheets 42-Dambulla, 43-Elahara, and 48-Matale at a scale of 1:50,000, were used to verify the developed DEM and to produce soil, land use, and agro-ecological region maps of the Amban Ganga sub-basin. ArcGIS 10.8 software was employed as the interface for data analysis.

2.3 Method

Initially, the Digital Elevation Model (DEM) was derived from a 20 m contour interval layer in ArcGIS 10.8. This DEM served as the fundamental layer for creating a smoothed stream network representation with the hydrology toolset in ArcGIS. The process included generating a filled DEM to establish flow directions, constructing a flow-accumulation map, and creating a stream-network map. The stream-order raster map, based on Strahler's law (1957), was then converted to a vector format using the ArcGIS Stream to Feature tool (Figure 2). The number of streams in each order was listed separately.

The complete delineation of the Amban Ganga sub-basin involved partitioning it into 18 distinct micro-watersheds by identifying pour points to demarcate boundaries. A micro-watershed map of the entire sub-basin area was prepared using the delineated layer (Figure 3).

Focusing on three main aspects: linear, areal, and relief aspects, morphometric analysis was conducted. Here, methods proposed by pioneers of geomorphologic studies (Horton, 1945; Strahler, 1964; Schumm, 1956; Miller, 1953) were used. Initially, all parameters were calculated for the entire Amban Ganga sub-basin, then for each micro-watershed. Six basic parameters were calculated, forming the basis for the calculation of other morphometric parameters in this study (Tables 1 and 2).

3. Results and Discussion

3.1 Basic Parameters of Amban Ganga Sub-basin

3.1.1 Strahler's Stream Orders

The first step in morphometric analysis is stream ordering, which refers to the position of a stream segment within the tributary hierarchy (Leopold et al. 1964). The smallest streams are classified as first-order streams, and when two first-order streams join, they form second-order streams. Similarly, two second-order streams combine to form a third-order stream, and so on.

Table 1: Morphometric parameters, formulas/definitions, and key references used for the six basic calculations (stream order, number of streams, stream length, area, perimeter, and basin relief) in the Amban Ganga Sub-basin analysis.

Morphometric Parameter	Formula/Definition	References
Stream Order (U)	Hierarchical rank	Strahler (1964)
Number of Streams (Nu)	Number of streams under GIS analysis tools	Horton (1945)
Stream length (Lu)	Length of the stream (km) under GIS analysis tools	Horton (1945)
Area in km^2 (A)	Area calculation under GIS analysis tools	Schumm (1956)
Perimeter in km (P)	Perimeter calculation under GIS analysis tools	Schumm (1956)
Basin Relief (R)	Vertical distance between the lowest and highest points of the watershed- using GIS analysis tools	Schumm, (1956)

Table 2: Formulas, definitions, and references for all additional morphometric parameters calculated in this study, grouped under linear, areal, and relief aspects

Morphometric Parameter	Formula/Definition	References
Linear Aspects		
Mean stream length (Lsm)	**Lsm = Lu/Nu** Lu = Total stream length of order 'u' (km) Nu = Total number of stream segments of order 'u'	Strahler (1964)
Stream length ratio (RL)	**RL = Lu/Lu1** Lu = Total stream length of order 'u' (km) Lu1 = The total stream length of its next lower order (km)	Horton (1945)
Bifurcation ratio (Rb)	**Rb = Nu/Nu + 1** Nu = Total no. of stream segments of order 'u' Nu + 1 = Number of segments of the next higher order	Schumm (1956)
Stream frequency (Fs)	**Fs = Nu/A** Nu = Total number of streams of all orders A = Area of the basin (km^2)	Horton (1945)
Drainage density (Dd)	**Dd = Lu/A** Lu = Total stream length of all orders (km) A = Area of the basin (km^2)	Horton (1945)
Drainage texture (Dt)	**T = Nu/P** Nu = Total no. of streams of all orders P = Basin perimeter (km)	Horton (1945)
Drainage Intensity (Id)	**Id = Fs/Dd** Fs = Stream frequency Dd = Drainage density	Faniran (1968)
Length of overland flow (Lo)	**Lg = 1/Dd*2** Dd = Drainage density	Horton (1945)
Areal Aspects		
Length of the basin in km (Lb)	Length calculation	Schumm (1956)
Form factor (Ff)	**Ff = A/Lb2** A = Area of the basin (km^2) Lb = Basin length (km)	
Circulatory ratio (Rc)	**$Rc=4\pi A/P^2$** π= 3.141 A = Area of the basin (km^2) P2 = Square of the perimeter (km)	Miller (1953)
Elongation ratio (Re)	**$Re =\sqrt{(Au/\pi)}/ Lb$** A=Area of basin	Schumm (1956)

	π=3.14 Lb=Basin length	
	R_e = (4*A/π) A = Area of the basin (km^2) π= 3.141 Lb = Basin length (m)	Miller (1953)
Compactness coefficient (Cc)	**Cc = 0.2821 P/A 0.5** A = Area of the basin (km^2) P = Basin perimeter (km)	Horton (1945)
Relief Aspects		
Relief Ratio (Rhl)	**Rh = H/Lb** H = watershed relief Lb = basin length (km)	Schumm (1956)
Ruggedness Number (Rn)	**Rn = H*Dd** H = watershed relief Dd = Drainage density	Schumm (1956)

The entire stream network map was utilised to generate Strahler's stream-order map (Figure 2). According to the results, the Amban Ganga extends up to Srahler's 7th order. The total number of streams or stream segments in the Amban Ganga river network is 8581, covering an area of 1,555.98 km^2.

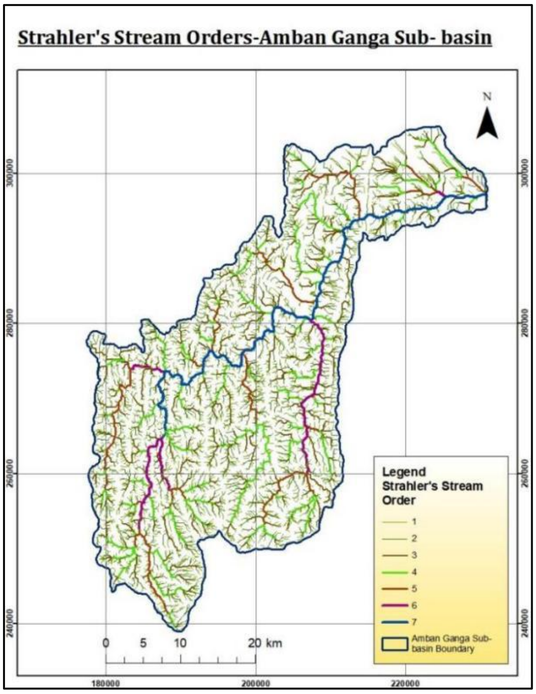

Figure 2: Strahler's stream order classification of the Amban Ganga drainage network. *Stream orders range from 1st (smallest tributaries) to 7th (main channel). The map displays 8,581 stream segments covering 1,555.98 km². The dendritic drainage pattern*

As stream order increases, the stream number decreases, following Horton's law of stream numbers. This law explains an inverse relationship between the number of streams and their order. Accordingly, first-order streams exhibit the highest total stream length, reflecting their abundance and extensive coverage across the basin (Abdeta et al., 2020). As the stream order increases, the total stream length in each order gradually decreases, in line with Horton's law of stream lengths, indicating fewer but longer streams in higher orders.

The hierarchical distribution of stream numbers and lengths reflects the drainage density and geomorphic characteristics of the river basin.

After deriving the stream orders, the Amban-Ganga sub-basin was divided into 18 micro-watersheds using the Hydrological toolset in ArcGIS 10.8. Figure 3 shows the delineated 18 micro-watersheds of the Amban Ganga sub-basin.

3.2 Linear Aspects

3.2.1 Bifurcation Ratio (Rb)

Bifurcation ratio (Rb) is defined by Schumm (1956) as the ratio between the total number of stream segments of a given order and the number of segments in the next higher order within a drainage basin. Horton (1945) considered Rb as a measure of the landscape's ruggedness and complexity. Strahler (1957) revealed that the variation in bifurcation ratios across different regions or environments is generally limited, except where significant geological control exists. Generally, Rb values range between 3 and 5. Higher Rb values indicate lower and more prolonged peak flows, thereby reducing flood risk (Chorley et al., 1957), whereas lower Rb values suggest fewer structural disturbances in the watershed (Nag and Chakraborty, 2003). According to Table 3, many of the micro-watersheds studied fall within this typical range, except for MW1, MW10, and MW16, which exhibit Rb values below 3.

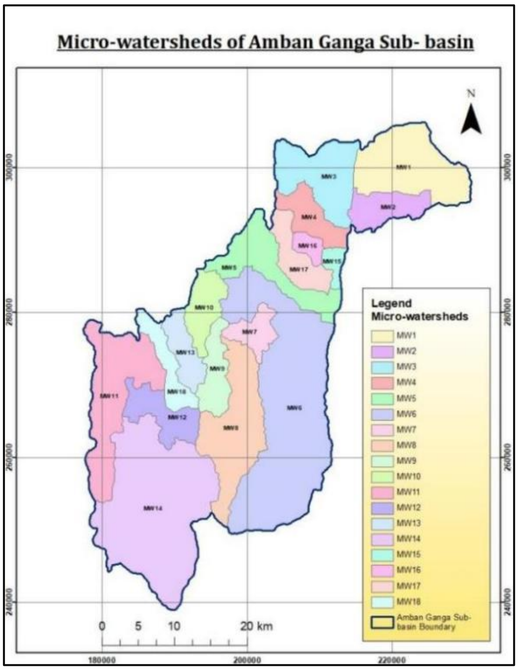

Figure 3: Delineation of the 18 micro-watersheds (MWS1 to MWS18) within the Amban Ganga Sub-basin. *Each micro-watershed is numbered and colour-coded. 18 units were derived from pour-point analysis using the hydrological toolset in ArcGIS 10.8. The sub-b*

3.2.2 Stream Frequency (Fs)

Fs indicates the relationship between the total stream count (Nu) within a basin and its area (A). It is defined as the number of streams per unit area (Horton, 1932). Fs reflects the texture of the drainage network and is influenced by basin Lithology. As shown in Table 3, Fs values in the study area range from 3.12 (MW 1) to 6.87 km/km² (MW 18), suggesting a progression toward late maturity and older stages of the sub-basin's topography. These values indicate increased surface water infiltration through permeable rocks (Ahmed et al., 2010).

3.2.3 Drainage Density (Dd)

It is a key geomorphological metric that provides profound insights into river basin dynamics. It measures the extent of stream channels in a unit area, reflecting the permeability of the landscape and potential for runoff. Initially emphasised by Horton (1945) and Schumm (1956), drainage density aids in assessing a basin's susceptibility to hydrological response and sediment transport. High drainage density indicates rapid runoff and intense erosion, while a low density suggests prolonged infiltration. The type of rocks, intensity of run-off, soil type and infiltration capacity can influence drainage density (Kottagoda and Abeysingha, 2017). Low Dd values indicate dense vegetation, low relief, and permeable subsoil, whereas high Dd values are associated with sparse vegetation and mountainous relief (Uniyal and Gupta, 2013). In the study area, Dd values range from 1.05 to 2.88 km/km² (Table 3), suggesting moderately permeable subsoil, substantial vegetation, and moderate relief.

3.2.4 Drainage Texture (Dt)

Dt is an important geomorphological concept that refers to the relative spacing of drainage lines. It is influenced by factors such as infiltration capacity, underlying lithology, and the relief aspect of the basin terrain (Rai et al., 2019). Dt is calculated as the total number of stream segments of all orders divided by the perimeter of the watershed (Horton, 1945). According to Smith (1950), drainage texture can be classified into five classes: Very Coarse (values below 2), Coarse (2 to 4), Moderate (4 to 6), Fine (6 to 8), and Very Fine (values over 8). In the study area, MWS10 shows predominantly fine drainage texture (Table 3). MWS4, MWS7, MWS16 and MWS17 show a moderate Dt, while MWS6, MWS8, MWS11, and MWS14 show a very fine Dt, indicating a potential risk of erosion as stated by Horton (1945) and Rai et al. (2019).

3.2.5 Drainage Intensity (Id)

The ratio of the stream frequency to drainage density is defined as Id (Faniran, 1968). Drainage intensity (Id) measures how rapidly water moves across a landscape (Singh, 2014). According to Table 3, Id values range from 1.49 (MWS 1) to 4.70 (MWS 5), indicating low drainage intensity, which leads to more water infiltrating into the soil, which reduces erosion, enhances groundwater recharge, supports vegetation, and contributes to flood regulation (Rai et al., 2017a, 2017b, 2018).

3.2.6 Length of Overland Flow (Lo)

This term refers to the distance rainwater travels across the ground surface before it converges into defined river channels (Horton, 1945). Lo measures the distance water travels over the land before reaching a stream. In the study area, Lo values of the micro-watershed ranged from 0.17 to 0.48 km. Values exceeding 0.25 km indicate minimal structural disturbance, reduced runoff, longer flow paths, and higher infiltration (Muthukrishnan et al., 2013). MWS 9, MWS 10, MWS 12, MWS 13, MWS 14, and MWS 18 have lower Lo values, indicating more structural disturbances and higher runoff, while the remaining micro-watersheds show moderate conditions.

Table 3: Linear morphometric parameters for each of the 18 micro-watersheds (MWS1–MWS18) in the Amban Ganga Sub-basin: bifurcation ratio (Rb), stream frequency (Fs in streams/km²), drainage density (Dd in km/km²), drainage texture (Dt), drainage intensity (Id), and length of overland flow (Lo in km). Micro-watershed numbers correspond to Figure 3.

Micro-watershed	Rb	Fs	Dd	Dt	Id	Lo
MWS1	2.69	3.12	2.09	7.39	1.49	0.24
MWS2	4.02	4.91	2.41	6.16	2.04	0.21
MWS3	3.56	4.01	2.39	7.18	1.68	0.21
MWS4	4.95	4.68	2.24	5.03	2.09	0.22
MWS5	3.58	4.94	1.05	6.10	4.70	0.48
MWS6	3.80	5.43	2.55	15.06	2.13	0.20
MWS7	3.92	4.80	2.35	4.65	2.04	0.21
MWS8	4.64	6.07	2.51	10.46	2.42	0.20
MWS9	4.92	6.57	2.72	6.88	2.41	0.18
MWS10	2.91	5.78	2.63	7.17	2.20	0.19
MWS11	3.31	6.01	2.41	9.70	2.49	0.21
MWS12	4.04	6.78	2.88	7.22	2.35	0.17
MWS13	3.07	6.03	2.65	6.61	2.28	0.19
MWS14	3.49	6.67	2.79	21.23	2.39	0.18
MWS15	4.30	4.97	2.19	3.39	2.27	0.23
MWS16	2.97	5.08	2.45	4.09	2.07	0.20
MWS17	3.49	4.73	2.42	5.41	1.95	0.21
MWS18	3.98	6.87	2.63	6.21	2.61	0.19

3.3 Areal Aspects

3.3.1 Form Factor (Ff) and Circulatory Ratio (Rc)

Form factor (Ff) is defined as the ratio of the basin area to the square of the basin length (Horton, 1932). Circulatory Ratio (Rc) is a quantitative measure expressed as the ratio of selected basin area (A) to the area of a circle having the same perimeter as the basin (Miller, 1953; Strahler, 1964). A lower Ff value indicates an elongated basin, whereas values closer to 1 suggest a more circular basin. The Ff value for a perfectly circular basin is typically less than 0.7584 (Withanage et al., 2015). Similarly, a low Rc value signifies an elongated basin often associated with impermeable lithological formations, while higher Rc values indicate a more circular shape, often linked to moderate to high relief (Thacker et al., 2022).

In the 18 micro-watersheds studied, Ff values varied from 0.17 to 0.54, and Rc values varied from 0.24 to 0.63. These lower Ff values indicate an elongated shape of the river basin, with flatter hydrographs having lower peak discharges and longer durations. Singh and Singh (1997) highlighted that flood flows from such elongated basins are easier to manage compared to those from circular basins. Furthermore, these low values suggest the basins are characterised by elevated surface runoff, a dense stream network, structural distortions, and limited lithological permeability. The elongated shape of the basin thus supports longer peak flow durations, facilitating flood management compared to circular basins (Withanage et al., 2015).

3.3.2 Elongation Ratio (Re)

Re is defined as the ratio of the diameter of the circle with the same area as the basin to the maximum basin length (Schumm, 1956). Re-values below 0.7 generally indicate elongated basins, values from 0.7 to 0.8 indicate less elongated basins, values from 0.8 to 0.9 suggest oval-shaped basins, and values above 0.9 represent circular basins (Thacker et al., 2022).

Table 4: Areal morphometric parameters for 18 micro-watersheds (MWS1–MWS18) of the Amban Ganga Sub-basin: circulatory ratio (Rc), elongation ratio (Re), form factor (Ff), and compactness coefficient (Cc).

Micro-watershed	Rc	Re	Ff	Cc
MWS1	0.57	0.77	0.47	1.32
MWS2	0.45	0.62	0.3	1.5
MWS3	0.45	0.69	0.38	1.49
MWS4	0.35	0.59	0.28	1.7
MWS5	0.24	0.58	0.27	2.06
MWS6	0.29	0.66	0.34	1.84
MWS7	0.4	0.72	0.41	1.58
MWS8	0.3	0.49	0.19	1.84
MWS9	0.34	0.52	0.21	1.72
MWS10	0.45	0.60	0.29	1.49
MWS11	0.25	0.54	0.23	1.99
MWS12	0.29	0.62	0.30	1.86
MWS13	0.42	0.66	0.35	1.55
MWS14	0.44	0.70	0.39	1.5
MWS15	0.48	0.65	0.33	1.45
MWS16	0.63	0.83	0.54	1.26
MWS17	0.38	0.62	0.31	1.62
MWS18	0.27	0.46	0.17	1.91

These parameters describe basin shape, which influences peak flow duration and flood risk.

In the study area, Re values for micro-watersheds ranged from 0.46 to 0.83. Most micro-watersheds have Re values less than 0.7, except for MWS 16 (0.83), indicating elongated shapes. Elongated basins with high bifurcation ratios yield low but extended peak flows; such types of river basins contribute to controlled peak flow and reduced flood risk. Therefore, these Re values together with Ff and Rc values, confirm that the Amban Ganga sub-basin has a lower susceptibility to flooding due to the morphometry of its river network, which efficiently disperses the generation of peak flow.

3.3.3 Compactness Coefficient (Cc)

The compactness coefficient (Cc) quantifies how closely a drainage basin resembles a circular watershed of the same area. A Circular watershed has a Cc value of 1, indicating the minimal time for maximum flow to occur. Values greater than 1 indicate increasing deviation from circularity (Thacker et al., 2022). Across the 18 micro-watersheds studied, Cc values range from 1.26 to 1.99, indicating that the basins deviate from circularity. This deviation suggests that the basin experiences less rapid peak flows, contributing to more controlled hydrological responses.

3.4 Relief Aspects

3.4.1 Relief Ratio (Rhl)

The relief ratio is a measure of the mean slope of a basin (Schumm, 1956) and is particularly relevant for understanding elongated basins (Morisawa, 1962). Among the 18 micro-watersheds analysed, Rhl values range from 0.01 (MWS 1) to 0.08 (MWS 12). Higher Rhl values are associated with greater basin relief, smaller basin areas, and more circular shapes, which are typical of mountainous regions (Bhadran et al., 2018). For example, MWS 9 and MWS 12, exhibiting the highest Rhl values, show steep slopes and concentrated drainage patterns, indicating their elevated terrain and smaller, more circular shapes. In contrast, MWS 1 and MWS 16, with the lowest Rhl values, have gentler slopes and more elongated forms, aligning with characteristics of flatter terrains.

These results highlight the hydrological significance of the Rhl, where basins with higher values tend to experience rapid surface runoff and increased flood risk due to their steep gradients. Conversely, basins with lower Rhl values have slower runoff, reducing flood risk and contributing to a more gradual hydrological response.

3.4.2 Ruggedness Number (Rn)

Rn measures the topographic ruggedness of a river basin. High Rn values occur when slopes are both steep and long, and it is directly proportional to relative peak discharge (Patton, 1988). Higher Rn values indicate a rugged landscape with significant elevation differences and a higher potential for peak discharge, while lower values correspond to gentler slopes with lower peak discharge. The Rn values for the micro-watersheds ranged from 0.17 to 4.46. Micro-watersheds MWS 6 (4.46), MWS 8 (4.37), MWS 9 (2.83), MWS 12 (3.05), MWS 14 (3.73), and MWS 18 (2.42) may require specific management strategies to mitigate risks such as erosion, sedimentation, or landslide. Other micro-watersheds with lower Rn values are less susceptible to flooding.

Table 5: Relief morphometric parameters for 18 micro-watersheds (MWS1–MWS18) of the Amban Ganga Sub-basin: relief ratio (Rhl) and ruggedness number (Rn).

Micro-watershed	Rhl	Rn
MWS1	0.01	0.38
MWS2	0.02	0.44
MWS3	0.03	1.13
MWS4	0.03	0.96
MWS5	0.04	0.65
MWS6	0.06	4.46
MWS7	0.04	0.85
MWS8	0.07	4.37
MWS9	0.08	2.83
MWS10	0.05	1.66
MWS11	0.04	2.31
MWS12	0.08	3.05
MWS13	0.05	1.40
MWS14	0.05	3.73
MWS15	0.04	0.54
MWS16	0.01	0.17
MWS17	0.04	1.02
MWS18	0.06	2.42

These parameters indicate slope steepness and terrain ruggedness, which influence runoff speed and erosion potential.

According to the overall results of morphometric analysis, the Amban Ganga sub-basin exhibits a landscape with permeable subsurface materials beneath dense vegetation, which facilitates the generation of extended, gradual direct runoff, thereby reducing the likelihood of flooding. Several micro-watersheds (MWS 1, MWS 6, MWS 8, MWS 9, MW 12, MWS 18) show deviations in certain linear, areal, and relief attributes, suggesting distinct geomorphic characteristics within them.

3.5 Micro-watershed Prioritization

Table 6 shows the results of the micro-watershed prioritization conducted using the method proposed by Uniyal and Gupta (2013), which incorporates different linear, areal and relief parameters estimated for all 18 micro-watersheds.

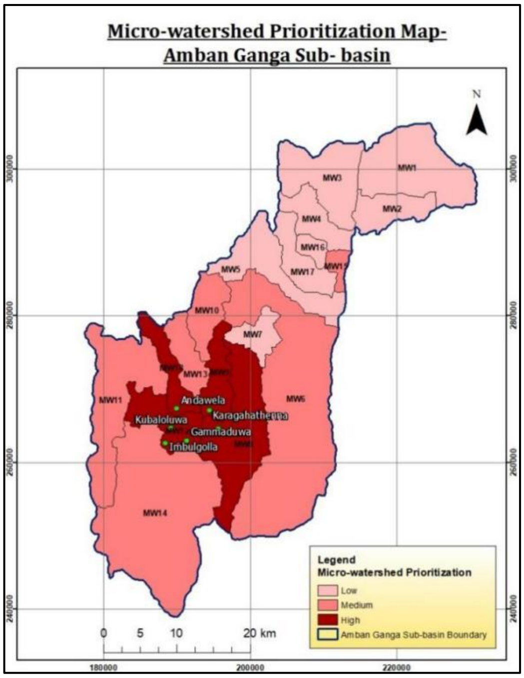

Figure 4: Prioritization map of the 18 micro-watersheds in the Amban Ganga Sub-basin based on composite morphometric analysis (linear, areal, and relief parameters). *Priority categories: High (red) – MWS8, MWS9, MWS12, MWS18 (require immediate mechanical soil conservation measures); Medium (peach) – six micro-watersheds; Low (pink) – eight micro-watersheds. Prepared using ArcGIS 10.8. Numbers refer to micro-watersheds 1–18 as shown in Figure 3.*

Figure 4 represents the micro-watershed prioritization map developed. According to the analysis, MW8, 9, 12 and 18 were identified as high-priority areas requiring immediate action to establish soil and water conservation methods (Biswas et al., 1999). Furthermore, these four high-priority micro-watersheds were among those identified as showing deviations in specific geomorphic characteristics. This congruence highlights the robustness and accuracy of the prioritization approach, revealing its usefulness for soil and water conservation in watershed management.

Table 6: Compound prioritization ranking of 18 micro-watersheds (MWS1–MWS18) based on 11 morphometric parameters (Rb, Dd, Dt, Fs, Lo, Rhl, Rn, Ff, Re, Cc, Rc). For each parameter, micro-watersheds were ranked from 1 (highest priority for conservation) to 18 (lowest priority). Composite priority (CP) value = average of all ranks. Final priority categories: High (CP rank 1–4), Medium (5–10), Low (11–18). High-priority micro-watersheds (MWS8, MWS9, MWS12, MWS18) require immediate mechanical soil conservation measures.

Micro-watershed	Morphometric Parameters											CP value	CP Rank	Priority
	Linear					Relief			Areal					
	Rb	Dd	Dt	Fs	Lo	Rhl	Rn	Ff	Re	Cc	Rc			
MWS1	18	17	5	18	2	18	17	17	17	2	2	12.23	17	Low
MWS2	6	12	12	13	7	16	16	9	9	6	6	10.33	12	Low
MWS3	11	13	7	17	6	15	10	14	14	5	5	10.69	13	Low
MWS4	1	15	15	16	4	14	12	6	6	11	11	10.17	11	Low
MWS5	10	18	13	12	1	12	14	5	5	18	18	11.49	15	Low
MWS6	9	7	2	9	12	5	1	12	12	14	14	8.66	7	Medium
MWS7	8	14	16	14	5	9	13	16	16	9	9	11.71	16	Low
MWS8	3	8	3	5	11	3	2	2	2	13	13	5.83	1	**High**
MWS9	2	3	9	4	16	2	5	3	3	12	12	6.39	2	**High**
MWS10	17	5	8	8	14	7	8	7	7	4	4	8.11	6	Medium
MWS11	14	11	4	7	8	11	7	4	4	17	17	9.44	8	Medium
MWS12	5	1	6	2	18	1	4	8	8	15	15	7.41	4	**High**
MWS13	15	4	10	6	15	6	9	13	13	8	8	9.68	10	Medium
MWS14	12	2	1	3	17	8	3	15	15	7	7	8.10	5	Medium
MWS15	4	16	18	11	3	10	15	11	11	3	3	9.63	9	Medium
MWS16	16	9	17	10	10	17	18	18	18	1	1	12.41	18	Low
MWS17	13	10	14	15	9	13	11	10	10	10	10	11.39	14	Low
MWS18	7	6	11	1	13	4	6	1	1	16	16	7.40	3	**High**

4. Implications and Recommendations

The identified high-priority watersheds are highly susceptible to soil erosion and demand urgent attention for implementing soil conservation measures. Mechanical measures such as contour bunding, checking dams, and terracing, etc. should be applied to prevent further topsoil loss. Medium and low-priority micro-watershed areas show less susceptibility to erosion and can be effectively managed through agronomic measures to protect against sheet and rill erosion (Uniyal and Gupta, 2013).

5. Conclusions

The Amban Ganga river network features a dendritic drainage pattern. This long river basin, approximately 81 km in length, extends up to the 7^{th} order according to Strahler's classification. The results of the linear-morphometric analysis suggest that the river network generates flatter peak runoff due to the presence of permeable subsoil and dense vegetative cover, which helps reduce flood risk. The areal aspects revealed that the basin is more towards an elongated shape, confirming flatter peak flow generation and making the sub-basin less susceptible to flooding and soil erosion. The results of the relief aspects further revealed that the sub-basin, overall, has gentle and gradual slopes, which also contribute to lowering flood risk. Based on the results of micro-watershed prioritisation, MWS 8, MWS 9, MWS 12 and MWS 18 micro-watersheds were identified as high-priority areas where immediate implementation of mechanical soil conservation and management measures is necessary. The remaining 14 micro-watersheds can be adequately managed using agronomic soil conservation methods. Therefore, this study provides valuable information on hydrological characteristics and soil erosion potential of the Amban Ganga sub-basin, offering important guidance for decision-making and the sustainable management of watersheds within the longest and most prominent Mahaweli River basin in Sri Lanka.

Author Contributions

Ekanayake: Data curation, Formal analysis, Investigation, Methodology, writing original draft; Withanage: Conceptualization, Methodology, Supervision, Validation, Writing review and editing; Abeysekara: Data curation, Software, Visualization, Writing review and editing.

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Declaration of Conflict of Interest

The authors declare no conflicts of interest.

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