Examining meandering stream by using geomorphological characteristics with GIS-based analysis

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Abstract. An assessment of the meandering stream type using its classification system to geomorphology characteristics combined with GIS-based analysis is presented in this paper. It describes geomorphology characteristics consisting of 8 parameters with GIS-based analysis that differ in the zone of sediment position, stream width, stream sinuosity, amplitude, wavelength, bend sharpness, meander pattern, and slope. The selected case study in this paper is the Barito Stream, South Kalimantan, Indonesia. Based on the results, the variability varied in all the geomorphology characteristics except bend sharpness and slope. The transport zone is the longest zone with classified as a very wide river with moderate sinuosity and high amplitude (< 1500). It is also categorized as a moderate wavelength and sharp bend with a relatively shallow slope. This approach is a simple, appropriate, and easy-to-use practice in examining meandering stream since there is no data or lack of supporting field data. The implementation of this meandering stream classification method is suitable for stream restoration projects, fish habitat enhancement, and water resource management. Further research is the study of possible geomorphic responses of a channel to natural and anthropogenic disturbances including channel-bed degradation, channel-bed aggradation, channel widening, and channel straightening.

1 Introduction

Meandering streams are one of the most ubiquitous patterns in fluvial morphology [1]. Previous research revealed that the uniqueness and applicative importance of these nearly regular loops in river planimetry have attracted the interest of several researchers in fluid mechanics and morpho-dynamics [2], geomorphology [3-4], river engineering [5], riparian ecology [6-7], and ecological engineering [8-9]. The stream processes itself is directed by fluid velocity and morphodynamical processes, which cause lateral bank erosion and the constant migration of meanders, as well as by intermittent cutoffs that prevent self-intersections of the stream and create sudden reductions in stream length and sinuosity [8]. The variability of large natural streams characteristics is proof that some variables controlled the stream's type or stream's pattern.

Geographic Information System (GIS)-based model and analysis have become quite common for collecting and processing secondary data in many water-subject purposes including watershed and stream management [10-11]. However, few efforts have been dedicated to develop meandering stream classification method regarding water stream management. It is clear that basic stream information is needed to make stakeholder's decisions. However, comprehensive field sampling over many streams in large study areas can be too costly in time and labor. Thus, geographic information system (GIS)-based models and analysis that can synthesize multiple characteristics have become particularly valuable in streams where stream assessments have not been completed or are difficult to perform. Therefore, the main purpose of this study is to examine meandering stream type using its classification system to geomorphological characteristics combined with GIS-based analysis.

2 Methodology

In fact, lack of stream classifications was focused on meandering type. Therefore, previous research [10] tried to develop the conceptual model for classification of meandering streams. This study is the extension research by using geomorphology characteristics with GIS-based analysis in certain study area. The process study was investigated 8 parameters in zone of sediment position: stream width, stream sinuosity, amplitude, wavelength, bend sharpness, meander pattern, and slope.

2.1 Study area

The Barito Stream is one of the most important streams in South Kalimantan, Indonesia, with coordinate location 3°19′11.53″S 114°35′26.7″E and total length 1090 km with a drainage basin of 81,675 km2 also its tributaries flow across various geomorphology characteristics. Barito Stream is also the largest and

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second longest stream in South Kalimantan, Indonesia (Fig. 1). It originates in the Muller Mountain Range, from where it flows southward into the Java Sea with the average discharge is 5,497 m^3/s. Its most central affluent is the Martapura Stream, and it passes through Banjarmasin City. The stream flows in the southeast area of Kalimantan with predominantly tropical rainforest climate. The annual average temperature is 24 °C and the average annual rainfall is 2,735 mm.

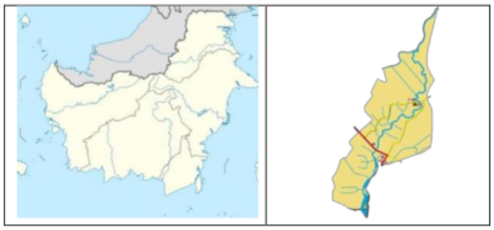

Fig. 1. Location of study area.

2.2 Method and analysis

This study was investigated and analysed 8 parameters:

1. Zone of sediment positions

   At first, Barito Stream was divided by three zone of sediment positions: zone of deposition, zone of transport and zone of production, by using google-earth combined with ArcGIS software, the length of zone of sediment can be measured and defined considering the slope of stream. For the zone of deposition, the slope is slightly meanwhile for the zone of production the slope is very steep. The results can be seen on Table 1 and Fig. 2.

Table 1. Zone of deposition.

Zone of Sediment	Length
Zone of deposition	141330 m
Zone of transport	453868 m
Zone of production	144255 m

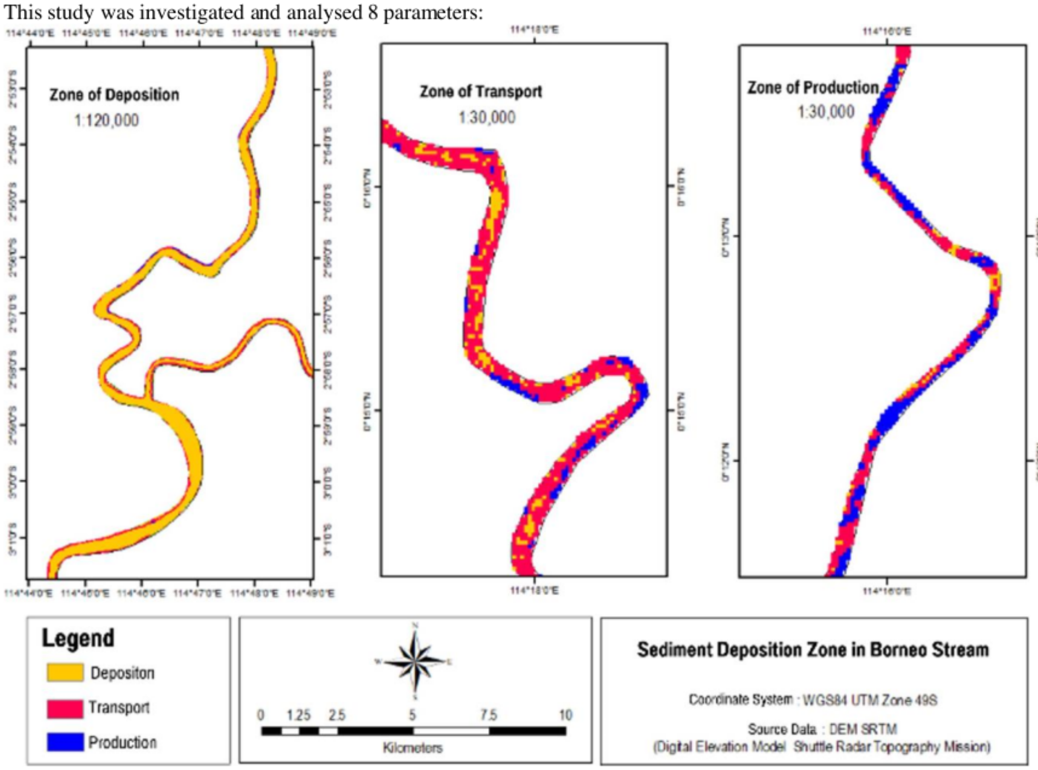

Fig. 2. Classification of sediment deposition.

2. Stream width

   The type of river can be classified by its width. For the large river, the width should be more than 220 m. Moreover, previous research classified the stream's width > 10 m as a large stream. Therefore, the classification is shown in Table 2.

3. Stream sinuosity

   Sinuosity is the result of the stream naturally dissipating its flow forces. According to previous research, meandering streams have a sinuosity larger than 1.25. Therefore, the classification is shown in Table 3.

Table 2. Stream width classification.

Types of Streams	Range of width (m)
Very Large Stream	>300
Large Stream	100 – 300
Middle Stream	50 – 100
Small Stream	<50

Table 3. Stream sinuosity classification.

Types of Streams	Range of sinuosity (m)
Very highly meandering	>2
Highly meandering	1.5 – 2
Moderate meandering	1.25 – 1.5
Low meandering	<1.25

4. Amplitude

The maximum distance from the down-valley axis to the sinuous axis of a loop is the meander width or amplitude. The developed classification can be seen in Table 4.

Table 4. Stream amplitude classification.

Types of Streams	Range of Amplitude (m)
Very highly amplitude	>2000
Highly amplitude	1500-2000
Moderate amplitude	1000-1500
Low amplitude	<1000

5. Wavelength

According to previous study, a meander consists of a pair of opposing loops, but in common practice also a single river bend is often called "meander". In this study a meander is a single river bend. The distance of one meander along the down valley axis is the meander length or wavelength. The classification can be seen on Table 5.

6. Bend sharpness

The bend sharpness (γ) is represented by the ratio of river width to radius of curvature of the river centerline. The classification can be seen on Table 6.

Table 5. Stream wavelength classification.

Types of Streams	Range of Wavelength (m)
Long meandering	>5000
Moderate meandering	2000 – 5000
Short meandering	<2000

Table 6. Stream bend sharpness classification.

Types of Streams	Range of Bend sharpness (m)
Sharp meandering	>0.5
Moderate meandering	0.1 – 0.5
Mild meandering	<0.1

7. Meander pattern

A variety of river changes are listed under pattern change (Fig. 3). In meander changes, meander enlarges if its amplitude and width increase. Meander shift involves the displacement of the meander in a downstream direction.

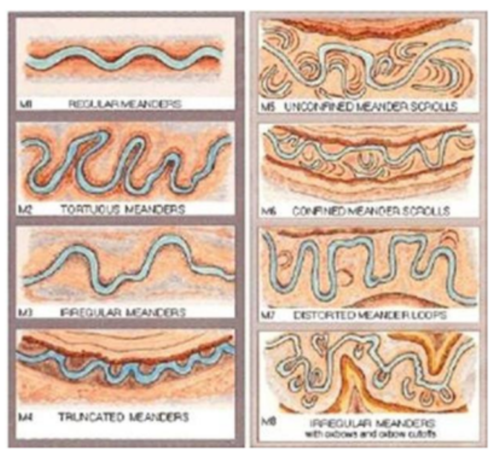

Fig. 3. Classification of meander pattern.

8. Slope

Slope can be calculated from the elevation and the length of each reach of stream. The classification can be seen on Table 7.

3 Results and discussions

The selected parameters (stream width, stream sinuosity, amplitude, wavelength, bend sharpness, meander pattern, and slope) have been assessed by using

GIS. The comprehensive results can be seen in Tables 8-13 and Fig. 4-10.

Table 7. Stream slope classification.

Types of Streams	Range of Slope
Steep	> 0.05
Moderate	0.01 – 0.05
Shallow	<0.01

Table 8. Results of stream width.

Zone of Sediment	Range of width (m)	Types of Streams
Zone of deposition	481	Very Large Stream
Zone of transport	354	Very Large Stream
Zone of production	203	Large Stream

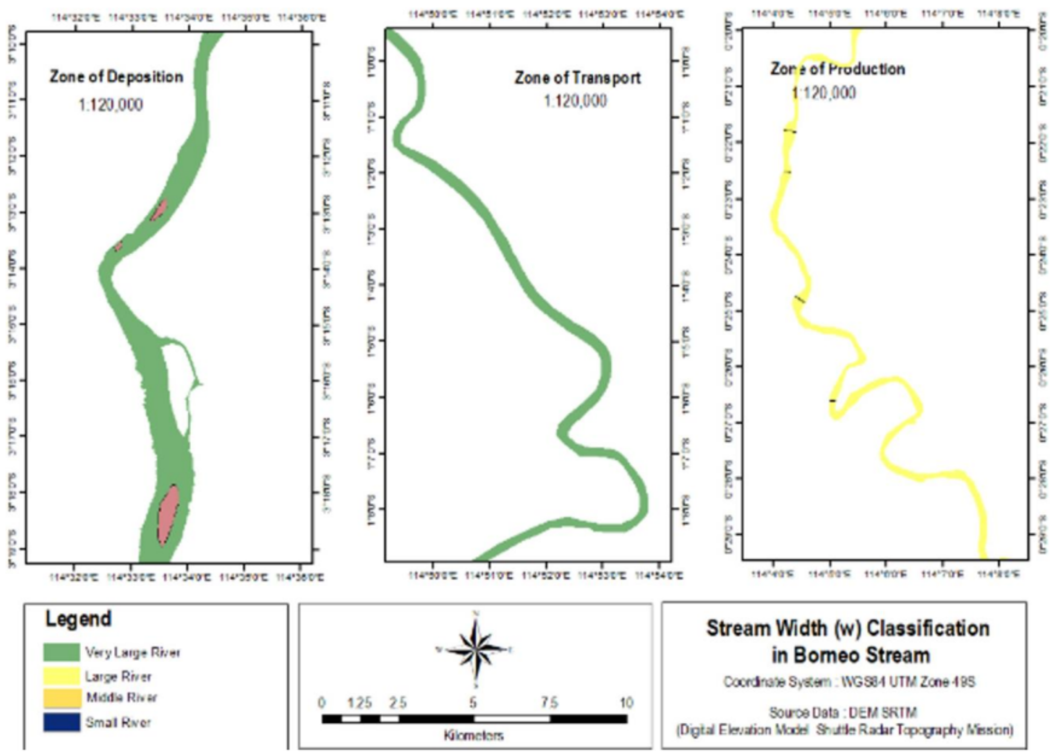

Fig. 4. Classification of stream width

Table 9. Results of stream sinuosity.

Zone of Sediment	Range of sinousity (m)	Types of Streams
Zone of deposition	1.21	Low
Zone of transport	1.46	Moderate
Zone of production	1,54	High

Table 10. Results of stream amplitude.

Zone of Sediment	Range of amplitude (m)	Types of Streams
Zone of deposition	1509	Highly Amplitude
Zone of transport	1632	High Amplitude
Zone of production	1610	High Amplitude

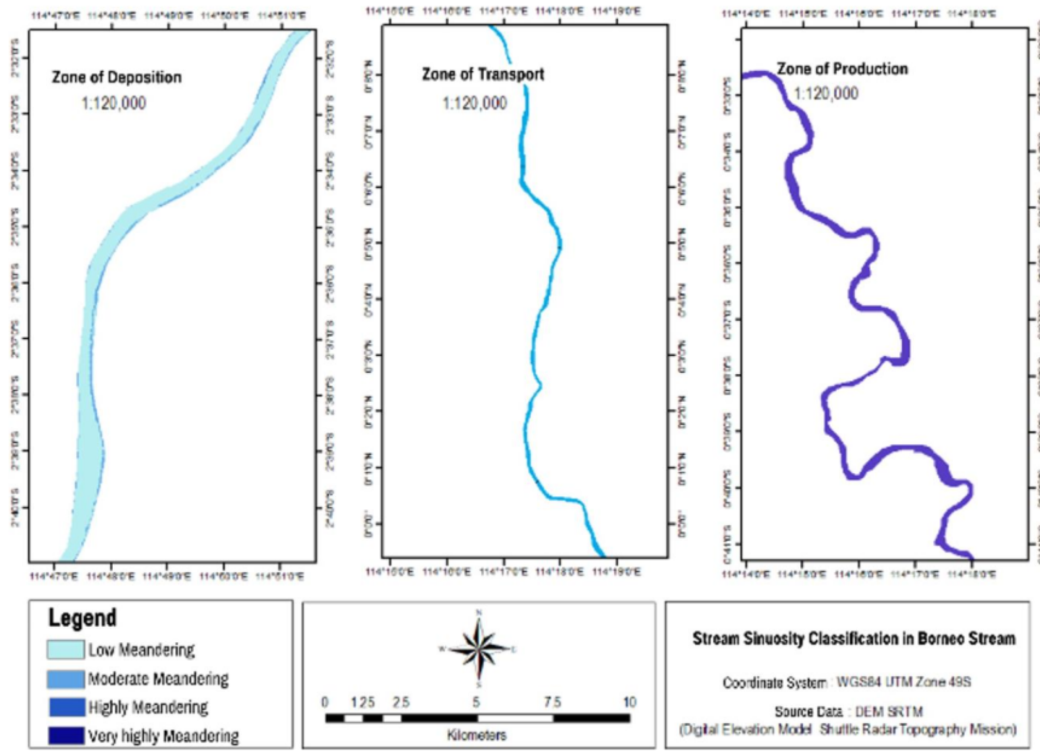

Fig. 5. Classification of stream sinuosity.

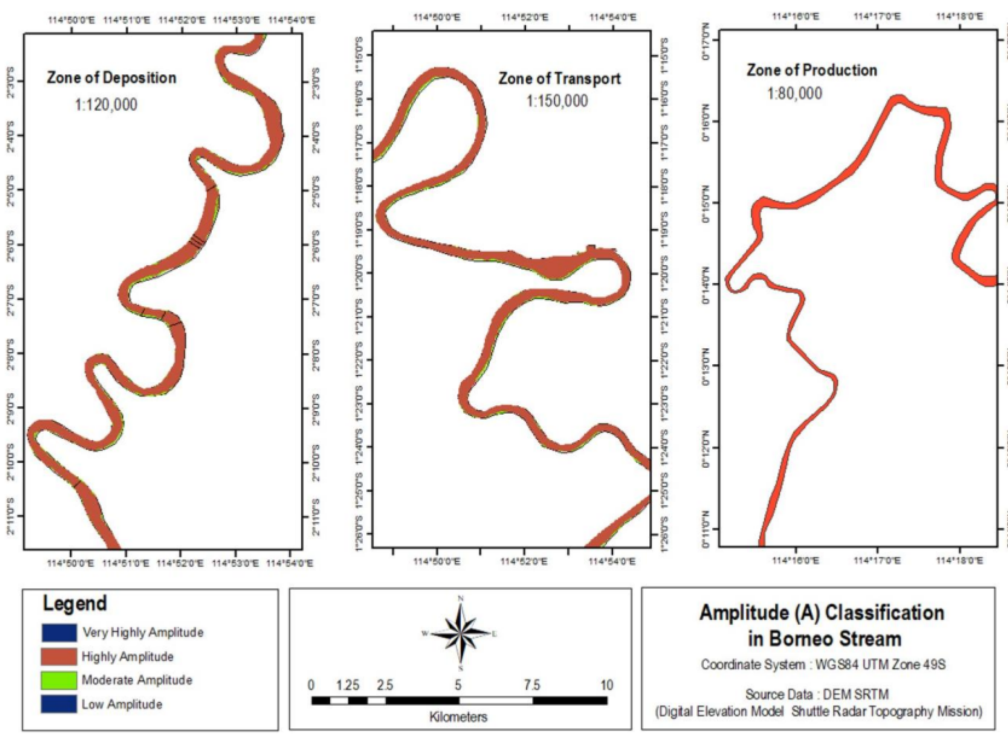

Fig. 6. Classification of stream amplitude.

Table 11. Results of stream wavelength.

Zone of Sediment	Range of wavelength (m)	Types of Streams
Zone of deposition	7144	Long
Zone of transport	4839	Moderate
Zone of production	4558	Moderate

Table 12. Results of stream bend sharpness.

Zone of Sediment	Range of bend sharpness	Types of Streams
Zone of deposition	0,30	Moderate
Zone of transport	0,23	Moderate
Zone of production	0.17	Moderate

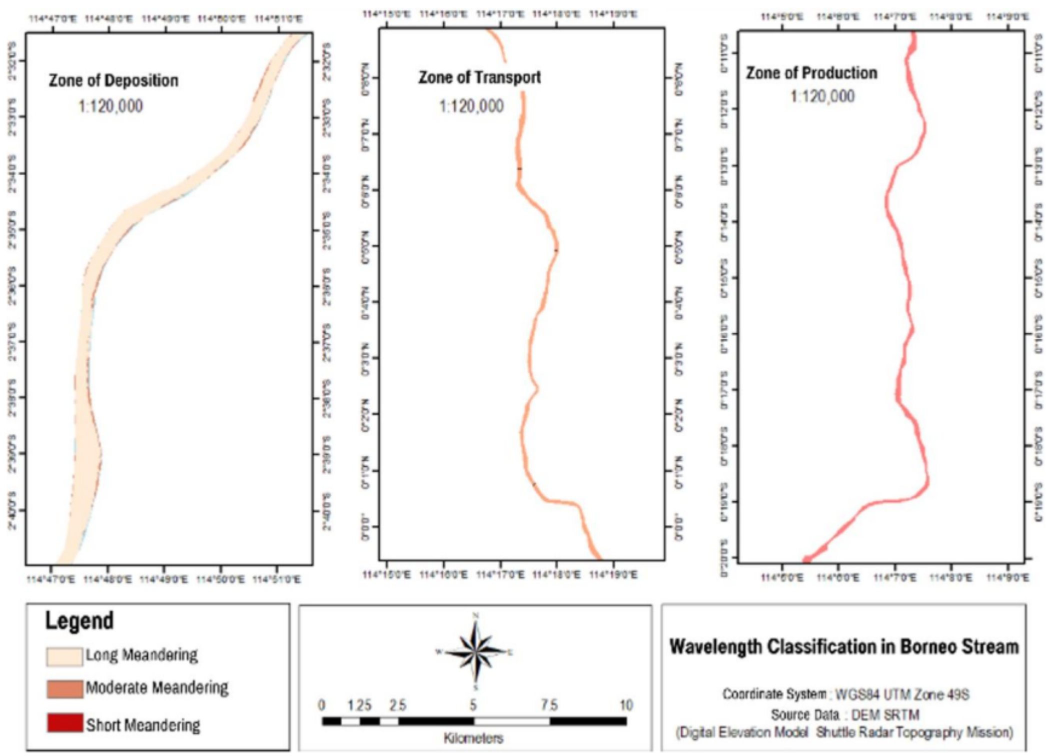

Fig. 7. Classification of stream wavelength.

Table 12. Results of stream meander pattern.

Zone of Sediment	Types of Streams
Zone of deposition	Irregular Meander
Zone of transport	Irregular Meander with oxbow
Zone of production	Distorted Meander Loop

Table 13. Results of stream slope.

Zone of Sediment	Range of slope	Types of Streams
Zone of deposition	0,0006	Shallow
Zone of transport	0,0050	Shallow
Zone of production	0,0189	Moderate

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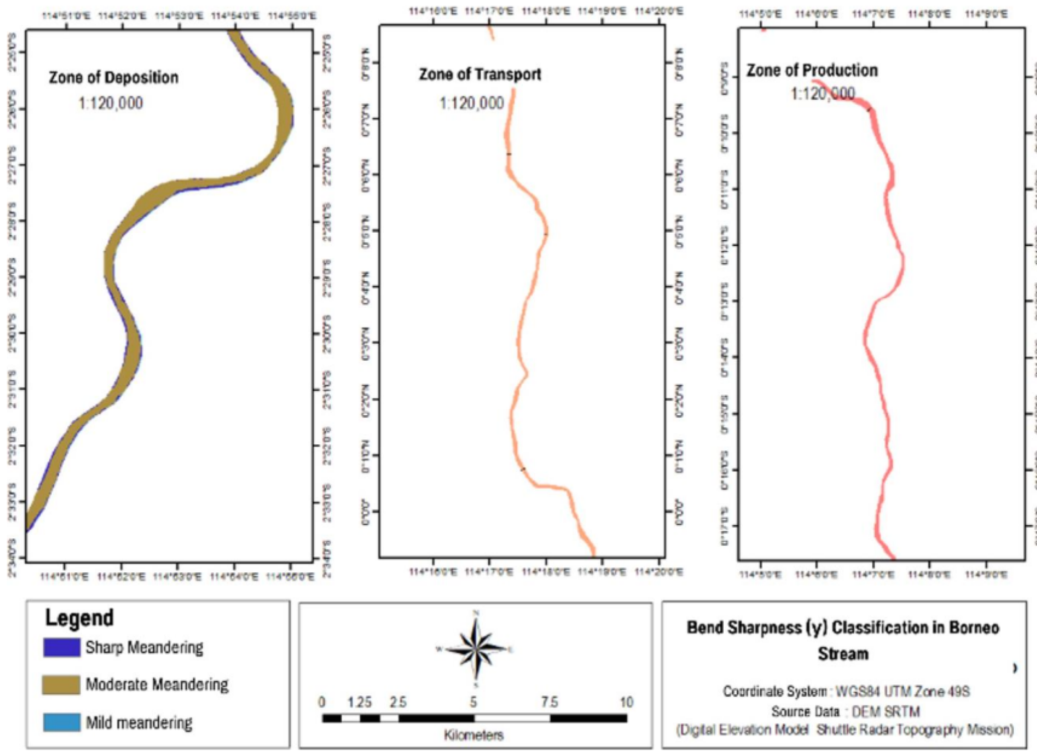

Fig. 8. Classification of stream bend sharpness.

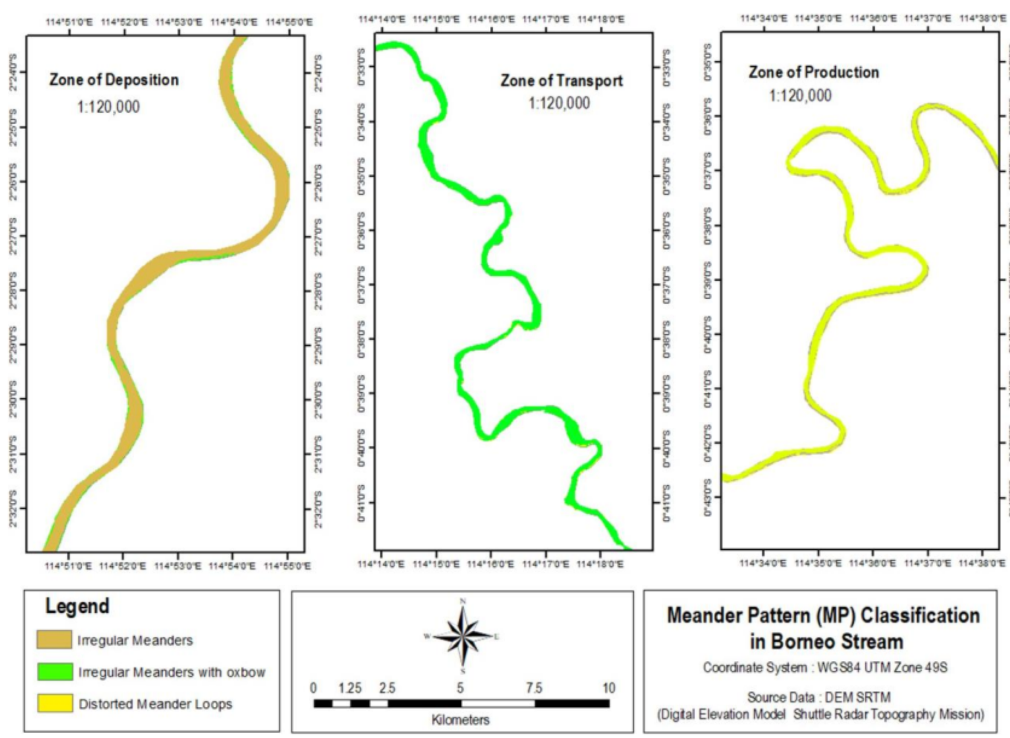

Fig. 9. Classification of stream meander pattern.

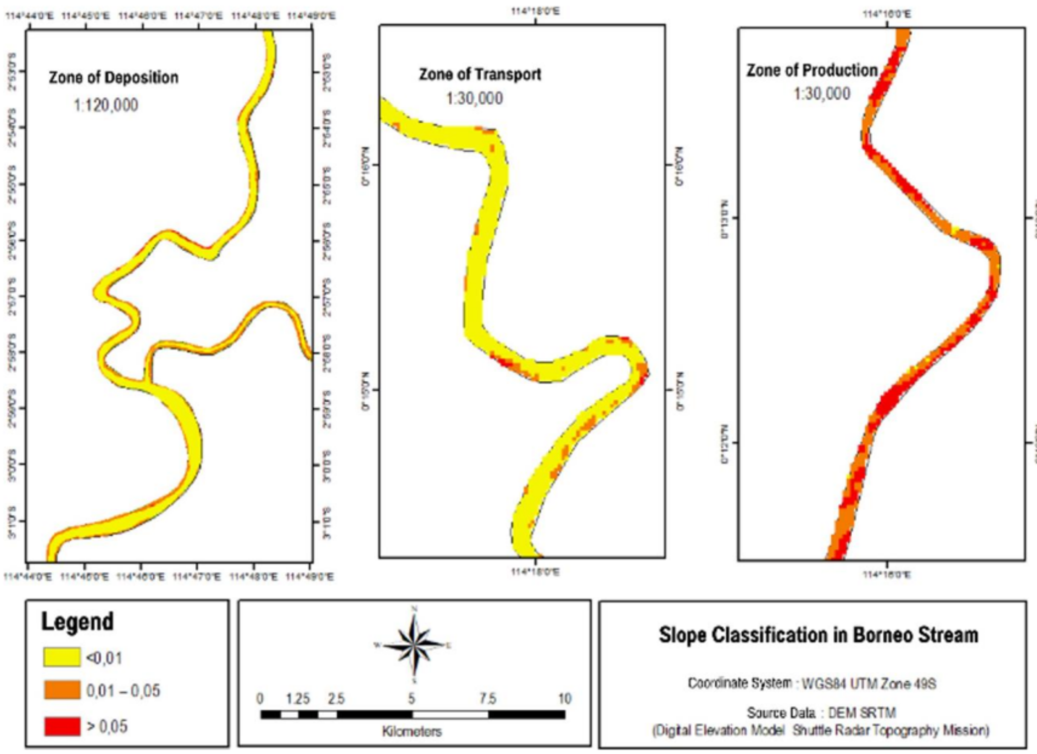

Fig. 10. Classification of stream slope.

The meandering stream classification in study area based on the stream width is categorized as very large stream. Based on its sinuosity is categorized as low meandering stream in zone of deposition, moderate meandering stream in zone of transport and highly meandering stream in zone of production. Based on its amplitude is categorized as highly meandering stream. Based on its wavelength is categorized as low meandering stream in zone of deposition, moderate meandering stream in zone of transport and in zone of production. Based on its bend sharpness is categorized as moderate meandering stream. Based on stream meander pattern is categorized as irregular meandering stream in zone of deposition, irregular meandering with oxbow in zone of transport and distorted meander loop in zone of production. Based on its slope is categorized as shallow meandering stream.

4 Conclusion

In conclusion, meandering streams are a fascinating and important feature that play a critical role in shaping the surrounding environment and supporting a diverse range of streams. Meandering streams form when a combination of factors, including water flow, sediment transport, and channel morphology, work together to create a distinct pattern of channel migration. Based on the results, the variability varied in all the geomorphology characteristics except bend sharpness and slope. The transport zone is the longest zone with classified as a very wide river with moderate sinuosity and high amplitude (< 1500). It is also categorized as a moderate wavelength and sharp bend with a relatively shallow slope. This approach is a simple, appropriate, and easy-to-use practice in examining meandering stream since there is no data or lack of supporting field data. The implementation of this meandering stream classification method is suitable for stream restoration projects, fish habitat enhancement, and water resource management. Further research is the study of possible geomorphic responses of a channel to natural and anthropogenic disturbances including channel-bed degradation, channel-bed aggradation, channel widening, and channel straightening.

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