Journal of Information System and Technology Research

journal homepage: https://journal.aira.or.id/index.php/jistr/

Modeling Flood Hazards in Ambon City Watersheds: Case Studies of Wai Batu Gantung

Heinrich Rakuasa[1], Benson Joshua[3], Glendy Somae[2],

[1] National Research Tomsk State University, Russian Federation
[2] University of Calabar, Nigeria
[3] Universitas Indonesia, Indonesia

ARTICLE INFO

Article history:

Received 14 April 2024
Accepted 31 May 2024
Available online 31 May 2024

Keywords:

Ambon
Flood
Geogle Eart Engine
Watershed

ABSTRACT

Flood hazard modeling in watersheds is an important step in natural disaster risk mitigation, especially in vulnerable areas such as Ambon City. This research focused on the Wai Batu Gantung, Wai Batu Gajah, Wai Tomu, Wai Batu Merah, and Wai Ruhu watersheds, using JRC Global Surface Water Mapping Layers data, NASA SRTM Digital Elevation 30 m data, and USGS Landsat 8 Level 2, Collection 2, Tier 1 data analyzed on the Google Earth Engine (GEE) platform. Prediction of built-up land in flood-prone areas was conducted by utilizing flood history analysis, hydrological modeling, and flood zone mapping. The results show that flood hazard modeling provides a better understanding of flood risk, assists in the development of safer land use planning, and increases public awareness of flood risk in Ambon City. It is hoped that the results of this research can contribute to flood risk management and sustainable regional development in the future.

Corresponding Author:

Heinrich Rakuasa
National Research Tomsk State University
Address: Lenin Ave, 36, Tomsk, Tomsk Oblast, 634050
Email: heinrich.rakuasa@yandex.ru

1. INTRODUCTION

Flood hazard modeling in river basins is an important step in natural disaster risk mitigation, especially in vulnerable areas such as Ambon City[1], [2]. Ambon City, located on Ambon Island, Maluku, is one of the important cities in Eastern Indonesia that often experiences floods due to natural and anthropogenic factors[3]. By using advanced technology such as Google Earth Engine, researchers can conduct accurate and detailed modeling of flood-prone areas around major rivers in Ambon City[4].This case study focuses on several major rivers in Ambon City, namely Wai Batu Gantung, Wai Batu Gajah, Wai Tomu, Wai Batu Merah, and Wai Ruhu. These rivers play a vital role in the lives of local communities, but they also carry the potential for serious flooding hazards, especially during the rainy season[5], [6]. Therefore, modeling flood hazards along these rivers is essential to assist the government and communities in mitigating and managing disaster risks[7], [8], [9].

Google Earth Engine is a platform that enables sophisticated spatial analysis and massive processing of satellite images[10], [11], [12]. By utilizing this technology, researchers can access high-resolution satellite imagery data from multiple sources to map and analyze topographic conditions, land use, vegetation, and other factors that affect water flow along the rivers being studied[7], [13], [14]. Flood hazard modeling with Google Earth Engine allows researchers to estimate potential flood vulnerabilities along these rivers in a high level of detail. Through careful analysis, they were able to identify flood hotspots, determine water flow patterns, and predict the potential impact of flooding on surrounding settlements and infrastructure[15], [16].

The modeling method used in this study involves processing and analyzing satellite image data using specialized algorithms available in the Google Earth Engine[17]. The steps include image segmentation, extraction of important features, such as rivers, and mapping of water flow patterns using a proven hydrological model. The results of this flood hazard modeling are expected to provide a better understanding of the water flow dynamics and potential flood risks in the studied watershed. This information can be used by local governments in spatial planning, disaster risk management, and decision-making related to infrastructure and settlement development[18]. In addition, the results of this modeling can also be the basis for the development of a more effective and accurate flood early warning system. By utilizing real-time satellite imagery data and calibrated hydrological models, early warning systems can provide early warnings to the public so that they can take preventive or evacuation measures in a timely manner[8], [19].

However, flood hazard modeling also has several challenges and limitations. One of them is the limitation of input data, especially in terms of satellite image resolution and topographic data accuracy[7], [20]. In addition, the hydrological models used also need to be calibrated and validated with field data to ensure their accuracy in predicting flood risks. Nonetheless, the use of Google Earth Engine in flood hazard modeling offers great potential in improving the understanding and mitigation of disaster risk in Ambon City and other areas prone to flooding. By continuing to develop and improve modeling methods and increasing access to quality satellite imagery data, it is hoped that flood risk mitigation and management efforts can become more effective and efficient in the future[2], [13].

2. RESEARCH METHOD

This research was conducted in the watershed of Wai Batu Gantung, Wai Batu Gajah, Wai Tomu, Wai Batu Merah and Wai Ruhu, Ambon City. This research uses JRC Global Surface Water Mapping Layers, v1.4, NASA SRTM Digital Elevation 30 m data, and USGS Landsat 8 Level 2, Collection 2, Tier 1 data analyzed on the Google Earth Engine (GEE) platform. Google Earth Engine is a cloud computing platform developed by Google for large-scale geospatial data analysis and processing [17]. By providing access to a wide range of satellite image datasets and powerful geospatial analysis tools, Google Earth Engine enables users to perform modeling, mapping, and monitoring of the earth's environment with high efficiency [18]. The platform facilitates temporal and spatial analysis, predictive model building, as well as interactive visualization of geospatial data, making it a very useful tool for researchers, scientists, and practitioners in various fields to run complex geospatial analyses without the need to download or process data locally. The flood analysis process in Google Earth Engine can be seen in Figure 1.

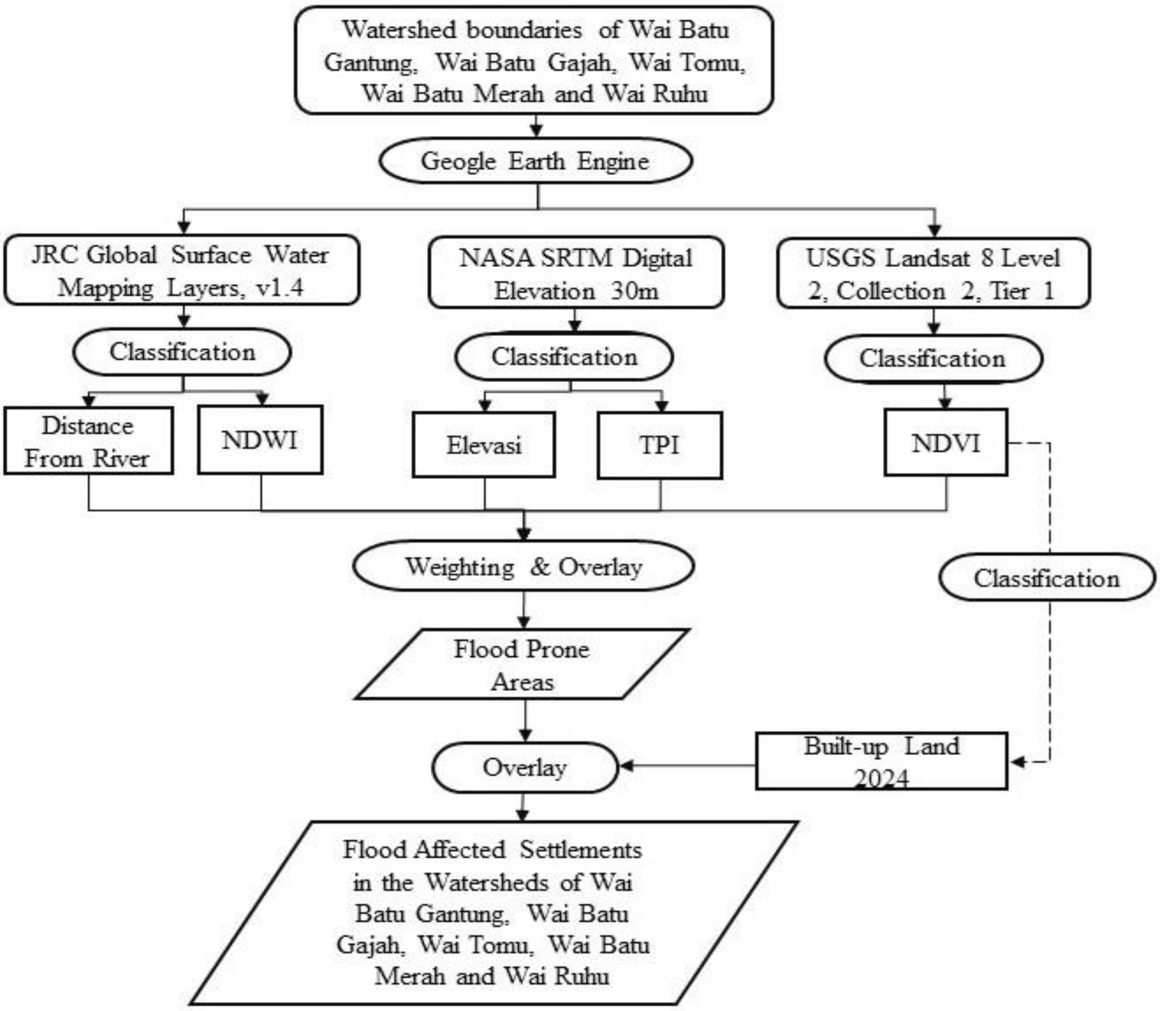

Figure 1. Workflow

The variables used in this study consisted of distance from the river, Normalized Difference Water Index (NDWI), elevation, Topographic Position Index (TPI) and Normalized Difference Vegetation Index (NDVI), all of which were analyzed on the Google Earth Engine (GEE) platform; https://earthengine.google.com. JRC Global Surface Water Mapping Layers data in Google Earth Engine (GEE) can produce Normalized Difference Water Index (NDWI) data which is very important for flood analysis[12], [21], [22]. NDWI is an index used to monitor and identify water surfaces, including rivers, lakes and other bodies of water. By utilizing NDWI data from JRC, researchers and practitioners can accurately and quickly identify waterlogged areas during flood events[23]. This information is essential for flood monitoring, mapping and risk management, enabling relevant parties to respond quickly and effectively in emergency situations and plan appropriate mitigation measures to reduce the impact of future floods[7], [8]. The flood analysis process in Google Earth Engine can be seen in Figure 1.

NASA SRTM Digital Elevation 30m data and USGS Landsat 8 Level 2 data are used to generate elevation and TPI (Topographic Position Index) which are important in flood analysis. Elevation data from SRTM allows for accurate topographic modeling, while Landsat 8 Level 2 data can be used to extract information on land texture and structure that affect surface water flow[24]. By utilizing both, users can identify low areas susceptible to inundation during floods and determine the relative topography of an area to its surroundings through TPI, thus providing more comprehensive insights in anticipating and managing flood risks[20], [25]. USGS Landsat 8 Level 2, Collection 2, Tier 1 data in Google Earth Engine (GEE) provides Normalized Difference Vegetation Index (NDVI) data that is critical for flood analysis. NDVI is an index used to measure the amount and quality of vegetation in an area based on the reflectance of near infrared and red light from the ground surface. Using NDVI data from Landsat 8, researchers and practitioners can evaluate the state of vegetation before and after flooding, which provides valuable insights into the impact of flooding on ecosystems[26], [27]. This information can be used to evaluate environmental damage, plan habitat restoration, and identify areas that may experience soil erosion or flooding after a flood event, enabling more precise and effective mitigation and adaptation efforts.

These variables are considered important in this study because, distance from the river is relevant as areas closer to the river tend to be more vulnerable to flooding. NDWI provides a clear visual indication of waterlogged areas, while elevation enables water flow modeling and identification of low areas prone to inundation. TPI provides an understanding of the relative topography of an area, while NDWI provides information on vegetation that can affect drainage and water absorption. The use of GEE allows for efficient processing and analysis of these data, enabling faster and more informed decision-making in flood risk mitigation and adaptation[22], [28]. All variables were then given weights and values before being overlaid on the Google Earth Engine (GEE) platform to produce flood-prone areas and then overlaid with data on the distribution of built-up land in the Wai Ruhu watershed to determine settlements that are predicted to be affected by flooding in the Wai Ruhu watershed, Ambon City. The whole process of analyzing flood-prone areas was carried out on the Google Earth Engine (GEE) Platform with a modified script based on previous research [10], [11], [12], [29].

3. RESULTS AND DISCUSSION

3.1. Flood Hazard Level

Flood hazard level is a measure or classification used to assess how much threat or potential damage flooding can cause in a given area. The flood hazard level usually includes several factors, including rainfall intensity, water flow velocity, topography of the area, infrastructure condition, and other human factors. This helps governments, environmental experts, and communities to take appropriate prevention and countermeasures to reduce flood risks and protect lives and property. Factors such as extreme rainfall, topography, land use, drainage systems, and river conditions can affect the level of flood vulnerability of an area. The results of the analysis of the flood hazard level of the Wai Batu Gantung, Wai Batu Gajah, Wai Tomu, Wai Batu Merah and Wai Ruhu watersheds on the Geogle Earth Engine (GEE) platform show that the area with low hazard level is 2,662.65 ha, medium hazard is 1,739.60 ha and high hazard is 543.79 ha.

Areas with high flood hazard levels are marked in red, medium flood hazard with medium color, low flood hazard marked in green. The flood hazard level of Wai Batu Gantung watershed consists of low hazard of 63.21 ha, medium hazard of 142.36 ha and high hazard of 73.25 ha. The flood hazard level of Wai Wai Ruhu watershed consists of low hazard of 278.44 ha, medium hazard of 278.44 ha and high hazard of 87.74 ha. The flood hazard level of Wai Wai Batumerah watershed consists of low hazard of 75.03 ha, medium hazard of 170.22 ha and high hazard of 38.20 ha. The flood hazard level of Wai Tomu watershed consists of low hazard of 114.03 ha, medium hazard of 91.56 ha and high hazard of 80.58 ha. The flood hazard level of Wai Batu Gajah watershed consists of low hazard of 65.39 ha, medium hazard of 61.22 ha and high hazard of 78.39 ha. Assessing the level of flood hazard is important to assist in flood risk mitigation planning, developing early warning systems, and increasing preparedness in the face of flood disasters. By understanding the level of flood vulnerability, relevant parties can identify vulnerable areas and take preventive or adaptive measures to reduce the adverse impacts of flooding. The map of flood hazard levels in the watersheds of Wai Batu Gantung, Wai Batu Gajah, Wai Tomu, Wai Batu Merah and Wai Ruhu can be seen in Figure 2.

3.2. Predicted built-up land located in flood hazard areas

Predictions of potential built-up land in flood-prone areas of the Wai Batu Gantung, Wai Batu Gajah, Wai Tomu, Wai Batu Merah, and Wai Ruhu watersheds can be made using historical flood analysis, hydrological modeling, and flood zone mapping. By combining historical flood data, geographical characteristics of the rivers and topography in the area, and predictions of potential water flows in flood scenarios, experts can identify areas most vulnerable to flooding, assisting stakeholders in safer and more effective land use planning in the future.. Predicting flood-affected residential areas is the process of estimating areas around rivers or other flood-prone areas that are likely to be inundated or affected during a flood. The results of the analysis of the flood vulnerability level of the Wai Batu Gantung, Wai Batu Gajah, Wai Tomu, Wai Batu Merah, and Wai Ruhu watersheds on the Geogle Earth Engine (GEE) platform are then overlaid with built-up land data extracted from Normalized Difference Vegetation Index (NDVI) data which shows that residential areas are in flood-prone areas. The spatial map of flood-affected settlements can be seen in Figure 3

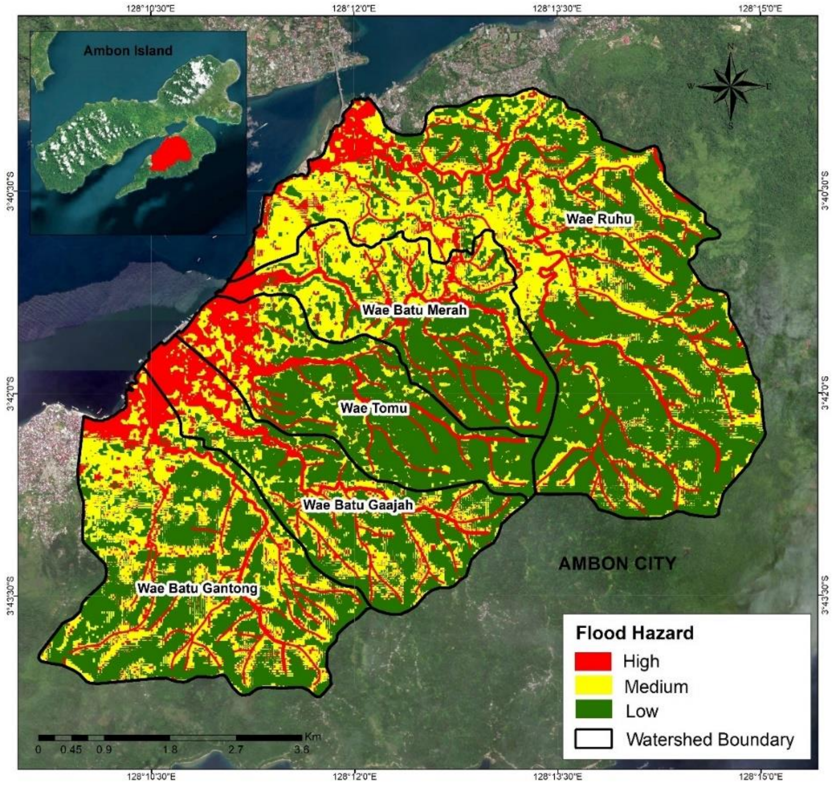

Figure 2. Flood Hazard Map

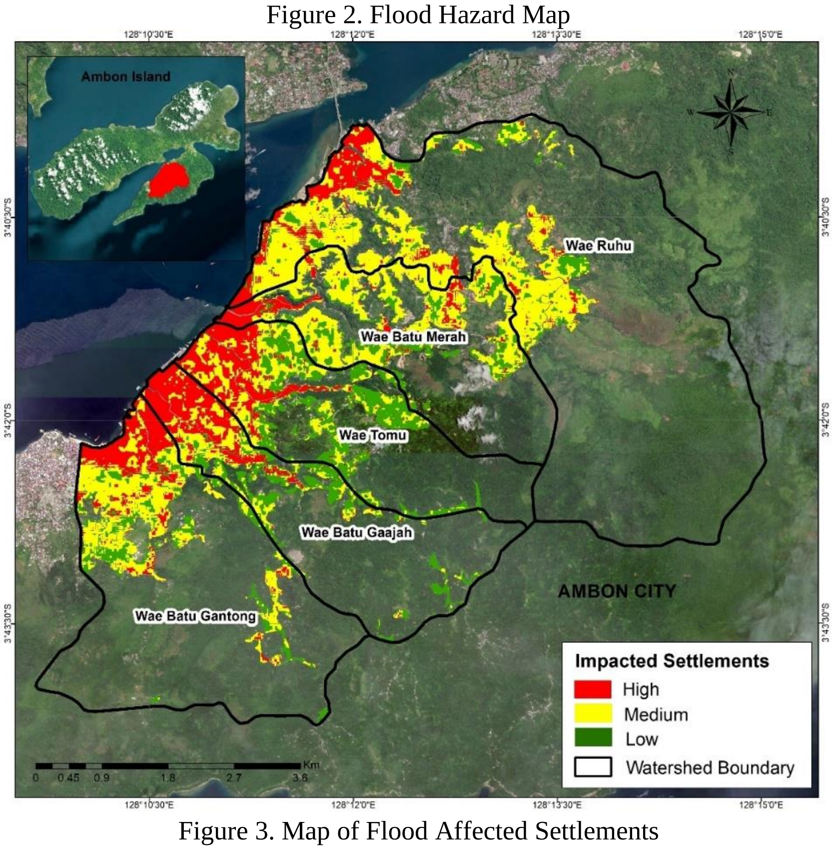

Figure 3. Map of Flood Affected Settlements

The analysis results show that settlements predicted to be in high flood hazard areas are 543.79 ha, settlements predicted to be in moderate hazard areas are 1,739.60 ha and settlements predicted to be in low flood hazard areas are 2,662.65 ha. Settlements predicted to be affected by flood hazards in the Wai Wai Ruhu watershed consist of low hazard of 1048.45 ha, medium hazard of 725.23 ha and high hazard of 165.34 ha. Settlements predicted to be affected by flood hazards in the Wai Batu Gantung watershed consist of low hazard of 538.98 ha, medium hazard of 425.25 ha and high hazard of 125.63 ha. Settlements predicted to be affected by flood hazards in the Wai Tomu watershed consist of low hazard of 406.70 ha, medium hazard of 126.13 ha and high hazard of 87.79 ha. Settlements predicted to be affected by flood hazards in the Wai Batu Gajah watershed consist of a low hazard of 326.26 ha, a medium hazard of 205.74 ha and a high hazard of 109.52 ha. Settlements predicted to be affected by flood hazards in the Wai Batumerah watershed consist of a low hazard of 342.26 ha, a medium hazard of 257.25 ha and a high hazard of 55.52 ha.

The flood hazard modeling study in the Ambon watershed, particularly in the case of Wai Batu Gantung, Wai Batu Gajah, Wai Tomu, Wai Batu Merah, and Wai Ruhu, provided several significant benefits: (1) Better Understanding of Flood Risk: The study helps in understanding the potential flood risk in the area by analyzing the pattern and intensity of flooding that has occurred and predicting the potential for future flooding. This enables the government and stakeholders to take appropriate mitigation measures. (2) Development of Better Land Use Planning: By understanding the zones most vulnerable to flooding, the modeling can assist in the development of safer and more sustainable land-use planning. This includes restrictions on development in high-risk areas as well as the promotion of better drainage infrastructure. (3) Preparation for Climate Change: By considering climate change in the modeling, the study helps in preparing for the impacts of floods that may become more frequent or intense in the future due to changes in extreme weather. (4) Public Awareness Raising: Information from this study can be used to raise public awareness about flood risks in the area. This can help people to take personal measures in preparation for flooding, such as the development of evacuation plans and investment in self-protection infrastructure. Thus, the flood modeling study in the Ambon watershed provides a solid foundation for better decision-making in flood risk management, environmental protection, and sustainable regional development.

4. CONCLUSION

It can be concluded that flood hazard modeling provides significant benefits in understanding flood risks, developing safer land use planning, preparing for climate change, and raising public awareness. By analyzing existing flood patterns and predicting potential future floods, this research provides a solid basis for appropriate mitigation measures, sustainable infrastructure development, and improved flood preparedness. It is hoped that the results of this research can make a positive contribution to flood risk management, environmental protection and sustainable regional development in the future.

REFERENCES

[1] P. C. Latue and H. Rakuasa, “Spatial Analysis of Landscape Suitability of Ambon City for Settlement Using Geographic Information System,” *J. Ris. Multidisiplin dan Inov. Teknol.*, vol. 1, no. 02, pp. 59–69, 2023, doi: 10.59653/jimat.v1i02.218.

[2] H. Rakuasa, J. K. Helwend, and D. A. Sihasale, “Pemetaan Daerah Rawan Banjir di Kota Ambon Menggunakan Sistim Informasi Geografis,” *J. Geogr. Media Inf. Pengemb. dan Profesi Kegeografian*, vol. 19, no. 2, pp. 73–82, Dec. 2022, doi: 10.15294/jg.v19i2.34240.

[3] H. Rakuasa, D. A. Sihasale, M. C. Mehdila, and A. P. Wlary, “Analisis Spasial Tingkat Kerawanan Banjir di Kecamatan Teluk Ambon Baguala, Kota Ambon,” *J. Geosains dan Remote Sens.*, vol. 3, no. 2, pp. 60–69, Nov. 2022, doi: 10.23960/jgrs.2022.v3i2.80.

[4] C. Latue, Philia, J. S. Imanuel Septory, G. Somae, and H. Rakuasa, “Pemodelan Daerah Rawan Banjir di Kecamatan Sirimau Menggunakan Metode Multi-Criteria Analysis (MCA),” *J. Perenc. Wil. dan Kota*, vol. 18, no. 1, pp. 10–17, Mar. 2023, doi: 10.29313/jpwk.v18i1.1964.

[5] S. Oei, “Group Decision Support System for Business Place Establishment using Fuzzy SAW Borda,” *J. RESTI (Rekayasa Sist. dan Teknol. Informasi)*, vol. 4, no. 5, pp. 964–969, Oct. 2020, doi: 10.29207/resti.v4i5.2459.

[6] H. Rakuasa, D. A. Sihasale, and P. C. Latue, “MODEL TUTUPAN LAHAN DI DAERAH ALIRAN SUNGAI KOTA AMBON TAHUN 2031MODEL TUTUPAN LAHAN DI DAERAH ALIRAN SUNGAI KOTA AMBON TAHUN 2031: STUDI KASUS DAS WAI BATU GANTUNG, WAI BATU GAJAH, WAI TOMU, WAI BATU MERAH DAN WAI RUHU,” *J. Tanah dan Sumberd. Lahan*, vol. 9, no. 2, pp. 473–486, Jul. 2022, doi: 10.21776/ub.jtsl.2022.009.2.29.

[7] J. Jakubik, M. Muszynski, M. Vossing, N. Kuhl, and T. Brunschwiler, “Toward Foundation Models for Earth Monitoring: Generalizable Deep Learning Models for Natural Hazard Segmentation,” in *International Geoscience and Remote Sensing Symposium (IGARSS)*, 2023. doi: 10.1109/IGARSS52108.2023.10282643.

[8] A. Mehta and K. S. Rawat, “Monitoring flash flood using Optical and Microwave Sensor dataset:- A case study of Cachar district, Assam (India),” in *Proceedings - IEEE International Conference on Device Intelligence, Computing and Communication Technologies, DICCT 2023*, 2023. doi: 10.1109/DICCT56244.2023.10110185.

[9] J. M. A. Opella and A. A. Hernandez, “Developing a Flood Risk Assessment Using Support Vector Machine and Convolutional Neural Network: A Conceptual Framework,” in *Proceedings - 2019 IEEE 15th International Colloquium on Signal Processing and its Applications, CSPA 2019*, 2019. doi: 10.1109/CSPA.2019.8695980.

[10] M. B. Ujjinakoppa, U. Kumar, R. Thottolil, and A. Dasgupta, “Multimodal and Multitemporal Spatial Data Analysis in Google Earth Engine Cloud Computing Platform to Detect Human Settlements Without Electricity: A Case Study of Bangalore City,” in *2021 IEEE India Geoscience and Remote Sensing Symposium, InGARSS 2021 - Proceedings*, 2021. doi: 10.1109/InGARSS51564.2021.9792041.

[11] T. Yang and Y. Wang, “STUDYING SPATIOTEMPORAL FRACTIONAL VEGETATION COVER VARIATIONS FROM 2000 TO

2020 IN CHANGJIANG BASIN, CHINA WITH GOOGLE EARTH ENGINE," in *International Geoscience and Remote Sensing Symposium (IGARSS)*, 2021. doi: 10.1109/IGARSS47720.2021.9553983.
[12] P. S. Thenkabail *et al.*, "Global Cropland-Extent Product at 30-m Resolution (GCEP30) Derived from Landsat Satellite Time-Series Data for the Year 2015 Using Multiple Machine-Learning Algorithms on Google Earth Engine Cloud," *US Geol. Surv. Prof. Pap.*, vol. 2021, no. 1868, 2021, doi: 10.3133/pp1868.
[13] H. Rakuasa and P. C. Latue, "ANALISIS SPASIAL DAERAH RAWAN BANJIR DI DAS WAE HERU, KOTA AMBON," *J. Tanah dan Sumberd. Lahan*, vol. 10, no. 1, pp. 75–82, Jan. 2023, doi: 10.21776/ub.jtsl.2023.010.1.8.
[14] A. Bris *et al.*, "KNIGHTS, RAIDERS, AND TARGETS - THE IMPACT OF THE HOSTILE TAKEOVER - COFFEE,JC, LOWENSTEIN,L, ROSEACKERMAN,S," *J. Bank. Financ.*, vol. 37, no. 1, 2021.
[15] A. Ospan, M. Mansurova, E. Kakimzhanov, and B. Aldakulov, "KazRivDyn: Toolkit for Measuring the Dynamics of Kazakhstan Rivers with a Graphics Based on Google Earth Engine," in *SIST 2021 - 2021 IEEE International Conference on Smart Information Systems and Technologies*, 2021. doi: 10.1109/SIST50301.2021.9465902.
[16] A. Yang, B. Zhong, and J. Wu, "Monitoring winter wheat in ShanDong province using Sentinel data and Google Earth Engine platform," in *2019 10th International Workshop on the Analysis of Multitemporal Remote Sensing Images, MultiTemp 2019*, 2019. doi: 10.1109/Multi-Temp.2019.8866975.
[17] A. Ikhwan and N. Aslami, "Implementasi Data Mining untuk Manajemen Bantuan Sosial Menggunakan Algoritma K-Means," *JurTI (Jurnal Teknol. Informasi)*, vol. 4, no. 2, 2020, [Online]. Available: http://jurnal.una.ac.id/index.php/jurti/article/view/2103
[18] A. C. Cuellar, L. Cenci, C. Santella, and C. Albinet, "Evaluating the Copernicus Dem Dataset Potential for the Identification of (Flash) Flood-Prone Areas by Using a Geomorphological Approach," in *International Geoscience and Remote Sensing Symposium (IGARSS)*, 2022. doi: 10.1109/IGARSS46834.2022.9884948.
[19] N. Gopinath, J. Aruneraj, and V. B. Ragul, "IoT based model for flood warning system in waterfall," in *2022 1st International Conference on Computational Science and Technology, ICCST 2022 - Proceedings*, 2022. doi: 10.1109/ICCST55948.2022.10040286.
[20] U. Shastrakar, P. Ghule, A. Jagtap, and V. Degaonkar, "Flood risk mapping using GIS of Mumbai District, India," in *Proceedings - 2023 3rd International Conference on Innovative Sustainable Computational Technologies, CISCT 2023*, 2023. doi: 10.1109/CISCT57197.2023.10351332.
[21] X. Zhang and X. Liu, "Comparative study on Extraction of banded water and surface water in urban area based on MNDWI," in *2022 3rd International Conference on Geology, Mapping and Remote Sensing, ICGMRS 2022*, 2022. doi: 10.1109/ICGMRS55602.2022.9849259.
[22] Y. A. Liou, M. S. Le, and H. Chien, "Normalized Difference Latent Heat Index for Remote Sensing of Land Surface Energy Fluxes," *IEEE Trans. Geosci. Remote Sens.*, vol. 57, no. 3, 2019, doi: 10.1109/TGRS.2018.2866555.
[23] W. M. Wilda and L. Hanum, "Information System Application Alanysis And Design Web-Based Network Complaints Using Php And Bootsrap On Diskominfo," *J. Inf. Syst. Technol. Res.*, vol. 1, no. 2, pp. 68–78, May 2022, doi: 10.55537/jistr.v1i2.131.
[24] C. Kelleher and L. McPhillips, "Exploring the application of topographic indices in urban areas as indicators of pluvial flooding locations," *Hydrol. Process.*, vol. 34, no. 3, pp. 780–794, Jan. 2020, doi: 10.1002/hyp.13628.
[25] H. Darabi *et al.*, "Urban flood risk mapping using data-driven geospatial techniques for a flood-prone case area in Iran," *Hydrol. Res.*, vol. 51, no. 1, 2020, doi: 10.2166/nh.2019.090.
[26] K. T. Huang, "Mapping the Hazard: Visual Analysis of Flood Impact on Urban Mobility," *IEEE Comput. Graph. Appl.*, vol. 41, no. 1, 2021, doi: 10.1109/MCG.2020.3041371.
[27] I. S. Raungratanaamporn, J. Klaylee, S. Chayaphong, and V. Sornlertlamvanich, "Quantifying Flood Risk and its Exposure Using Catastrophic Model. A Case Study of the Pathumthani Province," in *ICBIR 2022 - 2022 7th International Conference on Business and Industrial Research, Proceedings*, 2022. doi: 10.1109/ICBIR54589.2022.9786410.
[28] L. Chai *et al.*, "Estimating Corn Canopy Water Content from Normalized Difference Water Index (NDWI): An Optimized NDWI-Based Scheme and Its Feasibility for Retrieving Corn VWC," *IEEE Trans. Geosci. Remote Sens.*, vol. 59, no. 10, 2021, doi: 10.1109/TGRS.2020.3041039.
[29] K. Djerriri, A. Safia, and R. Adjoudj, "Object-Based Classification of Sentinel-2 Imagery Using Compact Texture Unit Descriptors Through Google Earth Engine," in *2020 Mediterranean and Middle-East Geoscience and Remote Sensing Symposium, M2GARSS 2020 - Proceedings*, 2020. doi: 10.1109/M2GARSS47143.2020.9105181.