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Bridging Hydrology and Environmental Geography in Disaster Rehabilitation: Insights from the 2016 Bedugul-Baturiti Natural Disaster

Wa Ode Annisha Munasari*, Guntur Bagus Pamungkas

Universitas Terbuka, Urban and Regional Planning Study Program, Tangerang Selatan, Banten, Indonesia, 15437

Abstract - The study seeks to integrate hydrology and environmental geography in sustainable land rehabilitation following the 2016 hydrometeorological disaster in Bedugul-Baturiti, Bali. This paper also aims to emphasize the importance of understanding the integration between interrelated disciplines. When these fields are comprehended together, they can foster greater awareness and understanding of the importance of environmental sustainability within a given region. The method used for this study include field observations, GIS Mapping, and community involvement to rehabilitation efforts. The study aims to offer an adaptable post-disaster rehabilitation framework for regions affected by similar disasters and the importance of understanding between hydrological and geographical environment in the region.

Keywords: environmental geography, land rehabilitation, hydrometeorological, bedugul-baturiti

1 Introduction

Indonesia is a region that is highly prone to natural disasters [14]. Besides being located between two major oceans, it links mainland Asia with the Pacific world [16]. This archipelago also has several active volcanoes. Therefore, the climate in Indonesia plays an important role in determining the occurrence of various natural disasters. Indonesia has implemented early warning systems for several types of natural disasters that frequently occur in the country. Mitigation efforts also include disaster education and simulation activities in schools and communities, although these initiatives have not yet been evenly distributed or fully integrated across all regions [6, 7, 10]. Although Indonesia frequently faces the risk of natural disasters, the understanding and integration of interdisciplinary knowledge remain limited. As a result, responses often focus solely on rehabilitation efforts. However, interdisciplinary understanding is crucial to ensure long-term resilience and sustainability of affected areas [9].

The Bedugul-Baturiti is located in central of Bali, surrounded by mountains and lakes, it is known for its cool climate, rich biodiversity, its agrotourism area [6]. In December 2016, Hydrometeorological disasters such as flash floods and landslides pose significant challenges in several regions of Indonesia [15]. These events are caused by climate change and environmental degradation. One of the significant impacts happened in Bedugul-Baturiti area of Bali. It caused serious damage to infrastructure, agricultural land and local ecosystem, including blocking important

*Corresponding Author: infoannishaode9@gmail.com

access to vital roads. One of the most affected sites was Pura Teratai Bang, located in the area of Bali Botanical Garden, with estimated of damages at 5 billion Rupiah.

However, this is was not the first time this area faced this disaster. Similar disaster with smaller-scale were also recorded in the Tabanan Region including Bedugul-Baturiti, in number total of 31 natural disasters have occurred over the past 10 years [4].

Moreover, this study combines two disciplines to address the impact of disasters and offer more comprehensive rehabilitation solutions. Hydrology is used to analyze water flow patterns and erosion potential caused by flashfloods. Meanwhile, environmental geography helps in understanding the interaction between the environmental geograph and human activities, particularly in the context of land use and environmental management as [17] explained.

This multidisciplinary approach offers a more comprehensive framework by considering both ecological processes and human-environemnt interactions. Until now, most disaster mitigation and land rehabilitation efforts in Indonesia relied on mono disciplinary approach and often lack to address the complex and interlinked nature of post-disaster conditions. Although the integrated models this study using are still rarely applied in post-disaster land rehabilitation in Indonesia, This study aims to fill that gap by demonstrating the potential of combining these two disciplines to produce sustainable strategies.

2 Materials and Methods

The methodology used in this observation mixed methods approach, combining qualitative field observations and spatial analysis with quantitative secondary data. The study was conducted in Bedugul-Baturiti, a highland area in Bali with a history of hydrometeorological disasters. Primary data included on-site observations using GPS, photographic documentation, and semi-structured interviews with 15 residents and 1 local authorities. Secondary data sources included satellite imagery (Google Earth Pro), QGIS-based land use maps, and official government reports from BNPB.

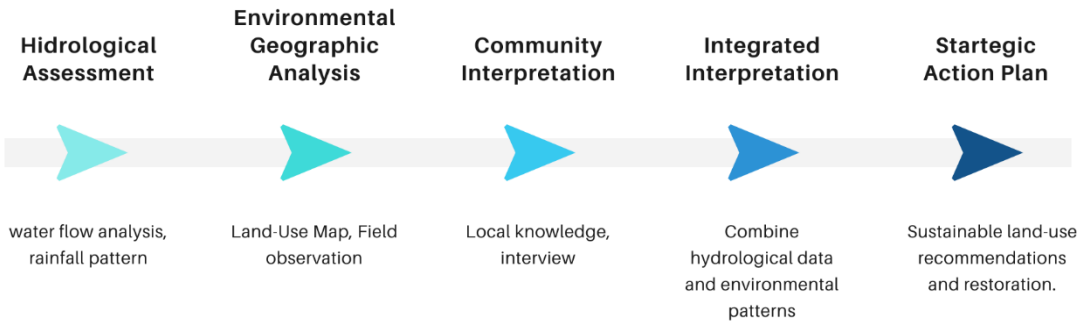

Fig. 1. Framework of Integrated Hydrological and Environmental

3 Results and Discussion

3.1 Physical Description

The topography of Bedugul-Baturiti is characterized by prominent mountainous features, with approximately 1,200 to 1,500 meters above sea level. Bedugul Bedugul consists of a basin area set in a volcanic mountain region [1]. The climate in Bedugul-Baturiti is characterized by cool and humid

conditions throughout the day. In the morning, the temperature typically ranges from 14°C to 18°C, with high humidity levels of 85% to 90%. During the day, the temperature starts to rise, reaching 20°C to 24°C with humidity decreases slightly to 75% to 85%. At night, temperatures drop again to between 13°C and 17°C, with humidity above 90% [3].

Meanwhile, the area experiences significant rainfall. Most of this rainfall occurs during the rainy session. Which lasts from October to April, when rain often falls regularly every day, particularly in the afternoon and evening when temperatures are at their lowest. At the time, several regions in Indonesia experiencing several disasters and similar events with Baturiti region [8, 11, 12, 13].

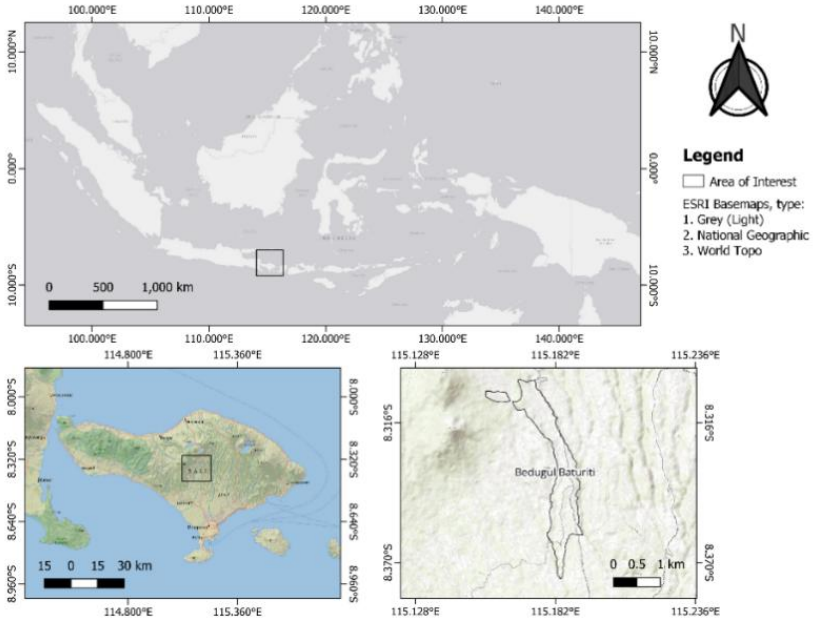

Fig. 2. Map of the Case Study Location Bedugul-Baturiti

Table 1. Number of Disasters, Damaged and their Impacts December 2016 in Indonesia

Type of Disasters	Number of Events	Damages		
		Severely Damaged House	Moderately Damaged House	Lightly Damaged House
Whirlwind	69	93	77	950
Landslide	65	45	42	100
Flood	49	951	773	83
Flood & Landslide	2	-	-	
Earthquake	1	2.561	2.562	4.184
Tidal Wave/Abrasion	1	-	-	6

Data as of January 1, 2017

The present study revealed that post-disaster land recovery in Bedugul-Baturiti has reached 85%, although hill area still faces the risk of erosion and needs additional mitigation. Land use has also impacted water flow patterns and erosion processes. In the case of Bedugul-Baturiti, the increased of agriculture, tourism and residential areas has makes change to the land use that lead to the loss of vegetation that can be serves as an erosion barrier.

3.2 Land Use

Fig. 3. Satelite Imagery history imagery of land use (Google Earth Pro)

Figure 3 shows significant land use and expansion over 5 years prior to the flooding and landslides. Furthermore, it also illustrates that the 2016 satelite imagery captured the extreme weather conditions of La Nina at that time, which lasted over a month, leading to the hydrometeorological disaster in the Bedugul-Baturiti area.

Population growth is one of the main reasons for land-use change, especially in Bedugul, which is known as a tourist area. Some lands have been turned into buildings and tourism developments. This change affects the physical resilience of the land.

Although community participations are highly involved in post-disaster rehabilitation efforts, maintaining environmental strong and safe needs a good understanding of both hydrology and environmental geography. By combining these two disciplines can helps to manage the land better for long-term.

Moreover, the land-use change can contribute to climate change due to several factors. For many of farmers, it can bring a positive economic benefits. However, farmers also need to be aware and consider the potential of the long-term risks. Farmers must approach land-use change with consideration of both the economic benefits and the environmental consequences [2].

3.3 Field Observation Result Before and After Disaster

Fig. 4. The image shows severe damage in the Bedugul-Baturiti area in 2016

Field observation conducted in the affected areas following the flash floods and landslides, as shown in the images above. The extent of damage caused by the flash floods and landslides including destruction of infrastructure and the surrounding environment in Bedugul-Baturiti area.

The left image illustrtates the aftermath of landslides that impacted a local cultural and religious site, Pura Teratai Bang in Bali Botanical Garden. Meanwhile, the right image shows damage to road

infrastructure, which is important for access in the area. As mentioned, both flashfloods and landslides affects not only the environment but also local communities.

Fig. 5. Rehabilitation progress at Pura Teratai Bang, illustrating significant changes between 2016 and 2024.

Pura Teratai Bang has shown significant recovery since the 2016 disaster, Land use and reconstruction have stabilized with more careful management than last. However, some areas still needs additional mitigation structures, especially around landslide-prone regions, particularly in populated areas near cliffs. Land use for agriculture has also been reorganized to reduce the risk of future damage. This method is consisted with the approach outlined by [5], where flood risk and the land rehabilitation are assessed using field observation to track environmental changes over time. Its provide visual of successful rehabilitation that have reduced the vulnerability of the area to future flood risks. However, continuous rehabilitation without a full understanding of the site's natural characteristics could lead to further environmental stress, particularly in areas with cultural significance and ecological fragility.

Fig. 6. The Rehabilitation Location in local access as the significant impact for local communities.

These following images shows the success of land-use rehabilitation with restored road access and efforts to mitigate future environmental risks. This comparison helps assess the effectiveness of rehabilitation strategies in the region. However, although post-disaster rehabilitation—as shown in the image—provides many benefits, it can also lead to negative impacts if not carefully planned and implemented. Without a proper understanding of the area's resilience and environmental conditions, rehabilitation efforts may proceed without an environmental foundation. For example, roads that are rebuilt might open access to forested areas or landslide-prone zones, potentially triggering uncontrolled land expansion and land-use conversion. This could ultimately increase environmental vulnerability and lead to further ecological degradation.

3.4 Community Engagement

Fig. 7. The role of the local community in the rehabilitation process

The rehabilitation process involved the participation of both the local community and thegovernment. In this case, the community worked together to repair several places of temple and especially the main roads used for public access. The tools used by community were manual tools like hoes, saws, and similar equipment. Additionally, the government provided support and directly participated in rehabilitation efforts. In this section, we could see that the participations and collaboration from both the local community and the government are important.

3.5 Integrating Disciplines

The intersection between hydrology and environmental geography in this study lies in the integration of physical environmental data such as rainfall patterns, waterflow, and erosion-prone zones. Hydrology provides quantitative understanding of disaster causes. Environmental geography contextualizes the impact of physical forces in relation to land use, settlement patterns, community vulnerability and local participation.

By combining and understanding these aspects, the study is able to identify risk zones and prioritize actions for sustainable land rehabilitation. This approach can also be applied to other regions vulnerable to similar disasters, especially where land use does not align with environmental capacity. In this way, rehabilitation becomes not only technical but also socially adaptive.

4 Conclusion

This study emphasizes the importance of understanding the integration between hydrology and environmental geography at the local level to reduce the severe impacts of natural disasters. It also recommends applying a rehabilitation model based on the understanding of these two disciplines, while involving the local community in other areas that are also prone to similar disasters. Community involvement in the rehabilitation process is crucial. However, local communities need a better understanding of water flow patterns and the physical conditions of the land, especially in relation to land use. Applying these two areas of knowledge can raise awareness about the importance of maintaining ecosystem resilience and encouraging environmental awareness.

Using the case study of the 2016 flash flood and landslide in Bedugul-Baturiti, the research found that a combination of spatial analysis, field observation, and community participation has enabled around 85% land recovery in the area. However, vulnerable zones, especially hillside regions, are still at risk and require further mitigation efforts. Ultimately, successful post-disaster land rehabilitation depends not only on technical interventions but also on socio-environmental integration through knowledge sharing, policy alignment, and community empowerment.

An additional recommendation is the importance of understanding the natural resources, resilience, and environmental geography of a region—especially when the area functions as a tourism zone. Without an interdisciplinary understanding, issues such as land expansion may occur without proper knowledge of the land's capacity and local climate patterns.

If rehabilitation is carried out repeatedly without addressing the root causes, the process becomes temporary and unsustainable. Erosion will continue, and financial resources will be repeatedly spent on the same problems. For example, if land in a landslide-prone area is rebuilt without considering slope gradients and drainage systems, future disasters are likely to occur—and possibly with even more severe consequences.

References

[1] Böhlen, M., Liu, J., & Iryadi, R. (2022). Who Speaks for The Forest? Local Knowledge, Participatory Mapping and Collaborative Evaluation for GIS Analysis in The Tropics of Central Bali, Indonesia. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *XLVIII-4-W1-2022*(4/W1-2022), 73–80. https://doi.org/10.5194/ISPRS-ARCHIVES-XLVIII-4-W1-2022-73-2022

[2] Casanova Noviyanti, E. & Sutrisno, I. (2024). *Analisis Dampak Alih Fungsi Lahan Pertanian Terhadap Pendapatan Petani di Kabupaten Mimika*.

[3] Curah Hujan - Tabel Statistik - Badan Pusat Statistik Kabupaten Tabanan. (2025). Retrieved April 14, 2025, from https://tabanankab.bps.go.id/id/statistics-table/2/NzYjMg==/curah-hujan.html

[4] Data Informasi Bencana Indonesia (2025). Retrieved April 13, 2025, from https://dibi.bnpb.go.id/statistik_menurut_wilayah

[5] Diaconu, D. C., Costache, R., & Popa, M. C. (2021). An Overview of Flood Risk Analysis Methods. *Water 2021, Vol. 13, Page 474*, *13*(4), 474. https://doi.org/10.3390/W13040474

[6] Fathani, T. F., Karnawati, D., Wilopo, W., & Setiawan, H. (2023). *Strengthening the Resilience by Implementing a Standard for Landslide Early Warning System*. 277–284. https://doi.org/10.1007/978-3-031-16898-7_20/FIGURES/6

[7] Husrin, S., Annunziato, A., Prasetya, G.S., & Hidayat, R. (2022). IDSL for Tsunami Early Warning System in Indonesia. *IOP Conference Series: Earth and Environmental Science*, *1117*(1), 012028. https://doi.org/10.1088/1755-1315/1117/1/012028

[8] Kade, I. B., Manuaba, A., Made Atmaja, D., Krisna, W., & Putra, E. (2021). Identifikasi Potensi Ancaman Bencana Tanah Longsor Berbasis Sistem Informasi Geografis di Kecamatan Baturiti Kabupaten Tabanan. *Jurnal ENMAP (Environment and Mapping)*, *2*(1), 15–20. https://doi.org/10.23887/EM.V2I1.33374

[9] Maryono, J. I. M., Seruningtyas, K., Roynaldi, A.D., Fuady, M., Munadi, R., & K Fuady, M. A. (2021). Disaster Mitigation in Indonesia: Between Plans and Reality. *IOP Conference Series: Materials Science and Engineering*, *1087*(1), 012011. https://doi.org/10.1088/1757-899X/1087/1/012011

[10] Nikonovas, T., Spessa, A., Doerr, S. H., Clay, G. D., & Mezbahuddin, S. (2022). ProbFire: A Probabilistic Fire Early Warning System for Indonesia. *Natural Hazards and Earth System Sciences*, *22*(2), 303–322. https://doi.org/10.5194/NHESS-22-303-2022

[11] Putra, A. C. P., Widhaningtyas, T. U., & Fariz, T. R. (2024). Pemetaan Lahan Kritis Untuk Kajian Penataan Ruang di Kabupaten Tabanan. *Plano Madani: Jurnal Perencanaan Wilayah Dan Kota*, *13*(2), 188–199. https://doi.org/10.24252/JPM.V13I2.40000

[12] Ramadhan, R., Marzuki, M., Suryanto, W., Sholihun, S., Yusnaini, H., Muharsyah, R., & Hanif, M. (2022). Trends in Rainfall and Hydrometeorological Disasters in New Capital City of Indonesia from Long-Term Satellite-Based

Precipitation Products. *Remote Sensing Applications: Society and Environment*, *28*, 100827. https://doi.org/10.1016/J.RSASE.2022.100827

[13] Setiyono, H., Bambang, A. N., Helmi, M., & Yusuf, M. (2022). Effect Rainfall Season on Coastal Flood in Semarang City, Central Java, Indonesia. *International Journal of Health Sciences*, *6*(I), 7584–7595. https://doi.org/10.53730/IJHS.V6NS1.6618

[14] Simanjuntak, T., & Ririmasse, M. (2021). Archaeology of Disaster in Indonesia: Where are We Now? *Berita Sedimentologi*, *47*(3), 17–21. https://doi.org/10.51835/bsed.2021.47.3.351

[15] Sujarwo, W. (2019). Bedugul Portrait: An Ethnoecological Study of The Relationship Between Man and The Environment. *Jurnal Wilayah Dan Lingkungan*, *7*(1), 52. https://doi.org/10.14710/jwl.7.1.52-62

[16] Tumonggor, M. K., Karafet, T. M., Hallmark, B., Lansing, J. S., Sudoyo, H., Hammer, M. F., & Cox, M. P. (2013). The Indonesian Archipelago: An Ancient Genetic Highway Linking Asia and the Pacific. *Journal of Human Genetics*, *58*(3), 165–173. https://doi.org/10.1038/jhg.2012.154

[17] Zimmerer, K. S. (2017). Geography and the Study of Human–Environment Relations. In *International Encyclopedia of Geography* (pp. 1–23). Wiley. https://doi.org/10.1002/9781118786352.wbieg1028