Comparison of Geometry Characteristics and River Island Resistance: Case Study of Progo River and Solo River

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Abstract. The river island is one of the important components in river ecology development because of its function as a restraining components to river flow velocity and increasing the diversification of river flow distribution. Various occurrences of river island erosion that occur in river restoration projects are thought to be due to its high resistance to river flow. Based on these problems, this study aims to identify and compare the geometric characteristics of river islands in Progo River and Solo River related to their resistance. The research will be carried out by measuring the geometry of the islands such as length (p) and relative width (l), river width (L), and the distance of the island from the riverbank (d) using satellite imagery and then continuing with the measurement of the coefficient of resistance. The hypothesis proposed in this study is that the geometric characters of the river islands of these two rivers show similarities which will be analyzed further by considering various parameters. The future benefits obtained from this research are information regarding geometry of the island and its implications to river islands development in river restoration activities.

Keywords: Island Geometry · Island Resilience · River Restoration · Progo River · Solo River

1 Introduction

Increasing the implementation of sustainable development goals (SDGs) requires more careful and thorough consideration of ecosystems, including river ecosystems because they are directly related to SDGs point 14 (Life under Water) and indirectly with point 6 (Clean Water and Sanitation).

River islands is one of the important components in the development of river ecology because of its function as a component of anchoring the speed of river flow and increasing the diversification of river flow distribution [6]. In addition, river islands as a morphological unit of the river also include the following functions:

- River islands serve as temporary storage sites for sedimentary flows and provide a way to dissipate flow energy [4].

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- The formation and development of river islands is particularly relevant to flood control, waterway navigation, and river ecosystems [11, 17]
- River islands and sandbars play a role in the stability of river flows [3].
- Islands in the lower reaches of rivers and sand dunes are important for the process of material and energy exchange, regulating flooding, and reducing pollutants before rivers flow into the sea [5].

The loss or destruction of the existence of river islands will also disrupt the ecological functioning of the river island and create new problems. Therefore, various artificial river islands have been carried out for restoration, but many have undergone erosion allegedly due to high resistance to river flows. The formation and development of sandbars and river islands in alluvial rivers is strongly influenced by variations in hydraulic geometric elements, including channel width and curvature at riverbed boundary conditions, and are closely related to bank erosion [8, 9, 12, 15, 16].

In the technical guidelines for river restoration by the Ministry of Environment and Forestry, it is stated that the restoration of river islands and sandbars is classified as a necessary morphological restoration. However, studies on the geometry of river islands are still very limited, especially in the context of rivers in Indonesia. Based on these problems, this study aims to identify and compare the geometric characteristics of river islands in the Progo River and Solo River related to resistance. The benefits obtained from this study are information regarding the geometry of the island and its implications for the development of river islands in river restoration activities.

2 Study Location

This study collected river islands located in the Progo river and the Solo river. There are 56 river islands identified from Progo river and 40 islands from the Solo river. The consideration for choosing a site to be studied is both rivers has increasing human activities around them over time that potentially affecting the river islands and sandbars existence.

3 Literature Review

Komar, 1983 [10] and Tooth & Nanson, 2000 [13] show similar research results, namely in general streamlined islands and island length-width ratios are usually stable in the range of 3 – 4 to achieve island stability and minimal resistance conditions.

In 1999 Harm conducted an analysis of changes in the Elba River from l90l to 1999 [6]. One of the results obtained was the geometry of the island in the form of an ellipse stream line.

Maryono, 2008 [1] conducted research on island geometry, especially those that focused more on quantitative characteristics of island geometry. Meanwhile, the results showed that the stability of the island is directly related to the hydrological conditions of a river, the stability of the river bank, and human activities [9, 12].

4 Methods

The research will be carried out by measuring the geometry of the islands such as the length (p) and relative width (l), the width of the river (L), and the distance of the island from the river bank (d) using satellite imagery then continued with analysis and discussion. The research steps are described as follows (Fig. 1):

1. Identify river islands using satellite imagery from Google Earth. The satellite imagery used is satellite imagery in 2022.
2. Measuring the length and width of the island (p and l), the distance from the center of the island to the river bank (d), and the width of the river (L)
3. Continuing the data and calculating the geometric characteristics of the island such as p/l, L/l, L/d, and L/p
4. Analyzing the data
5. Discussing the results and comparing them with relevant previous research
6. Draw conclusions

Description:
p = island length.
l = island width.
d* = distance from the midpoint of the island to the edge of the river.
L** = river width.
*) the distance that will be use is the closest distance from the island to the riverbank. Hence it will be different for each island.

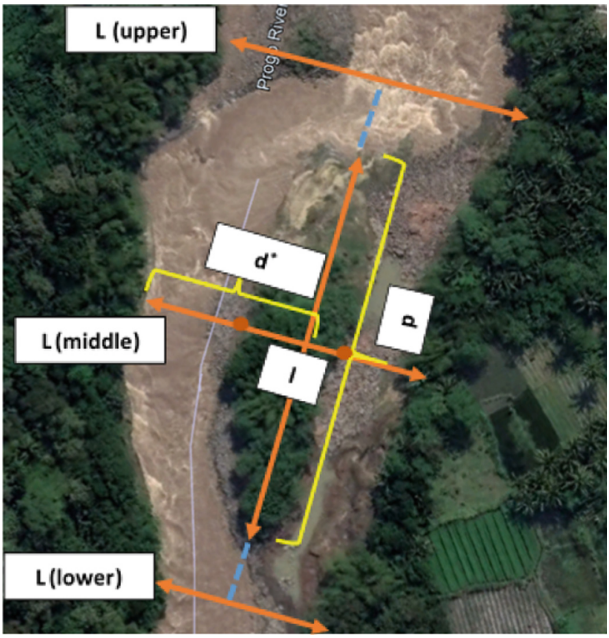


Fig. 1. The geometric character of the river island (Google Earth, 2022)

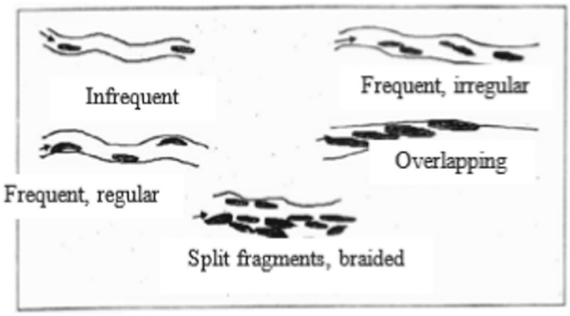


Fig. 2. Island configuration along the river (Kellerhals et al. 1976)

Table 1. Island Formation Comparison

Formation	Progo river	Solo river
Infrequent	4	14
Frequent, regular	-	-
Frequent, irregular	36	3
Overlapping	6	16
Braided fragments	10	7

**) the average L of the upper, middle, and lower parts of each island is used as the final value of each island.

5 Result and Discussion

This research is limited to river islands that are still protected from human activities such as sand mining, agriculture, and other human activities. Any island that has been touched by human activities is not included. Sandbars is not included because it is considered still not fully developed into a stable river island.

5.1 Island Formation

Through the tracing process through satellite images, the results were obtained that the Progo river has 56 islands and the Solo river has 40 islands, most of which have frequent and irregular formations (Fig. 2).

Based on the type of island configuration as shown in previous figure, the river islands in Progo and Solo river are classified as following Table 1.

5.2 Geometric Characteristics Related with River Island Resistance

Island Length to Island Width Ratio (p/l). A comparison of the length of the island and the width of the island indicates how an island is shaped. If the p/l ratio is close to

the value of 1, then the island has a shape that tends to be rounded and not elongated because the p value and l values are almost the same. While the greater the p/l value indicates the shape of the island the more elongated it is. If the p/l value is more than 5, it will tend to be unstable and more prone to splitting. If the value is less than 3, the sides may be eroded or there is sediment behind the island. Some previous studies suggested that p/l values that have a relatively small resistance is $3 < p/l < 5$ [1, 10, 13].

River Width to Island Width Ratio (L/l). The ratio of river width (L) to river island width (l) has been previously studied since the ratio could be used to indicate a certain width of a river island that exists in a certain width of river channel. High value of L/l indicates the width of river channel is way too large than the width of the river islands. Meanwhile low value of L/l indicates a wide shaped river island in a relatively narrower river channel. Both too high and too low of L/l value could possibly increase lateral accretion of river islands. The previous study and laboratory experiment with island model [1] showed that L/l value with the minimum resistance to river flow falls between 2.5 and 6.

River Width to Distance of Island to River Edge Ratio (L/d). The river width is divided by the distance of river island to the closest side of riverbank is considered highly relevant since it indicates if a river island tends to be in the middle of river channel or tend to be closer to the edge. Previous study suggest that L/d values that are in the range of 2 – 4 [1] indicates the location of the island in the middle of the river channel, while values less than 2 and more than 4 indicate the location of the island that tends towards the edge of the river.

River Width to Island Length Ratio (L/p). The comparison between the length of the sandbar and the width of the river has similarities with the previously described L/l values. The value indicates the proportion of the size of the sandbar to the width of the river channel. The range of L/p values indicating minimal resistance is $0.67 < L/p < 1.2$ [1]. An L/p value of less than 0.67 indicates a sandbar that is too elongated in a relatively narrow river.

From several previous studies, we summarize some information related to its resistance and stability as follows:

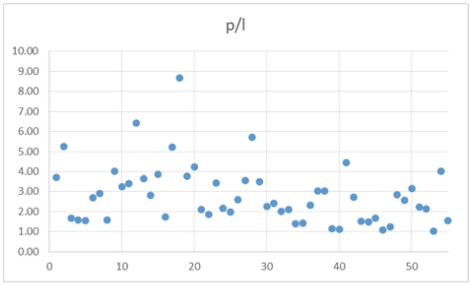
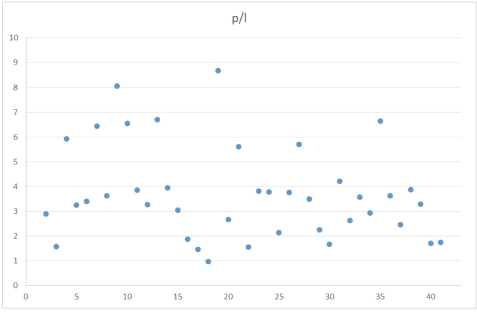
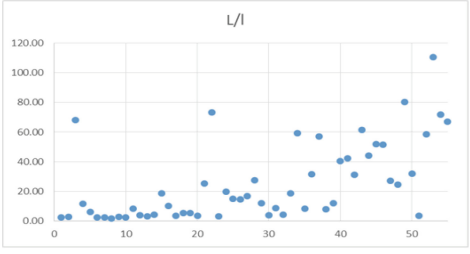
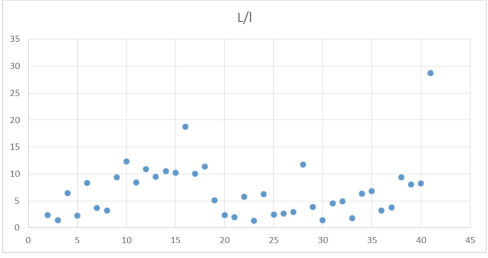
- $3 < p/l < 5$.
- $2.5 < L/l < 6$.
- $2 < L/d < 4$.

From the explanation above, the results of measuring the geometry of river islands in the two rivers are summarized and presented in the following Table 2.

Based on previous studies, it is stated that human activities are one of the things that affect the stability of river islands [9, 12].

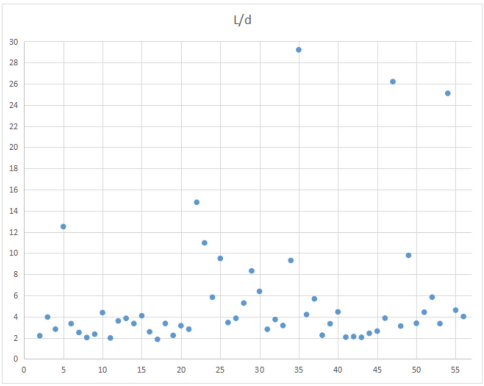
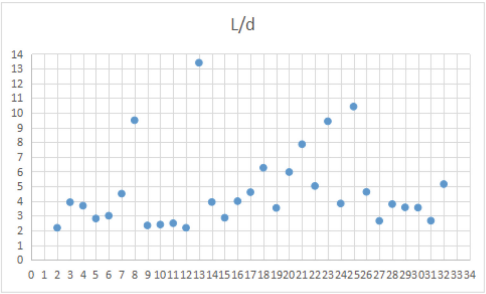
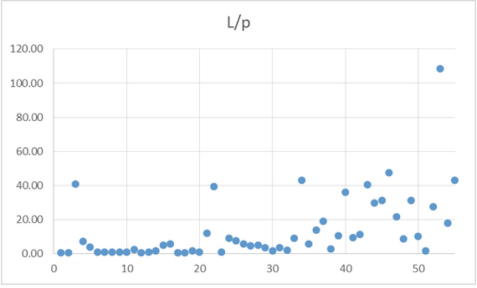
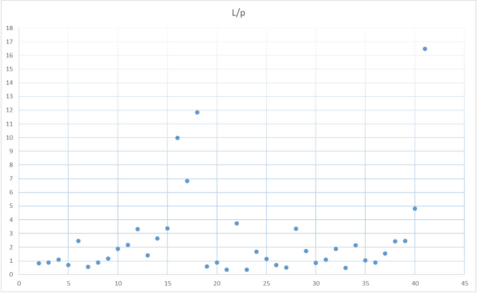
When compared to the number of islands in the initial search and after the release of islands that have been inhabited by human activities, the difference is quite significant in the two rivers.

Table 2. Comparison of Geometric Characteristics of River Islands in Progo River and Solo River

	CHART	DESCRIPTION
p/l		
Progo		The range of p / l values obtained is 1.02 – 8.67. There are 16 of the 56 islands that are in the value range 3 - 5 which shows streamline shaped island. This streamline shaped river island has been suggested in several previous studies of the shape with most stability and least resistance to flow.
Solo		The range of p / l values obtained is 0.96 – 8.67. There are 17 out of 40 islands that meet the range of these values
L/l		
Progo		The range of L / l values found is 1.40 – 110.65 The range where the resistance of the island will be minimal: 2.5 < L/l < 6 There are 13 of the 56 islands that meet the p / l value
Solo		The range of L / l values found is 1.35 – 28.73 The range where the island resistance will be minimal: 2.5 < L / l < 6 Out of the 40 river islands, 11 of them meet the range of ideal L / l values
L/d		

(*continued*)

Table 2. (*continued*)

	CHART	DESCRIPTION
Progo		The range of L/d values found is 1.33 – 2.58 The range where the island resistance will be minimal: 2 < L/d < 4 There are 39 islands out of 56 river islands meeting these conditions There are 3 outliers.
Solo		The range of L/d values found is 1.33 – 4.04 The range where the resistance of the island will be minimal: 2 < L/d < 4 10 river islands have L/d value above 4, indicating the islands location tend to be nearer to the riverbank. Some of them are even attached to the floodplain.
L/p		
Progo		The range of L/p values found is 0.50 – 108.44 The range where the island resistance will be minimal : 0.67 – 1.2
Solo		The range of L/p values found is 0.36 – 16.48 The range where the resistance of the island will be minimal : 0.67 – 1.2

6 Conclusion

The comparison of the geometric characteristics separately based on the ratios (p/l, L/l, L/d, and L/p) of the river islands from both river shows little similarities. The results can be concluded as these following points:

a) Both river has similar number of river islands with p/l value in range of 3 – 5 which indicating streamline shaped and more stable form.
b) For L/l value, Progo river and Solo river respectively has 13 and 11 islands with L/l value in range of 2.5 – 6. However in Progo river, those island with high L/l tends to be in downstream while in Solo river, they are distributed from upstream to downstream.
c) Both river has several river islands with high L/d value indicating the islands tend to be in nearer to riverbank.

Further study about river islands development over time is needed. Historical data and discussion is needed to analyze the dynamics of river islands changes and development and how it correlate with human activities.

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