

Landslide Hazard Analysis and Damage Assessment for Tourism Destination at Candikuning Village, Tabanan Regency, Bali, Indonesia

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Abstract. Landslide is a movement down the slope by the soil mass or slope constituent rock, a result of disturbance of the stability of the soil or rocks that make up the slope. Bali as one of the best tourism destinations in the world, also has landslide prone areas. Tourism attraction in Bali that is prone to landslides are Lake Beratan and Pura Ulun Danu Beratan in Candikuning Village, Tabanan Regency, Bali Province, Indonesia. Candikuning village area has tourism destination, settlements and agricultural land. This study aims to analyze landslide-prone areas and the losses caused by landslides include damage analysis for the attractions of Beratan Lake and Ulun Danu Beratan Temple and settlements. The method used is matching and scoring with parameters of rainfall, soil type, slope and land use. The result is, Beratan Lake area has moderate to high landslide prone areas in the eastern and southern parts where most of the settlements in Candikuning Village are located in areas prone to moderate and high landslides hazard.

Keywords: Landslide Hazard, Damage Assessment, Tourism Destination

1. Introduction

Landslide is a movement of soil down the slope, resulting from the disturbance of the stability of the soil or the rock that makes up the slope. If this moving mass is dominated by soil mass and its movement down a slope, then the process of movement is called a landslide. Landslide has a very complex impact on land use or on the environmental conditions. Landslide will occur if there are three conditions, (1) the slope is quite steep so that the soil mass can move or slide downward quickly (2) has a semi permeable glide layer below the soil surface (3) the presence of a mass water content that gives weight to the soil, so that the ground mass will be able to move or glide downwards [1]. Landslides occur in mountainous area with steep slope with a slope of 15° - 45° and high rainfall intensity. Other factors causing landslides are the morphology of the Earth's surface ie land use, lithology, geological structures, and earthquakes. In addition to natural factors, there's also factors of human activity that affect a landscape, such as the conversion of forest to agricultural land, settlement, mining and slope cutting [2].

One example of the phenomenon of landslide problems occurred in the area of Bali, especially in Candikuning Village, Tabanan Regency. Tabanan Regency physiographically has two regional models, lowland or coastal areas in the southern part and mountainous area in the northern part. One of the mountainous area in Tabanan Regency is Candikuning village in Baturiti Sub-district.



Candikuning Village is one of the villages in Baturiti Sub-district that lately had been struck by landslide in December 21, 2016. The damage from landslides in this area includes damage of settlements, agricultural land, the Denpasar – Singaraja main road also tourism destination such as Lake Beratan and Pura Ulun Danu Beratan. The tourism destinations in Candikuning Village has already well-known worldwide due to its uniqueness and the beauty of the traditional architectures. These tourism destinations, Lake Beratan and Pura Ulun Danu Beratan, are exposed to landslides hazard due to the topographic conditions and rainfall conditions of Candikuning Village.

The spatial distribution of landslide potential areas can be identified more easily through mapping process. Visual representation with maps is necessary to provide a spatial information of the lands affected by landslides. Responding from the absence of information about the map of landslides hazard prone areas, this research aims to spatially map potential landslide-prone areas especially to the tourism destination in Candikuning Village and to estimate damage for the settlements in Candikuning Village. The map of disaster prone areas in Baturiti Sub-district is expected to be used as a reference for the government, especially in tourism planning in Candikuning Village and make future disaster mitigation efforts so that the risk of landslide disaster can be minimized.

2. Literature Review

2.1. Landslide

Landslides also referred as land movements. It is defined as the soil mass or clay, gravel, sand, and crusty material and lumps and mud, moving along the slopes or out of the slopes due to the earth's gravitational factors [3]. Movement of the soil is a product of the process of disturbance of the slope balance which causes the movement of the soil and rock mass to a lower area. The force that trigger the soil mass movements along the slope is the physical properties of the soil and the angle in the soil shear resistance acting along the slope. The change of forces is caused by the influence of natural change and human action. Changes in natural conditions can be caused by earthquakes, erosion, change in moisture slopes due to rainwater absorption, and changes in surface flow. Human influence on the changes of forces, among others, is the addition of loads on the slopes and the edge of the slope, excavation of soil at the edge of the slope, and sharpening of the slope angle. The pressures of the population that many land use change of the slopes into settlements or cultivated land greatly affect the increased landslide hazard [4].

Type of landslide based on the speed of movement can be divided into 5 (five) types, namely [5]: (1) Stream; Landslides simultaneously / suddenly at high speed; (2) Avalanches; The avalanche material moves slowly with the former horseshoe-shaped slide; (3) Collapse; Generally landslide material in the form of stone and soil move quickly to very fast on a cliff; (4) Compound; An avalanche that develops from collapse or landslides and progresses further into streams; (5) Land Subsidence; Occurs in underground mining, excessive ground water suctioning, soil erosion processes and in areas where soil compaction processes occur.

Land subsidence may occur due to consolidation process, i.e. the subsidence of the soil surface due to the compaction process or the change in the volume of a soil layer. This process can take place faster if there is a load that exceeds the carrying capacity of the soil or excessive groundwater extraction. Excessive groundwater retrieval may result in lower groundwater levels and lower hydraulic pressures, while the pressure between rocks increases. Land subsidence generally occurs in the plains areas of soft rocks / soils [5].

Soil types are critical to the potential for landslides. Loose soil will be more potential to landslides than the massive soil like clay. This can also be seen from the sensitivity of soil erosion. The soil value of soil erodibility (K) indicates whether or not soil is eroded, determined by soil physical and chemical properties. The smaller K value becomes less sensitive to the soil against erosion [5].

The depth or soil solum, texture, and soil structure determine the size of the surface runoff water and the saturation rate of the soil. In deep soil (> 90 cm), loose structures, and dense land cover, most of the rainwater is infiltrated into the soil and only a small part of it becomes surface runoff water. Conversely, in shallow soil, solid structures, and less dense land cover, only a small percentage of infiltrated rainwater and much of it becomes surface flows which triggers landslide [7].

Rain with high intensity, for example 50 mm which lasts longer than 6 hours has the potential to cause landslide, because in that condition there still saturation process of soil by which increase soil mass. There are two types of rain, the heavy rainfall that can reach 70 mm / h or more than 100 mm / day. This type of heavy rain is very effective in triggering landslide, especially in clay and sandy soil. While the normal rainfall which less than 20 mm / day can cause landslides on slopes if rain lasts for several weeks to over a month [6].

2.2. Tourism

Tourism is a travel activity undertaken by a person or group of people by visiting a particular place for recreational purposes, personal development, or studying the unique attractions of the visited tourist in the interim period. Tourism industry is a collection of tourism businesses are inter-related in order to produce goods and services for the needs of tourists in the implementation of tourism. Tourism Business is a business that provides goods and / or services for meeting the needs of tourists and the implementation of tourism. Tourism facilities are all types of facilities specifically intended to support the creation of convenience, comfort, safety of tourists in making visits to tourism destinations. Tourism facilities are products and services needed to support the fulfillment of the needs of tourist travel [7].

The relationship between tourism and the environment might initially be characterized as one of 'coexistence'[8].The environment, be it predominantly natural or largely human-made, is one of the most basic resources for tourism and a core element of tourism products [9].Tourism is an entire activity related to tourism and is multidimensional and multidisciplinary that emerges as a manifestation of the needs of every person and country as well as the interaction between tourists and the local community, fellow travellers, government, local government, and entrepreneurs. Tourists are people who do tours [10].An area can be developed into tourism area if there's natural resources in the form of minerals, water sources, fertile land, animal and vegetation sources or adequate human resources, high level of culture, technological level and sufficient capital to be able to develop the natural resources available for the prosperity for mankind. Tourism potential can be grouped into 3 namely the potential of nature, cultural potential, and human potential. The potentials are described below [11]: Natural Potential, consisting of physical potential, flora and fauna. These three natural potentials can be a tourist attraction that plays a similar role, but one of the attractions can be more prominent. In general, tourists are more interested in the open like the mountains, forests and beaches; Culture Potential, i.e. culture in the broad sense, not only includes high culture but includes customs and all activities that live in the midst of society.; Human Potential, namely the ability that exists in human beings that can be utilized for the benefit of tourism.

Tourism planning is closely related to the physical geography and environmental components. The initial effects of trampling of vegetation by tourists become compounded through related processes of environmental change that may, in extreme circumstances, culminate in the collapse of local ecosystems.

In physical planning, the issues of concern may be control over land development by both public and private sectors, zoning of land use. In the environment, issues of concern such as control of pollution and assessment of hazards [12].

3. Methodology

3.1. Area of Study

Area of study is located in Candikuning Village, Baturiti Sub-district, Tabanan Regency, Bali Province, Indonesia. Geographically, Candikuning Village located in UTM Zone 5o S, with easting 297258.12 m E and northing 9084770.92 m S. Candikuning Village bordering with Sukasada Village, Sawan Village and Kubutambahan Village of Buleleng Regency in the north, Belok Village of Badung Regency in the east, Batunya Village of Baturiti Sub-District in the south and Pancasari Village of Buleleng Regency in the west.

3.2. Tools and Material

The material used in this research are spatial datas as follows: (1) Slopes Map Scale 1: 25,000; (2) Soil Map Scale 1: 25,000; (3) Landuse map Scale 1: 25,000; (4) Rainfall Map (isohyet) Scale 1: 25,000. While the tool used are: (1) Computer or laptop used to process the spatial data; (2) GPS (Global Positioning System) to determine the coordinate point of observation.; (3) Camera; (4) Stationary.

3.3. Data collection

Data collection method used in this research is primary data and secondary data method: (1) Secondary data collection in the form of slope map, rainfall data, soil type and land use. To create a landslide hazard map in the Candikuning Village. Then documentation techniques used in the research are conducted to obtain almost all the required data, ie slope map, rainfall map, soil type map, geological map and land use map; (2) Primary data collection through is by conducting a field survey. Field surveys were made using land unit samples made from intersections of slope map, soil map, land use map and isohyet map.

3.4. Data Analysis

Data analysis of the data in this study used the matching and scoring system from soil data, slope data, landuse data and rainfall data. Then the analysis technique using overlay method using geographic information system to generate new landslide hazard area from slope map, rainfall map, soil type map, and land use map which has been scored.

Scoring was used to determine or assess the landslide hazard in the research area. The scoring value was based on the size of the influence of the supporting variable of landslide in the research area. The landslide hazard is indicated by the total number of scores from each of the supporting parameters of landslide, ie slope map, rainfall map, soil type map, geological map and landuse map [13].

3.4.1. Rainfall scoring

The rainfall score, divided into five classes as listed in Table 1 [13].

Table 1. Rainfall Score

No	Rainfall (mm/yr)	Score
1	< 1.500	1
2	1.500 - 1.800	2
3	1.800 - 2.100	3
4	2.100 - 2.400	4
5	> 2.400	5

3.4.2. Slope Scoring

In the landslide hazard, slope factor is very influential, the steeper slope then the possibility of the occurrence of landslide is higher. The slope score, listed in Table 2 [13].

Table 2. Slope Score

No	Slope (%)	Score
1	0 – 8	1
2	8 – 15	2
3	15 – 30	3
4	30 – 45	4
5	> 45	5

3.4.3. Landuse Score

Settlements have a smaller share because runoff is more prevalent and infiltration because of the impermeable surface properties. The landuse score, listed in Table 3 [13].

Table 3. Landuse Score

No	Landuse	Score
1	Forest, Mangrove, swamp, irrigated rice field, ponds, salting, sand	1
2	Rice Fields non irrigated	2
3	Building, settlement	3
4	Shrubs, gardens / plantation	4
5	Grass, bare land, moor	5

3.4.4. Soil Score

Land is more sensitive to landslide then the higher the score given. The degree of sensitivity to landslide is related to the level of soil's ability to release incoming water, ie, soils with very slow permeability. The soil score listed in Table 4 [13].

Table 4. Soil Score

No	Soil type	Score
1	Brown mediteran, red brownis mediteran	1
2	Brown yellowish latosol, red brownis Latosol, brownish latosol andlitosol,	2
3	Aluvial brownish grey, alluvial hidromorf	3
4	Brownish regosol, brown yellowish regoso, grey brownish regosol, Regosol Humus, greyish regosol	4
5	Greyish brown andosol	5

3.4.5. Landslide score

The score for landslide hazard is the total of slope score, rainfall score, soil type score, and landuse score. The total landslide score based on the following equation [13]:

$$\text{Landslide Score} = (5 \text{ SI}) + (5 \text{ R}) + (4 \text{ LU}) + (2 \text{ St})$$

SI= slope score; R = rainfall score; LU = Landuse score;

St = Soil score

The landslide classes listed in Table 5 [15].

Table 5. Landslide Hazard Class

No	Landslide Hazard Score	Landslide Hazard Class
1	<120	Very low
2	120 – 150	Low
3	150 – 195	Medium
4	> 195	High

Analysis of damage assessment of settlements and analysis the tourism object that affected by landslide is conducted by the result of scoring and overlay of landside hazard parameter. The summary of methodology in this research featured in Figure 1.

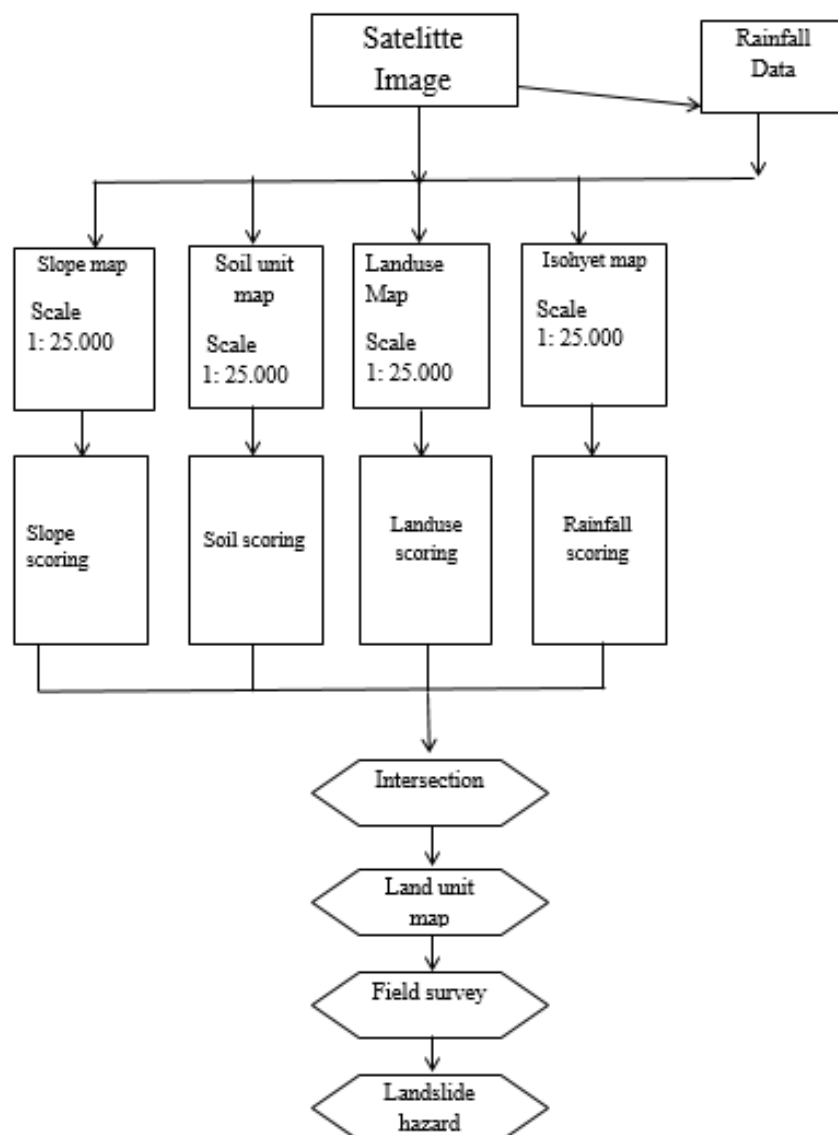


Figure 1. Methodology Diagram

4. Results and Discussion

4.1. Landslide Hazard Analysis

The Landslide hazard in Candikuning Village is divided into three classes which are high, medium and low. Landslide hazard map is created by using overlay method and scoring methods to degree of landslides hazard Physical condition in Candikuning Village which triggers landuse are slope, rainfall, soil and landuse. Slope in Candikuning village varies between 0%-8%, 15%-45% and more than 45%. Rainfall intensity is very homogen with intensity between 2500-3000 mm/ year. Meanwhile the soil in the research area is andosol which has the characteristic of sensitivity in erosion and landslides. Majority of landuse in Candikuning village is forest (54.69%) and ricefields (23.40%) followed by plantation (14.94%), Settlements (6.67%) and moor (0.30%). Steep to very steep topography with a slope of more than 30%, heavy rainfall which occur more than 2500 mm/ year is the main factors that triggers landslide in Candikuning Village. Medium hazard until high hazard are located in the steep slope east and west of Beratan Lake. Meanwhile low hazard located along the Denpasar – Singaraja highway. Figure 2 shows the landslide hazard area in Candikuning Village.

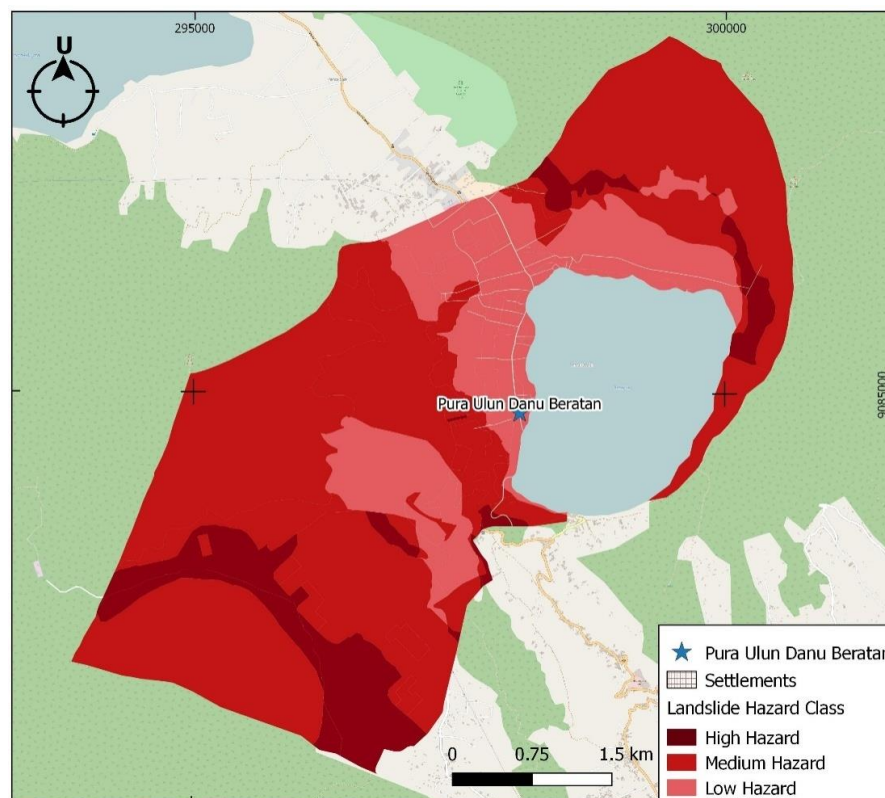


Figure 2. Landslide Hazard Class

Maps of the landslide hazard were created by using overlay method and scoring methods to degree of landslides hazard. Low landslide hazard area in total is 394.14 Ha or occupied 20.92% of total area of Candikuning Village. Low hazard consist of rice field, forest and settlement which located on 0%-8% slope and andosol soil. The rainfall intensity is 2500 – 3000 mm/ year. Medium landslide hazard area in total is 1258.88 Ha or occupied 66.82% area of Candikuning Village. Medium landslide hazard located at various landuse namely rice field, forest, settlement, plantation and moor. The slope is varies between 0% until 45% with 2500 mm/year until 3000 mm/ year of rainfall and andosol soil. Meanwhile the high hazard is occupied 230.89 ha area of Candikuning Village or 12.25% of total area. High hazard consist of more than 15% slope until more than 45% slope. The slope steepness is mainly the triggering factor of landslide. The landuse in the high hazard are settlements, plantation and moor.

The rainfall intensity is 2500 mm/ year until 3000 mm/ year and the soil type is andosol. Landslide hazard area is listed in Table 6.

Table 6. Landslide Hazard Area (a)

No	Hazard Class	Slope	Landuse	Soil Type	Rainfall Intensity	Area (Ha)	Area (%)
1	Low Hazard	2 - 5%	Ricefield	Andosol	2500 - 3000 mm/yr	212.03	11.25
2	Low Hazard	2 - 5%	Forest	Andosol	2500 - 3000 mm/yr	105.90	5.62
3	Low Hazard	2 - 5%	Settlements	Andosol	2500 - 3000 mm/yr	76.21	4.05
4	Medium Hazard	15 - 40%	Settlements	Andosol	2500 - 3000 mm/yr	42.18	2.24
5	Medium Hazard	2 - 5%	Moor	Andosol	2500 - 3000 mm/yr	3.11	0.17
6	Medium Hazard	2 - 5%	Plantation	Andosol	2500 - 3000 mm/yr	53.39	2.83
7	Medium Hazard	> 40%	Ricefield	Andosol	2500 - 3000 mm/yr	209.64	11.13
Table 6 (b)							
8	Medium Hazard	> 40%	Forest	Andosol	2500 - 3000 mm/yr	950.56	50.46
9	High Hazard	15 - 40%	Moor	Andosol	2500 - 3000 mm/yr	2.54	0.13
10	High Hazard	> 40%	Plantation	Andosol	2500 - 3000 mm/yr	228.35	12.12
Total						1883.91	100

4.2. Damage Assessment

Damage for settlements were calculated by using the scoring result of the landslide hazard calculation. The damage are basically caused by the soil mass that struck the settlement's building. The damage divide into three class, which are minor damage, moderate damage and severe damage. Minor damage apply to settlements with low hazard along the Denpasar – Singaraja highway which has flat to undulating topography with 0% to 8% slope. The moderate damage will occur to settlements at medium hazard at east and west side of Beratan Lake with hilly until mountainous topography with 15% to 45% slope. Figure 3 shows the damage class to settlements which exposed to landslide hazard in Candikuning Village.

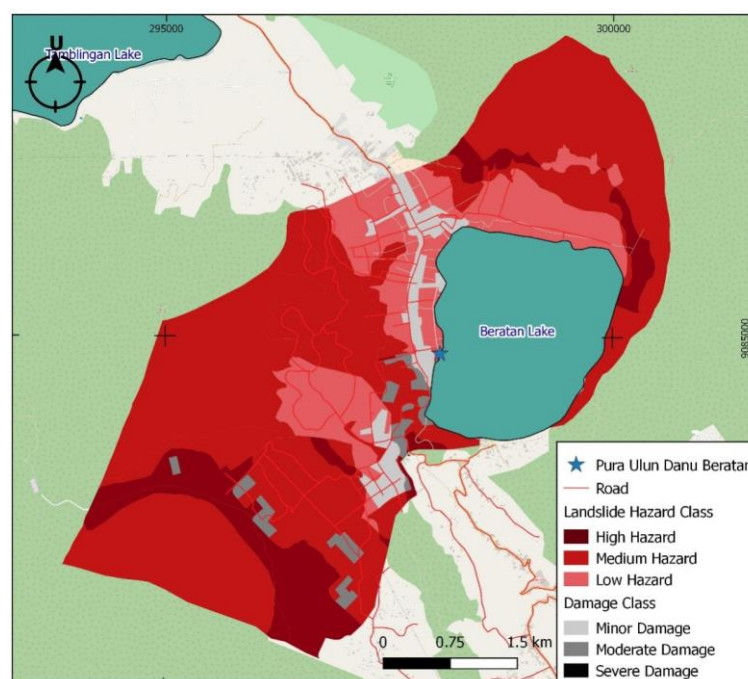


Figure 3. Damage Class

The total area of settlements that has minor damage if landslide occur is at 83.59 Ha or 33.53% of total area. Meanwhile total area of moderate damage is at 42.18 Ha or 66.46% of total area of settlements in Candikuning Village.

4.3. Landslide Impact to Tourism Destination at Candikuning Village

Tourism destination in Candikuning Village is Ulun Danu Beratan Temple and Beratan Lake. These two tourism destinations are a very popular destination for local tourist and foreigners. Ulun Danu Beratan Temple is one of nine “Kahyangan Jagat Temples” which is surrounding Bali Island that makes it becomes one of the most important Temples for the Balinese, especially for Hindu. It consists of five compounds of temples and one Buddhist Stupa. Ulun Danu Beratan Temple is both a famous landmark and a significant temple complex located on the western side of the Beratan Lake in Candikuning Village, or well-known as Bedugul area. The whole Bedugul area is actually a hilly and mountainous area with cold weather and heavy rainfall which became favourite holiday destination for locals and foreigner. The reflective surface of the lake surrounding most of the temple creates a unique panorama, while the mountain range of the Bedugul area encircling the lake provides the temple with a very beautiful panorama. Figure 4 shows the image of Ulun Danu Beratan Temple and Beratan Lake.



Figure 4. Ulun Danu Beratan Temple and Beratan Lake

Located in hilly and mountainous area makes Ulun Danu Beratan Temple and Beratan Lake becomes vulnerable to landslide hazard. The location of Ulun Danu Beratan is located road side of Denpasar - Singaraja highway. Ulun Danu Beratan Temple is included in low hazard class. The challenge for tourism activities in Ulun Danu Beratan Temple and Beratan Lake related to landslides that the potential of landslide to cover Denpasar – Singaraja Highway. Denpasar – Singaraja Highway is the only major road to accesUlun Danu Beratan Temple and Beratan Lake. The south part of Denpasar – Singaraja Highway in Candikuning Village is located in medium hazard and high hazard to landslides. This condition makes the Denpasar – Singaraja Highway become prone area to landslides.

Landslide that occurred on the eastern slope of Lake Beratan impacts on the preservation of the lake as a potential for tourism. Landslide material can conflate the lake water. In addition, landslide material can also reduce lake water volume. This will impact on the preservation of Pura Ulun Danu

Beratan as a tourism icon in Bedugul area. The existence of spillway buildings in Lake Beratan will reinforces the fear of iconic loss in this area. The view of Pura Ulun Lake that flooded the lake water will be damaged and will be difficult to stored as before. Therefore, landslide that occurred in Candikuning Village has negatively impact on Bedugul tourism destination.

5. Conclusions

Landslide hazard areas in Candikuning village are divided into three classes. Low hazard located along the Denpasar – Singaraja highway, medium hazard until high hazard are located in the steep slope east and west of Beratan Lake. Low hazard area in total is 394.14 Ha (20.92%), Medium landslide hazard is 1258.88 Ha (66.82%) and the high hazard 230.89 ha (12.25%) of Candikuning Village.

Two damage class for settlements are found due to landslide hazard in Candikuning Village. Minor damage area is 83.59 Ha (33.53%) and moderate damage is at 42.18 Ha (66.46%). Meanwhile the tourism destinations in Candikuning Village, namely Ulun Danu Beratan Temple and Beratan Lake, is located at low hazard class, but the access to reach the destinations, the Denpasar – Singaraja Highway, is located in medium hazard and high hazard to landslides. Which makes the accessibility to reach the tourism destination in Candikuning Village is a prone area to landslides.

Landslide that occurred in Candikuning Village has a negative impact on tourism potential in this village. Candikuning village is the location of Pura Ulun Danu and Lake Beratan which is the icon of tourism area Bedugul. So that the destruction of tourism potential in Candikuning Village will damage the tourism potential in this area.

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