

# Landslide Risk Analysis on Agriculture Area in Pacitan Regency in East Java Indonesia Using Geospatial Techniques

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## ABSTRACT

Pacitan is one of the regencies in East Java Province, dominated by hills and mountain landforms covering 85% of its area. Since 2011, more than 16 landslides have occurred significantly in this area. These disasters have engulfed more than 350 ha of agricultural land in Pacitan. This study analyzed the risk of future landslides due to land use change. The parameters used were rainfall, slope, topography, geology, soil, and land use which were assessed and weighed by the Paimin method. Land-use classification from Landsat 8 OLI in 1998, 2008, and 2018 were analyzed using regression formula to calculate the trend of change in 2030. Land use was also classified from the land capability classification (LCC) and regional spatial planning (RSP) as land use options in 2030. The results showed that land use changed over time due to the changes in landslide hazards, which increased three-fold from 1998 to 2018 and will peak tremendously in 2030. There are 29.47 ha of agricultural land in 2018 that have a high potential landslide hazard if no intervention is made. The accuracy for prediction of the 2018 data mapping was 82%. The LCC strategy suggests land use planning to reduce a high level of the landslides.

## 1. INTRODUCTION

The landslide is defined as the movement of a mass of rock, debris, or earthflow (Cruden, 1991). The landslide is one of the natural disasters with severe damages (Jiao et al., 2019), especially in mountainous areas and there is a tendency for landslides to increase in the era of climate change (Dagdelenler et al., 2015; Kirschbaum et al., 2015) and natural resource exploitation activities, including in the Asia Region. Globally, from 2004 to 2016, there were 4,800 landslides with 56,000 fatalities. Furthermore, Frounde and Petley (2018) suggested that 300 million people are affected by this disaster. Based on BNPB (2019) data from 1998 to 2020, there were 5,157 landslides in Indonesia. In Indonesia, tectonic conditions form faults, volcanic rocks are easily fragile, and supported by the climate in Indonesia, which is wet tropics, so the potential for landslides is high. This condition is supported by the recent

changes in land use and the high erosion triggered by rainfall which causes landslides to increase (Fan et al., 2017; Naryanto et al., 2019). Indonesia is ranked in the top three countries with the highest percentage (32%) of landslide fatalities (Frounde and Petley, 2018; Hidayat et al., 2019). Especially in Pacitan, landslides occurred more than 16 times from 2011 to 2020. Landslides are one of the most common natural risks that threaten the safety and property of mountain farmers (Conforti et al., 2014). This disaster causes soil erosion (Panagos et al., 2018), which can directly result in cropland abandonment. Meanwhile, landslides may damage farmland irrigation systems and increase the difficulty of cropland management (Zhao et al., 2018), which can indirectly result in cropland abandonment. Based on Geological Map of 1:100,000, Pacitan Regency is identified to have a sufficient number of faults that can potentially cause landslides. This condition is exacerbated by the

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topography of which 85% is formed from hills and small mountains with a slope of more than 40% (Nita et al., 2020). Landslides hit Pacitan and cause damage to paddy fields covering more than 350 ha. Therefore, the potential for disaster-prone areas in Pacitan Regency have become a strict concern because the topography is mostly mountains and hills with slopes with varying levels of slope (Faturahman, 2018).

The efforts to prevent landslides are carried out by post-incident handling, and a small part uses geographic information systems and remote sensing to predict or mitigate it. These prevention efforts aim to reduce the consequences of disaster risk, both through physical development and awareness as well as to enhance the ability to deal with the threat of disaster called mitigation. Disaster mitigation is very important as the main point in disaster management. One of the most important things in disaster mitigation is the provision of information and maps of disaster-risk areas for each type of disaster (Sulistyo, 2016). Using a training point area from existing landslides, the expert can assess the hazard of the area by identifying areas with similar geological and geomorphological conditions. The possibility of landslides will occur in the future by correlating several main factors causing landslides with the distribution of landslides in the past (Hidayah and Dzakiya, 2018; Hidayat et al., 2019).

The information and maps of landslide-risk areas can be obtained by estimating landslide disasters to reduce the impact and losses due to disasters. One of the ways that can be done in this mitigation effort is to evaluate areas with the potential for landslides by using geographic information systems (GIS) and remote sensing by using the parameters that cause these disasters. Nusantara and Setianto (2015) suggested that remote sensing technology, GIS and global positioning systems (GPS) that are used together can predict the landslide risk in Piyungan and Plered Districts, Bantul Regency, Special Region of Yogyakarta with a good level of prediction accuracy of 70.5%. Landslide monitoring using remote sensing has proven to be an effective method for getting a general picture quickly and accurately (Arif et al., 2017; Jaya, 2005; Mohd et al., 2019; Sulistyo, 2016).

This study also used the Paimin method to analyze the level of landslide susceptibility. The preparation of landslide susceptibility is one of the most practical approaches to landslide hazard assessment and proper management tasks. Although there are many models developed for the landslide

susceptibility map, there is no universal guideline for selecting a model to better model landslide susceptibility map. One of the main approaches to developing hazard reduction strategies is to create a landslide susceptibility map (Nohani et al., 2019). This method begins with the preparation of information in thematic maps about the level of vulnerability. This information is then used for the preparation of management plans in the form of a matrix or map of proposed activities such as forest and land rehabilitation. Proposed activities to determine the type of activity can be in line with the direction for land use or regional spatial planning (RSP). Alignment of the level of vulnerability with the function of the area to determine the planned location of activities is carried out using GIS tools, namely by overlapping the map of the level of vulnerability with the map of the function of the area (Paimin et al., 2012).

This study aims to analyze the landslide risks in Pacitan Regency in 1998 and 2018, projecting future landslide disasters through land capability classification (LCC), regional spatial planning (RSP), and business as usual (BAU). The data from 1998-2018 are used to predict land use in 2030 and analyzed the potential for landslides in Pacitan Regency, especially agricultural lands and their land-use scenarios.

## 2. METHODOLOGY

### 2.1 Description of the study area

This study was conducted in Pacitan Regency, East Java Province, with an area of 138,987.16 ha (Figure 1). Pacitan Regency is in the border area between East Java Province, and Central Java Province, with an area coordinate of 110°55'-111°25' East Longitude and 7°55'-8°17' South Latitude. Most of it is mountainous and rocky and had a few rocky canyons. The geography covers about 88% of the regency area because Pacitan is located in the Sewu Mountains. The highest mountain in Pacitan is Mount Lima in Kebonagung, and Mount Gembes in Bandar as the Spring of Grindulu River. The study is located about 946 m.a.s.l. It was in the Southern Mountains of Java Island which consists of coastal areas, plains, hills, and mountainous areas with flat to undulating landforms. Generally, the land in Pacitan was divided into two categories, calcium-rich in the south, and fertile land in the north. The soil consisted of Litosols association, red Mediterranean lithosol, tuff and volcanic compounds, reddish lithosol complexes, and grey alluvial, clay sediments containing many potential



**Figure 1.** Location of the study area

minerals. Based on data from the Regional Disaster Management Agency of Pacitan Regency, there were at least 14 landslides disasters in Pacitan Regency in 2011-2013 (Avridianto, 2016).

## 2.2 Tools and materials

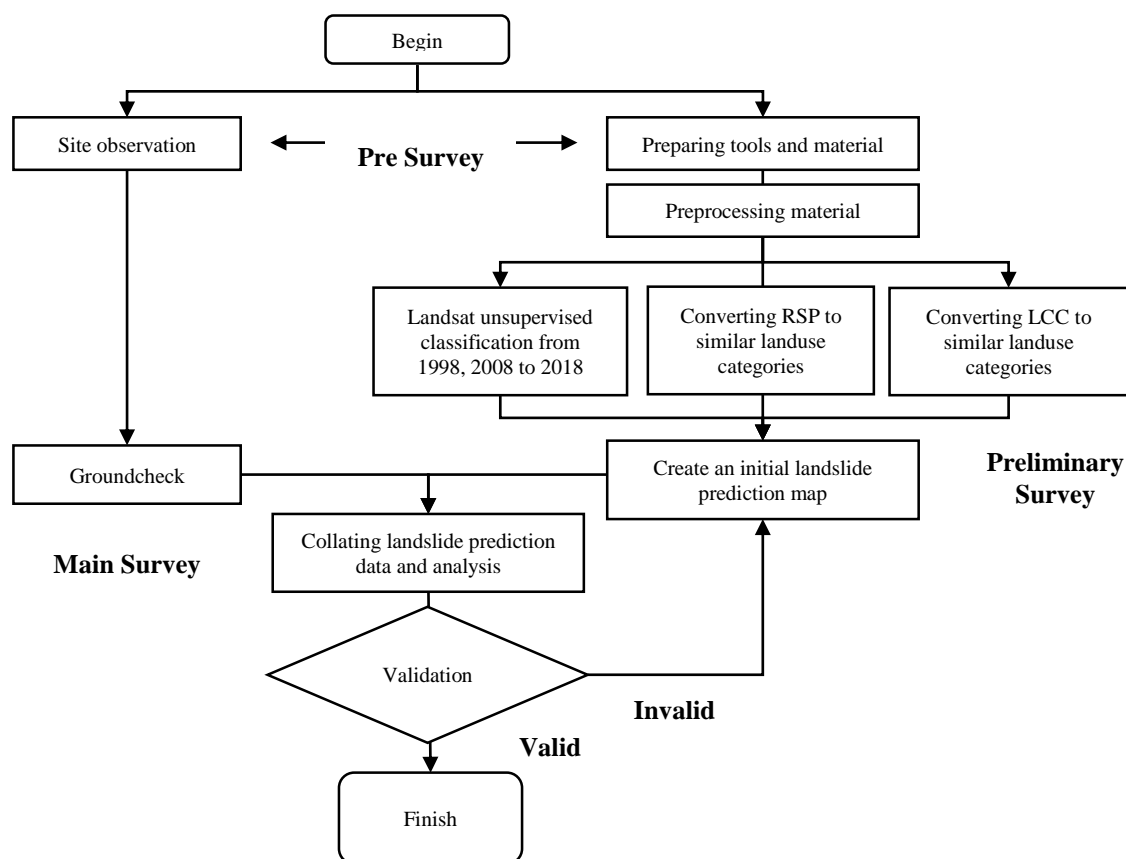
The tools used in this study consisted of stationery for compiling reports. Then a set of computers, ArcGIS 10.6 software (Putra and Nita, 2020), PCI Geomatica software, all of these were used for making maps of the survey location regencies. The global positioning system (GPS) tools, a set of survey tools (survey set), a camera, and observation sheets, were used for soil sampling at the research location. While the materials used consisted of Indonesian Topography Maps of 1:25,000, digital elevation model map with a resolution of 8.25 m, climate data, landform maps, and geological data, water management data, and watershed maps.

## 2.3 Research stages

Landslide risk analysis in Pacitan Regency consisted of several survey activities. It was started with a pre-survey consisting of preparing tools and materials, arranging for research permits at the research location, and processing initial materials to compile a survey location map and determining the location for taking soil samples. Then proceed with the preliminary survey stages and the primary survey with

ground check activities to take intact and disturbed soil samples. Then, the post-survey stage was carried out to analyze the soil samples, research data, and validation process. The research flow diagram is presented in Figure 2. The study started with preparing tools and material, especially in collecting the secondary data such as Indonesian Topography Maps (RBI), digital elevation model (DEM), climatology data, landform data, geological map (Samodra et al., 1992), water management data, and watershed map.

The pre-processing materials consisted of radiometric correction activities to improve image quality, eliminate noise, and determine the portion of the image to be examined using PCI Geomatica. Then the haze cloud removal was carried out to remove the fog or dust contained in satellite imagery. Land use classification at different time scales used Landsat imagery of 30 m × 30 m resolution. Landsat image analysis was carried out to classify the different land uses, namely forests; agroforestry; drylands; settlements; water bodies; and other land uses. Landuse change analysis was carried out using Landsat 5 TM imagery for 1998, Landsat 7 ETM for 2008, and Landsat 8 OLI for 2018. Because the reporting period was quite long (10 years), the Landsat imagery used was also different. The classification method used in Landsat image processing was the unsupervised classification method. The results of image analysis for three different years were used to



**Figure 2.** The flow chart of the study

determine business as usual (BAU), which contained predictions of the risk of landslides in 2030 concerning changes in disaster patterns and land use simulations according to land capability classification.

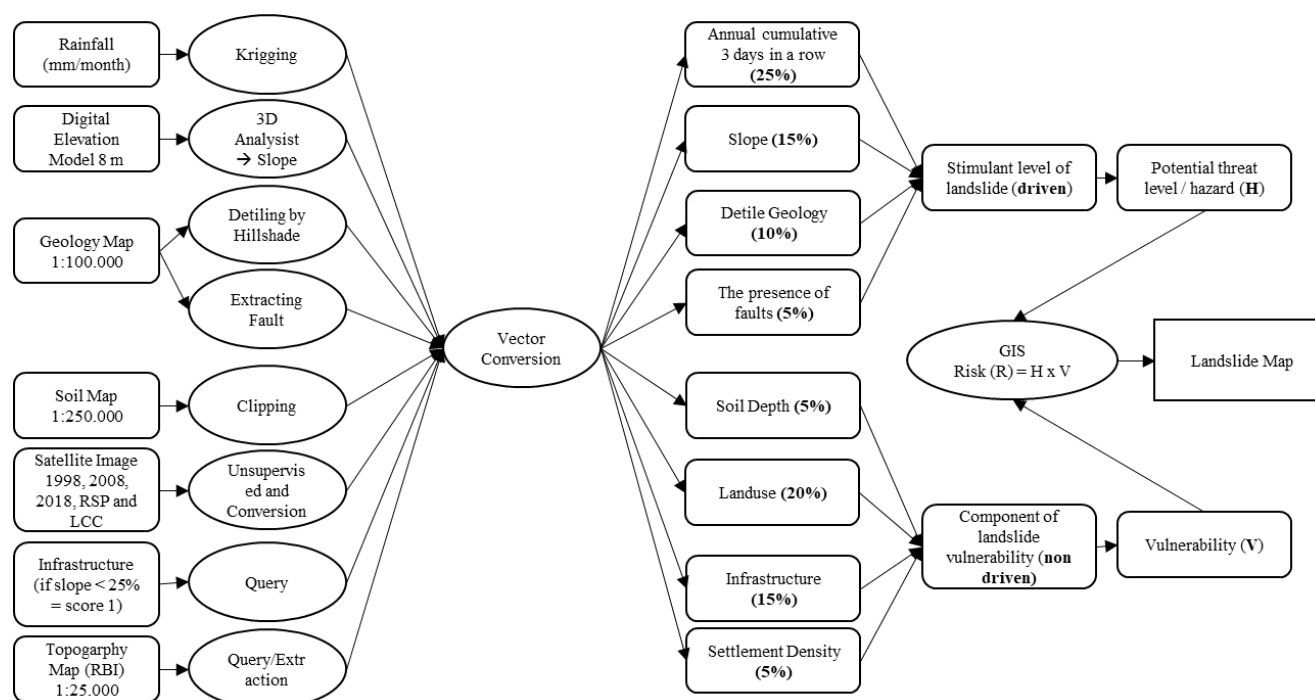
The parameters were divided into natural factors causing landslides (three consecutive days of cumulative annual rainfall, land slopes, rock types, faults/claws, and soil depth to impermeable layers) and management factors (land use and infrastructure as well as a settlement if the land slopes were below 25%). The land use share management factor was a parameter modified by including three main scenarios: land capability classification (LCC), regional spatial planning (RSP), and business as usual (BAU). Land capability classification illustrated the intensity of land that can use without damage. The analytical method followed the land capability analysis method by Arsyad (1989). The lands were classified using roman letters from class I to class VIII. Meanwhile, the subclass was a limiting factor or damage hazard consisting of erosion (e), excess flooding or flood risk (w), rooting area or sufficient soil depth (s), and climate (c).

In this study, the researcher employed the Paimin et al. (2012) method, which has been

approved. Paimin et al. (2012) explained that scores and weights carried out the novelty analysis on increasing parameters. Remote sensing and GIS analysis was conducted using Geomatica and ArcGIS 10.3 software to process the primary data. The scoring and weighting scores were carried out according to the compiled value categories (Paimin et al., 2012). The arithmetic overlay operation was carried out with a weighted overlay based on a predetermined weight (Figure 3).

This study focused on the weighted overlay using parameters that have been scored so that the final stage was analyzed using Algebra Map of the weighted overlay results. The analysis results were validated to ensure the data that needed to be proven correct by observing and knowing the actual situation or presence in the field (ground check). The data collection and observation of slopes, sensitivity, and level of erosion, depth of soil, rock, and vegetation were compiled. The confusion matrix was used to validate overall accuracy data. The parameters for the preparation of landslide prediction maps included; (1) natural parameters of three consecutive days, namely cumulative annual rainfall, land slopes, rock types, faults, and soil depths to impermeable layers; and (2)





**Figure 3.** Model analysis of the landslide risks modified from Paimin et al. (2012)

management factors of the land use as well as infrastructure and settlement if the land slope was below 25%. An analytical model of a landslide prediction analysis in an area was carried out by performing vector data, which was then overlaid to obtain a landslide prediction analysis using remote sensing and GIS.

### 3. RESULTS AND DISCUSSION

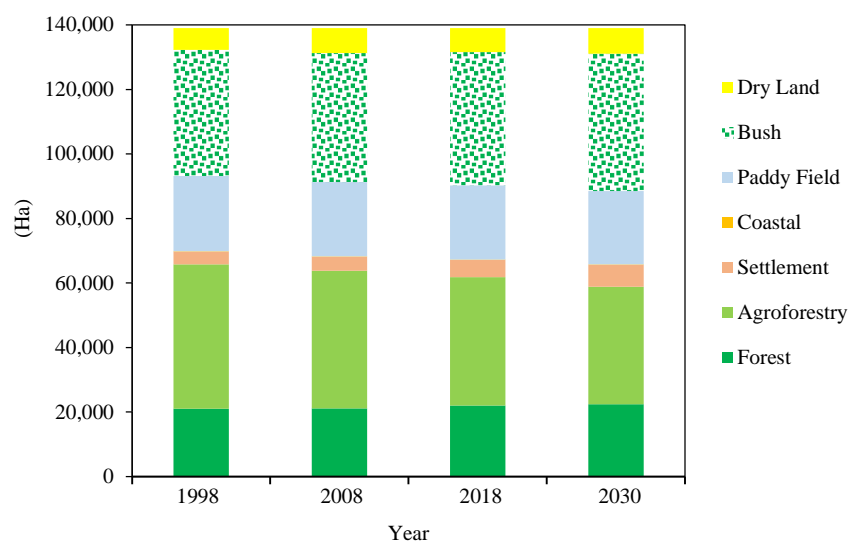
#### 3.1 Land use change and business as usual (BAU) analysis

The changes in forest land use have increased from 1998 to 2018 so that in 2030, it is estimated that forest land use will increase to 22.45 ha (Figure 4). In contrast to forests, plantations had decreased significantly from 44.74 ha in 1998 to 39.79 ha in 2018. Thus, the pattern of decline that occurs in 2030 will reduce the area of agroforestry to 36.44 ha. In addition to forests, other land uses that have increased are predicted to reach 6.82 ha in 2030, shrubs around 42.54 ha, and dryland farming around 7.93 ha in 2030. These increases affect the decline in plantations and affect the decrease in paddy and coastal areas with a prediction of 22.77 ha and 64 ha. Precisely, in paddy fields and dry fields, the decrease in paddy land areas followed by an increase in drylands in 2008, 2018, and predictions in 2030. This change is assumed to be

more influenced by land management and plant species selection. The next change that may occur is that paddy fields are very large to change their private functions, given the location of paddy fields around the district center with adequate public facilities, centralized offices, and suitable topography for use in settlements. This condition causes areas close to public facilities to become densely populated areas. Besides, the increase in population every year in an area followed by the need for shelter is the main reason many changes in land use for settlements, one of them is paddy fields (Yasta and Yarmaidi, 2019). Moreover, paddy fields, dry fields, and settlements are very close to the Grindulu River, the main and the largest river in Pacitan Regency, which is directly connected to the sea.

#### 3.2 Analysis of land use according to regional spatial planning (RSP)

The regional spatial planning (RSP) in Pacitan Regency consists of cultivated and protected areas. The classification of land use in Pacitan Regency is based on a protected area development plan, consisting of protected forest areas, karst areas, border areas, areas around springs, areas of nature reserves and cultural reserves, areas risk to natural disasters, and other protected areas. The cultivation area consists of allotment areas for production forests, community



**Figure 4.** Chart of land use change in Pacitan Regency

forests, agriculture, fisheries, mining, industry, tourism, settlements, mainstays, and a safe area for flight operations at Iswahyudi Air Force Base. Most of the land use plans in Pacitan Regency until 2028 will be designated as community forests. This is because

Pacitan Regency has a various community forest area. The second-largest land use is cultivated land, namely green open areas, agriculture, and settlement. [Table 1](#) shows an area of regional spatial planning (RSP) in the Pacitan Regency and its conversions.

**Table 1.** Regional spatial planning (RSP) in Pacitan Regency and its conversion

Land use plan	Area (ha)	Conversion to
Public forest area	65,951.00	Forest
Nature/cultural reserves	1,254.13	Forest, production forest, and agroforestry
Production forest	1,484.39	Production forest and agroforestry
Agriculture	13,033.00	Paddy fields and dryland farming
Settlement	16,253.31	Settlement
Green open space/reserve land	26,720.37	Settlement and agroforestry
Other	14,291.00	Various land use

### 3.3 Land use analysis according to the land capability classification (LCC)

Land capability classification carried out in Pacitan Regency is a systematic evaluation of land characteristics and is grouped into various categories based on the potentials and obstacles in land use ([Arsyad, 1989](#)). The land characteristics assessed are slope, erosion, solum depth, texture (top and bottom layers), permeability, drainage, drought risk, and salinity. Based on the land capability grouping, a land capability map is compiled according to land capability classification (LCC), as shown in [Table 2](#).

**Table 2.** Types of land use based on the capability and area classification in Pacitan Regency

Land use	Area (ha)
atural forest	31,832.20
Production forest	61,816.90
Agroforestry	1,909.35
Settlement	5,856.06
Paddy fields	6,805.09
Bush	2,061.13
Dryland farming	28,709.27
Total area (ha)	138,990.00

### 3.4 Landslides risk potential

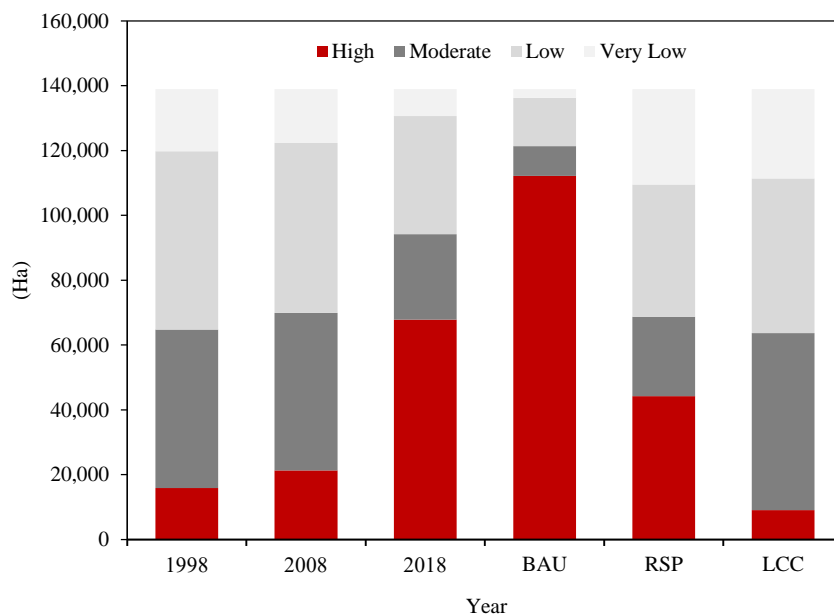
The differences in land use in 1998, 2008, 2018, 2030, regional spatial planning (RSP), and land capability classification (LCC) affect disasters' potential. The potency levels in 1998, 2008, and 2018 increase at high levels and assume to be very high due to land-use changes. The changes in land use will affect runoff so that when it rains, some falling water will seep into the ground and some will pool in the soil surface, depending on the conditions at the ground level. In addition, land use affects the shelf life of water in the soil. Based on land changes that have occurred, the prediction of future land-use changes is based on the patterns that occurred. Furthermore, this land-use is called business as usual (BAU). The results of the BAU analysis shows that if there are no interventions in the current land-use change patterns in Pacitan Regency, there will be an increase in the level of potential landslides from low to moderate, high to high, and high to very high in 2030 (Table 3).

The landslide risk class in 2030 (BAU) will have an impact on lowering the moderate class if intervened by the regional spatial planning (RSP) in Pacitan Regency. However, on the other hand, it also affects increasing moderate to very high classes. The land-use planning based on the RSP increases the potential for landslides compared to business as usual (BAU). The regional spatial planning (RSP) should pay attention to the land capability classification (LCC), which is proven to be able to reduce the landslide class from high to medium and low to very low. The results of the overall accuracy calculation show that the reliability of the data reaches 82%. There are 12 data errors based on the assumption that data inequality is at a very low level. Figure 4 shows the pattern of potential changes in landslide risks in 1998 to 2018 and predictions for 2030 based on BAU, RSP, and LCC. Meanwhile, Figure 5 shows the landslide risk map in Pacitan Regency

**Table 3.** The results of the potential landslides in Pacitan Regency in ha

Level	1998	2008	2018	2030 (BAU)	RSP	LCC
High	15,878	21,349	67,801	112,219	44,223	9,094
Moderate	48,911	48,617	26,388	9,194	24,467	54,613
Low	55,016	52,650	36,479	14,898	40,859	47,652
Very low	19,182	16,656	8,319	2,676	29,380	27,628
Total	138,987 ha					

Explanation: BAU=business as usual; LCC=land capability classification; RSP=regional spatial planning



**Figure 5.** The pattern of landslides potential in Pacitan Regency

### 3.5 Discussion

Landslide is influenced by human activities, geographical conditions, topographical conditions, river channel conditions, rainfall, and land-use changes. Pacitan Regency is one of the regencies located in the Southern part of Java, and morphologically almost 50% of its area is mountains with slopes ( $>40\%$ ) (Budiono, 2012). In Pacitan Regency, the landslides risk in 1998, 2008, and 2018 continues to increase at moderate to high landslide risk levels. This condition happens because of changes in land use in the area. The differences in land use in 1998, 2008, 2018, 2030, RSP, and LCC will affect the landslides in the Pacitan Regency (Figure 6).

The changes not only lead to growth and can reduce the landslide risk, but also land-use changes can also increase the landslide risk. It is predicted that through business as usual (BAU), in 2030, there will be an increase in the landslide risk from low to moderate and medium to high. This will happen if there is no intervention in the pattern of land-use change in the Pacitan Regency. The high-risk landslide level happens in the forest (16%), agroforestry (27%), settlement (1%), paddy field (11%), bush (39%) and dry land (6%). There are around 29,473 ha of agricultural land in 2018, which has a high landslide risk and will increase if no intervention made. Landslides can occur due to natural conditions and the influence of human activities. This is based on Naryanto et al. (2019) statement that landslides occur due to two main factors: controlling and triggering factors.

Controlling factors affect the condition of the material itself, such as geological conditions, slope, lithology, faults, and burly of rocks. Triggering factors cause the movement of these materials, such as rainfall, earthquakes, slope foot erosion, and human activities. Landslides can occur at any time and cause various unintended consequences in the form of physical, social, economic, and environmental impacts. Landslides cause extensive damage to property and infrastructure and the loss of human lives almost every year (Hidayah and Dzakiya, 2018). Additionally, landslides cause many losses that will felt by residents, both directly and indirectly. Some of the losses are damaging to the infrastructure, damage to agricultural areas, disruption to watersheds, and disease spread. The high level of loss experienced by

the community due to natural disasters can cause a lack of public information about the possibility of disasters occurring nearby so that public awareness of disaster response becomes very minimal. The historical data shows that 95% of disasters in East Java are related to hydro-meteorological disasters such as floods, landslides, and strong winds (BNPB, 2019). This number can increase if we consider climate change in the East Java Region. In 2018, the potential for damage due to landslides in Pacitan Regency, especially on the dry land, paddy field, and agroforestry was 29,473 ha.

Based on the study conducted by Hidayah and Dzakiya (2018) about analysis geological and geophysical data for landslide hazard zone prediction with the weight of evidence method in Pacitan Regency, East Java to predict the potential landslide using weight of evidence method. The geological data used lithological data, structural data, contour data, and alteration data. The results from this data analysis are six evidence maps, such as NE-SW lineament, NW-SE lineament, host rock, heat source, kaolinite alteration, and iron oxide alteration maps. The geophysical data analysis the distribution of rock density to interpretation the landslides. The evidence maps are analyzed by weight of evidence method to produce a good map where the validity is tested using conditional independence (CI), the pairwise and overall tests. Then, the analyses have a posterior probability map of the landslide. The checking field validates the posterior probability map (potential mineral maps). The posterior probability map (after validation) or favourable map predicts approximately favourable zone and non-favourable zones. Favourable zones of potential landslide hazard zonation divides into three classes: high-potential hazard, moderate hazard, and low hazard. The analysis of the susceptibility map developed shows that the high susceptibility is mostly concentrated in the northern and west parts of the study area. The local environmental conditions are very favourable to triggering (a combination of a slope gradient  $>25^\circ$ ; relief delivered; strong fracturing; extremely degraded soils or dissected; the presence of forest and vegetation or not properly maintained). High hazard is about 140 km<sup>2</sup>, the moderate hazard is about 238 km<sup>2</sup>, and the low hazard is about 194 km<sup>2</sup>. The biggest landslide in Pacitan Regency increases at moderate and high levels.



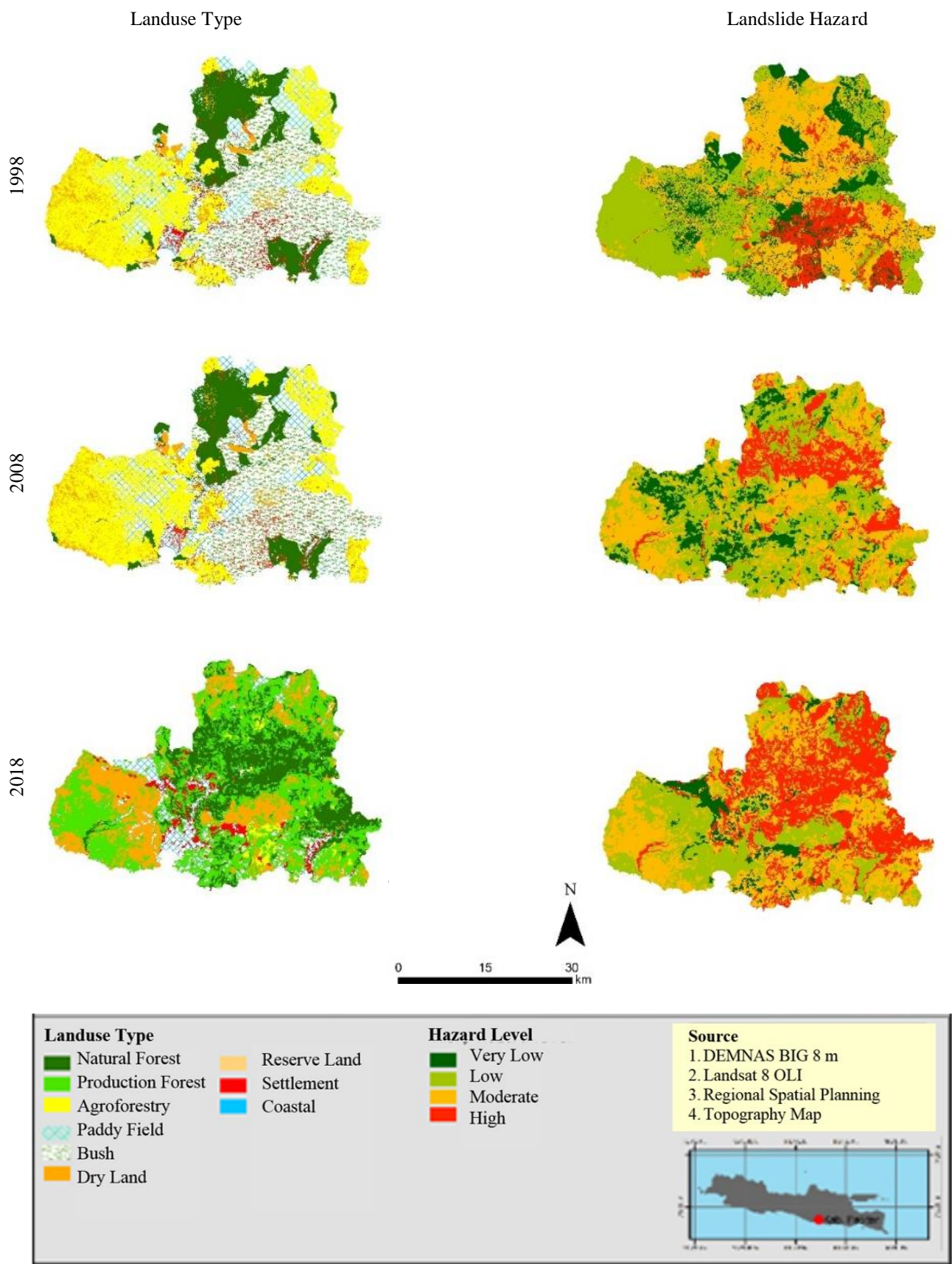
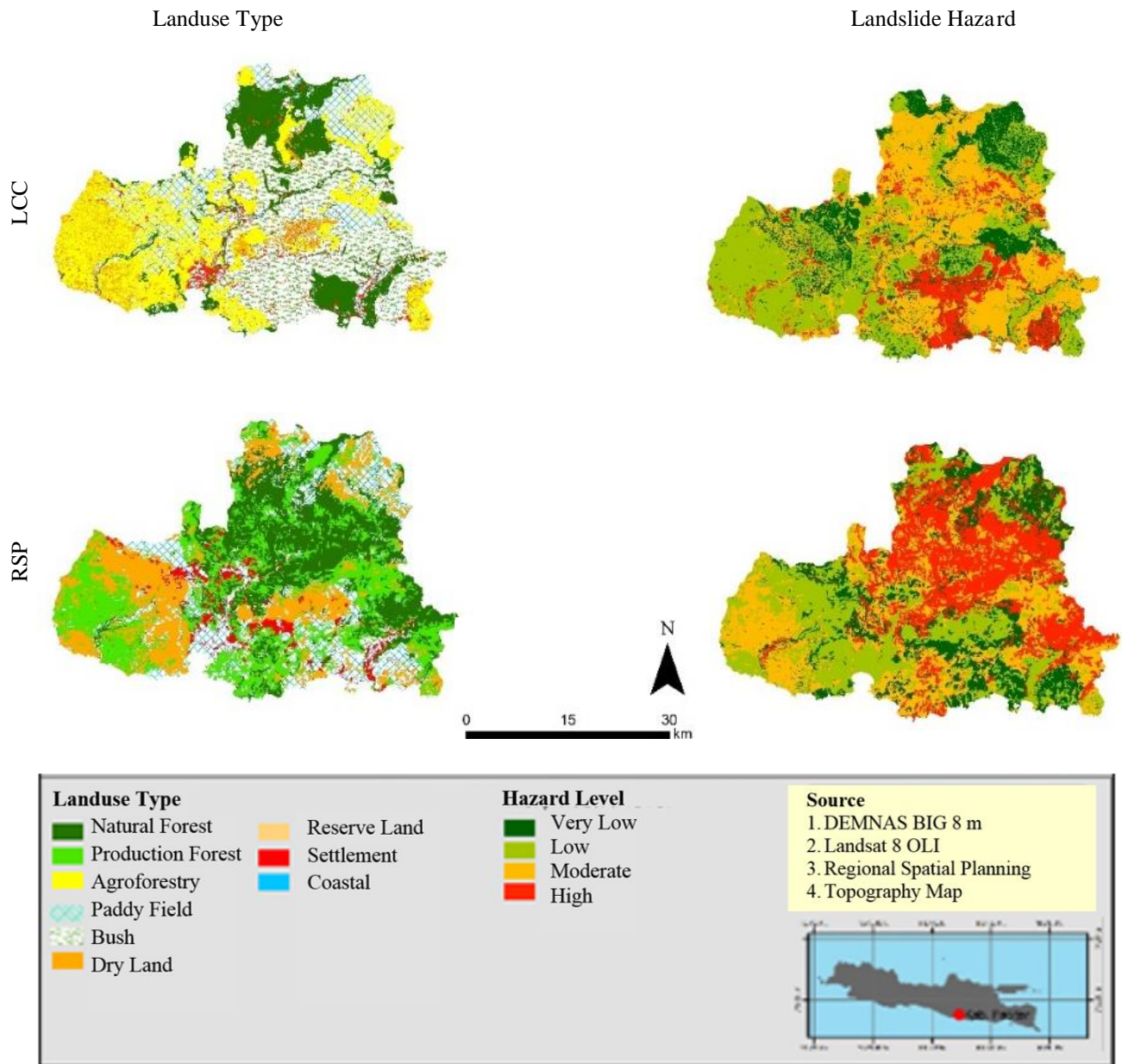


Figure 6. Landslide risk maps in Pacitan Regency



**Figure 6.** Landslide risk maps in Pacitan Regency (cont.)

Based on the study conducted by Sipayung et al. (2014), a vulnerability of landslides was used (Paimin et al., 2009) to determine the degree of landslide vulnerability using the natural factors, namely the formula for cumulative daily rainfall for three consecutive days (25%), soil slope (15%), geology/rocks (10%), presence of layers/faults (5%), and soil depth (5%). Meanwhile, the management factors included land use (20%), infrastructure (15%), and settlement density (5%). From the results of empirical equations, testing potential predictions of landslide events in Citarum watershed show quite good predictions. The above empirical equation applies to the category of moderate, high, and very high vulnerability levels. In order to obtain better

prediction, additional parameters such as fault, rock geology, infrastructure, and additional landslide event data can be considered.

A study by Susanti et al. (2017) regarding the vulnerable landslides in Banjarnegara Regency using Paimin et al. (2009) method showed that the information on the vulnerable landslides dominated by "somewhat vulnerable". Thus, to increase the level of accuracy of landslide susceptibility classes in Banjarnegara, it is necessary to modify the setting of landslide vulnerability parameters, especially the classification of slopes and the area affected by disasters. The research accuracy in the Pacitan area is 82%.

The improvement of the accuracy has also been modified to regulate landslide vulnerability such as faulting, rock geology, infrastructure, and even adding mudslide event data of the affected area. As for the natural factors that cause landslides, according to Paimin et al. (2009), the parameters in the landslide vulnerability assessment process is the geological condition and regolith depth. One of the geological conditions is the type of soil that has a significant effect on landslides (Setiadi, 2013). Solle and Ahmad (2016) also said that soil with clay mineral content, especially kaolinite and vermiculite in water-saturated condition, will become unstable. Regarding this matter and based on the results of the field survey, it is known that most of the soil types in Pacitan are Ultisol and Inceptisol. This condition causes the area to be a vulnerable area of landslide. Priyono (2012) conveyed that the lands in the development period, such as Inceptisol is a type of soil prone to landslide.

In this study, the landslide increases at moderate and high levels due to changes in land use. The interaction between forest coverage and landslides is complex (Haigh et al., 1995). Land-use change is an essential factor in the occurrence and movement of rainfall triggered landslides (Glade, 2003; Karsli et al., 2009; Kingsbury, 1994). The presence of landslides is directly related to variations in land use (Glade, 2003). There is currently no consensus on the effect of covered vegetation on slope stability. Some studies have found that plants may not contribute to slope stability (Wu and Sidle, 1995), while other researchers argued that vegetation roots increase slope stability (Jakob, 2000; Karsli et al., 2009). The higher proportion of forest cover, the lower the amount of soil eroded by rainfall. Thus, lumbering a slope can accelerate its movement to failure and extend its area. Since it takes 30-35 years or longer for a slope to recover naturally, slope land development will cause a slope to lose equilibrium which is more easily inducing slope failure during torrential rain.

#### 4. CONCLUSION

The prediction of landslide risk in Pacitan using the Paimin modification method has an accuracy rate of 82%. The most influential factor is land use. If there is no intervention (BAU) for land use in Pacitan Regency, the risk of high-level landslides will increase to 65.51%. However, suppose there is land use intervention, according to RSP. In that case, landslide incidence will decrease as indicated by a decrease in the level of risk, namely at a low level (12%) and a

very low level (253.17%). The regional spatial planning (RSP) should consider the land capability classification (LCC), which is proven to be able to reduce the landslide classes from high to medium and low to very low. It means that the high risk of landslides is reduced if the intervention refers to the LCC, which reaches 86.59%.

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#### REFERENCES

- Arif N, Projo D, Hatono H. Raster-based qualitative spatial erosion modeling (case study in das serang, kulonprogo district. *Journal of Environmental Science* 2017;15(2):127-34.
- Arsyad S. Soil and Water Conservation. Bogor, Indonesia: Institut Pertanian Bogor Press; 1989.
- Avridianto DF. Landslides risk level in ketro village, tulakan sub-district, Pacitan District. *Swara Bhumi* 2016;1(2):18-27.
- Badan Nasional Penanggulangan Bencana (BNPB). Indonesian Disaster Information Data [Internet]. 2016 [cited 2020 Jul 21]. Available from: <http://dibi.bnpb.go.id/>.
- Budiono UF. White Book of Pacitan District Sanitation Chapter I. Preliminary. Pacitan, Indonesia: Pacitan Distric Government. 2012.
- Conforti M, Pascale S, Robustelli G, Sdao F. Evaluation of prediction capability of the artificial neural networks for mapping landslide susceptibility in the Turbolo River catchment (northern calabria, italy). *Catena* 2014;113(2-3):236-50.
- Cruden DM. A simple definition of a landslides. *Bulletin of the International Association of Engineering Geology* 1991; 43(1):27-9.
- Dagdelenler G, Nefeslioglu HA, Gokceoglu C. Modification of seed cell sampling strategy for landslide susceptibility mapping: An application from the eastern part of the gallipoli peninsula (canakkale, turkey). *Bulletin of Engineering Geology and the Environment* 2015;75(2):575-90.
- Fan W, Wei X, Cao Y, Zheng B. Landslide susceptibility assessment using the certainty factor and analytic hierarchy process. *Journal of Mountain Science* 2017;14(5):906-25.
- Faturahman BM. Strategy of emergency response of flood and landslide disaster in pacitan regency. *Jurnal Ilmu Administrasi Media Pengembangan Ilmu dan Praktek Administrasi* 2018;15(2):133-47.
- Frounde MJ, Petley DN. Global fatal landslide occurrence 2004 to 2016. *Natural Hazards and Earth System Sciences* 2018;18:2161-81.
- Glade T. Landslide occurrence as a response to land use change: A review of evidence from New Zealand. *Catena* 2003;51(3-4):297-314.
- Haigh MJ, Rawat JS, Batarya SK, Rai SP. Interactions between forest and landslide activity along new highways in the kumaun himalaya. *Forest Ecology and Management* 1995;78(1-3):173-89.



- Hidayah RA, Dzakiya N. Analysis geological and geophysical data for landslide prediction hazard zone with weight of evidence method in pacitan district east java. *Journal of Applied Geospatial Information* 2018;2(1):117-23.
- Hidayat R, Sutanto SJ, Hidayah A, Ridwan B, Mulyana A. Development of a landslide early warning system in indonesia. *Geosciences* 2019;9(10):451.
- Jakob M. The impacts of logging on landslide activity at clayoquot sound, british columbia. *Catena* 2000;38(4):279-300.
- Jaya I. Landslide detection techniques using multi-time spot imagery, case studies in Teradomari, Tochio and Shidata Mura, Niigata, Japan. *Journal of Tropical Forest Management* 2005;10(1):31-48.
- Jiao Y, Zhao D, Ding Y, Liu Y, Xu Q, Qiu Y, et al. Performance evaluation for four gis-based models purposed to predict and map landslide susceptibility: A case study at a world heritage site in southwest china. *Catena* 2019;183:104221.
- Karsli F, Atasoy M, Yalcin A, Reis S. Effects of land-use changes on landslides in a landslide-prone area (ardesen, rize, ne turkey). *Environmnet and Monitoring Assesment* 2009;156(1-4):241-55.
- Kingsburry PA. Preliminary Assessment of the Johnson Hill Landslide, Palliser Bay. Contract Report 94.205. North Island, New Zealand: Wellington Regional Council; 1994.
- Kirschbaum D, Stanley T, Zhou Y. Spatial and temporal analysis of a global landslide catalog. *Geomorphology* 2015;294:4-15.
- Mohd MH, Rahman MAA, Azman FNUZ, Jusoh A. Landslide susceptibility mapping at lebri and galas river basins after extreme flood event using weights of evidence. *Journal of Sustainability Science and Management* 2019;14(2):103-15.
- Naryanto HS, Soewandita H, Ganesha D, Prawiradisastra F. Analysis of the causes of the occurrence and evaluation of landslides in Banaran Village, Pulung District, Ponorogo Regency, East Java Province. *Journal of Environmental Science* 2019;17(2):272-82.
- Nita I, Putra AN, Fibriantingtyas A. Analysis of drought hazards in agricultural land in Pacitan Regency, Indonesia. *Journal of Soil Science and Agroclimatology* 2020;17(1):7-15.
- Nohani E, Moharrami M, Sharafi S, Khosravi K, Pradhan B, Pham BT, et al. Landslide susceptibility mapping using different gis-based bivariate models. *Water* 2019;11(7):1402.
- Nusantara YP, Setianto A. Landslide hazard mapping using the frequency ratio method in piyungan and pleret sub-districts, bantul district, yogyakarta special area. *Proceedings of 8<sup>th</sup> Academia-industry Linkage National Earth Seminar*; 2015 Oct 15-16; Graha Sabha Permana, Yogyakarta: Indonesia; 2015.
- Paimin, Pramono IB, Purwanto, Inrawati DR. Watershed Management Planning System. Jakarta, Indonesia: Ministry of Forestry, Forestry Research and Development Agency, Research and Development Center for Conservation and Rehabilitation; 2012.
- Paimin, Sukresno, Pramono IB. Flood and Landslide Mitigation Techniques. Balikpapan, Indonesia: Tropenbos International Indonesia Programme; 2009.
- Panagos P, Standardi G, Borrelli P, Lugato E, Montanarella L. Cost of agricultural productivity loss due to soil erosion in the European Union: From direct cost evaluation approaches to the use of macroeconomic models. *Land Degradation and Development* 2018;29:471-84.
- Priyono KD. A study of clay mineral in the occurences of landslide disaster area at kulonprogo mountains yogyakarta special province. *Geography Forum* 2012;26(1):53-64.
- Putra AN, Nita I. Reliability of using high-resolution aerial photography (red, green and blue bands) for detecting available soil water in agricultural land. *Journal of Degraded Mining and Lands Management* 2020;7(3):2221-32.
- Samodra H, Gafoer S, Tjokrosapoetro S. Geological map sheet pacitan, java, scale 1: 100.000. Bandung, Indonesia: Geological Research and Development Center; 1992.
- Setiadi T. Designing a geographic information system for mapping landslide prone areas, mitigation and disaster management in Banjarnegara District. *Kes Mas* 2013;7(1):33-43. (in Indonesian)
- Sipayung SB, Cholianawati N, Susanti I, Aulia SR, Maryadi E. Development of empirical equation model in predicting the occurrence of landslide at watershed of citarum (west java) based on thetrmm satellite data. *Journal of Sains Dirgantara* 2014;12(1):12-21.
- Solle MS, Ahmad A. Identification of soil, rock and tectovolcanisme on landslides intensity in tondano watershed. *Journal of Geological Resource and Engineering* 2016;6:271-82.
- Sulistyo B. The role of geographic information systems in mitigating landslides. *Proceedings of the National Seminar on Disaster Mitigation in Regional Development Planning*; 2016 Mar 28; Agricultural Faculty, Bengkulu University, Bengkulu: Indonesia; 2016.
- Susanti PD, Harjadi B, Miardini A. Vulnerability analysis as a basis for landslide mitigation in banjarnegara regency. *Journal of Watershed Management Research* 2017;1(1):49-59.
- Wu W, Sidle RC. A distributed slope stability model for steep forested basins *Water Resources Research* 1995;31(8):2097-110.
- Yasta RD, Yarmaidi Y. Analysis of changes in the use of paddy fields to settlements in the north pagelaran district. *Journal of Geographic Research* 2019;7(3):1-11.
- Zhao L, Zuo S, Deng D, Han Z, Zhao B. Development mechanism for the landslide at xinlu Village, Chongqing, China. *Landslides* 2018;15:2075-081.