Analysis of the Seasonal Change on the Sediment Transport in the Primary Channel of Saddang Irrigation Area

Gatok Hasan Syamsuddin
Civil Engineering Department, Faculty of Engineering, Hasanuddin University, Indonesia
gatokhasansyamsuddin@gmail.com (corresponding author)

M. Saleh Pallu
Civil Engineering Department, Faculty of Engineering, Hasanuddin University, Indonesia
salehpallu@gmail.com

F. Maricar
Civil Engineering Department, Faculty of Engineering, Hasanuddin University, Indonesia
fkmaricar@yahoo.com

B. Bakri
Civil Engineering Department, Faculty of Engineering, Hasanuddin University, Indonesia
bambangbakri@gmail.com

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ABSTRACT

Irrigation channels are a vital component of an agricultural system, functioning to distribute water to agricultural land and support food security. The Saddang irrigation area, one of the main irrigation regions in Indonesia, plays a crucial role in enhancing agricultural productivity. However, the sediment accumulation in irrigation channels can significantly impact water distribution efficiency and environmental quality. The current research aims to analyze the influence of flow parameters during the rainy and dry seasons, examine the relationship between seasonal changes and sediment transport, and assess the impact of sediment discharge in the primary channel of the Saddang irrigation area. The tests conducted included sieve analysis, specific gravity, sediment concentration, and hydrometer analysis. Based on the research results, the average sediment discharge during the rainy season in the primary channel of the Saddang irrigation area is 2,702 tons/day, while during the dry season, the average sediment discharge is 100 tons/day. The ratio of the average sediment discharge between the rainy and dry seasons is 27:1. Additionally, linear equations were obtained to predict sediment discharge in the primary channel of the Saddang irrigation area. For the rainy season, the linear equation used is y = 857.67x - 1618.3, while for the dry season, it is y = 38.811x - 79.937. These equations have a validation rate of 98% between the linear equation and the actual calculation results, indicating high accuracy in modeling sediment discharge in the channel.

Keywords-seasonal changes; sediment discharge; Saddang irrigation area

I. INTRODUCTION

The Saddang River is one of the main rivers in South Sulawesi, with a length of approximately 181.5 km, flowing through the districts of North Toraja, Toraja, Enrekang, and Pinrang in South Sulawesi Province. The Saddang River flows right through the center of the Enrekang city and flows toward the Makassar Strait. One of the problems in this area is the change in land use in the upstream section of the river, which contributes to increased land erosion, resulting in a greater amount of sediment being carried in the channel [1]. Therefore, a study on the sedimentation rate is necessary. This study focuses on the suspended load parameters at the upstream, middle, and downstream sections of the river and channel.

In the Saddang River, fluctuations in suspended sediment can be observed over the past few years, where sediment transport activity in the middle section is higher than in the upstream and downstream sections. This may be caused by the erosion in the upstream area, which causes degradation and transports a large amount of sediment to the middle of the river. In the middle section, sediment deposition occurs, leading to aggradation. Over the years, it can be seen that the sediment transport activity decreases when reaching the downstream area. Using the empirical formula of Meyer-Peter Müller, the analysis from recent years indicates that the suspended sediment transport processes vary: the suspended sediment discharge (Qs) in the upstream section is 104.204 kg/day or 0.104 tons/day, in the middle section it is 1347.473 kg/day or 1.347 tons/day, and in the downstream section it is 2128.906 kg/day or 2.128 tons/day [2, 3].

The Saddang irrigation area is one of the irrigation regions under the central authority located in South Sulawesi, covering an area of 60,300 hectares. Based on data from 13 technical implementation units, the total area of the Saddang irrigation area is recorded at 59,128 hectares, while satellite imagery updates from 2019 indicate an area of 61,226 hectares, encompassing three regions: (i) Pinrang Regency, (ii) Sidenreng Rappang Regency, and (iii) Wajo Regency.

The main crop cultivated in this area is rice. Currently, the Saddang irrigation area does not receive water uniformly, partly due to a decline in network capacity. This reduction in capacity may be attributed to sedimentation at the bottom of the channels and damaged lining conditions, which result in leakage as well as malfunctioning structures and gates [4-7].

The research related to the sediment transport in the Primary Channel of the Saddang irrigation area still has several significant gaps, especially in understanding the influence of seasonal changes on sedimentation patterns. Previous studies tend to ignore seasonal variations, specific quantitative data, and direct relationships between sedimentation and irrigation efficiency and agricultural productivity. Additionally, existing studies rarely consider damage to channel infrastructure and local characteristics, such as rainfall and regional geomorphology, that can significantly influence sediment transport. Therefore, more comprehensive research based on direct research data in the field is needed to answer these gaps and provide more relevant solutions for irrigation management, especially regarding sediment problems in irrigation canals in the Saddang area.

II. RESEARCH SIGNIFICANCE

This research has great significance in the management of the Saddang irrigation area irrigation system, with a focus on the influence of seasonal changes on sediment transport in primary channels. Seasonal changes, especially between the rainy and dry seasons, have a significant effect on water discharge and erosion processes that carry sediment to the irrigation canals. A deeper understanding of these sediment transport patterns can help in designing more efficient irrigation management, reducing maintenance costs such as dredging, and ensuring optimal water distribution for agriculture. In addition, this research contributes to reducing the impact of sedimentation on agricultural productivity, supports sustainable environmental management, and provides useful data in facing the challenges of climate change which affects rainfall and sedimentation patterns. Thus, the results of this research will provide important insights to improve the sustainability of irrigation systems and food security in the region.

III. MATERIALS AND METHODS

This research was conducted from November 2021 to June 2022. The study was carried out on the Rappang Primary Channel from upstream to downstream, focusing on suspended sediment and bed load. Sample testing was conducted at the Soil Mechanics Laboratory of the Civil Engineering Department, Faculty of Engineering, Hasanuddin University, Gowa.

Fig. 1. Research channel location. © 2025 CNES/Airbus, Maxar Technologies

The research implementation process is divided into several parts: data collection, data processing, calculations and data analysis, and drawing conclusions. The procedure for conducting this research follows several stages, including:

- Preparation. This stage requires data on channel cross-sections in the field, as well as determining the locations for data collection.
- Data Collection. Collecting samples of suspended sediment and bed load at the upstream, middle, and downstream sections of the Rappang Primary Channel. This included: Measuring the flow velocity in the channel and measuring the flow discharge in the channel.

Research implementation in this stage includes: (a) Measuring the width of the channel, then stretching a rope along the width of the submerged channel. (b) After obtaining the channel length, divide the channel into five segments and measure the depth of each segment. (c) After obtaining the depth data, measure the flow velocity at 0.2, 0.6, and 0.8 of the depth, noting the number of revolutions of the current meter's propeller every 40 s. (d) After obtaining the flow velocity, proceed to collect suspended sediment samples using a Van Dorn bottle sampler (Figure 2). (e) After collecting suspended sediment samples, proceed to collect bed load data using a Grab sampler (Figure 2) in the middle of the channel. (f) The flow velocity data for each segment at the upstream, middle, and downstream of the Rappang main channel is entered into an observation table, followed by data analysis. (g) Sediment samples from the upstream, middle, and downstream sections were analyzed at the Soil Mechanics Laboratory of Hasanuddin

University. (h) From the analysis results, data on seasonal changes affecting sediment transport in the D.I. Saddang primary channel were obtained. (i) The results of this data analysis reveal the relationship between sediment volume and flow discharge in each season. [8, 9]. The calculations are conducted with the aim of (1)-(4):

$$V = \frac{V_{0.2} + V_{0.6} + V_{0.8}}{3} \quad (1)$$

$$Qw = A \times V \quad (2)$$

$$Cs = \frac{1000}{v}\, x\, (a - b) \times 1000 \quad (3)$$

$$Qs = 0.0864 \times Cs \times Qw \quad (4)$$

(a) (b)

Fig. 2. (a) Van Dorn bottle sampler, (b) Grab sampler.

IV. RESULTS AND DISCUSION

The flow velocity V (m/s) of the Saddang irrigation area was obtained using an A.OTT propeller current meter. The velocity measurements vary from the upstream to the downstream sections. Table I presents the velocity data from the upstream to the downstream of the channel.

TABLE I. SUMMARY FLOW VELOCITY RAINY SEASON AND DRY SEASON

Description	Channel Flow Velocity (m/s)								
Part	Upper			Middle			Downstream		
Depth	0.2	0.6	0.8	0.2	0.6	0.8	0.2	0.6	0.8
Rainy Season									
T1	0.15	0.14	0.13	0.14	0.13	0.13	0.13	0.12	0.11
T2	0.17	0.15	0.15	0.15	0.15	0.14	0.14	0.13	0.12
T3	0.18	0.16	0.15	0.16	0.16	0.14	0.15	0.14	0.12
T4	0.16	0.15	0.12	0.15	0.14	0.13	0.13	0.12	0.12
T5	0.14	0.13	0.12	0.14	0.13	0.12	0.13	0.11	0.11
Dry Season									
T1	0.14	0.13	0.12	0.14	0.12	0.12	0.11	0.10	0.09
T2	0.15	0.14	0.13	0.14	0.14	0.13	0.12	0.10	0.09
T3	0.16	0.15	0.14	0.16	0.15	0.13	0.14	0.12	0.12
T4	0.15	0.14	0.12	0.14	0.13	0.12	0.12	0.11	0.10
T5	0.14	0.13	0.12	0.14	0.12	0.12	0.11	0.10	0.09

The research results show that the flow velocity in the rainy season is greater than that of the dry season, with the fastest flow velocity occurring at the 0.2h depth, followed by 0.6h, and the smallest at 0.8h, measured from the water surface. In Figure 3, it can be seen that the average flow velocity during the rainy season is higher than that during the dry season. The highest average flow velocity is at section T3 during the rainy season, with a value of 0.139 m/s, while the lowest flow velocity is at section T1 during the dry season [10-11]. In Table II, it can be seen that the sediment concentration in the upstream part of the channel was greater than that in the middle and downstream of the channel. This sediment concentration is influenced by several drainage parameters such as flow speed and flowing flow discharge.

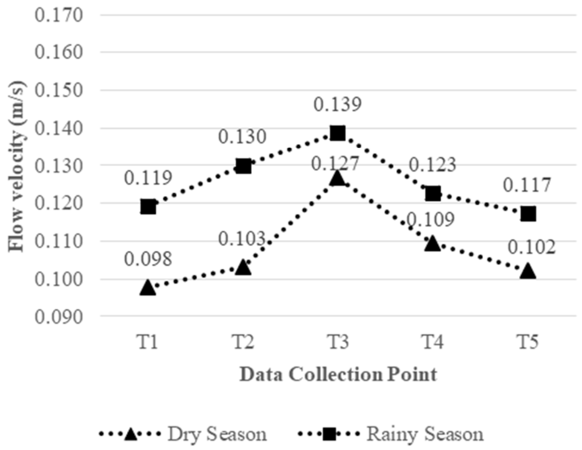

Fig. 3. Comparison graph of average flow velocity during the rainy and dry seasons in the down section of the channel.

TABLE II. SUMMARY SEDIMENT CONCENTRATION

Location	Sediment concentration (mg/l)		
Part	Upstream	Midstream	Downstream
Rainy Season			
T1	7704	4824	3487
T2	7744	4946	3341
T3	6298	3113	1616
T4	7814	5283	3522
T5	9120	5901	4707
Dry Season			
T1	320	200	100
T2	310	190	90
T3	300	180	80
T4	330	220	110
T5	340	240	120

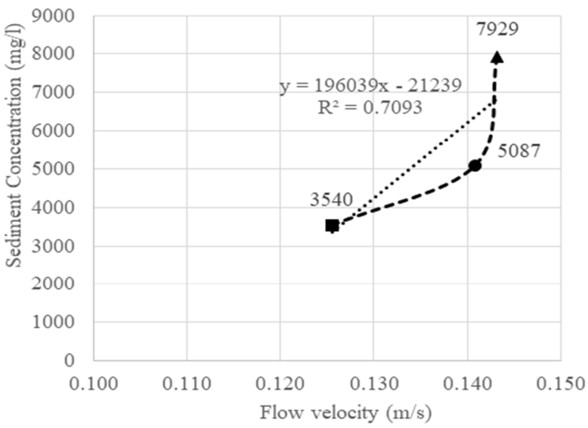

Fig. 4. Relationship between average flow velocity and sediment concentration during the rainy season.

In Figure 4, it can be seen that flow velocity affects the amount of the produced sediment concentration. The higher the flow velocity, the greater the sediment concentration, especially during the rainy season. The sediment concentration at the upstream of the channel is 7929 mg/l, at the middle it is 5097 mg/l, and at the downstream it is 3540 mg/l. In Figure 5, it can be seen that flow velocity affects the amount of the produced sediment concentration. The higher the flow velocity. the greater the sediment concentration, especially during the rainy season. The sediment concentration at the upstream of the channel is 320 mg/l. at the middle it is 208 mg/l. and at the downstream it is 100 mg/l, so it can be seen that there is a difference between sediment concentration and flow velocity. The faster the flow speed, the greater the sediment concentration produced.

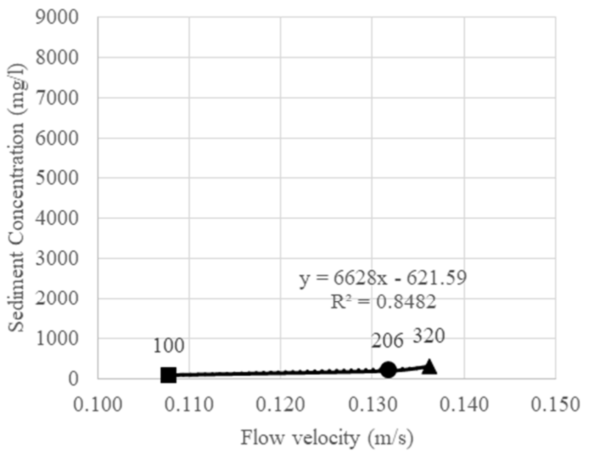

Fig. 5. Relationship between average flow velocity and sediment concentration during the dry season.

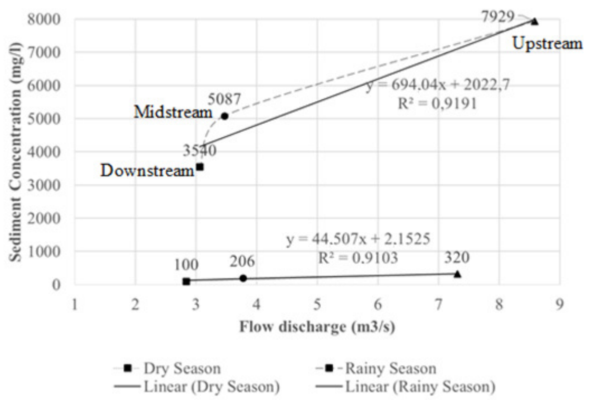

Fig. 6. Relationship between flow discharge and sediment concentration.

In Figure 6, it can be seen that the sediment concentration between the rainy season and the dry season has a ratio comparison of 1/24.7 for the upstream section. 1/24.7 for the middle section, and 1/34.4 for the downstream section of the channel. The highest sediment concentration is found in the upstream section of the channel. with an average value of 7929 mg/l, followed by the middle section with an average sediment concentration of 5087 mg/l, whereas the lowest sediment concentration is found in the downstream section with an average vale of 3540 mg/l. In Table III, it can be seen that the highest gravel material is found at upstream T5 with a value of 11.60%, while at upstream T3 the gravel material is 0.00%, attributed to the high flow velocity. The highest sand material is at upstream T3 with a value of 35.40%, while the lowest is at upstream T4 with a value of 13.80% [11]. The highest silt material is found in the middle section at T4 with a value of 59.89%, while the is at upstream T3 with a value of 26.66%. The highest clay material is also in the middle section at T4 with a value of 59.89%, while the lowest is at downstream T5 with a value of 6.59%.

TABLE III. SUMMARY RESULT SIEVE ANALYSIS AND HYDROMETER ANALYSIS IN RAINY SEASON

Sample Code		Sieve and Hydrometer Analysis			
		Gravel (%)	**Sand (%)**	**Silt (%)**	**Clay (%)**
Rappang Primary Channel (Upstream)	T1	0.4	18.8	48.34	32.46
	T2	0.8	25.2	35.64	39.16
	T3	0.0	19.2	26.66	54.14
	T4	0.2	13.8	28.01	58.19
	T5	11.6	21.8	36.47	30.13
Kulo. Sidenreng Rappang (Midstream)	T1	0.4	25.2	34.55	40.25
	T2	0.4	33.2	14.69	52.11
	T3	0.4	35.4	28.38	36.22
	T4	0.8	29.4	59.89	59.89
	T5	9.8	22.4	36.59	31.21
Maritengae. Sidenreng Rappang (Downstream)	T1	9.8	22.4	44.63	23.17
	T2	9.8	22.4	40.54	27.26
	T3	9.8	22.4	35.21	32.59
	T4	2.0	26.6	44.3	27.1
	T5	1.2	34.4	57.81	6.59

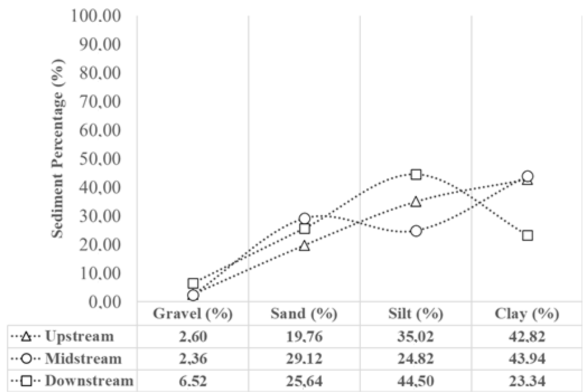

Fig. 7. Recapitulation of sediment percentage in the Saddang irrigation area during the rainy season.

Figure 6 shows the types of sediment distributed in the primary channel of the Saddang Irrigation Area during the rainy season. The average content of gravel sediment is 3.79%, the average content of sand sediment is 24.85%, the average content of silt sediment is 34.782%, and the average content of clay sediment is 39.393%. Therefore, it can be concluded that the highest sediment content during the rainy season is clay, followed by silt, sand, and gravel. Figure 8 shows the types of sediment distributed in the primary channel of the Saddang irrigation area during the dry season. The average content of gravel, sand, silt, and clay sediment is 0%, 12.8%, 19.03%, and 68.17%, respectively. Therefore. it can be concluded that the highest sediment content during the dry season is clay, followed by silt, sand, and gravel [12].

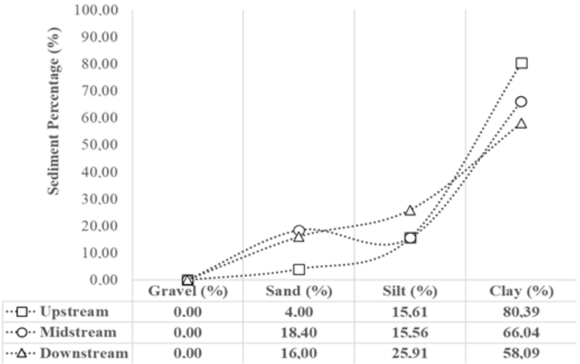

Fig. 8. Recapitulation sediment percentage in the Saddang irrigation area during the dry season.

TABLE IV. RESULTS OF SEDIMENT CONCENTRATION. FLOW DISCHARGE. AND SEDIMENT DISCHARGE CALCULATIONS

Data collection point	Sediment concentration (mg/l)	Flow discharge (m^3/s)	Sediment discharge (ton/day)
Rainy Season			
Upstream	7929	8.58	5735
Midstream	5087	3.45	1435
Downstream	3540	3.06	937
Dry Season			
Upstream	320	7.31	203
Midstream	206	3.77	68
Downstream	100	2.84	29

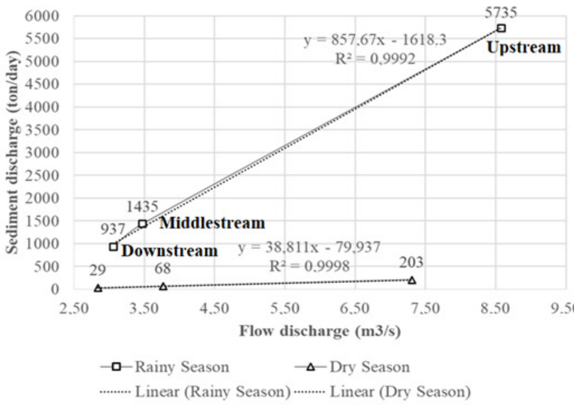

Fig. 9. Relationship between flow discharge and sedimen discharge during the rainy and dry seasons in the primary channel of the Saddang irrigation area.

Table IV shows the results of sediment concentration, flow discharge, and sediment discharge calculations for the rainy and dry seasons in the Saddang irrigation area. The highest sediment discharge is found during the rainy season at the upstream section of the channel, with a value of 5735 tons/day, while the smallest sediment discharge is observed during the dry season at the downstream section of the channel, with a value of 29 tons/day [12, 13].

Figure 9 shows that the relationship between flow discharge and sediment discharge is highly significant. Based on the research results, it was found that as the flow discharge increases, the sediment discharge increases. This is supported by the obtained linear equations: For the rainy season:

$$y = 857.67x - 1618.3 \quad (5)$$

and for the dry season:

$$y = 38.811x - 79.937 \quad (6)$$

These calculations are validated with an average validation rate of 98%. indicating that the linear model used accurately represents the relationship.

V. CONCLUSIONS

Seasonal changes between the rainy and the dry seasons are obvious in the comparison of flow speeds, where the fastest flow speed on average in the rainy season is the highest in the upstream section. The rainy season has an average speed of 0.163 m/s and the lowest flow speed of 0.117 m/s in the downstream section (T5). The highest flow speed is in the upstream section (T3) in the dry season is 0.149 m/s and the lowest flow speed in the downstream section (T1) in the rainy season has a value of 0.098 m/s. The research results show that the flow velocity during the rainy and dry seasons was highest in the upstream section of the primary channel of the Saddang irrigation area, and the lowest speed was recorded in the downstream section of the primary channel.

The sediment discharge is influenced by several parameters such as flow speed, flow discharge, and sediment concentration in the channel. Based on the calculation results, it can be concluded that the sediment discharge during the rainy season (2702 tons/day) is greater than that during the dry season (100 tons/day). The average ratio of sediment discharge between the rainy and dry seasons is 1/27. The research findings regarding the types of sediment contained in the channel during the rainy and dry seasons indicate that the highest amount of gravel is found at upstream T5, with a value of 11.60%. while at upstream T3, due to the high flow velocity. The highest amount of sand material is found at upstream T3, with a value of 35.40%, while the lowest sand content is at upstream T4 with a value of 13.80%. The highest amount of silt material was found in the middle section at T4 with a value of 59.89%, while the lowest silt content is at upstream T3, with a value of 26.66%. The highest amount of clay material is also in the middle section at T4, with a value of 59.89%, while the lowest was found at downstream T5 with a value of 6.59%. Thus. the largest recorded sediment is clay, followed by silt, sand, and gravel.

The linear equations (5) and (6) were obtained to predict the sediment discharge during the rainy and the dry seasons in the main channel of the Saddang irrigation area, with a ratio of 98% between the linear equations and the calculation results.

REFERENCES

[1] A. Benabid, M. Badis, F. Ali, M. Tarek, and M. Saadi, "Numerical Simulation of Gradually Varying Permanent Flows in a Prismatic Open Channel for Four Geometric Shapes," *Engineering, Technology & Applied Science Research*, vol. 14, no. 4, pp. 15274–15282, Aug. 2024, https://doi.org/10.48084/etasr.7715.

[2] Y. Arafat, M. Pallu, F. Maricar, and R. Lopa, "Morphology evolution of lower Jeneberang River, Indonesia," *International Journal of Earth*

Sciences and Engineering, vol. 8, no. 5, pp. 256–261, Oct. 2015, https://doi.org/10.5281/zenodo.7860791.

[3] P. Gao, V. Geissen, C. J. Ritsema, X.-M. Mu, and F. Wang, "Impact of climate change and anthropogenic activities on stream flow and sediment discharge in the Wei River basin, China," *Hydrology and Earth System Sciences*, vol. 17, no. 3, pp. 961–972, Mar. 2013, https://doi.org/10.5194/hess-17-961-2013.

[4] R. Karamma and M. S. Pallu, "Comparison of Model Hidrograf Synthetic Units (HSS) with the Model of Hidrograf Observations on DAS Jeneberang Gowa Regency, Indonesia," *International Journal of Innovative Science and Research Technology*, vol. 3, no. 2, pp. 617–623, 2018.

[5] J. Szilo and R. J. Bialik, "Grain Size Distribution of Bedload Transport in a Glaciated Catchment (Baranowski Glacier, King George Island, Western Antarctica)," *Water*, vol. 10, no. 4, Apr. 2018, Art. no. 360, https://doi.org/10.3390/w10040360.

[6] E. Li, "Effects of Extreme Rainfall Change on Sediment Load in the Huangfuchuan Watershed, Loess Plateau, China," *Sustainability*, vol. 16, no. 17, Jan. 2024, Art. no. 7457, https://doi.org/10.3390/su16177457.

[7] A. A. Mahessar *et al.*, "Sediment Transport Dynamics in the Upper Nara Canal Off-taking from Sukkur Barrage of Indus River," *Engineering, Technology & Applied Science Research*, vol. 10, no. 6, pp. 6563–6569, Dec. 2020, https://doi.org/10.48084/etasr.3924.

[8] M. P. Hatta and S. S. Yuni, "Changes in rainfall and discharge in Saddang Watershed, South Sulawesi, Indonesia," *IOP Conference Series: Earth and Environmental Science*, vol. 235, no. 1, Feb. 2019, Art. no. 012037, https://doi.org/10.1088/1755-1315/235/1/012037.

[9] G. H. Syamsuddin, M. S. Pallu, F. Maricar, and B. Bakri, "The Effect of Climate Changes on Sediment Concentration in the Saddang Irrigation Area," *IOP Conference Series: Earth and Environmental Science*, vol. 1117, 2022, Art. no. 012065, https://doi.org/10.1088/1755-1315/1117/1/012065.

[10] B. Bakri *et al.*, "Analysis of Sediment Distribution at the Intake Structure," *IOP Conference Series: Materials Science and Engineering*, vol. 875, Jun. 2020, Art. no. 012031, https://doi.org/10.1088/1757-899X/875/1/012031.

[11] Y. Saadi, I. G. Putra, and A. Suroso, "Suspended sediment transport map for disaster mitigation in the upper course of Jangkok River," *E3S Web of Conferences*, vol. 331, 2021, Art. no. 08005, https://doi.org/10.1051/e3sconf/202133108005.

[12] L. C. Van Rijn, *Principles of sediment transport in rivers, estuaries and coastal seas*. Amsterdam, Netherlands: Aqua Publications, 1993.

[13] S. Wang and X. Wang, "Changes in Water and Sediment Processes in the Yellow River and Their Responses to Ecological Protection during the Last Six Decades," *Water*, vol. 15, no. 12, Jan. 2023, Art. no. 2285, https://doi.org/10.3390/w15122285.