

Analysis of floodwater: A Case Study of the Tukad Buluk Poh River



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Abstract

One of the main causes of flooding is the disruption of river flow due to silting or narrowing of the river basin. The high volume of water in the rivershed will overflow and cause flooding in the surrounding area of the river. The object of this research is the Tukad Biluk Poh River, a river in the Jembrana district, Bali, which has 28 km long and empties into the Indian Ocean. The study aims to measure a flood water level limit at the river bridge that crosses the National Highway Gilimanuk-Denpasar so flooding on that section can be avoided. This quantitative descriptive research analysis uses the Nakayasu HSS (Synthetic Unit Hydrograph of Nakayasu) method for a while in 2, 5, 10, 25, 50, 100, 200, and 1000 years. Next, a hydraulics analysis to determine the flood water level limit uses the HEC-RAS model and results in MAB heights for a similar period. The research results revealed the height at the pavement section and the bottom of the girder section. At the end of this paper, the height of bridge that needs to be elevated at the bottom of the bridge's upper structure and a guard height for a certain repeat time are discussed. Therefore, it is believed that the research outcome will make an important contribution to the local government in issuing the Tukad Biluk Poh rivershed policy.

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INTRODUCTION

Flooding is one of the disasters that cause huge losses, according to the Global Forest Watch report, and is one of the causes of deforestation. It disrupts evaporation levels, decreases soil infiltration of water, and results in increased soil erosion. In this way, all the rainwater will enter the river, thereby immediately raising the river water level, which will ultimately overflow out of the river because the river water discharge exceeds capacity and the river flow is not smooth. This results in flooding in the area surrounding the watershed [1, 2, 3].

Tukad Biluk Poh is one of the rivers in Jembrana district, Bali, empties into the Indian Ocean, has a length of approximately 28 km with

a river basin area of approximately 84 km² and has a high potential for flooding with the Perennial River type. Floodings in this river have occurred quite frequently and the worst occurred at the beginning of 2018, which caused considerable losses to the people living around Tukad Biluk Poh. The Gilimanuk – Denpasar national road was also at that time hit by the overflowing waters of Tukad Biluk Poh, causing several houses in this residential area to be flooded.

Previously, there had been several floods in this area. Flooding often occurs on the inbound bridge due to the high intensity of rain and water discharge being hampered by the bridge girder's low level, which affects the lack of freeboard height, hampers river water flow[4][5].

The need for this research was triggered by indications that there are several causes of flooding in the area around the National Highway that crosses the Tukad Biluk Poh River. Firstly, deforestation causes a lack of infiltration in the watershed. Deforestation is mainly caused by illegal logging in protected forest areas around the rivers. The second reason is the design structure of the bridge itself. The bridge girder and the bridge span are not height and long enough. Hence, when the stream gets higher and the water level reaches above the bridge girder, the flow of water will be restrained. Data from the Jembrana Regional Government Forestry Service indicated almost three-quarters of the forest is damaged and denuded, with an area of 383 hectares of production forest and 299 hectares of protected forest. This condition causes the water not to seep into the ground but flow directly into the main river, so the water discharge at the surface is greater than normal [6][7].

In this case, the bridge can no longer be refurbished and needs to be dismantled. They need a new one with a better design structure based on current and future river water discharge to ensure the smooth flowing water that passes underneath [8].

Up to here, it is clear that flood control efforts are needed to reduce the risk damage due to flooding. Flood control planning in a watershed can be done if the planned flood discharge is known. Therefore, this research aims to conduct a hydrological analysis of flood discharge in the watershed area [8][9]. Also analyzing the cross-sectional capacity of the Tukad Biluk Poh River in the National Highway surrounding area where this river hydraulic analysis is intended to analyze the profile of flood water levels in the river with various return periods from the planned flood discharge [31]. The research outcome is believed to positively contribute to the local government by stating policies related to flood control at the Tukad Biluk Poh River.

METHOD

This descriptive quantitative research is based on a case study on the Tukad Biluk Poh River in the Jembrana region, Bali. This research method uses the rational and Nakayasu synthetic unit hydrographs to analyze flood discharge. Meanwhile, the flood water level simulation uses the HEC-RAS program. The research location is on the National Road bridge that crosses Tukad Biluk Poh.

The bridge is on the Gilimanuk - Denpasar Highway in Tegal Cangkring Village, Mendoyo District, Jembrana Regency. The exact location is

at coordinates 50L 247077.00 m E, 9072639.44 m S, and an elevation of 12 m above sea level. The flow chart for hydrology and hydraulics analysis is depicted in Figure 1.

The primary data gathered in this research is based on a direct observation of the river's location in September 2020, when the river was in normal condition. The data survey was taken directly from the river bridge and up to three kilometers in the upstream direction. During the data collection, the two residents were informed from the interview that the flood occurred in Tukad Biluk Poh mostly at night when there was heavy and long rain. Also, according to sources, the flood reached as height as one meter above the bridge girder [10, 11, 12].

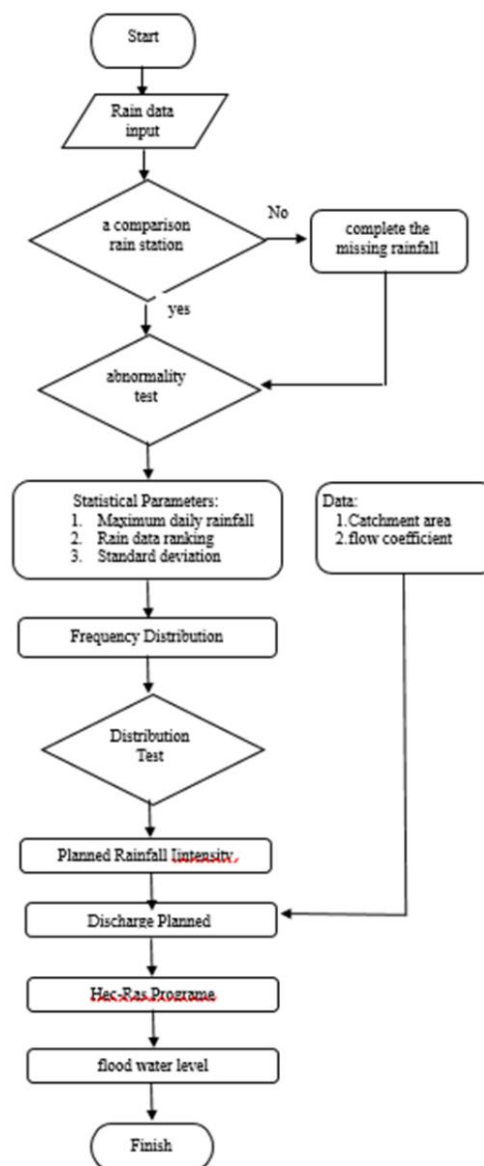


Figure 1. Flow Chart Research

As secondary data, the topographic map of the earth was obtained directly from the official website of the Geospatial Information Agency with a scale of 1: 50,000. The topographical map data obtained is in the form of a ship, which needs to be converted to AutoCAD and Google Earth formats using Global Mapper. Meanwhile, rainfall data was withdrawn from the official website of the National Meteorology, Climatology and Geophysics Agency [13][14].

Data processing stages

There are four major process stages in this research, i.e.:

1. Daily Rain Data Processing.

The data was gathered from the Meteorology, Climatology, and Geophysics Agency. The daily rainfall data is converted into maximum rainfall data.

2. Rainfall Analysis

In this analysis, some tools are being used to analyze rainfall, which include:

- a. Abnormality Test.
- b. Statistical Frequency Distribution.
- c. Distribution Suitability Test.
- d. Rain Intensity Analysis.

3. Hydrology Analysis

The approaches that are being used to do Hydrology Analysis are:

- a. Rational Methods
- b. Synthetic Unit Hydrograph Methods

4. Hydraulic Analysis

The purpose of the hydraulic analysis is to determine the ability of the cross-section to accommodate water discharge in the river. As previously explained, one of the causes of flooding is the inability of the cross-section to accommodate flood discharge. Hydraulics analysis in this study used the HEC-RAS program. Tukad Biluk Poh is categorized as a steady current river, which is eligible as an input in the HEC-RAS model. The analysis was based on an input of the river's length for about one kilometre upstream

and two hundred meters downstream from the bridge [6][15].

RESULTS AND DISCUSSION

Hydrological Analysis

Catchment Area (DAS)

The data needed to analyze River Watershed (DAS) boundaries is DEMNAS data gathered from the official website of the Geospatial and Information Agency. Then, the data were processed using Global Mapper software and converted into DWG format, which was finally plotted and analyzed using AutoCAD software. Figure 2 shows the determination of watershed boundaries and river length

The data that has been converted into a dwg file is then manually analysed to determine the watershed boundaries in Tukad Biluk Poh. The method used to determine watershed boundaries is topographic contour analysis, where peak contours were connected to determine the flow boundaries at Tukad Biluk Poh itself [16][17].

The results obtained from processing the topographic data are as follows:

- a. Catchment Area (DAS) = 84.704146 km²
- b. River Length = 28.0092752 km

Maximum Daily Rainfall Data

The rainfall data in the Tukad Biluk Poh hydrological analysis is taken from the closest station to Tukad Biluk Poh, i.e., the Jembrana Climatology station. The rainfall data used in this study was the data for ten years, from 2009 to 2018.

The daily rainfall data was gathered from the Meteorology, Climatology, and Geophysics Agency (BMKG) Database Center. Maximum daily rainfall data is listed in Table 1, and Maximum Annual Rainfall is listed in Table 2. In the next step, the planned flood discharge is calculated using the Rational method presented in Table 3.

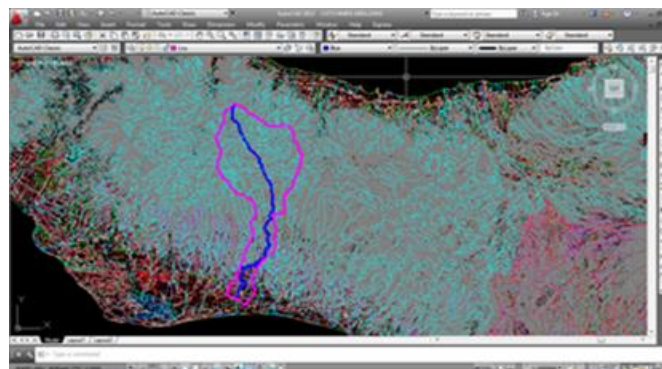


Figure 2. Determination of Watershed Boundaries and River Length

Table 1. Maximum daily rainfall

No.	Year	Jan	Feb	Mar	Apr	May	June	July	Augst	Sept	Oct	Nov	Dec	RR max
1	2009	113.7	507	303	573	82	188	143	65	235	976	94	111	235
2	2010	505	57	44	474	80	147	385	409	147	122	608	405	147
3	2011	684	38	96.5	33	138	85	20	1	75	54.2	78.1	67	138
4	2012	662	29	662	16	513	35	323	135	10	58	565	631	662
5	2013	0	0	0	0	0	0	0	0	0	0	296	539	539
6	2014	618	305	59	21	40	15	26	14	22	7	38	70	70
7	2015	557	22.8	35.4	72.1	43	128	7	15	4	28.3	82	67.7	128
8	2016	22	531	304	378	419	573	304	837	561	459	112.6	33.1	1126
9	2017	744	714	433	227	558	1042	305	149	364	564	95.7	69.3	1042
10	2018	1005	524	867	92	313	26	76	422	8	4	1653	709	1653

Table 2. Maximum Annual Rainfall

No	Year	RR Max (mm)
1	2009	235
2	2010	148.7
3	2011	133
4	2012	66.2
5	2013	53.9
6	2014	70
7	2015	123.7
8	2016	112.6
9	2017	104.2
10	2018	165.3

Table 3. The Planned Flood Discharge

No.	Year	Converse Factor	Flow Coeff	Rain Intensity (mm/hour)	Flow area (km ²)	Discharge (m ³ /s)
1	2	0.278	0.659	11.722	84.704	181.901
2	5	0.278	0.659	17.082	84.704	265.077
3	10	0.278	0.659	20.71	84.704	321.377
4	25	0.278	0.659	23.361	84.704	393.551
5	50	0.278	0.659	28.853	84.704	447.739
6	100	0.278	0.659	32.367	84.704	502.269
7	200	0.278	0.659	35.915	84.704	502.327
8	1000	0.278	0.659	44.381	84.704	688.702

The planned flood discharge is calculated using the rational method, i.e.:

$$Q = f \cdot a \cdot I \cdot A \tag{1}$$

Nakayasu Synthetic Unit Hydrograph equation with hydrograph curve is shown in Figure 3.

The design flood that will be used to determine the flood water level at Tukad Biluk Poh is HSS Nakayasu because, in SNI 2415:2016 concerning procedures for calculating flood plans, the Rational method cannot be used for catchment areas of more than 5000 hectares and design flood control is shown in Table 4.

The design flood discharge data using the HSS Nakayasu method will then be used as a basic reference for hydraulic calculations using HEC-RAS [15][17].

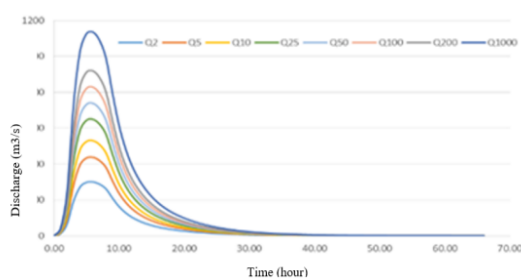


Figure 3. Nakayasu HSS curve

Table 4. Flood Return

No	Planned Discharge (year)	Discharge (m ³ /s)
1	Q2	299.72
2	Q3	436.76
3	Q10	529.52
4	Q25	648.43
5	Q50	737.7
6	Q100	827.555
7	Q200	918.270
8	Q1000	1..134.737

Hydraulics Analysis

The results of the calculation of the flood water level can be seen in Figure 4. The river profile and flood water level from each return period are presented in an image from the results of the HEC-RAS program running [18].

In the picture below, the flood water level rises during the 50-year return period due to the influence of the bridge, which blocks the flood discharge that occurs [19].

The flood water level's height in the river's cross-section is presented in Figure 5 to Figure 8, which will illustrate the simulation of the upstream part of the bridge with various flood water level conditions.

It can be seen from the simulation that starting from the 50-year anniversary of the bridge that crosses Tukad Biluk Poh at the bottom of the girder. The river has been affected by flooding.

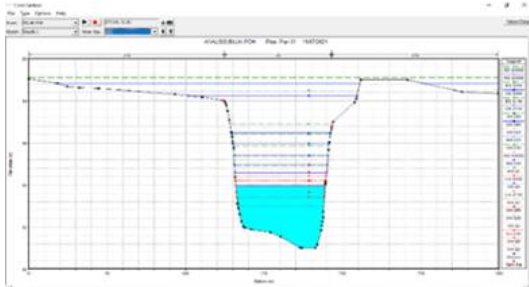


Figure 4. Floodwater Profile

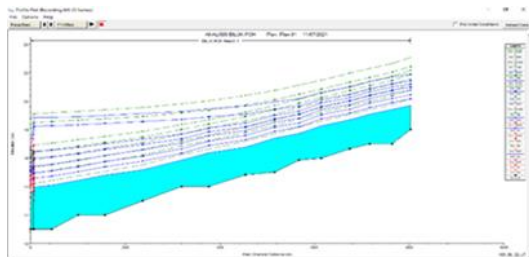


Figure 5. Flood Water Level Upstream of the Bridge

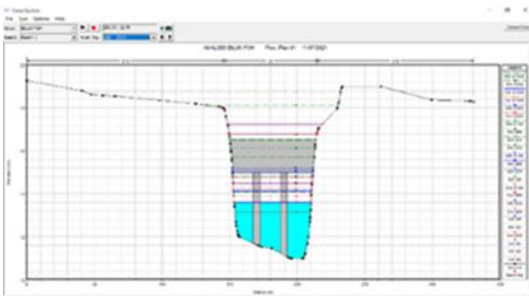


Figure 6. Flood Water Level on the Axle of the Bridge

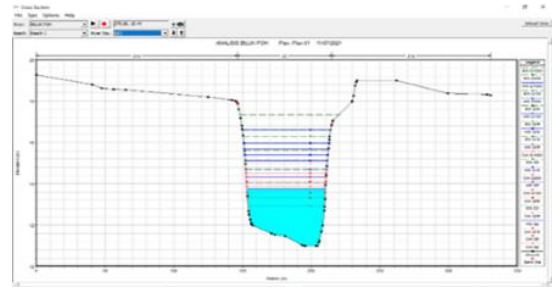


Figure 7. Flood Water Level Downstream on the Bridge

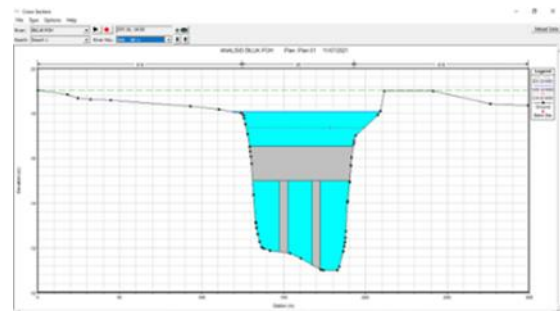


Figure 8. Flood Water Level Upstream of the 1000-Year Return Period Bridge

Moreover, when the bridge was 1000 years old, it was flooded, and the upstream section even experienced runoff on the right side of the bridge. In 2018, there was also a flood that submerged the bridge connecting Gilimanuk with Denpasar.

Data obtained from the field shows that the flood has reached residential areas. The flood water level in the simulation using HEC-RAS at a return period of 1000 years is 1.55m from the bridge floor plate and the flood water level from the river bed is 6.2m. The planned flood returns period regulation according to SNI 03-2415-1991 is Q100 or 100-year planned discharge. Still, for security reasons, several hydrologists from the Ministry of PUPR are advised to calculate the magnitude of the flood discharge at the 1000-year return period to be used as a comparison for the safety of bridge structures against future floods [20][21]. Recently, river flood discharge has been greater than usual.

The design flood discharge at Tukad Biluk Poh using the HSS Nakayasu method with each return period is as follows:

1. 2 year return period 299,720 m³/second
2. 5 year return period 436.764 m³/second
3. 10 year return period 529.525 m³/second
4. 25 year return period 648.435 m³/second
5. 50 year return period 737.716 m³/second
6. The 100 year birthday is 827.555 m³/second
7. 200 year return period 918,270 m³/second

8. The 1000-year return period is 1134.737 m³/second

The results of the analysis of the design flood water level for return periods of 2, 5, 10, 25, 50, 100, 200 and 1000 years using HEC-RAS software measured from the river land surface are as follows:

1. at 2 years birthday 1.78 m
2. at 5 years birthday 2.31 m
3. at 10 year anniversary 2.64 m
4. at 25 years old 3.03 m
5. at 50 years old 3.34 m
6. at 100 years birthday 3.51m
7. at 200 years return 5.76 m
8. at 1000 year anniversary 6.21m

From the above study results, estimated figures regarding flooding in the watershed can be obtained. It is essential for communities around the watershed, especially local governments, to use this data in their flood management programs. Other past research has revealed that large volumes of flash flood water will cause many disasters in the surrounding area [22, 23, 24]. The biggest loss is if the flash flood water hits agricultural areas [25][26], which causes crop failure [25][27]. Therefore, it would be good for data from research results like this one to become part of the practical implementation of digital technology [23, 28, 29, 30]. Hence, it is easier for various policy stakeholders to analyze and access the data.

CONCLUSIONS

The following conclusions are drawn after analyzing and calculating the design of flood discharge and the water level plan from the primary and secondary data at Tukad Biluk Poh.

The largest annual maximum rainfall occurred in 2018, namely 165.3 mm, when a major flood occurred in Tukad Biluk Poh, which cut off access to the Gilimanuk – Denpasar National Road. The design flood discharge at Tukad Biluk Poh using the HSS Nakayasu method with each return 200-year return period of 918,270 m³/second. The 1000-year return period is 1134.737 m³/second. The results of the analysis of the design flood water level for return periods of 2, 5, 10, 25, 50, 100, 200 and 1000 years using HEC-RAS software measured from the river land surface are as follows: 1.78 m, 2.31 m, 2.64 m, 3.03 m, 3.34 m, 3.51m, 5.76 m, and 6.21 m. The flood water level in the analysis and actual is not much different, namely at the 200-year return period, it is 1m from the pavement on the bridge. The 1000-year return period is used for control and safety factors for bridges against flooding.

The height of the MAB with a design discharge of 1000 years is 6.21 from the surface

of the river and the height of the guard or freeboard by SNI 03-3424-1994 is 1.5m. The flood water level designed with a return period of 50 years with a height of 3.34m has already hit the girders on the bridge so that it is no longer effective in channelling the flow to Tukad Biluk Poh and is also dangerous for the structure of the bridge itself. At the design flood water level with a return period of 200 years and 1000 years, the pavement on the bridge has been flooded so that it can no longer be passed by vehicles. Finally, the bridge's height from the ground level is 4.65m by measuring from the bridge pavement, while the height of the ground surface with girders or the lowest position of the bridge is 3.10m.

REFERENCES

- [1] A. Hidayat and M. R. Ariana, "Optimization Analysis of Plant Landscapes in Tandai Irrigation Area, Kerinci District, Jambi," *Neutron*, vol. 20, no. 01, pp. 63-71, 2020, doi: 10.29138/neutron.v20i01.50.
- [2] A. Hidayat and D. Ferdina, "Planning Optimization Planning Irrigation Area of Solok Sumatera West Regency," *IJEEIT: International Journal of Electrical Engineering and Information Technology*, vol. 2, no. 2, pp. 41–60, 2020, doi: 10.29138/ijeeit.v2i2.1156.
- [3] F. Fernalia, B. Keraman, Hindrean, and E. Yudha, "The Relationship Between Flood Disaster Mitigation Knowledge with Community Preparedness," *International Journal of Management and Education in Human Development (IJMEHD)*, vol. 1, no. 4, pp. 154-158, 2021.
- [4] A. Hidayat, B. Basysyar, Y. R. Alkhaly, and M. Ali, "Analysis of Flood Peaks Using The Mean Annual Flood Method," *International Journal of Engineering, Science and Information Technology*, vol. 2, pp. 53–59, Apr. 2022, doi: 10.52088/ijesty.v2i2.249.
- [5] T. Chrismadha, "Conservation of Water Resources," *www.opi.lipi.go.id*, 2008.
- [6] N. F. Margini, D. A. D. Nusantara, and M. B. Ansori, "Hydrograph analysis of the Nakayasu and ITB synthetic units in the Konto sub-watershed, East Java," *Jurnal Hidroteknik*, vol. 2, no. 1, pp. 41-45, 2016, doi: 10.12962/jh.v2i1.4401
- [7] A. D. Sultan, R. Hidayat, S. Mulyani, and W. A. Yusuf, "Analysis of the Effect of Cross-sectional Area on Water Flow Velocity by Using Venturimeter Tubes," *Jurnal Pendidikan Fisika*, vol. 8, no. 1, pp. 2527–4015, 1995, doi: 10.26618/jpf.v8i1.3199

- [8] F. Yanuar et al., "Water Level Control Prototype Using Fuzzy Logic Control Optimized by the Cuckoo Search Algorithm Method," *JEEE-U (Journal of Electrical and Electronic Engineering-UMSIDA)*, vol. 4, no. 2, pp. 150-168, 2020, doi: 10.21070/jeeeu.v4i2.876
- [9] A. W. Biantoro, S. I. Wahyudi, M. F. Niam, and A. G. Mahardika, "Analysis of Ciliwung river flood debit and city flood anticipation using floods early detection system (FEDS)," *IOP Conf Ser Earth Environ Sci*, pp. 1755–1315, 2022, doi: 10.1088/1755-1315/955/1/012011
- [10] A. A. Anggarda, H. Purnaweni, S. Suwitri, and T. Afrizal, "Analysis of Flood Disaster Mitigation Policy in Lamongan District," *International Journal of Social Science and Business*, vol. 5, no. 4, pp. 537-542, 2021, doi: 10.23887/ijssb.v5i4.37978.
- [11] A. B. Safarina, H. T. Salim, I. K. Hadihardaja, and M. S. Bk, "Clusterization of Synthetic Unit Hydrograph Methods Based on Watershed Characteristics," *International Journal of Civil & Environmental Engineering IJCEE-IJENS*, vol. 11, no. 06, pp. 76–85, 2011.
- [12] A. F. Makawimbang, L. Tanudjaja, and E. M. Wuisan, "Planning for a clean water supply system for Soyowan Village, Ratatotok District, Southeast Minahasa Regency," *Jurnal Sipil Statik*, vol. 5, no. 1, pp. 31-40, February 2017.
- [13] H. Rintis, S. Suyanto, and Y. P. Setyoasri, "Rainfall-Discharge Simulation in Bah Bolon Catchment Area by Mock Method, NRECA Method, and GR2M Method," *Applied Mechanics and Materials*, vol. 845, pp. 24–29, 2016, doi: 10.4028/www.scientific.net/AMM.845.24.
- [14] C. Emeribe et al., "Hydrological Assessments of Some Rivers in Edo State, Nigeria for Small-Scale Hydropower Development," *Nigerian Journal of Technology*, vol. 35, no. 3, p. 656, 2016, doi: 10.4314/njt.v35i3.26.
- [15] R. Wigati, Sudarsono, and I. D. Cahyani, "Flood Analysis Using HEC-RAS 4.1 SOFTWARE (Case Studi Sub DAS Cisimeut hilir HM 0+00 HM 69+00)," *Jurnal Fondasi*, vol. 5, no. 1, pp. 13-23, 2016.
- [16] R. Sihotang, M. Hazmi, and D. Rahmawati, "Design Flood Analysis Using HSS Nakayasu Method at Gintung Dam," *Proceeding of. Psikologi, Ekonomi, Sastra, Arsitektur & Sipil, Indoneisa*, 2011, vol. 4, pp. 100-106.
- [17] D. S. Saroso, I. Kristianto, and E. Rimawan, "A Framework of SCOR Model Based on Systematic Literature Review: Case Study in Micro and Small Industries in Indonesia.," *International Journal of Research and Innovation in Social Science (IJRISS)*, vol. VII, no. V, pp. 902–917, 2023, doi: 10.47772/IJRISS.2023.70571.
- [18] P. V Singh, *Elementary Hydrology*. Prentice Hal Englewood, New Jersey, 1992.
- [19] H. A. Saputri and D. D. Santika, "Flood Prediction Based on Weather and Water Level Historical Data Using Recurrent Neural Networks: A Case Study of Jakarta Flood Incidents," *International Journal of Intelligent System and Application in Engineering. IJISAE.*, vol. 10, no. 4, pp. 195–200, 2022.
- [20] A. Winatie, D. S. Saroso, H. H. Purba, and A. P. Wirani, "Reducing of defects in the drug tablets production process with DMAIC to improve quality - Study case of pharmaceutical industry," *IOP Conf Ser Mater Sci Eng*, vol. 852, no. 1, pp. 1–7, 2020, doi: 10.1088/1757-899X/852/1/012126.
- [21] A. Y. Bustommy, D. S. Saroso, and S. Hasibuan, "Improving the quality of Indihome services using Six Sigma DMAIC method: Case in industrial area," *Proceedings of the International Conference on Industrial Engineering and Operations Management*, no. November 2019, 2021, pp. 4677–4691, doi: 10.46254/an11.20210824.
- [22] S. Wu and Y. Lei, "Multiscale Flood Disaster Risk Assessment in the Lancang-Mekong River Basin: A Focus on Watershed and Community Levels," *Atmosphere (Basel)*, vol. 14, no. 4, 2023, doi: 10.3390/atmos14040657.
- [23] S. P. D. Thammadi and S. K. Pisini, "Soil Erosion mapping using Remote Sensing and GIS - A case study of Rewa River Watershed, Naitasiri province, Fiji," *IOP Conf Ser Earth Environ Sci*, vol. 1084, no. 1, pp. 1–11, 2022, doi: 10.1088/1755-1315/1084/1/012050.
- [24] Y. R. Hais, E. Saputra, A. T. I. Zk, and A. Raboula, "Design and Development of a Flood Detection Device for Drainage Systems Utilizing Float Switch Water Level Sensors.," *Jurnal Ilmiah Pendidikan Teknik Elektro*, vol. 8, no. 1, pp. 2549–3698, 2023.
- [25] R. A. Balgah, K. A. Ngwa, G. R. Buchenrieder, and J. N. Kimengsi, "Impacts of Floods on Agriculture-Dependent Livelihoods in Sub-Saharan Africa: An Assessment from Multiple Geo-Ecological Zones," *Land (Basel)*, vol. 12, no. 2, 2023, doi: 10.3390/land12020334.

- [26] J. L. Steiner *et al.*, "Environmental effects of agricultural conservation: A Framework for research in two watersheds in Oklahoma's Upper Washita River Basin," *Journal of Soil and Water Conversation*, vol. 63, no. 6, pp. 443–452, 2008, doi: 10.1016/j.jaci.2012.05.050
- [27] W. Kim, T. Iizumi, N. Hosokawa, M. Tanoue, and Y. Hirabayashi, "Flood impacts on global crop production: advances and limitations," *Environmental Research Letters*, vol. 18, no. 5, p. 54007, 2023, doi: 10.1088/1748-9326/accd85.
- [28] S. K. Sarkar *et al.*, "Developing Robust Flood Susceptibility Model with Small Numbers of Parameters in Highly Fertile Regions of Northwest Bangladesh for Sustainable Flood and Agriculture Management," *Sustainability (Switzerland)*, vol. 14, no. 7, pp. 1–24, 2022, doi: 10.3390/su14073982.
- [29] S. A. Hendrawan, A. Trihandoyo, and D. S. Saroso, "Implementing Technology Acceptance Model to measure ICT usage by smallholder farmers," *SINERGI*, vol. 27, no. 1, pp. 123–132, 2023, doi: 10.22441/sinergi.2023.1.014.
- [30] S. Suprpti, F. Hariati, A. Hidayat, N. Nuryanto, S. K. Syaja'ah, "Effectiveness of LID Infiltration Well Model Technology to Reduce Runoff in Bumi Citra Asri Housing Complex, Bogor," *Jurnal Komposit: Jurnal Ilmu-ilmu Teknik Sipil*, vol. 8, no. 1, pp. 153-162, 2024, doi: 10.32832/komposit.v8i1.14983
- [31] M. M. Haruna, A. U. Bashir, H. Ismail, M. Sani, "Modelling effects of water stress on the productivity of irrigated wheat (*Triticum Aestivum* L.) in a semiarid condition of Northeastern Nigeria," *SINERGI*, vol. 27, no. 2, pp 219-230, 2023, doi: 10.2241/sinergi.2023.2.010