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Geometric Characteristics of Sandbars Case Study of Progo River

Agus Maryono[1](✉), Alifia Darmayanti[2], Azmina Syahida Basyarudin[2], and Pratama Tirza Surya Sembada[1]

[1] Vocational Civil Engineering Department, Gadjah Mada University, Yogyakarta, Indonesia
agusmaryono@ugm.ac.id

[2] Master of Technology for the Sustainable Development of Postgraduate Schools, Gadjah Mada University, Yogyakarta, Indonesia

Abstract. Sandbar is one of river structures that functions to decrease river flow velocity and increase diversification of flow distribution leading to river channel stability. Sandbars have roles in sediment transport mechanism, reducing pollutants due to denitrification mechanism, and as a host for aquatic organism. However, the researches on sandbars' geometry, resistance to flow, sediment transport, and the correlation with aquatic ecosystem are relatively lacking. Based on these problems, this study aims to identify geometric characteristics of sandbars in Progo River as preliminary understanding of sandbar. The research will be conducted by measuring geometry of sandbars using satellite imagery such as sandbar length (p), sandbar width (l), river width (L), and distance of sandbar from riverbank (d), then proceed with calculating the ratio of p/l, L/l, L/d, and L/p. The importance of each ratio and the comparation to island geometry is presented in the results and discussion. The results show that the characteristic of geometry of the 47 sandbars found in Progo River are p/l = 1.39–5.51, L/l = 1.48–11.72, L/d = 1.61–7.00, and L/p = 0.65–5.45. The benefits of this research are to provide reference regarding the characteristic geometry of sandbar and its implications in river development and conservation.

Keywords: Sandbar · Sandbar Geometry · Sandbar Resistance · River Ecosystem

1 Introduction

Improving the implementation of the Sustainable Development Goals (SDGs) requires more careful and comprehensive consideration of ecosystems, including river ecosystems. This is reflected in SDGS points such as Life under Water (point 14) and clean water and sanitation (point 6) indicating that water resource conservation is an important thing that needs to be managed sustainably.

Sandbar in river ecology plays a role in decreasing river flow velocity and the diversification of flow distribution. When the ecological conditions of sandbars are disturbed, there will be changes in the river morphology, the sediment transportation, the scouring-silting patterns, and affecting the biological activity [12]. If this happens over a long

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time, then the effect will accumulate and there will be changes in the evolutionary characteristics of river landforms [17]. The sandbars play a role in the temporary storage of sediment transport [4], flood control and waterway navigation [18], river channel stability [3], and material and energy exchange [5, 6].

Changes in the area of sandbar can indirectly reflect the phenomenon of sedimentation and erosion, since sand dunes are more sensitive to lateral accretion and erosion than vertical accretion. Therefore, because the area is a more accurate indicator in describing the change in the scale of sandbar and can be used as a proxy for the volume of sandbar [6–9, 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. Nevertheless, the study of the geometry of sandbars is still very limited. Hence, the benefits of this research are to provide reference regarding the geometric characteristic of sandbar and its implications in river development and conservation.

2 Location

The study investigated sandbars in the Progo river in Yogyakarta. There were 47 sandbars identified from the Progo river. There were quite frequent activities of sand mining that impacted the sandbars. Hence this study is conducted as information source for future need of preservation and restoration or restoration of sandbars.

3 Literature Review

Gu et al. 2020 showed that there was a study of a significant decrease in sandbars in the Mekong delta, suspected to be climate change and human activities. The impact of human activities in particular, has led to the evolution of fluvial landforms downstream.

Hoque et al., 2021 conducted a study on erosion, silting, coastal evolution, morphology, and physical processes for 40 years to see geomorphology or due to human activities. The findings showed that there was a decrease in sediment that resulted in erosion and decreased sandbars area. Waterway engineering due to adjustments to human activities has changed the boundaries of sandbars in form of sand dunes and the evolution of coastal ecological interactions.

4 Methods

This study began with measurements of sandbars geometry using satellite imagery of sandbar geometry such ad sandbar length (p), sandbar width (l), river width (L), sandbar distance to riverbank (d). The steps of study are as follows:

1) Identification of sandbars by using Google Earth satellite imagery. The imagery is dated on June 2022 hence it is a recent view of the sandbars condition.

2) Measuring the length (p) and width (l) of sandbars, distance from the center of the sandbars to the river bank (d), and width of the river (L). As pictured in Fig. 1, width of river (L) will be measured from three different points (upper, mid, lower) and later being averaged. As for the distance from the sandbar to riverbank (d), it is measured from both left and right side. The d value that will be used is the closest distance to the riverbank.
3) Calculation of the geometric characteristics of the sandbar (p/l, L/l, L/d, and L/p).
4) Data analysis: in this step the data will be resumed, sorted, and plotted on graphs.
5) Discussion and comparison with previous studies, and,
6) Conclusion drawing

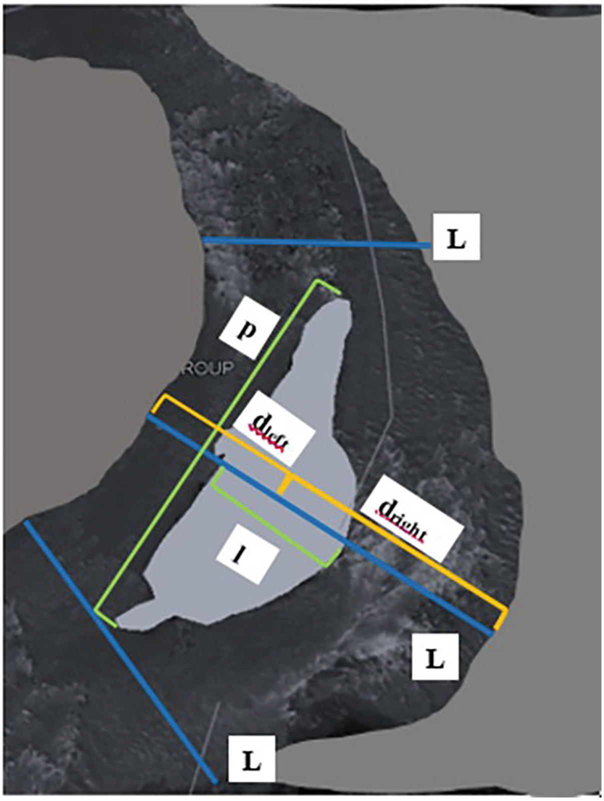


Fig. 1. Geometric characteristics of sandbar.

Information:
p = sandbar length (m)
l = sandbar width (m)
d* = distance from the center point of sandbar to the riverbank (m)
L** = river width (m)

**) the value of d is measured both to the left and right side of sandbar. Final value will be averaged from them.*

***) value of L is an averaged value from L of upper, middle, and lower part of the sandbar*

5 Result and Discussion

This research is limited to sandbars that are still intact from human activities. Any sandbars indicated to have been exploited by human activities are not included in the final data to be analyzed.

5.1 Sandbar Geometry and its Relation to Resistance

The geometric characteristics of sandbars from the results will be compared to the geometric characteristics of river islands from previous studies [1] according to following considerations:

- There is no study about sandbars related to its geometric characteristics.
- Still in accordance with previous point, hence the references about river island's geometric characteristics are used since they are the closest proximity to sandbar. The sandbars will be gradually stabilized due to vegetation and develop into river islands [5, 15].

5.2 Sandbar Length: Sandbar Width Ratio (p/l)

The comparison of the length with the width of the sandbar shows how the sandbar looks. If the value of p/l ratio close to 1, the value of p and the value of l are almost the same, so the sandbars have a rounded rather than rectangular shape. The greater the p/l value, the longer the shape of the sandbar. p/l values greater than 5 are unstable and prone to rupture. The values p/l less than 3 can result in side erosion or sedimentation behind the sandbars. The previous studies on river islands showed that ideal p/l range with relatively low resistance is $3 < p/l < 5$ [1, 14, 19]. The ideal geometric value of sandbars studied here is still the same as the ideal value of river islands. It becauses river island is originally build from sandbar.

5.3 River Width: Sandbar Width Ratio (L/l)

The ideal value as the ideal resistance for sandbar is $2.5 < L/l < 6$. If the value is less than 2.5 or more than 6, it shows a large resistance value hence the sandbar will be more easily subjected to erosion. The ideal range of values needs to be achieved in order for the sandbars to remain.

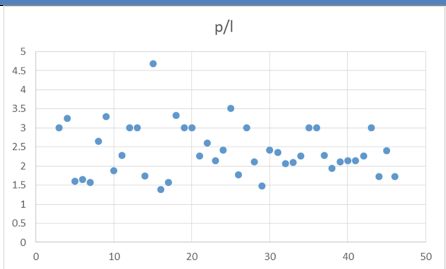
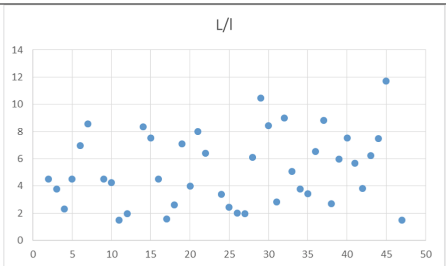
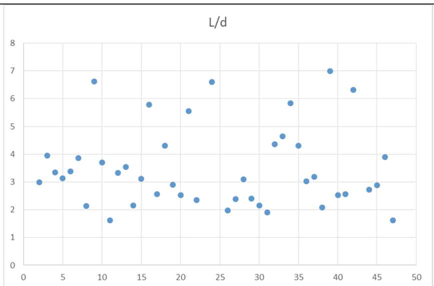
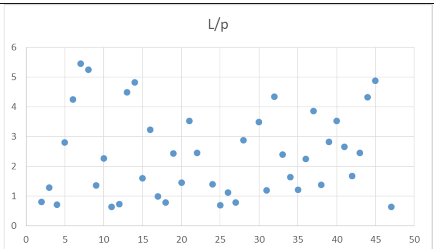
5.4 River Width: Distance from Sandbar to Riverbank Ratio (L/d)

The distance of the sandbar to the river bank illustrates the comparison of the midpoint of the sandbars to the riverbank so that it can be identified whether the sandbar is in the middle of the river channel. The sandbars' result will be compared to the ideal value of L/d for river islands according to Maryono 2008 is in the range of 2–4.

5.5 River Width: Sandbar Length Ratio (L/p)

The comparison between the width of the river and the length of the sandbar (L/p) has similarities with the previously described L/d 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

Table 1. Summary of geometric characteristics of 47 sandbars on the progo river (p/l, l/l, l/d, l/p)

Geometric Characteristics	Results	Desciption
p/l		Range : 1.39 – 5.53 Mean : 2.36 Mode : 1.73 There are 14 out of 47 sandbars that meet the range of value on the previous studies.
L/l		Range : 1.48 – 11.72 Mean : 5.11 Mode : 4.50 There are 21 out of 47 that meet the L/l value range on the previous studies.
L/d		Range : 1.61 – 7.00 Mean : 3.50 Mode : 1.61 There are 31 out 47 sandbars that meet the L/d value range on the previous studies
L/p		Range : 0.65 – 5.45 Mean : 2.40 Mode : 0.65 There are 13 out of 47 sandbars in the range of L/p value of 0.67 – 1.2

indicating minimal resistance is $0.67 < L/p < 1.2$. An L/p value of less than 0.67 indicates a sandbar that is too elongated in a relatively narrow river. While an L/p value of more than 1.2 indicates a relatively short sandbars in a much wide river channel. Both conditions will lead to high resistance to flow.

From the various referred literature of river island, it can be summarized that the minimum sandbar resistance is characterized (similar to island characteristic) in these following conditions:

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

The results of the measurement of the geometry of sandbars are summarized and presented in Table 1.

5.6 Impact of Human Activities on Sandbars

Based on previous studies, it is stated that human activities are one of the things that affect the stability of sandbars and river islands [10, 11, 13, 19].

There are quite a lot of sandbars that have been inventoried but are not included in the calculation because they have been touched by human activities, one of which is as shown in Fig. 2. On the Progo River, human activities in the sandbar and river island are mainly sand mining.

Fig. 2. Indications of sand dredging and mining activities

6 Conclusion

From the results of the study and discussion, it can be concluded that this study of sandbar geometry shows similarities with previous studies of river island geometry where the islands tend to develop into streamline shape where $3 < p/l < 5$ [1, 2]. This is also aligned with study conducted by Nachtigal in 1999 about animal and birds' streamline shape for minimal resistance. As discussed previously, the river islands references are also used in discussion due to no study related to sandbars' geometry so far. Hence the closest proximity is river islands.

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

References

1. A. Maryono, Karakteristik dan Resistensi Pulau di Sungai, Media Teknik, UGM, No. 4, 2008, pp. 479–487. ISSN: 0216-3012.
2. A. Maryono, Karakteristik Resistensi Kelompok Pulau di Sungai, Jurnal Teknik Sipil, ITB, Vol. 17, No. 3, 2010, pp. 191–203. ISSN: 0853-2982.
3. B.G. Ruessink, I. M. J. Van Enckevort, K. S. Kingston, M. A. Davidson, Analysis of observed two- and three-dimensional nearshore bar behaviour, Mar. Geol., Vol. 169, 2000, pp. 161–183.
4. B. Wyzga, J. Zawiejska, H. Hajdukiewicz, Multi-thread Rivers in the Polish Carpathians: Occurrence, decline and possibilities of restoration, Quaternary International, 2016, p. 415.
5. Garde, R.J., 2006. River Morphology. New Age International Heidelberg, 2007, pp. 220–270. https://doi.org/10.1007/978-3-540-72522-0_6
6. G. Champalbert, M. Pagano, R. Arfi, C. Chevalier, Effects of the sandbar breaching on hydrobiological parameters and zooplankton communities in the Senegal River Estuary (West Africa), Marine pollution bulletin, Vol. 82, No. 1–2, 2014, pp. 86–100. https://doi.org/10.1016/j.marpolbul.2014.03.015
7. Gu, Z., Fan, H., & Wang, Y. (2020). Dynamic characteristicsof sandbar evolution in the lower Lancang-Mekong River between 1993 and 2012 in the context of hydropower development. Estuarine, Coastal and Shelf Science, 237, 106678.
8. H. Junbao, S. Zhilin, X. Dongfeng, Morphological evolution of a large sand bar in the Qiantang River Estuary of China since the 1960s, Acta Oceanologica Sinica, Vol. 41, No. 2, 2022, pp. 156–165. https://doi.org/10.1007/s13131-021-1817-z
9. Hoque, M. E., Chowdhury, S. R., Chowdhury, M. Z. R., & Uddin, M. M. (2021). Morphological changes of a developing sandbar along the shoreline of Sonadia Island, Bangladesh between 1972 and 2006 using remote sensing. Geology, Ecology, and Landscapes, 1–9.
10. J.X. Xu, Wandering braided river channel pattern developed under quasi-equilibrium: An example from the Hanjiang River, China, Journal of hydrology, Vol. 181, No. 1, 1996. https://doi.org/10.1016/0022-1694(95)02910-9
11. J.X. Xu, Evolution of mid-channel bars in a braided River and complex response to reservoir construction: An example from the middle Hanjiang river, China, Earth Surface Processes and Landforms, Vol. 22, No. 10, 1998. https://doi.org/10.1002/(SICI)1096-9837(199710)22:10%3C953::AID-ESP789%3E3.0.CO;2-S
12. M. Habel, Effects of flow regulation and river channelization on sandbar bird nesting availability at the Lower Vistula River, Ecological Questions, Vol. 29, No. 4, 2018. https://doi.org/10.12775/EQ.2018.028

13. M. Klosch, B. Blamauer, H. Habersack, Intra-event scale bar-bank interactions and their role in channel widening. Earth Surface Processes and Landforms, Vol. 40, No. 11, 2015. https://doi.org/10.1002/esp.3732
14. Nanson, G.C., Tooth, S. and Knighton, A.D., 2002. 2 A Global Perspective on Dryland Rivers: Perceptions, Misconceptions. Dryland rivers: hydrology and geomorphology of semi-arid channels, p. 17.
15. R. Kellerhals, M. Church, D.I. Bray, Classification and analysis of river processes, Journal of the Hydraulics Division, Vol. 102, No. 7, 1976, pp. 813–829.
16. R. Luchi, G. Zolezzi, M. Tubino, Modelling mid-channel bars in meandering channels, Earth Surface Processes and Landforms, Vol. 35, No. 8, 2010. https://doi.org/10.1002/esp.1947
17. U. Goswami, J.N. Sarma, A.D. Patgiri, River channel changes of the Subansiri in Assam, India, Geomorphology, Vol. 30, No. 3, 1999. https://doi.org/10.1016/S0169-555X(99)00032-X
18. X.M. Yi, Y.Y. Huang, M.H. Ma, Z.F. Wen, J.L. Chen, C.D. Chen, S.J. Wu, Plant trait-based analysis reveals greater focus needed for mid-channel bar downstream from the Three Gorges Dam of the Yangtze River, Ecological Indicators, Vol. 111, 2020.
19. X. Yang, Z. Sun, J. Deng, D. Li, Y. Li, Relationship between the equilibrium morphology of river islands and flow-sediment dynamics based on the theory of minimum energy dissipation, International Journal of Sediment Research, Vol. 37, No. 4, 2022, pp. 514–52