

PAPER • OPEN ACCESS

## Analysis of Landslide Susceptibility of Belandingan Village, Songan A Village and Songan B Village of Kintamani, Bangli, Indonesia

To cite this article: N M D Pradnyasari *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **313** 012006

View the [article online](#) for updates and enhancements.

# Analysis of Landslide Susceptibility of Belandingan Village, Songan A Village and Songan B Village of Kintamani, Bangli, Indonesia

N M D Pradnyasari <sup>1</sup>, Wiyanti <sup>1</sup> and T Kusmawati <sup>1</sup>

<sup>1</sup> Faculty of Agriculture, Udayana University, Denpasar, Bali, Indonesia

Email: wiyanti1259@gmail.com

**Abstract.** The research conducted in order to find out how the susceptibility for landslides in the village of Belandingan, Songan A Village and Songan B Village. Scoring and overlay method used to determine the results of landslide susceptibility in the study area. Parameter used as the basis for overlay and scoring are soil types, rainfall data, structural geology, landform, slope and land use map. From the overlay result, 41 land unit were mapped on the research area. Based on scoring and GIS analysis, there are 4 classes of landslide susceptibility including not susceptible, low susceptibility, moderate susceptibility and high susceptibility. Most area of study area are included as low susceptibility and medium susceptibility. Meanwhile high susceptibility mainly concentrated on the ancient caldera on west part of Batur Lake. Belandingan, Songan A and Songan B villages have various levels of landslide susceptibility, starting from this non-susceptible category, covering land units 34 and 39. Low susceptibility on land units 26, 29, 25, 23, 21, 38, 3, 12 and 11. While on land units 36, 30, 31, 32, 14, 15, 16, 17, 19, 4, 20, 40, 24, 6, 13, 2, 37, 7, 8, 9, 27, 10, 22, 41, 1.5 and high susceptibility on land units 33, 18, 35, 28. The no susceptibility class mainly located in Songan A and Songan B Village with total area 94,405 Ha. Low susceptibility class are located mainly in Songan A Village with small amount in Songan B Village with total area 1196.768 Ha. Moderate susceptibility class located in all with total area 1866.346 Ha. High landslide susceptibility class located mainly in Songan B Village with small amount in Belandingan Village and Songan A Village with total area 339,979 Ha.

**Key words:** *landslide, matching and scoring, Bangli*

## 1. Introduction

Disasters are events or series of events that threaten and disrupt people's lives and livelihoods caused by both natural, non-natural and human factors. Landslide disasters are one of the natural disasters that often occur in Indonesia and generally occur in mountainous areas, especially in the rainy season [1]. Landslides are soil movements that are directly related to various natural physical conditions such as geological structure, parent material, soil, drainage patterns, slopes and landforms, rain and dynamic non-natural properties such as land use and infrastructure in addition to landslides. it is also a form of erosion where the transport or movement of the soil mass occurs at a relatively large volume [2] [3].

Soil mass movement that occurs in an area is affected by the characteristics of the physical environment and land use of the area. Furthermore, it is said that physical environmental factors that



affect the movement of soil or rock mass include slope, geological conditions, soil texture and permeability, rainfall, and water system [4]. Recently, some natural disasters occur in Bali, including floods and landslides. In the results of previous studies about the identification of landslides susceptibility in Candikuning Village and Pancasari Village in Bedugul area, Bali, Indonesia resulted that low landslides susceptibility is in residential areas, while the high susceptibility includes forest and farmland [5]

Regencies/ Cities in Bali Province such as Karangasem, Klungkung, Jembrana, Badung, Tabanan, Buleleng, Denpasar City, Bangli, Gianyar have a high landslide susceptibility class [6]. The susceptibility area for landslides in Bali Province are up to 85,121.55 ha [7]. In February 2017, there were a series of landslides in succession in the Gianyar Regency on 02/02/2017, Karangasem Regency on 09/02/2017, Bangli Regency on 09/02/2017, Bedugul area, Tabanan Regency on 10/02/2017, and Buleleng Regency on 11/02 / 2017. Landslides that occurred in Bangli regency were landslides which killed the most victims, as many as 12 people died and 5 people suffered severe injuries and minor injuries [8].

Bangli Regency is located in the middle of the Bali Province, Indonesia, at altitude between 100 - 2,152 meters above sea level, with the highest peak is Puncak Penulisan [9]. Bangli Regency consists of 4 Subdistrict namely Bangli Subdistrict, Susut Subdistrict, Kintamani Subdistrict and Tembuku Subdistrict. Kintamani Subdistrict has very steep slope that has the susceptibility for landslides. In 2012 there were landslides that hit Belandingan Village. Belandingan Village is located in the north of Songan A and Songan B Villages. On February 10, 2017, numbers of disasters occurred in Kintamani District, including landslides that occurred in Songan A and Songan B Villages. Disasters in Songan B Village occurred early in the morning precisely at 1:00 a.m., which caused the loss of 7 lives and 5 houses severely damaged [10]. This study is located Belandingan Village, Songan A Village and Songan B Village, Kintamani Sub-district, Bangli Regency, Bali, Indonesia.

## 2. Methodology

### 2.1 Area of Study

This research was carried out in the village of Belandingan, Songan A Village and Songan B Village, Kintamani Sub-district, Bangli Regency, Bali, Indonesia. Songan A Village has an area of about 17.01 km<sup>2</sup>, Songan B Village around 11.88 km<sup>2</sup> and Belandingan Village 6.00 km<sup>2</sup>. These three villages are located at an altitude of more than 1000 m above sea level. Land use in general as plantations and moor [11]. The location of the study area can be seen in Figure 1.

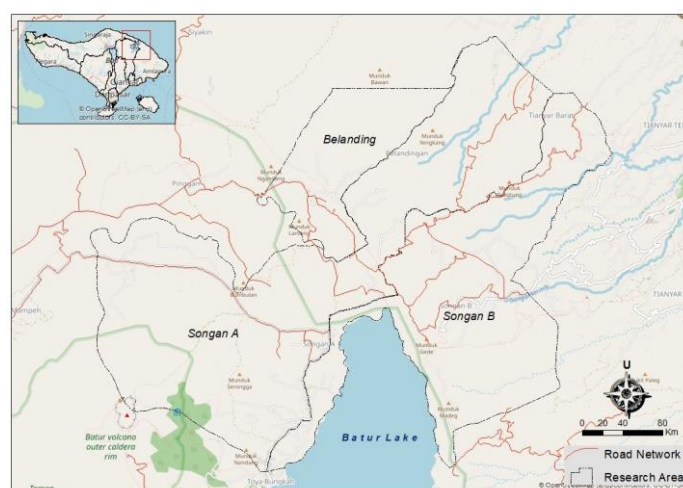


Figure 1. Research Area

### 2.2 Research Material and Tools

The research material including maps, satellite imagery and rainfall intensity data as mentioned in Table 1. The research tool is generally used for field survey as mentioned in Table 2.

**Table 1.** Research Materials

Materials	Item	Source
Maps	Slope Map of 1:25000 scale	Geospatial Information Agency of Republic of Indonesia Geology Agency, Ministry of Energy and Mineral Resources of Republic of Indonesia
	Landuse Map of 1:25000 scale	
	Geology map of 1:25000 scale	
Satellite Image	Worldview Image of Bangli Regency, 2015	Center of Spatial Data Infrastructure Development of Udayana University
Digital Elevation Model (DEM)	Digital Elevation Model of Bangli Regency	United States Geological Survey (USGS) Global Visualisation dan Land Cover Facility

**Table 2.** Research Tools

Tools	Utility	Source
GPS (Global Positioning System) Receiver	To triangulate location and position	Center of Spatial Data Infrastructure Development (PPID) of Udayana University
Compas	To determine direction	Center of Spatial Data Infrastructure Development (PPID) of Udayana University
Abney Level	To measure height and slope	Center of Spatial Data Infrastructure Development (PPID) of Udayana University
Survei form	To take notes	Personal
Digital camera	Documentation	Personal
Personal Computer (PC)	Analysis	Personal
Printer	Printing maps and reports	Personal

### 2.3 Research Stage

#### 1. Data Preparation and Collection

Preparation stages include literature, collecting secondary data, maps and satellite imagery and making field survey map. Maps and data are obtained from several related institutions and from the interpretation of high resolution satellite imagery

#### 2. Making Land Unit Map

The making of land unit map is by overlaying landform map, slope map, geological structure map, soil type map, rainfall intensity map and landuse map which become tentative land unit maps.

#### 3. Field Survey

Field surveys are carried out to check the data from landunit map and checking the condition of landform, slope, geological structure and landuse

#### 4. Calculation of Landslide Susceptibility

Determination of landslide susceptibility is calculated using scoring method by giving value to each parameter. The parameter are landform (LF), slope (SL), geological structure (GS), soil type (ST), rainfall intensity (RF) and landuse (LU). Score for each parameter are presented in Table 3 to Table 8. The score then multiplied by the weight of each parameter as shown in **Equation 1** [12].

**Tabel 3.** Landform Score

No	Landform	Score
1	Aluvial Plain	1
2	Limestone hills, caldera, volcanic foot slope, hilly area, lower slope	2
3	Lower volcanic slopes, lower hill slope, middle slope, flat area between mountains, steep slope mountains	3
4	Volcanic middle slope, upper hill slope, volcanic slope	4
5	Volcanic cone, volcanic slope, volcanic lining complex, valley, caterpillar caldera, lake cliff	5

**Tabel 4. Slope Score**

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

**Tabel 5. Geology Structure Score**

No	Layer Structure	Score
1	Horisontal	1
2	Horisontal/Oblique	2
3	Oblique	3
4	Cracks	4
5	Steep Oblique	5

**Tabel 6. Soil Type Score**

No	Soil Type	Score
1	Brow Mediteran, Reddish Brown Mediteran	1
2	Yellowish Brown Latosol, Reddish Brown Latosol and Litosol, Brown Latosol and Litosol	2
3	Greyish Brown Aluvial, Hidromorf Aluvial	3
4	Brownish Regosol, Yellowish Brown Regosol, Greyish Brown Regosol, Hummus Regosol, Grey Regosol	4
5	Greyish Brown Andosol	5

**Tabel 7. Landuse Score**

No	Landuse	Score
1	Forrest, Mangrove, Swamp, Irigated Ricefield, Ponds, Salting, sand	1
2	Non-Irigated Ricefield	2
3	Buildings, Settlements	3
4	Bush, garden / plantation	4
5	Grass, bare land, dry field / farm	5

**Tabel 8. Rainfall Intensity Score**

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

Landslide Susceptibility = (6LF)+(5SL)+ (5RF) + (4LU) + (3GS) + (2ST) [Equation 1]

The value of the landslide score then classified to obtain a landslide susceptibility class. Landslide susceptibility class can be presented in **Table 9** [12].

**Tabel 9. Landslide Susceptibility Classification**

No	Score	Class
1	<60	Not Susceptible
2	60 – 80	Low Susceptibility
3	80 – 100	Moderate Susceptibility
4	> 100	High Susceptibility

### 5. Landslide Susceptibility Mapping

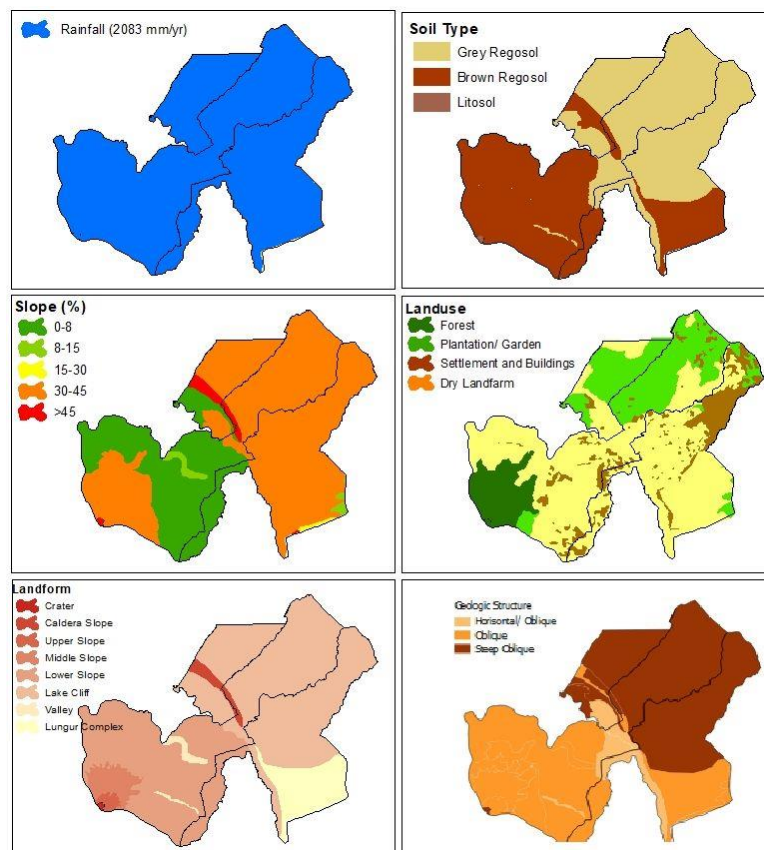
After the classification of landslide susceptibility, next is to make a landslide susceptibility map using QGIS 2.14.0. Landslide class will be divided into 4 classes, namely, not susceptible, low susceptibility, moderate susceptibility and high susceptibility [12].

## 3. Result and Discussion

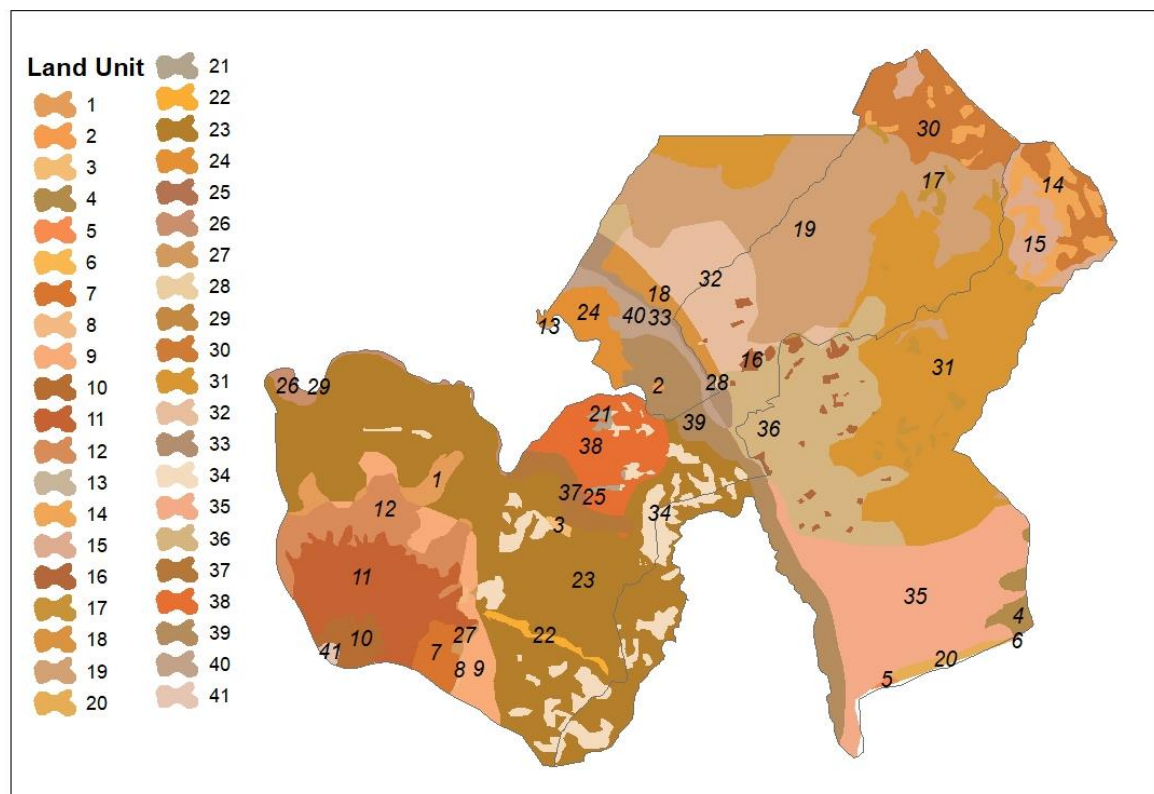
### 3.1 Land Unit Mapping

Based on the results of the analysis of rainfall data from Meteorology and Climatology Agency of Republic of Indonesia, it was found that the rainfall intensity in the study area was 2,083 mm/yr. The data was taken from the Toya Bungkah meteorology post for 11 years from 2007 to 2017. Rainfall is one of the factors that lead to the susceptibility occurrence of landslides. The rainfall intensity in research area is relatively high with a long duration which cause increases in the water content in the soil regime and triggers landslides [13]. Rain that seeps into the soil increasing soil saturation so and eventually the soil mass is easily transported by the flow of water. Rainfall factors that affect the landslides are the amount of rainfall, the intensity of rainfall, and the distribution of rainfall.

Soil type, slope, geological structure, landform and landuse are obtained from maps and are checked directly in the field. Soil types in the study area consisted of litosol soil, gray regosol and brown regosol. The slope varies greatly from class I (0-8) to class V (> 45). The structure of Geology namely horizontal / tilted, tilted, and steep slope, while the landforms in the area there are 8 types, namely: upper slope, lower slope, caldera slope, cliff, crater, lungur complex, valley and middle slope. The types of landuse vary greatly, including forests, plantations, settlements, and moor. Figure 2 shows soil type map, slope map, geological structure map, landform map, landuse map and rainfall intensity map. Based on the overlay processes on each parameter, 41 land units were found in the three villages of the study area. Figure 3 shows the land unit map.



**Figure 2.** Parameter for Determining Land Unit



**Figure 3.** Land Unit Map

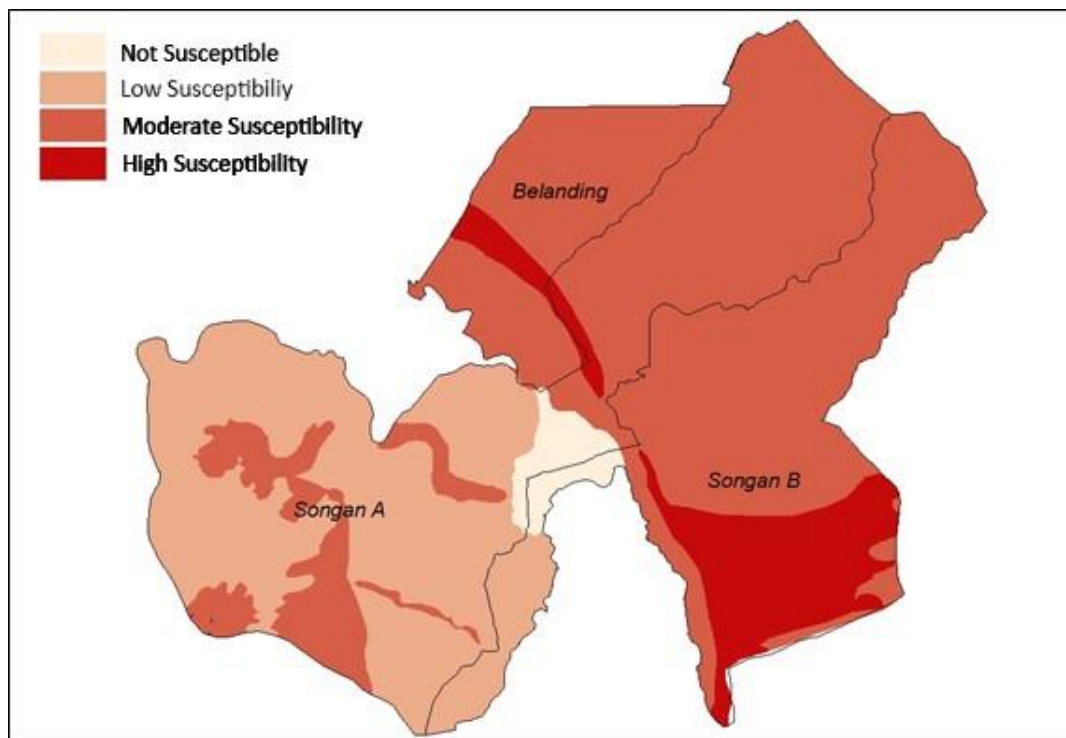
### 3.2 Landslide Susceptibility

In the study area there were 4 landslides susceptibility ranging from not susceptible, low susceptibility, moderate to high susceptibility. The distribution of the not susceptible category is in the villages of Songan A and Songan B. The distribution in the low susceptibility is in the village of Songan A. moderate susceptibility and high susceptibility are in the three villages, namely Belandangan, Songan A and Songan B. This susceptibility is influenced by 6 factors, namely, rainfall, soil type, geological structure, slope, landuse and landform. The distribution of landslides with moderate susceptibility has the most extensive area and spread in almost all research areas. Meanwhile not susceptible areas have the lowest area. The distribution of landslide susceptibility can be seen in Figure 4.

The no susceptibility class includes land units 34 and 39 in Songan A and Songan B Village with total area 94.405 Ha. Landuse in this area are settlements on sloping land with a slope of 0-8%. Low susceptibility class has slope of 15% up to 40%. Low susceptibility class are on the land unit of 26, 29, 25, 23, 21, 38, 3, 12 and 11 which located mainly in Songan A Village with small amount in Songan B Village with total area 1196.768 Ha. Moderate susceptibility class include land units 36, 30, 31, 32, 14, 15, 16, 17, 19, 4, 20, 40, 24, 6, 13, 2, 37, 7, 8, 9, 27, 10, 22, 41, 1, 5 which located in all villages in the research area, with highest area in Songan B village. Area of moderate susceptibility in Belandangan Village is 391.722 Ha, in Songan A Village with area 694.369 and in Songan B village with area 780.255 ha. Total area of moderate susceptibility class is 1866.346 Ha.

Soil type in the moderate class are brown regosol soil and gray regosol. This type of soil in general is unable to holding water because it has no binding capacity. Furthermore, regosol is a young soil type, has not experienced horizon differentiation, sand texture, single hilly structure, consistency off, pH is generally neutral, medium fertility, derived from parent material of pyroclastic volcanic material or beach sand. The distribution of regosol is in the area of young volcanic slopes and in coastal shoals and beach sandbanks [14]. The slope in the moderate class is generally from 30% to 45%. The types of land use in this area are generally plantation. The plantations on sloping land causes the soil to be exposed to rainwater and creating landslides.





**Figure 4.** Landslide Susceptibility Class

High landslide susceptibility class located mainly in Songan B Village with small amount in Belandian Village and Songan A Village in land units 33,18,35,28 with total area of 339,979 ha. High susceptibility class area is located in the Lungur complex landform which has a slope of 30% up to more than 45%. Land use in a very steep slope at lungur complex makes the land very susceptible to landslides. Land use can be a controlling factor for landslides and increasing the risk of land movement. Table 10 shows the area per each landslide class. Figure 5 shows the graphic of landslide susceptibility area.

The susceptibility for movement on the slope also depends on the condition geological structure, rainfall, cover vegetation, and landuse on the slope. Landuse such as moor and plantations, especially in areas with steep slopes mainly triggered landslides. The lack of soil surface cover and vegetation, so that the roots capacity binding soil become reduced and make it easier for the soil to fracture in the dry season. In the rainy season water will easily seep into the soil layer through the fractures to cause the soil saturated with water. This will triggers landslides [15].

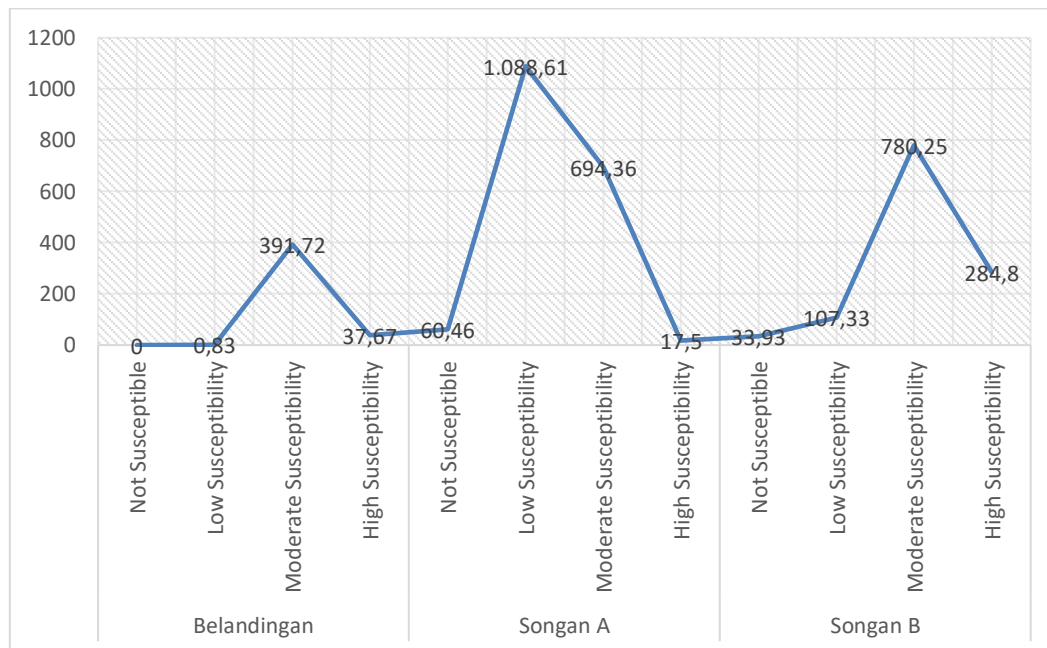
Landslides occur because the plant roots are not strong enough to hold the soil. The slope of 30 to 40% with regosol soil and landuse of plantations and moor have a great influence on the occurrence of landslides. Slope is the dominant factor in the process of landslides. Landuse in the form of forest plants will be able reduce landslides [13]. Planting of seasonal crops in research areas such as chili, tomato and onion plants on steep slopes can encourage soil movement to occur which caused by roots unable to withstand the weight of moving soil. Trees that are suitable for steep slopes are those that are not too high, but have a broad root range as soil binding [16]. Landslides will occur when there is a disturbance that triggers the movement[17]

**Table 10.** Area per Landslides Class

No	Village	Class	Area (Ha)
1	Belandian	Not Susceptible	0
		Low Susceptibility	0.832
		Moderate Susceptibility	391.722
		High Susceptibility	37.670
2	Songan A	Not Susceptible	60.467
		Low Susceptibility	1,088.61



3	Songan B	Moderate Susceptibility	694.369
		High Susceptibility	17.503
		Not Susceptible	33.938
		Low Susceptibility	107.336
		Moderate Susceptibility	780.255
		High Susceptibility	284.806



**Figure 5.** Landslide Susceptibility Area per Village.

#### 4. Conclusions

1. Belandangan, Songan A and Songan B villages have various levels of landslide susceptibility, starting from this non-susceptible category, covering land units 34 and 39. Low susceptibility on land units 26, 29, 25, 23, 21, 38, 3, 12 and 11. While on land units 36, 30, 31, 32, 14, 15, 16, 17, 19, 4, 20, 40, 24, 6, 13, 2, 37, 7, 8, 9, 27, 10, 22, 41, 1.5 and high susceptibility on land units 33, 18, 35, 28.
2. The no susceptibility class mainly located in Songan A and Songan B Village with total area 94.405 Ha. Low susceptibility class are located mainly in Songan A Village with small amount in Songan B Village with total area 1196.768 Ha. Moderate susceptibility class located in all with total area 1866.346 Ha. High landslide susceptibility class located mainly in Songan B Village with small amount in Belandangan Village and Songan A Village with total area 339,979 Ha.
3. Landslide susceptibility analysis depends on the parameters and on the results of the scoring and the weighting results. The dominant factors that cause landslides are soil type, land use and slope.

#### 5. Acknowledgments

Authors would like to thank the Rector of Universitas Udayana, Dean of Agriculture Faculty of Universitas Udayana, Dean of Tourism Faculty of Universitas Udayana, Head of Center for Spatial Data Infrastructure Development (PPIDS) Universitas Udayana, fellow staf, researchers and professors at Universitas Udayana for all the support, comments and suggestions that makes this paper finished.

#### 6. References

- [1] BPBD 2017 Mitigasi Bencana *Badan Penanggulangan Bencana Drh. Karanganyar*
- [2] Barus B 1999 Pemetaan Bahaya Longsoran Berdasarkan Klasifikasi Statistik Peubah Tunggal Menggunakan SIG: Studi Kasus Daerah Ciawi-Puncak-Pacet, Jawa Barat
- [3] Suripin 2002 *Pelestarian sumberdaya tanah dan air* (Andi)

- [4] Karnawati D 2001 Bencana Alam Gerakan Tanah Indonesia Tahun 2000 (Evaluasi dan Rekomendasi) *Jur. Tek. Geol. Fak. Tek. Univ. Gadjah Mada. Yogyakarta*
- [5] B A M *Identifikasi Potensi Longsoran di Desa Candikuning dan Desa Pancasari Kawasan Bedugul, Bali.* (Denpasar: Fakultas Pertanian , Universitas Udayana)
- [6] Bencana B N P 2014 Indeks Resiko Bencana Indonesia (IRBI) Tahun 2013 *Sentul Direktorat Pengurangan Resiko Bencana Deputi Bid. Pencegah. dan Kesiapsiagaan. Tersedia dalam [http://www.bnppb.go.id/uploads/publication/612/2014-06\\_03\\_IRBI\\_2013\\_BNPPB.pdf](http://www.bnppb.go.id/uploads/publication/612/2014-06_03_IRBI_2013_BNPPB.pdf) [Diakses 2 Maret 2017]*
- [7] Bali B and UNUD P 2006 Studi Identifikasi Potensi Bencana Alam Di Provinsi Bali *Lap. Penelitian, Badan Perencanaan Pembang. Drh. Provinsi Bali dan Pus. Penelit. Lingkung. Hidup Lemb. Penelit. Univ. Udayana, Denpasar*
- [8] BNPB 2017 Dua Belas Tertimbun Longsor di 3 Desa Kecamatan Kintamani Bali *Jakarta Badan Nas. Penanggulangan Bencana*
- [9] PEMKAB BANGLI 2017 Kondisi Fisik Dan Dasar Wilayah. Pemerintah Kabupaten Bangli Bali *banglikab.go.id*
- [10] Badan Informasi Geospasial 2017 Derah Terdampak Banjir dan Longsor 5 Desa Di kintamani\_Bali berhasil Dipetakan Secara Cepat oleh BIG
- [11] BPS 2017 *Kecamatan Kintamani Dalam Angka*
- [12] PSBA UGM 2001 Penyusunan Sistem Informasi Penanggulangan Bencana Alam Tanah Longsor di Kabupaten Kulon Progo *Yogyakarta PSBA UGM..(2001). Mitigasi Bencana Alam Tanah Longsor. Yogyakarta Bappeda Kabupaten Kulon Progo dan PSBA UGM*
- [13] Karnawati D 2003 Manajemen Bencana Gerakan Tanah *Diktat Kuliah. Yogyakarta Jur. Tek. Geol. Univ. Gadjah Mada*
- [14] Sugiharyanto M S, Khotimah N and Si M JURUSAN PENDIDIKAN GEOGRAFI FAKULTAS ILMU SOSIAL DAN EKONOMI UNIVERSITAS NEGERI YOGYAKARTA 2009
- [15] Wahyunto H 2010 Kerawanan Longsor Lahan Pertanian *Balai Penelit. Tanah Bogor*
- [16] Surono 2003 *Potensi Bencana Geologi di Kabupaten Garut* (Garut: Pemerintah Kabupaten Garut)
- [17] Dwikorita K 2005 Bencana Alam Gerak Massa Tanah di Indonesia dan Upaya Penanggulangannya *Yogyakarta Univ. Gajah Mada*