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Integrated DEMNas and Morphogenetic Analysis of Geomorphological Diversity in Salopa, Tasikmalaya, West Java

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ABSTRACT

This study presents an integrated geomorphological analysis of the Salopa area in Tasikmalaya Regency, West Java, combining field observations with advanced DEMNas (National Digital Elevation Model). The Salopa area has varied morphology with interesting relief. The diverse morphological features in the Salopa region are evidence of geological processes that have occurred. The focus of this research is to analyze and observe the geomorphology in the study area, aiming to identify the characteristics of the landscape and classify them. This study pioneers the combined use of DEMNas and morphogenetic analysis in Salopa, revealing seven landform units and their tectonic-fluvial interactions. Findings provide a baseline for landslide hazard mapping and sustainable land-use planning in West Java. The research methods used include field observation and systematic analytical approach in terms of morphometry, morphography, and morphogenetics, as well as analysis of the National Digital Elevation Model (DEMNas). Denudational High Hills (15%), Denudational Hills (60%), Structural Hills, Alluvial Plains (6%), Floodplains (10%), Denuded Karst Hills (25%), and Irregular Meander Channels (10%). These units reflect the interplay of tectonic activity, lithological variation, and fluvial processes. The study highlights the dominance of denudational processes, evidenced by landslides and dendritic river patterns, and contrasts the Salopa basin's geomorphology with adjacent regions like Cibalong.

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1. INTRODUCTION

Geomorphology plays a pivotal role in understanding the dynamics of Earth's surface processes and landform development. The study of landform characteristics and their formative processes is fundamental to regional planning, natural hazard assessment, and environmental management. In tropical regions with active tectonics and diverse lithologies, such as West Java, geomorphological studies provide valuable insights into surface processes and landscape evolution. Previous research has highlighted the significance of Digital Elevation Models (DEMs) in geomorphological investigations, enabling high-resolution analyses of topography and drainage systems (Aulia et al., 2025; Trisnawati et al., 2020). Integrating remote sensing and field-based observations has become standard in assessing landform types and geomorphic processes (Lin et al., 2022).

Despite numerous studies in the region, comprehensive geomorphological analyses specifically focusing on Salopa in Tasikmalaya remain limited. Preliminary investigations in adjacent areas, such as Cibalong, have revealed distinct geomorphological units and tectonic influences (Aribowo et al., 2022). However, Salopa's complex morphology and varied lithological settings necessitate localised and detailed geomorphic studies. To address this limitation, the present study combined digital terrain analysis with field validation to comprehensively characterise the geomorphological features of Salopa and classify its landform units. The general solution adopted involves integrating morphometric, morphographic, and morphogenetic approaches within a digital elevation framework supported by DEMNas data.

A robust methodology for delineating landform units in tectonically active regions involves the integration of DEM analysis with morphogenetic and morphometric techniques. This approach facilitates the detailed classification of slope, elevation, and drainage patterns, which are essential for understanding geomorphic processes such as denudation and fluvial development. Previous studies support this methodological foundation, highlighting the use of DEMNas data and field-based validation to enhance mapping accuracy (Adamsyah & Rochmana, 2024; Widyatmanti et al., 2016). Additionally, QGIS tools for slope and aspect analysis, in conjunction with geological field data, have proven effective in capturing topographic and structural variability (Zhang et al., 2023). These techniques collectively form the analytical framework used in the present study.

While adjacent areas, such as Cibalong, have been studied for their tectonic landforms and lithological control on landscape evolution, Salopa has not received equal scholarly attention. Previous findings have focused on general geological mapping without in-depth geomorphological classification, leaving a gap in understanding the detailed landform distribution and their formative processes (Hibatullah et al., 2024; Ouyang et al., 2022). Additionally, the presence of karst hills and irregular meander channels in Salopa presents unique morphological features that have not been previously analysed using an integrated approach in the literature. Thus, the lack of comprehensive morphogenetic analysis in the Salopa area highlights the need for a focused study that bridges this knowledge gap.

This study aimed to conduct an integrated geomorphological analysis of the Salopa area in Tasikmalaya Regency using DEMNas data and field-based morphogenetic validation. The novelty of this research lies in its systematic combination of morphographic, morphometric, and morphogenetic techniques to classify and interpret diverse landforms within tectonically influenced regions. Unlike prior studies, this study provides a detailed spatial categorisation of landform units, including denudational, structural, and karst hills, with implications for hazard assessment and sustainable land use planning. The scope of this study encompasses digital elevation analysis, slope classification, drainage pattern evaluation, and geomorphological mapping, thereby contributing to regional geomorphic databases and applied geoscience in West Java.

2. METHOD

2.1. Materials

This study employed various geomorphological tools and datasets to analyse the landform units in the Salopa area. The primary source was the 1:25,000-scale DEMNas for morphometric and morphogenetic analyses. Geospatial analysis using QGIS 3.28 focused on extracting the slope, aspect, and contour data. Fieldwork utilised handheld GPS, Brunton compasses and rock hammers. High-resolution satellite imagery and topographic maps supported the studio analysis and field validation. The study area is illustrated in Figure 1.

2.2. Sample Preparation

The sampling phase focused on collecting empirical observations of landform units and geomorphic processes across various elevations and slope gradients of the study area. Field observations recorded lithology, structural features, and current geomorphic processes such as landslides and erosion patterns. Rock samples, especially from areas classified as Denudational High Hills and Structural Hills, were described in terms of texture, composition, and weathering profile. The spatial distribution of the sampling sites ensured coverage of all seven landform types identified in the preliminary DEM analysis.

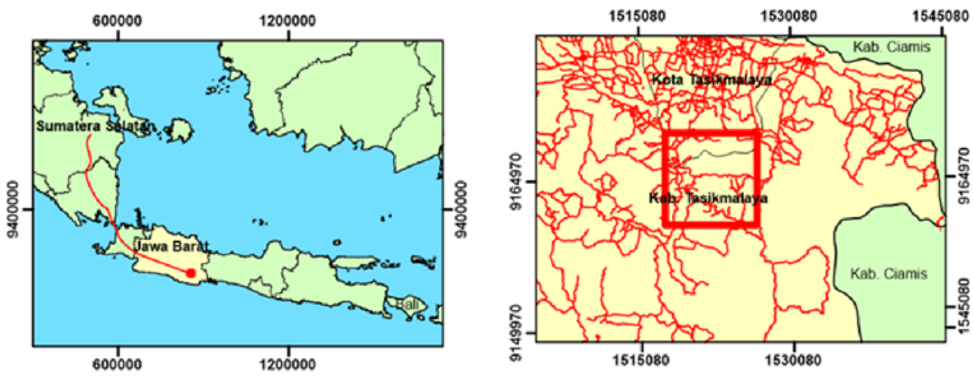

Figure 1. Administrative Location of the Research Area.

2.3. Analytical Framework

An analytical framework was constructed using a three-pronged geomorphological approach consisting of morphometric, morphographic, and morphogenetic analyses. The morphometric aspect included slope classification, elevation stratification, and topographic segmentation, following Widyatmanti (Widyatmanti et al., 2016). Morphographic analysis identified landform features and flow patterns based on their relationship with relative height and absolute elevation. Morphogenetic classification was applied to associate landforms with formative processes, such as denudation, fluvial activity, and structural deformation. DEMNas data were processed using QGIS tools to generate slope and aspect maps, and field data were used to validate and adjust the interpretation of the digital outputs.

2.4. Parameters

The key parameters assessed in this study were elevation, slope gradient, flow direction, and sinuousity ratios for meandering rivers. Elevation and slope data were derived directly from DEMNas, with slope classes categorised as follows:

Table 1. Class slope

Elevation Class (m)	Relative Height	%	Class
<50	Lowland	0-2	Flat–Very Flat
50-200	Low Hills	3-7	Gently Sloping
200-500	Hills	8-13	Moderately Sloping
500-1000	High Hills	14-20	Slightly Steep
>1000	Mountains	21-25	Steep
-	-	56-140	Very Steep
-	-	>140	Upright

Slope variation maps were developed to assess spatial differences in geomorphic conditions, with steeper areas corresponding to higher landslide incidences. Flow pattern identification was conducted using Twidale's classification, distinguishing dendritic and parallel types (Twidale, 2004). Sinuosity ratios were computed to classify river meandering stages, aiding in the identification of floodplain evolution and channel maturity.

2.5. Data Analysis

Statistical evaluation was performed to quantify the relationship between slope steepness and landslide occurrences. Regression analysis was used to determine the correlations between geomorphic parameters, such as slope class and landslide frequency. Descriptive statistics, including the mean, range, and standard deviation, were applied to summarise the sinuousity ratios of the Ciwulan and Cipinaha rivers. All statistical analyses were performed using Microsoft Excel and QGIS integrated plugins.

3. RESULTS AND DISCUSSION

3.1. Results

The morphographic classification of the study area identified three major elevation-based landform types: low hills, hills, and high hills. The DEMNas data indicate an elevation range from 137 to 611 m, which corresponds to the classification system by Widyatmanti et al. (2016). The terrain is dominated by hills (70%), followed by low (20%) and high hills (10%). Low hills are mainly concentrated along the Cihaur and Cipinaha rivers, whereas the elevation increases progressively toward the eastern zone of the area. This variation is illustrated in the block diagram and slope map derived from the DEM analysis.

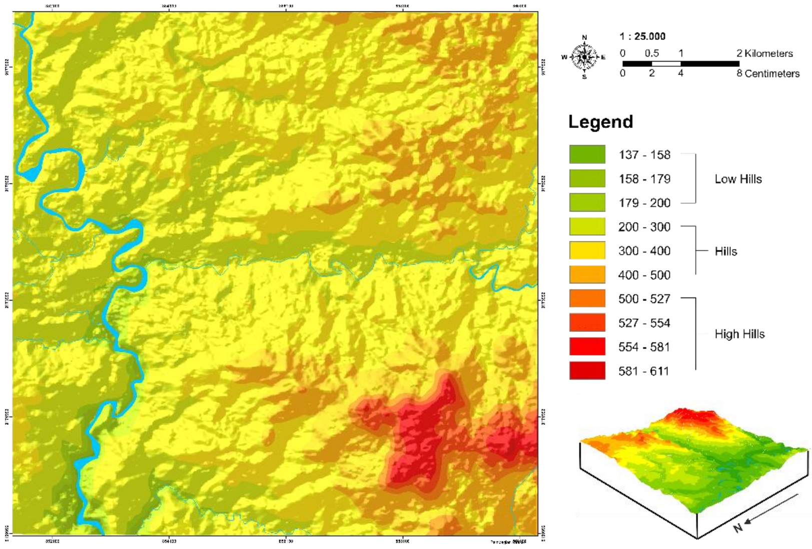

Figure 2. Morphological Map of the Study Area.

Slope analysis yielded six classifications: flat, slightly sloping, moderately sloping, slightly steep, steep, and very steep slopes. These classifications demonstrated a significant correlation between steep slopes and landslide occurrence. Field observations confirmed active erosion and degradation processes, particularly in hilly terrains.

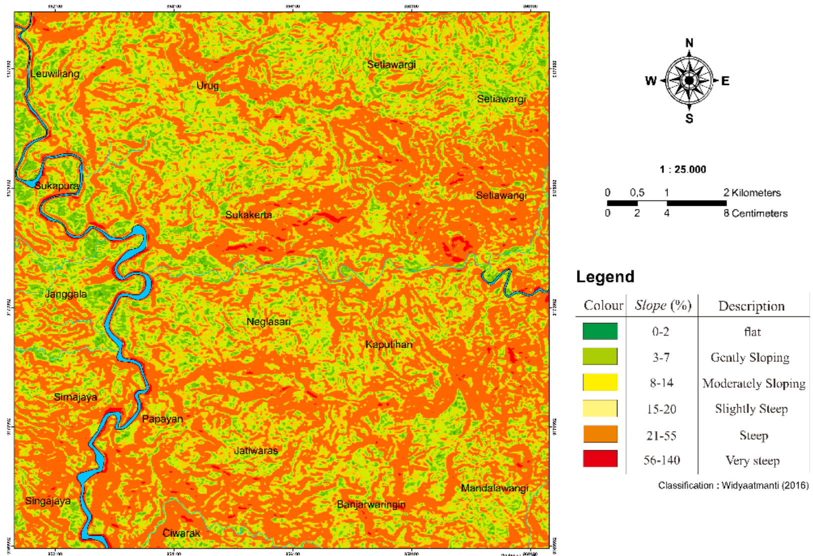

Figure 3. Slope Map of the Research Area.

Hydrological pattern analysis using Twidale's classification (2004) revealed two dominant river flow types: dendritic and parallel river flows. Dendritic patterns occupy approximately 60% of the area and are generally aligned in a north–south orientation. In contrast, parallel patterns occupy the remaining 40%, typically aligned with steep topographic gradients.

Landslide phenomena, especially debris falls and slides, were documented in multiple villages, such as Setiawangi, Urug, and Sukakerta. Landslides are linked to weak lithologies, such as tuffaceous sandstone, and steep slope gradients.

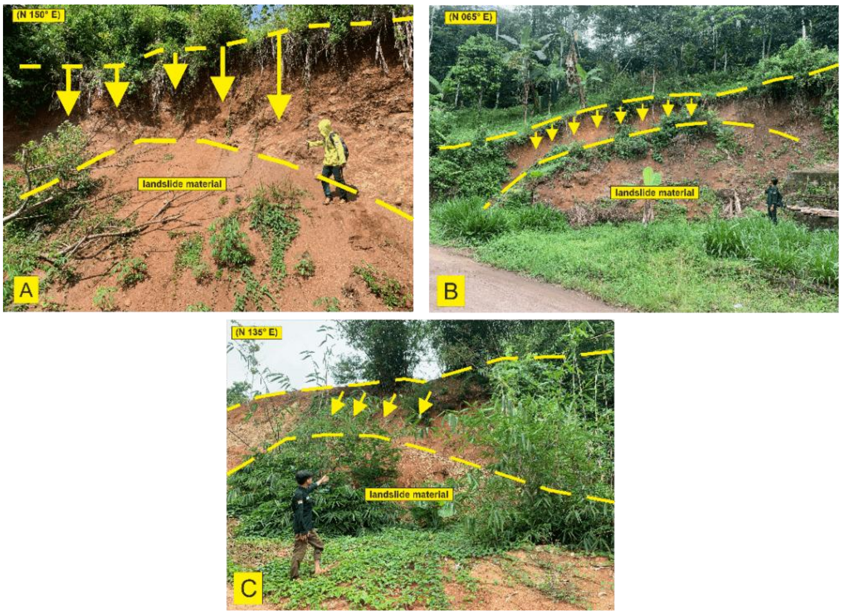

Figure 4. Landslide Types in the Study Area: A) Debris Fall in Setiawangi Village; B) Debris Fall in Urug Village; C) Debris Slide in Sukakerta Village.

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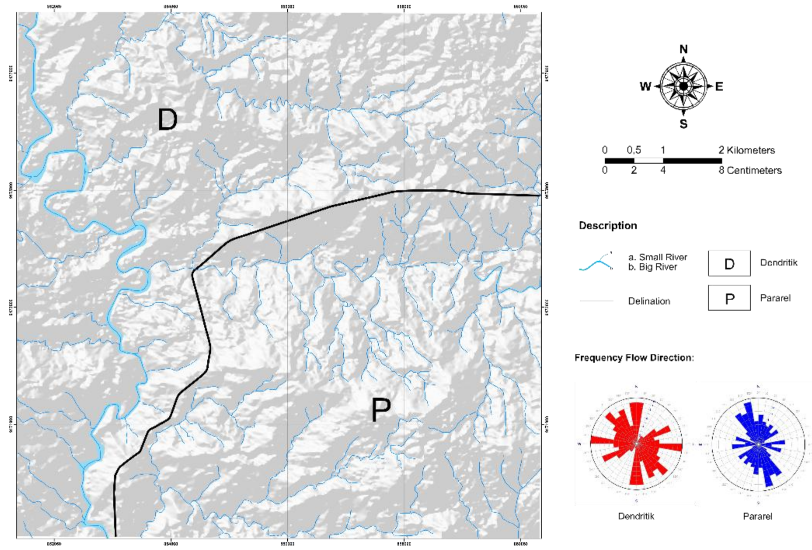

Figure 5. Flow Pattern Map of the Study Area.

Meander analysis of the Ciwulan and Cipinaha Rivers categorised river segments into sinuous and meandering types based on their sinuosity ratio (SR). The Ciwulan River exhibited an average SR of 1.91, which signifies a mature meandering stage with high lateral migration. The Cipinaha River shows a slightly lower average SR of 1.55, indicating an intermediate evolutionary stage with both sinuous and meandering segments. These classifications help interpret the geomorphic maturity of rivers and their influence on adjacent landforms. Details of these segmental divisions are presented in Tables 1 and 2.

Table 2. Morphometry and Sinuosity Ratios of Ciwulan River

Segment	S (m)	L (m)	Sinuosity (SR)	Meander Pattern
1	681	443,00	1,54	*Meandering*
2	722	637	1,13	*Sinuous*
3	1034	781	1,32	*Sinuous*
4	1034	576	1,80	*Meandering*
5	1373	536	2,56	*Meandering*
6	1174	572	2,05	*Meandering*
7	472	346	1,36	*Sinuous*
8	1009	650	1,55	*Meandering*
9	637	490	1,30	*Sinuous*
10	584	476	1,23	*Sinuous*
11	1451	935	1,55	*Meandering*
12	1919	972	1,97	*Meandering*
13	1627	826	1,97	*Meandering*
14	1431	460	3,11	*Meandering*
15	976	802	1,22	*Sinuous*
16	706	597	1,18	*Sinuous*
17	2211	848	2,61	*Meandering*
18	2568	403	6,37	*Meandering*
19	2344	741	3,16	*Meandering*
20	1697	1366	1,24	*Sinuous*
21	767	702	1,09	*Straight*
22	1105	982	1,13	*Sinuous*
23	649	469	1,38	*Sinuous*
	Average		1,91	Meandering

The morphometric characteristics of the Cipinaha River are summarised below to illustrate the distribution of sinuosity values and their corresponding meander evolution patterns across different segments of the river. These data provide additional insights into the hydrodynamic behaviour of rivers and complement the findings from the Ciwulan River.

Table 2. Morphometry and Sinuosity Ratios of Cipinaha River

Segment	S (m)	L (m)	Sinuosity (SR)	Meander Pattern
1	247	216	1,14	*Sinuous*
2	274	249	1,10	*Sinuous*
3	444	400	1,11	*Sinuous*
4	383	351	1,09	*Sinuous*
5	631	374	1,69	*Meandering*
6	894	302	2,96	*Meandering*
7	702	406	1,73	*Meandering*
	Average		1,55	Meandering

Seven landform units were identified using integrated morphometric, morphographic, and morphogenetic analyses, reflecting the diverse geological and geomorphological characteristics of the study area. Denudational High Hills, which cover 15% of the area, appear in high elevation zones with steep gradients and exhibit intensive erosion and weathering processes. Denudational Hills are the most dominant unit, occupying 60% of the study area, and are spread across various terrain types with varying lithological compositions. Structural Hills, comprising 15% of the area, result from tectonic folding and faulting, as indicated by ridge alignments and structural lineaments. Alluvial Plains, covering 6%, are found along major riverbanks and are formed by sediment deposition in low-energy environments. Floodplains, which account for 10% of the area, are typically situated adjacent to the Ci Wulan River and are characterised by their flatness and periodic inundation. Denuded Karst Hills, occupying 25% of the area, feature limestone lithologies subjected to dissolution, resulting in a distinctive karst topography. Lastly, the Channel Irregular

Meander units, which cover 10% of the region, represent the meandering course of the Ci Wulan River, influencing the adjacent floodplain development and sedimentation patterns.

3.2. Discussion

The results of this study confirm the significant role of geomorphometric and morphogenetic processes in shaping the landscape of Salopa. The identification of seven landform units dominated by denudational forms (75%) indicates that the area is under intense surface degradation influenced by tectonic activity, slope instability, and lithological susceptibility. This finding aligns with the theoretical understanding of tropical morphodynamics, in which high rainfall and steep terrain accelerate weathering and mass wasting. The dominance of Denudational Hills and Denudated Karst Hills reflects not only erosional processes but also the lithological diversity of the region, especially the presence of tuffaceous sandstones and limestones.

A comparative analysis with the Cibalong area, which lies within the same basin, highlights geomorphological diversity despite the shared tectonic framework. While Cibalong is characterized by more simplified units such as Folding Hills and Fault Zone Hills, Salopa displays a more complex landform structure with irregular meandering channels and karstic features (Bernard et al., 2022). This distinction suggests that local lithological variations and river evolution stages significantly contribute to the divergence in landscape development. Additionally, the flow pattern analysis in Salopa revealed dendritic and parallel systems, indicative of both homogenous lithology and active tectonic controls, respectively (Suratinoyo et al., 2024; Zwaan et al., 2022).

The presence of high sinuosity ratios in the Ciwulan and Cipinaha rivers (SR = 1.91 and 1.55, respectively) further supports the geomorphological maturity of the fluvial systems in Salopa. These mature meanders, associated with low gradient floodplains and alluvial deposits, mark the transition from erosional to depositional processes in the lower landscape zones (Marder & Gallen, 2023; Uno et al., 2025). The observed lateral migration and sediment deposition along river bends are consistent with fluvial evolution in humid tropical environments, emphasizing the necessity for detailed hydrological and sediment management in future land use planning (Modalavalasa et al., 2023; Ruhimat et al., 2024).

Landslide occurrences in the study area, particularly in steep terrain zones with weak lithologies, reinforce the importance of integrating geomorphological assessments into hazard-risk mitigation. Debris fall and debris slide types documented in the field are typically associated with active slopes and weathered rock formations (Basharat et al., 2023). The relationship between slope classes and landslide frequency, as confirmed by statistical analysis, underscores the potential application of slope data and DEM-derived parameters in early warning systems and spatial planning (Liu et al., 2023).

Overall, the findings of this study fill a critical gap in the geomorphological characterisation of Salopa and provide a comprehensive database for regional planning, conservation, and disaster mitigation. The integration of DEMNas and field-based verification presents a reliable framework for future geomorphological studies, particularly in regions with similar tectonic and climatic conditions. It is recommended that future work incorporate higher resolution data such as UAV-LiDAR and real-time monitoring tools to capture dynamic changes, especially in karstic and high-risk slope areas (Zhang et al., 2023).

4. CONCLUSIONS

This study presents a comprehensive geomorphological assessment of the Salopa region in Tasikmalaya Regency, West Java, by integrating DEMNas analysis and field-based observations. The classification of seven distinct landform unitsdominated by denudational featuresdemonstrates the complexity and diversity of geomorphic processes in the area. Notably, the interplay between lithological variations, tectonic controls, and fluvial dynamics governs the formation and evolution of landforms. The identification of mature meandering rivers and karst zones highlights the advanced geomorphic development and depositional characteristics of the region. Furthermore, the observed correlation between slope steepness and landslide distribution underscores the need for geomorphology-informed land-use planning and hazard mitigation. This study provides valuable insights into the geomorphic framework of West Java and serves as a reference for future studies employing high-resolution terrain analysis and real-time monitoring systems to address environmental and geological challenges. Limitations related to spatial resolution and temporal coverage may be addressed through UAV-based surveys and IoT-enabled slope monitoring in future studies.

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