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Suitability Analysis of Tourist Accommodation Locations Towards Landslide Hazard In Malaka Village, North Lombok Regency

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ABSTRACT

Malaka Village is located in the southwest part of North Lombok Regency. The natural beauty of wavy landscape along coastal area has attracted many tourist-accommodation investments took place in this village, although this brings up a dilemma since the potential economic growth in this place faces a complex natural hazard, especially landslides. The purpose of this study is to get an overview of landslide hazard and examine location suitability of tourist accommodation sites in this area, which can later be used as a reference in advocating disaster risk reduction (DRR) measures. The method used in determining landslide hazard index is spatial (GIS) technique that accommodates variables of: slope rise, rock type, land cover, and rainfall. Based on the weighted overlay result, it is concluded that landslides in Malaka can be devastating (dominated by high hazard), which is confirmed by landslide occurrences at the end of 2022 that were very close to the accommodation sites. Also, an occurrence in 2021 has killed a resident in this village. Digital data on tourism-business locations within this area were taken from online platforms and combined with the findings of a geospatial-based landslide analysis. Based on the suitability analysis through an overlay and buffering operation towards accommodation-location and landslide-hazard layer, it is found that 6 of 30 accommodation sites in Malaka are categorized as low suitability accommodation or dominated by a high and very high hazard category. After comparing landslide features on a related literature and characteristics of past landslides in this area, it is suggested that landslides in Malaka are in form of translational-landslide and rockfall type. Collaborative mitigation efforts that are adapted to the landslide hazard problems are urgently needed to prevent high risks in the future.

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1. INTRODUCTION

Landslide is a movement of soil down a slope that happens when the stability of rock or soil makes up the slope is disturbed (Sunarta, et al., 2018). Landslides generally occur in a sloping area due to the influence of gravity by soil or rock mass. However, slope is not the only factor that affects landslide hazards. According to Husain (2015), slope movement also depends on the type of rock or soil, geological structure, rainfall, vegetation cover and land use on the slopes. Highland & Bobrowsky (2008) divided the triggering factors of landslide into two main factors: natural and man-made factors. Natural factors have three main types of mediums: water, volcanic eruption, and seismic activity, while human-made triggers may be in form of vegetation removal, slope destabilization, drainage pattern change, etc.

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With its complex morphology and tropical climate, Indonesia is an ideal place for landslides to occur. According to DIBI, an Indonesia's disaster-database platform developed by BNPB (www.dibi.bnpb.go.id), there have been 7,178 landslide occurrences in Indonesia since 2014. This figure has led to a significant impact for Indonesia especially locations where the landslides happened, both in live and property loss.

Landslide identification is indeed essential, especially in areas that attract people to visit so that the impact attributed to landslide can be prevented. Unfortunately, not all such stakeholders as tourist destination authority have sufficient information about landslide hazards that potentially harm their areas so that some landslide events have caused considerable losses in some tourist destination areas. Not only tourism authorities, government institutions in Indonesia (especially local disaster management agencies) still face obstacles in presenting detailed information on disaster risks (UNISDR, 2015).

On this basis, this study aims to investigate the landslide-hazard circumstances of the study area and examine the suitability of accommodation locations towards landslide hazard as a basis for formulating recommendations for future landslide mitigation efforts.

Disaster Risk Issues in Tourism Sector

Tourism sector is one of the primary contributors to Indonesia's state revenue. According to the World Travel and Tourism Council (2022), travel and tourism have contributed USD 13.2 billion in 2021, which is 3.2% of Indonesia's GDP.

Although tourism sector can lead to economic growth, it may indirectly exploit the nature where tourism is developed. Not only due to the waste generated, tourism activities may also change the landscape and land cover in an area. Such an exploitative tourism tends to neglect ecosystem sustainability and only focuses on economical benefits. Land clearing and building associated to tourism have physical impacts, but so do continuing tourist activities and long-term modifications to regional economies and ecologies (Sunlu, 2003).

Tourism development and disaster risk reduction (DRR) has a significant linkage. Both can influence each other. Apart from causing damage to facilities, disaster events can also trigger a more serious impact, even massive unemployment, which in turn may disrupt the local and global economy. The 2018 Lombok earthquake and the covid-19 pandemic are ideal instances of how disaster events devastated this sector. Hotel occupancy in Indonesia dropped drastically to 20%, far below the low season, when Covid-19 was first announced in Indonesia (Anele, 2021). Also, due to the enormity of the 2018 Lombok earthquake, 17 countries issued travel warning to their citizens to not visit Lombok (Febriani & Kurniawan, 2021), while many tourist destinations in Indonesia have been dependent on international tourist spend. The World Travel and Tourism Council (2020) notes that total spend by international tourists in Indonesia reached 48% of the total spend in travel and tourism sector in 2019.Based on the literature review by Rossello, et al. (2020), disaster events in several countries have also caused a significant reduction in the number of visits.

One of the current tourism segments in great demand is nature-based tourism. There is an important question that accompanies the rise of nature-based tourism interest, whether nature-based tourism supports local conservation or accelerates environmental damage (Tisdell & Wilson, 2012). Jones & Nguyen (2021) collected several motivations that underlie the visits to nature-based tourism on literatures, but from the conclusion, nature-based tourism is driven by both pull factors (tourist attraction) and push factors (internal desires to take a vacation).

Nature-based tourism has a strong marketing appeal to tourists that care about and are interested in the environment (Dawson, 2001). Based on this, nature-based tourism insignificantly contributes to disaster risks if it truly applies the principle of sustainability, even though there are economic goals that underlie the business. It is obvious that nature-based tourism does not solely about the enjoyment of nature, even more important, being responsible towards environmental risks that may be caused by its activities.

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In addition to its significance on sustainability benefits, environmental issues have been a major requirement for nature-based tourist destinations to attract a bigger market. Environmental issue has become an essential aspect in terms of competitiveness among tourist destinations as the quality of environment determines the travel decision (Mihalic, 2000).

The likelihood of disasters in tourist destinations, however, might vary depending on a variety of circumstances. The site selection is one of them. Natural disasters may expose tourist destinations if tourism authorities do not account for hazard-forming aspects even though they declare their service as nature-based tourism. The interest in scenic natural features even goes beyond considerations of safety from natural hazards. This presents a challenge as the growth of nature-based tourism is closely correlated with the likelihood of localized natural hazards such as landslide. Regardless of the environment's carrying capacity, landslides frequently have a significant impact on regional development.

In the context of human safety, international tourists are considered vulnerable as they are frequently unfamiliar with evacuation routes, local language, and even the characteristics of natural hazards in areas they visit. Therefore, risk communication has been a key action to reduce disaster impacts as failure communication may worsen vulnerability (Rahman & Munadi, 2019)

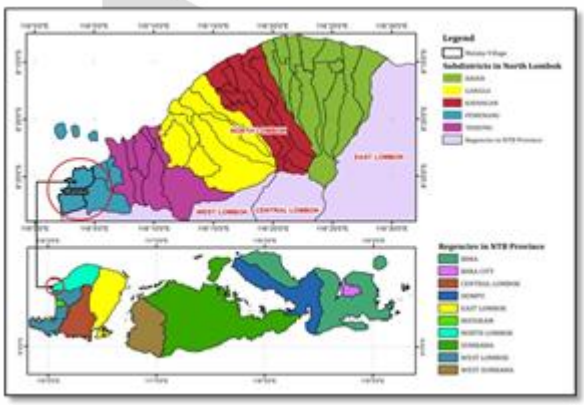
In managing tourism sector, Indonesian government has established a policy named “Sapta Pesona” (six charms) in 1989, as a fundamental principle in presenting tourism products that includes: security, order, cleanliness, coolness, beauty, friendliness and memories. According to Sapta Pesona, the safety factor is placed as top principle that shows the significance of tourist destination protection. Not only protecting the tourists and surrounding community from harmful acts, but also relating to protection from natural hazards. After a devastating covid-19 pandemic, Sapta Pesona is improved into CHSE (cleanliness, health, safety, and environment) policy that encourages quality standard scale-up in tourism service. In addition, the Minister of Tourism Regulation issued a regulation (No. 10 of 2019) concerning Tourism Crisis Management. In article 8, it states the importance of identifying information on potential tourism crisis as part of mitigation and preparedness effort in tourism sector.

2. METHODS

Research Area

This research took place in Malaka Village, one of the four villages in Pemenang Subdistrict, North Lombok (Lombok Utara) Regency, West Nusa Tenggara (Nusa Tenggara Barat - NTB) Province. Geographically, this village is situated at 8.401836 to 8.4707oS and 116.032013 to 116.083122oE. The area of Malaka Village is 24.4 square kilometers with an elevation of 0-581 meters above sea level (masl).

Based on the digital tracing of tourism businesses inside the area of interest (AOI, polygon of Malaka Village), there are 30 tourist accommodations in this area. In this paper, the author merely attaches the code as a marker for each accommodation, omitting the business’s name (brand) because of ethical reasons. However, given this study is spatial-based research, the author complemented the accommodation list with coordinates as information for accommodation locations (see Table 2). These accommodations have different star class and marketing targets, but in general they have similarities in the object offered, nature-based tourism.



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Figure 1. Location of Malaka Village based on administrative map of North Lombok Regency and West Nusa Tenggara Province.

Limitations of Study

The discussion of this study focuses on the description of landslide-hazard parameters, potential exposure based on the landslide-hazard index, suitability of existing tourist accommodation locations, and types and characteristics of landslides that harm accommodations. This study also proposes some recommendations for mitigation measures based on the landslide hazard issues in Malaka Village.

Method

This study used GIS (geographic information system) technique, a method known as the most effective tool in spatial-based analysis nowadays. GIS with its spatial based-tools is able to provide several conveniences in improving decisions on various matters (Al-Fareed, et al., 2008)). In terms of suitability analysis, GIS techniques have been widely used for suitability analysis in many previous researches, such as urban development (Jain & Subbaiah, 2007), industrial locations (Sarath, et al., 2018), residential locations (Ilayaraja, et al., 2017), crop sites (Mustafa, et al., 2011), etc. Each suitability analysis applies certain parameters which are considered to influence the suitability value. The suitability analysis in this research is elaborated both in a qualitative and quantitative way. The quantitative approach focuses on the results of the suitability analysis of accommodation locations based on the spatial formula used, while the qualitative approach emphasizes findings other than the statistical data, such as the opinions of experts who have highlighted landslides as well as the correlation between tourism and disaster resilience.

Specifically, landslide hazard analysis on this research used weighted-overlay method, an analysis tool on GIS-based application that enables users to gather a few layers to result in an expected layer. This method requires determinants (parameters), which are then weighted according to the probable impact they could have on triggering landslides. The parameter layers used in this overlay are: slope, land cover, rock/ lithology type, and annual precipitation, with weight as shown by this equation:

HI = 0.4*SL + 0.2*LC + 0.2*RT + 0.2*RF

Where, HI is Hazard index, SL is slope, LC is land cover, RT is rock type/ lithology, and RF is rainfall.

$4.0 < HI \leq 5.0$ → Very High HI
$3.0 < HI \leq 4.0$ → High HI
$2.0 < HI \leq 3.0$ → Moderate HI
$1.0 < HI \leq 2.0$ → Low HI
$0.0 < HI \leq 1.0$ → Very Low HI

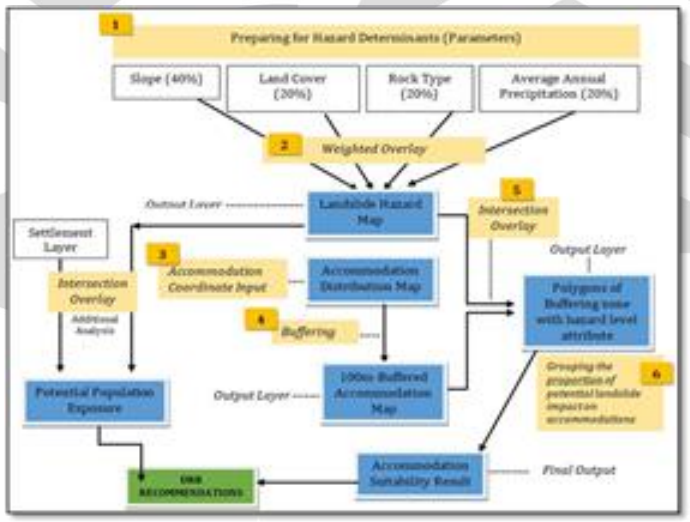


Figure 2. Flow chart of research process

This study took advantage of the coordinates of tourist accommodations in online platforms. To gain an overview of surrounding areas of accommodation coordinates, this research conducted a buffering process in a 100-meter radian. Among vector data types, coordinate is a type of point. If the suitability analysis model relies on the hazard type that overlaps with a spot (point), bias will undoubtedly arise as the areas

around the point are not considered. This is the background of this model, allowing the buffer layer, which is also a polygon layer, to be compared to the hazard polygon layer. By using these coordinates as a center point and accommodating the surrounding areas based on the radian input, the suitability information goes beyond just describing the location at the coordinate point. The radius of 100 meters is the value that is considered to be an ideal radius of activity area in a accommodation site.

The result of intersect overlay between landslide hazard and buffering layer were then classified according to the proportion of landslide-hazard area in output layer which is the reference in determining the suitability category of each accommodation location towards landslide hazard.

To classify the suitability level for each accommodation, this research divides it into three categories,

1) Low suitability, if buffered area is dominated by high or very high hazard;
2) Moderate suitability, if buffered area is dominated by moderate hazard; and
3) High suitability, if buffered area is dominated by low or very low hazard.

3. RESULT AND DISCUSSION

Slope

There are many models for landslide hazard analysis. As far as observation through literature reviews by author, all calculation methods include slope as one of the analysis parameters. Slope has two types of units: percent and degrees. The slope degree refers to the angle formed by the slope of the plane (sinus angle), while the percent slope is the ratio between the vertical and the horizontal plane in a square area. In this study, the slope used is slope in percent (slope rise)

The slope analysis used a DEM (Digital Elevation Model) data from DEMNAS with a cell grid of 0.27-arcsecond (8.1 meter). Since DEMs can be used to forecast the geographical distribution of maximum slope angles, they become an efficient tool for calculating slope instability levels (Fenton, et al., 2013). Following the slope classification on Guidelines for Compiling Land Rehabilitation and Soil Conservation Patterns classification (1986, cited in Lesmana, et al. 2021), it was found that this area was dominated by slope > 45% (extremely steep) which is 45.32% of the AOI (1,104 hectares). The area with this type is a hilly complex that is evenly distributed for almost all sides of the village polygon. The flat slope category (0-15%) is only 14.08% of the village area (343 hectares). The steeper the slopes resulted, the more the score given on the slope classes.

Land Cover

It is reasonable to engage the role of vegetation density in parameters as it is recognized can contribute to reducing the impact of excess water when it rains. Vegetation roots are recognized to be able to bind natural water or rainwater (Aji, et al., 2021; Purnomo, 2022).

This land-cover data is generated from a digitization process using the last-update "GIS Imagery" data, which was verified through a field observation. Even though digitization takes longer to produce the overall data, this model is able to increase the detail of land-cover analysis result. Automated analysis techniques, such as supervised image classification, are quick but may produce errors since some areas may be cloud-covered. Additionally, raster data analysis using a cell grid often results in square-shaped polygons (following resolution), which causes some data to lack smoothness.

This research used five land cover categories based on the quality (density) of vegetation: 1) dense tree canopy, 2) tree canopy, 3) shrubs, 4) open land, and 5) built-up areas. This model is applied to recognize the area with quality vegetation and differ from areas that have been built up. This study considers that built-up areas have consequences for the vegetation loss, as well as soil loading which can cause landslides.

Based on the results of land-cover interpretation, it was found that the AOI (from higher to lower respectively) is covered by: 988 hectares of tree canopy (40.49% of the AOI), 730 hectares of open land (29,92% of AOI), 444 hectares of dense tree canopy (18.20% of AOI), 177 hectares of shrubs (7,25% of AOI), and 101 hectares of built-up areas (4.14% of AOI).

The development of tourism areas in Malaka has also changed the function of the area significantly. The built-up areas (mainly settlement and tourist accommodations) are dominantly located on the west side of the AOI which is in form of coastal area. Although some upstream areas are forest, the vegetation is suspected of having changed to vegetations with insignificant density. In 2022, three rivers in Malaka

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Village (Lendang Luar, Pandanan, and Badung River) were exposed by devastating flash floods with full of logs along the river. It was suspected of being the result of illegal logging in the upstream areas.

Rainfall

Rainfall holds a vital role in triggering landslide, as emphasized by Sassa, et al. (2017) that rainfall can raise ground water level in a soil layer on the slope's bed rock (stable) layer. Oktorie (2017) added that water seeping into the ground can trigger a landslide process since it increases the weight of the soil.

Table 1. Parameters and weight used on landslide hazard overlay and exposure quantitative result

Parameters	Class	Score	Weight	Area (Ha)	% of Village Area
Slope	*0-8% (Flat)*	1	40%	343	14,08
	8-15% (Sloping)	2		146	5,99
	15-25% (Slightly Steep)	3		243	9,98
	25-45% (Moder-ately Steep)	4		600	24,63
	> 45% (Extremely Steep)	5		1104	45,32
Land Cover	*Dense Tree Canopy*	1	20%	444	18,20
	Tree Canopy	2		988	40,49
	Shrubs	3		177	7,25
	Open Land	4		730	29,92
	Built-Up Area	5		101	4,14
Rainfall	*1700 - 2000 mm*	1	20%	2427	99,47
	2.000 - 2.300 mm	2		13	0,53
Lithology	*Alluvial*	1	20%	198	8,11
	Volcanik Rocks	3		2242	91,89

To complement rainfall parameter, this study used CHIRPS (Climate Hazards Group InfraRed Precipitation with Station) raster data which is processed by raster calculator operation towards the last ten-year rainfall to gain an average annual rainfall rate. Based on the analysis result, is was found that rainfall in Malaka Village ranges from 1,700-2,100 mm per year, where rainfall in the northern area is slightly lower than in the southern area. It is also obvious that higher rainfall rate spreads over areas with higher elevations. Referring to the classification of the Estimation Method by Puslittanak (2004, cited in Rahmad, et al., 2018), Malaka Village is exposed by dry rainfall category (1,501-2,000 mm) and moderate rainfall category (2,001-2,500 mm). Dry rainfall spreads on area of 2,427 hectares (99.47% of the AOI) while moderate rainfall does on 13 hectares (0.53% of the AOI).

Despite the fact that the range of precipitation is typically low to moderate, the precipitation rate in Malaka Village cannot be underestimated. Several landslides in recent years have been triggered by heavy rains that lasted only a few hours. The wavy hill morphology has contributed to the high water accumulation in the valley and stream area that also led to flash floods. In 2022, a few houses were even swept away by horrible flash flood.

Lithology

In addition to the rainfall factor, the lithology may also contribute to a landslide hazard. Crozier (2010, as cited in Aristizábal, et al., 2022) believes that rock type is related to the permeability which is regarding the ability to initially control soil infiltration, that then excessive rainfall causes surface runoff.

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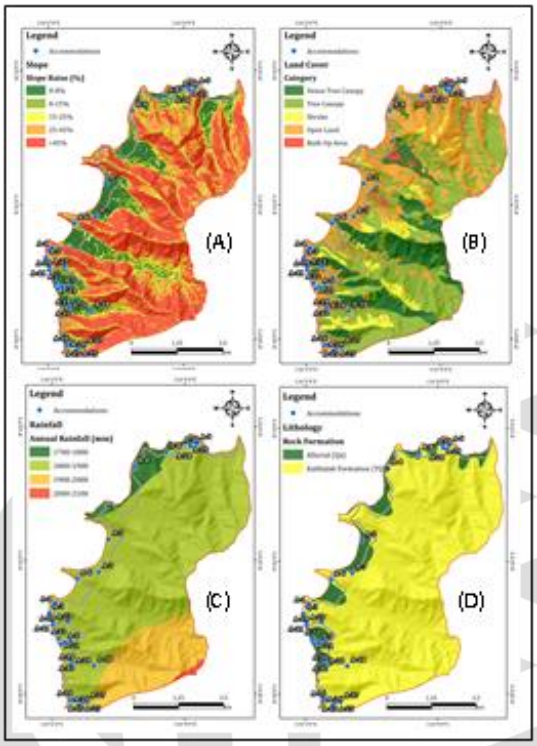


Figure 3. Parameters used in determining landslide hazard index: A) Slope map, B) Land cover map, C) Lithology map), and D) Rainfall map. The colors on maps represent the influencing level score, from higher to lower: Red > Brown >Yellow > Light Green > Dark Green

The lithology data used is gained from geological map of Lombok sheet (Mangga, et al., 1994) which is detailed based on the field finding during the research. Malaka Village is composed of two types of rock formations, namely Kalibalak Formation (Qtb) and Alluvial Formation (Qa). The Kalibalak Formation consists of breccias and lava (Middle Pliocene - Middle Plistocene), while Alluvial Formation (Recent age) in Malaka Village is mainly in the form of coastal alluvial but insignificantly found in river plain as a river alluvial. The alluvial in this area consists of gravel, sand, and coral fragments.

The Kalibalak volcanic rock formation in Malaka is characterized by intense columnar joints and spheroidal weathering on the rock's surface. This has a correlation with what Hirata and Chigira (2019) stated that these two traits are primarily present in basaltic lavas or igneous rocks that have undergone rapid cooling. Spheroidal weathering is a type of chemical weathering that has an onion skin-like appearance. Numerous studies have connected this phenomenon with a rock that is related with landslide susceptibility as it may allow large rainwater infiltration and may cause landslides when the rock becomes saturated.

Following the classification of the Landslide Prediction Model by Puslittanak, volcanic rock is placed as the highest-score rock type. Based on the calculation result, the area with volcanic rocks (Qtb) covers about 91.89% of AOI (2,242 hectares), while alluvial area covers only about 8.11% of AOI (198 hectares).

Landslide Hazard of Malaka Village

Based on the results of hazard-parameters overlay, it was found that Malaka Village consists of four types of landslide hazard categories: very low, low, medium, and high index. The absence of very high category is due to the influence of parameters with low scores, such as dry-rainfall-rate category which is dominant within the AOI. The intersection of these parameters affects the resulting total value so that the maximum hazard level in AOI is in high category.

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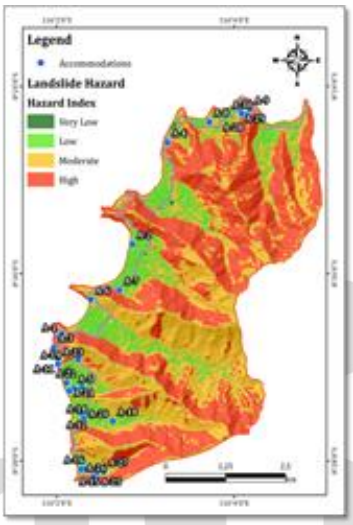


Figure 4. Landslide Hazard Map of Malaka Village

The analysis result shows that Malaka Village is dominated by high hazard category, which is 1,080.26 hectares (44.27% of AOI), followed by moderate hazard category with an area of 949.99 hectares (38.94% of AOI), low hazard category of 403.71 hectares (16.55% of AOI), and very low hazard category of 5.95 hectares (0.24% of AOI). This represents that this village may be exposed by landslides in a significant area.

Apart from the indicators used, North Lombok Regency (including Malaka Village) is also prone to seismic activity (earthquake). According to the Disaster Risk Assessment of North Lombok Regency (Government of North Lombok Regency, 2021), this region is considered at moderate to high hazard of earthquake. As evidence, in addition to 564 people killed, the 2018 Lombok 7-Mw earthquake also caused landslides in several places, including Malaka Village.

Accommodation Suitability

Some accommodation coordinates basically show a low hazard index area, but they are averagely adjacent to a high landslide hazard zone. Therefore, the determination of location suitability for landslide hazard does not only refer to the accommodation's coordinate points, but also takes into account the surrounding conditions based on method mentioned above.

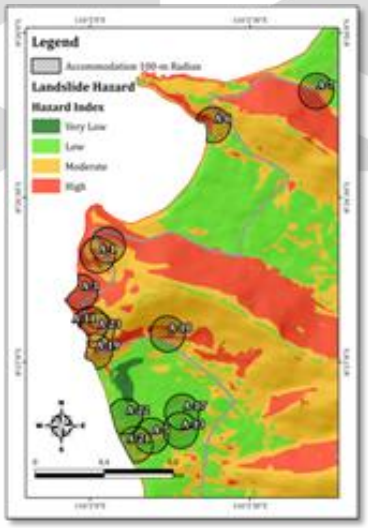


Figure 5. Polygons formed by the accommodation's coordinate buffering on a landslide hazard map to determine the suitability index for accommodation locations in Malaka Village

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Based on the results of a 100-meter buffering from each accommodation coordinate point, it was found that six tourist accommodations are located in a low suitability category included A-3, A-4, A-7, A-24, A-26, and A-28. These accommodations are considered as the accommodation with the most potential landslide as their location and surrounding are dominated by high landslide-hazard. Ten of the 30 tourist accommodations in Malaka Village are in moderate suitability, including: A-1, A-6, A-9, A-10, A-11, A-19, A-23, A-27, A-29, and A-30, while the rest (16 accommodations) are located in the high suitability category (see Table 2).

Not all accommodations in Malaka put the proximity to the coastline as a primary consideration although beach-front accommodations still become one of the top favorite destinations. The current travel trend also considers the nature view. Hence, many investors chose the beauty-of-scenery from high-elevation as the main consideration instead of slope-safety factor. The accommodation situation in Malaka Village is, in fact, a dilemma. Low-hazard accommodations are typically safer, but the views are not as breathtaking as in higher landslide-hazard areas. The majority of low-suitability accommodations are situated in the higher elevation range of 10 to 75 masl. Such locations have a broader view that has successfully attracted investors and tourists to invest and visit. An ideal instance is the A-3, a new 5-star santorini-style accommodation in Malaka. This accommodation puts a high-class image for this region as a luxury travel destination although it started to open the service since 2021. Based on the result of location suitability analysis, this accommodation is more susceptible than others, with a slope angle reaches over 50 degrees. With the existence of a large-area building in this area, it will definitely put a load on the slopes which may strengthen the push of the masses down the slopes.

Table 2. Suitability category of accommodations in Malaka Village

Acc. Code	Coordinates (Long.; Lat.)	Dominant Hazards	Percentage of Dominant Hazard- Index (%)	Suitability Category
A-1	116,033728; -8,444577	Moderate	53,90	Moderate
A-2	116,047563; -8,428087	Low	96,18	High
A-3	116,032815; -8,446462	High	99,22	Low
A-4	116,054119; -8,446462	High	54,36	Low
A-5	116,036523; -8,453735	Low	79,10	High
A-6	116,039744; -8,437993	Moderate	61,44	Moderate
A-7	116,045132; -8,436289	High	41,85	Low
A-8	116,061988; -8,406333	Low	71,01	High
A-9	116,069603; -8,404134	Moderate	55,10	Moderate
A-10	116,037363; -8,448575	Moderate	69,80	Moderate
A-11	116,03335; -8,448098	Moderate	59,46	Moderate
A-12	116,037815; -8,458032	Low	98,21	High
A-13	116,038036; -8,453454	Low	95,96	High
A-14	116,038432; -8,459034	Low	79,32	High
A-15	116,037962; -8,468158	Low	85,78	High
A-16	116,038777; -8,468095	Low	49,56	High
A-17	116,03812; -8,452521	Low	99,96	High
A-18	116,043882; -8,459608	Low	64,11	High
A-19	116,033585; -8,449454	Moderate	69,91	Moderate
A-20	116,038496; -8,459932	Low	48,97	High
A-21	116,035688; -8,454174	Low	70,04	High
A-22	116,035156; -8,452743	Low	90,09	High

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A-23	116,033672; -8,448384	Moderate	77,45	Moder-ate
A-24	116,03425; -8,444091	High	53,97	Low
A-25	116,04087; -8,468612	Low	58,81	High
A-26	116,04019; -8,46953	High	66,30	Low
A-27	116,042184; -8,468569	Moderate	54,63	Moder-ate
A-28	116,068784; -8,405094	High	60,76	Low
A-29	116,06788; -8,404482	Moderate	48,77	Moder-ate
A-30	116,068073; -8,404894	Moderate	54,06	Moder-ate

A-28, a three-star villa on the north side of Malaka, also shows a quite similar phenomenon. Among all the accommodations, this villa is located at the highest elevation. This place is considered to be in a low-suitability location. In terms of slope, A-28's slope angle is not as great as A-3's, yet this area exhibits poor-quality vegetation. According to the field observation, there were numerous locations around A-28 planted with legumes, which, of course, had little to no effect on bolstering the slopes.

Based on a comparative study towards past landslide occurrences compared with landslide types stated by Highland & Bobrowsky (2008), landslides in Malaka fit into the category of “translational landslide” and “rock fall”.

Translational landslides in this area seems to be elongated (stream erosion) with comparison of length to wide averagely equals to 10 to 1, which spreads on the lower side (forming toe-look appearance) and shows an indication of translational movement. Drone photos of landslide locations in 2022 also show a long movement. These landslides have a 50-to-200-meter length and are located in areas with a moderate to high landslide hazard. Significant thickness of soil layer on surface in several places also strengthens this type of landslide.

In addition to the four locations listed, a rock-fall landslide have also occurred in 2021 and killed a resident of Malaka Village. Rock fall is highly possible to occur as solid rocks (basaltic lava and breccias) are intensely situated in high altitude areas.

So far, landslides in Malaka mostly occurred during a raining time. Of the four landslide locations in 2022, two of them (Fig. 6: B & C) are very close to tourist accommodations (A-19 and A-10), and the other two (Fig. 6: A & D) are close to community settlements. This proves that the current accommodation construction sites are very susceptible to landslide hazards.

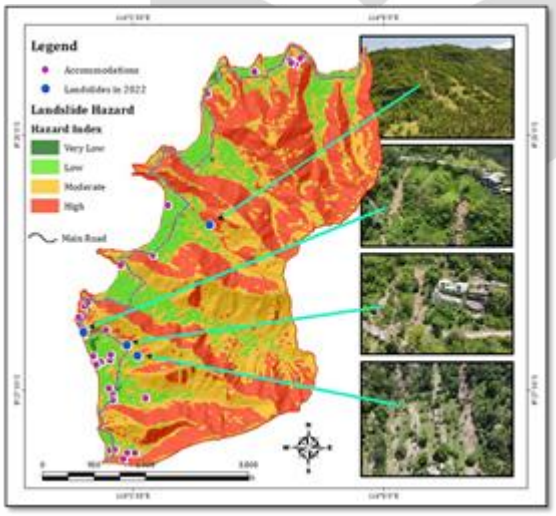


Figure 6. Landslides in 2022 (captured by drone).

An interesting finding from aerial observation conducted is that the quality of vegetation at landslide A and D location (Fig. 6) seems quite dense, but the resistance of rock at these locations is, in fact, not able to hold water load when it rains which has caused the movement of soil and rock masses. The location of landslide B and C shows the presence of low quality vegetation around the accommodation.

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Not only does a landslide pose potential exposure to tourist accommodations, but it could also potentially expose the surrounding settlement. Based on the overlay results between the settlement and landslide hazard layer, it was found that 3.13% of the settlements in Malaka are located in high landslide hazard areas, 75.30% are in moderate landslide hazard areas, and 21.56% are in low landslide hazard areas. The percentage of settlement exposure may represent the percentage of potential population exposure by landslide.

According to their distribution, the settlements in the high landslide-hazard area spread in almost every group of settlement with insignificant differences in the area of the polygons.

Recommendations

Given the high potential hazard and risk of landslides in the study area, disaster mitigation measures, both structural and non-structural are absolutely necessary to avoid serious damage and losses due to landslides. According to the Law No. 24 concerning Disaster Management, mitigation is defined as all efforts to reduce disaster risk, both physical development (structural measures) and efforts to raise awareness and increase capacity (non-structural measures) in dealing with disasters.

Although a disaster management agency (BPBD) has been established in North Lombok Regency, the availability of supporting infrastructures, equipments, and human resources in this organization is still very limited so that cooperation scheme must be encouraged to maximize the efforts. Accommodation companies have received various benefits from their activities in Malaka, so it is also their responsibility to care for the sustainability of the environment in this area. And this requirement is a normal feedback. They can participate in maintaining green space in areas they manage. To prevent dangerous landslides in the accommodation areas, every accommodation in the landslide-hazard area needs to be equipped with adequate warning signs, evacuation signs and assembly points. In terms of protection, the World Bank (2020) emphasized that disaster management planners should take into account the presence of tourists (which fluctuates seasonally and can increase the local population in tourism sites), connect establishments and tourist attractions to emergency communications systems using real-time information, and be ready to use assets as evacuation shelters for visitors and locals when necessary. However, the DRR partnership must be in “open eyes”, which underlies with dialogues so that stakeholders can understand each other's role (NGO Voice, 2013). A memorandum of understanding (MoU) between the government and accommodation managements regarding disaster/emergency response (including landslides) is required to strengthen this strategy so that, in the event of a landslide in Malaka, the safe zone in the accommodation areas can switch to serving as an assembly point, or even temporary shelter, until a decent evacuation site is constructed for those who are affected.

According to Eccles & Costa (1996), sustainable tourism can be encouraged by education and training for people involved in tourism in order to initiate a balance between environment and tourism. It is further stated that this effort is ideally encouraged by both government and business. In the context of tourism development in Malaka, this concept is very likely to be applicable as technical training in DRR has often been carried out by NGOs and the government organizations, yet there has been no direct partnership with the tourism-business stakeholders on this issue.

In terms of prevention policy, land cover deserves the most serious interference since it seems worsened in recent years. Strengthening the spatial regulation by applying strict penalties on those who cut down the tress in prohibited zone must be applied to anticipate worse impactful events in the future. Some areas in Malaka’s upstream are part of protected forest (West Mt. Rinjani National Park), so all forms of illegal logging in those areas are indeed prohibited. However, this must be applied with a wise approach as local communities have interacted with forests for a long time. Local government can implement a livelihood-based approach by providing more job occupations for local communities so that they do not rely on trees for living.

The authorities should take relocation into account in order to eliminate mortality and property loss on nearby communities. Despite the fact that relocation is generally regarded as the last option in terms of disaster prevention due to the significant costs involved, the government can implement this

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approach gradually. This can utilize hazardous-zone settlement data generated by this research as a consideration to select priorities.

Table 3 shows the proposed mitigations that can be applied in Malaka Village, both landslide-focusing and multihazard-focusing efforts, to reduce potential risks by disasters.

Table 3. Mitigation measure recommendations for landslide risk reduction in Malaka Village

Proposed Mitigation Actions	Purposes	Potential Stakeholders	Landslide Hazard (LH)/ Multi-Hazard (MH) Purposes
Structural Mitigations			
Installing landslide early warning devices	To be more alert	BPBD, BNPB, PVMBG, BMKG	LH
Assembly points and evacuation sites	To support evacuation when necessary	BPBD, Village Govt., accommodation companies	LH/ MH
Green space requirements in accommodation areas	To keep the portion of vegetation in the built environment (accommodation areas)	Accommodation companies, Environment Dept.	LH
Landslide warning and evacuation signs	To support evacuation when necessary	BPBD, Village Govt., accommodation companies	LH
Planting and or replanting program in low-density-vegetation slopes	To enhance slope resistance and land cover quality	Environment Dept, local communities, accommodation companies.	LH
Providing firmly rooted and economic tree-seedlings for local farmers	To encourage local farmers to prioritize landslide-preventing trees, to support locals' income	Agriculture and Plantation Dept.	LH
Installing wire netting rockfall protection system (rockfall barrier)	To anticipate rockfall in areas with rockfall symptoms	General Work Dept., BPBD, accommodation companies.	LH
Building an adequate drainage system especially around accommodations, settlements, and along the roads.	To flow water properly	General Work Dept., BPBD, accommodation companies	MH
Building ground terraces (*teraser-ing*) on high risk cliffs	To reduce load on slopes; anticipate debris slide/ translational landslide	General Work Dept., BPBD, accommodation companies	LH
Non-Structural Mitigations			
Landslide socialization and education	Improving knowledge on landslide risks	BPBD, PVMBG	LH
Arranging *MoU* (between government and accommodation companies) in emergency response	To build a cooperation in disaster response	BPBD, accommodation companies, Village Govt.	MH
Safety- briefing (with landslide hazard introduction) for visitors	Improving knowledge on landslide risks.	Accommodation companies	LH
Relocating communities on high and very high landslide hazard zone	To protect those who live in landslide-prone areas	Related government institutions	LH
Strengthening the building code implementation	To prevent spatial-based regulation violation	Spatial Planning Dept.	MH
Capacity building program for tourism stakeholders (simulation and evacuation training, conservation education, etc.)	To prepare emergency-response-skilled human resources	BPBD	MH
Continues vegetation control	To gain regular updated-information of vegetation changes	Environment Dept., Spatial Planning Dept.	MH
Providing more job opportunities for local communities	To reduce and eliminate illegal logging acts	Accommodation Companies, Labor Dept.	MH
Arranging contingency plan for landslide response	To build preparedness in landslide response	BPBD, Village Govt.	LH
Strengthening contribution of private sector on conservation	To build a partnership DRR; mainstream conservation in tourism business.	Tourism Dept., Environment Dept, Investment Dept.	MH

4. CONCLUSION

Based on the analysis of landslide hazard with parameters of slope, rainfall, land cover, and rock type, Malaka Village is dominated by a high landslide-hazard index. In addition to potential exposure on residential areas, landslide hazard in Malaka Village also has the potential to expose tourist accommodations as most of them are situated in landslide-prone zones. Suitability analysis of the location was conducted through a buffering process. Based on this, most of the buffering-polygons resulted are dominated by accommodations in moderate to high hazard. Landslide hazards that threaten Malaka Village including accommodation locations are typically in translational-landslide and rock-fall. From these conditions, all disaster management stakeholders working with tourist accommodation companies need to build both structural and non-structural mitigation measures, to reduce disaster risks attributed to landslides.

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