

Preliminary Detection Model of Rapid Mapping Technique for Landslide Susceptibility Zone Using Multi Sensor Imagery (Case Study in Banjarnegara Regency)

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Abstract. This study as a preliminary stage as part of disaster mitigation landslide in Banjarnegara Regency, by utilizing a combination of multi-sensor image to overview the pattern forest cover changes with supported by other parameters such as rainfall, slope, aspect, curvature patterns hill (curvature). The objective is how to develop detection model in rapid mapping technique for detection landslide susceptibility zone. This information is used as basis an early detection for estimating landslide potentially happen in the future. there are four main processes which are optical image processing, SAR image processing, DEM processing and Scoring Geoprocessing. The final zone might be verified by particular landslide event location whether it exist on the result map. It obtain “big five” district with higher prone landslide susceptibility zone such as Batur district, Pejawaran district, Wanayasa district, Kalibening district and Rakit district. Total susceptibility zone in Banjarnegara regency approximately 604.79 Ha with 15,250 prone point location. Thus, it classified as 14.16 Ha of low zone, 286.41 Ha of moderate zone and 304.22 Ha of high zone. This study demonstrates as rapid mapping the enormous potential landslide occurrences investigated by susceptibility zone. In term of landslide prone point, the combination optical image and SAR image quite enough to perform post forest cover changes and it also can overlay with another causative parameter.

1. Introduction

More than hundred victims were buried by landslide at hilly Karangobar Village, Banjarnegara Regency, in December two years ago. Material losses reached nearly two billion rupiah accompanied by the destruction of irrigation channels, curve of roads and damage to the bridges, which connecting between villages. According to the landslide map occurrences issued by National Disaster Relief Agency shows the location affected by landslides that occurred in three villages in Banjarnegara Regency, which are Tunggoro Village, Sidengkok Village and Sampang Village. The biggest landslide occurred in Jemblung, Sampang Village, Karangobar district. The disaster resulted in the deaths of 108 people unaccounted (missing), 54 families affected, two people died, four people were seriously injured, 11 people were injured lightly and the number of refugees still in accounted. Damage and loss of material in the form of 30 houses and some vehicles buried by landslide material. Compared with other natural hazards such as volcanic eruptions and floods, landslides cause considerable damage to human beings and massive economic losses.



Data from the Indonesian Agency for Meteorology Climatology and Geophysics shows that 11 days before the disaster occur the area was hit by huge rain, around 50% from its annual rainfall. The Indonesian Institute of Sciences later explained that the ground on the area were soaked by the rain, hence the ground to moved.

Geologically, Indonesia is located at the confluence of three tectonic plates, the Indo-Australian plate, the Eurasian plate and the Pacific plate. Therefore, Indonesia is known as the state is prone to geological disasters, such as earthquakes, volcanic eruptions and tsunamis. Landslide often occur due to higher geological and climatological potential risk with large numbers impact of swallow losses and casualties. Landslide occurred mainly in the hilly areas and during the rainy season. Geological condition of Indonesia is prone to seismic vibrations or volcanic vibration. The vibrations can lead to landslide. Based on events Research Group of Gajah Mada University (UGM), around 60% of the land in Indonesia is an area prone to landslides.

A landslide is a movement of a mass of rock, debris, or earth down a slope, under the influence of gravity [1] in [2]. Landslides involve flowing, sliding, toppling, falling, or spreading, and many landslides exhibit a combination of different types of movements, at the same time or during the lifetime of the land slide. Landslides are present in all continents, and play an important role in the evolution of landscapes. In many areas they also pose a serious threat to the population [3]. For instance, landslides in Java, the most densely populated island in Indonesia, caused 2,095 casualties and 522 injuries in 1981-2007 [4].

Basic disaster management concepts and basic knowledge of landslide phenomena were introduced in order to improve understanding, awareness, motivation and empowerment and to develop effective disaster management measures and mitigation. Therefore, mitigation system become crucial step towards the lead human resources to guarantee the sustainability of life and the environment an areas susceptible to landslides. Disaster risk reduction is part of an effort to maintain the sustainability of human well-being. Resistance and resilience are necessary to adapt to the danger of landslide, as well as to survive the devastating of landslide impacts. Integration between disaster risk reduction and sustainable development becomes urgent in order to reduce and eliminate future damage and loss [4].

Several factors that cause landslide such as settlement of geology, slope and vegetation distribution in identification. Remote sensing techniques well used to determine the zoning of areas susceptible to ground movement, especially to observe areas that are difficult to reach [5].

On satellite images and SRTM 30m DEM, land movement symptom expression is shown by its distinctive shape like a horseshoe shape, a steep escarpment, fracture pattern parallel to the cliff landslides, soil moisture on the slope below the cliff, steps topography along the river bank, and so on. Although these types of avalanches are not always recognizable in the images, preliminary estimates can still be expected from the avalanche product form that shows the appearance of ground motion formation on it [6].

Landslide Susceptibility Zone Map is a map that contain visual information to region tendency of ground movement occurrences. Landslide susceptibility zone is a zone that has the same relative susceptibility for ground movement occurrences. Determination of the susceptibility is based on the parameters, the magnitude of slope, soil and rock types, rainfall, and the amount of movement of soil, land use, seismicity, the numerical values of slope stability, etc. Classification of landslide susceptibility zone is divided into four, namely high, medium, low and very low [7].

This study as a preliminary stage as part of disaster mitigation landslide in Banjarnegara Regency, by utilizing a combination of multi-sensor image to overview the pattern forest cover changes with supported by other parameters such as rainfall, slope, aspect, curvature patterns hill (curvature). The objective is how to develop detection model in rapid mapping technique for detection landslide susceptibility zone. This information is used as basis an early detection for estimating landslide potentially happen in the future.

2. Method

The indirect analysis emphasis in desk study by the overlap between the map of the distribution of landslide occurrences and several parameters (geological, slope and land use), then do the estimation using the data unit geology, grade slope, and units of land use effect on the incidence of ground

movement. This method is based on a model calculation of density (density) of ground movement and the weight value (weight value) per unit of geology, grade slope, and units of land use (on each map parameter). The weight values obtained are summed and divided into a maximum of four classes using the upper limit value (upper bound) for each class, which susceptibility zones is very low, the zone of susceptibility is low, the zone of susceptibility medium, and the zone of zone of susceptibility High [7]. This research used indirect analysis to combine optical image and radar image with applying some overlay analysis and scoring for particular parameters. The threshold of vegetation indices and water indices might be used in order to sharp slicing forest cover changes. Elevation model might also need due to significant parameter in obtaining the susceptibility.

2.1. Location

This study located at 109°29'00" - 109°45'50" E and 7°12'00" - 7°31'00" S in Mensiku miniwatershed of Banjarnegara Regency covers 1,70 Km² approximately 3.1 % of Central Java Province. It consists of 19 districts (Banjarmangu, Banjarnegara, Batur, Bawang, Kalibening, Karangkoobar, Madukara, Mandiraja, Pagentan, Pandanarum, Pejawaran, Punggelan, Purwonegoro, Purworejo Klampok, Rakit, Sigaluh, Susukan, Wanadadi, and Wanayasa).

2.2. Spatial Dataset

This research required spatial data such as i) Landsat 8 OLI images path 120 Row 065 (1 scene before landslide captured in August 30, 2014 and 1 scene after landslide captured in February 22, 2015) gathered from USGS Global Visualization Viewer (<http://glovis.usgs.gov/>); ii) Sentinel-1A C-band Synthetic Aperture Radar (SAR) image (1 scene before landslide captured in November 24, 2014 and 1 scene after landslide captured in December 18, 2014) gathered from National Institute of Aeronautics and Space; iii) Digital Elevation Model (DEM) derived from Shuttle Radar Topography Mission (SRTM) Arc-second 30 m gathered from The CGIAR Consortium for Spatial Information (CGIAR-CSI); iv) Rainfall annual data (acquisition in 2014) produced by Ministry of Agriculture scale 1:250.000; v) Landslide coordinate survey on October 2014. Beyond that also need Banjarnegara administrative boundary in district scale. Data processing required geoprocessing software such as Quantum GIS 2.12.3 Lyon.

2.3. Process Flow

The process flow of this research described in Figure 1, where all the data will be confined by study location (AOI) thus data layout focused on district level. Commonly there are four main processes which are optical image processing, SAR image processing, DEM processing and Scoring Geoprocessing.

Performing first step is Landsat images starting from preprocessing for reducing radiometric and geometric effects, thus to generate vegetation indices (NDVI) and water indices (NDWI) for both images (pre and post landslide) in order to overview forest cover changes during landslide occurrences.

The normalized difference vegetation index (NDVI) is the most widely used index for remote sensing of vegetation in the past two decades. It is equal to $(\rho_{\text{NIR}} - \rho_{\text{RED}})/(\rho_{\text{NIR}} + \rho_{\text{RED}})$, where ρ_{RED} is the radiance (in reflectance units) of a red channel near 0.66 μm , and ρ_{NIR} the radiance (in reflectance units) of a near-IR channel around 0.86 μm . Remote sensing of vegetation liquid water has important applications in agriculture and forestry. A normalized difference water index (NDWI) that uses two near-IR channels centered approximately at 0.86 μm and 1.24 μm for remote sensing of vegetation liquid water from space is proposed. The 1.24 μm channel has not been used previously in the formation of vegetation indices [8]. NDWI extraction from Landsat 8 by channel 3 (ρ_{GREEN}) and channel 5 (ρ_{NIR}) through formula $(\rho_{\text{GREEN}} - \rho_{\text{NIR}})/(\rho_{\text{GREEN}} + \rho_{\text{NIR}})$ [9]. A new vegetation index, the normalized difference water index (NDWI), is proposed for remote sensing of vegetation liquid water from space. This index uses two narrow channels centered near 0.86 μm and 1.24 μm . Both channels sense similar depths through vegetation canopies, unlike the two channels used in NDVI. NDWI is a measure of liquid water molecules in vegetation canopies that interacted with the incoming solar radiation. It is less sensitive to atmospheric scattering effects than NDVI [8]. Threshold deviation result of the vegetation indices and water indices deviation will be determined such for NDVI (forest changed area > 0.1) and NDWI (forest water content changed < -0.06).

Performing second step is SAR images starting from preprocessing for reducing radiometric and geometric effects, thus to emphasis cover changes by Red-Green Different (RG Different) where post Sentinel-1A as red layer and pre Sentinel-1A as green layer. Yellow color image will be produced without any changes of both layers, contrary some red color (post-changed area) and green color (pre-changed area) appearance if there has land cover changes. Segmentation with object based analysis is used to perform clear object in supervised classification with required some training area. Furthermore, post-changed area from SAR image will be interacted with forest cover changed area from Landsat image (post forest changed area).

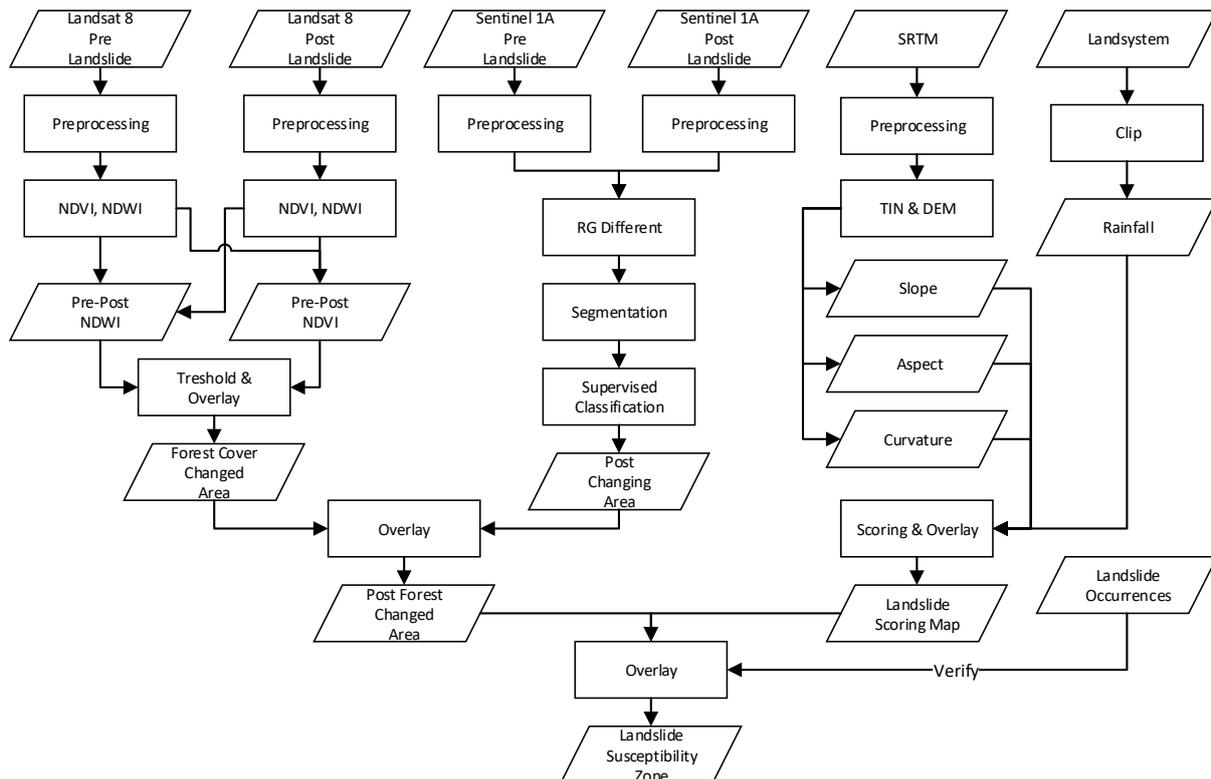


Figure 1. Data processing flow

Performing third step by using DEM extraction method is needed to generate slope data, aspect and curvature data. Rainfall annual data which derived from landsystem map as also causative factors of landslide. Slope map could be classified as flat ($< 8\%$), gently slope ($8 - 15\%$), moderate ($15 - 25\%$), steeply slope ($25 - 40\%$), and very steeply slope ($> 40\%$). Aspect map could be classified as flat, north ($0 - 23^\circ$), northeast ($23 - 68^\circ$), east ($68 - 113^\circ$), southeast ($113 - 158^\circ$), south ($158 - 203^\circ$), southwest ($203 - 248^\circ$), west ($248 - 293^\circ$), northwest ($293 - 338^\circ$), and north ($338 - 360^\circ$). Curvature map could be classified as plus (+), minus (-) and zero (0). Curvature map combined with planform curvature and profile curvature. Scoring technique is needed to deploy the detection model of landslide susceptibility zone as shown on Figure 2.

Plan curvature is described as the curvature of a contour line formed by intersecting a horizontal plane with the surface, and therefore controls the convergence or divergence of landslide debris and water in the direction of landslide motion. The positive, zero and negative value indicate convexity, concavity and flat surface, respectively. Profile curvature relates to the convergence and divergence of flow across a surface, and affects the acceleration or deceleration of flow across the surface (concave and convex). In locations with convex (negative) profile curvature the erosion will prevail and in locations with concave (positive) curvature the deposition [10].

Landslide susceptibility map generated by the sum of weight value from the map results alignment between ground motion distribution maps with geological aspect, slope and land use maps by using

spatial analysis using GIS [5]. Performing the fourth step by using some overlay analysis of each raster layers and spatial features which are clip, dissolve, raster conversion, intersect to achieve susceptibility zone. The final zone might be verified by particular landslide event location whether it exist on the result map.

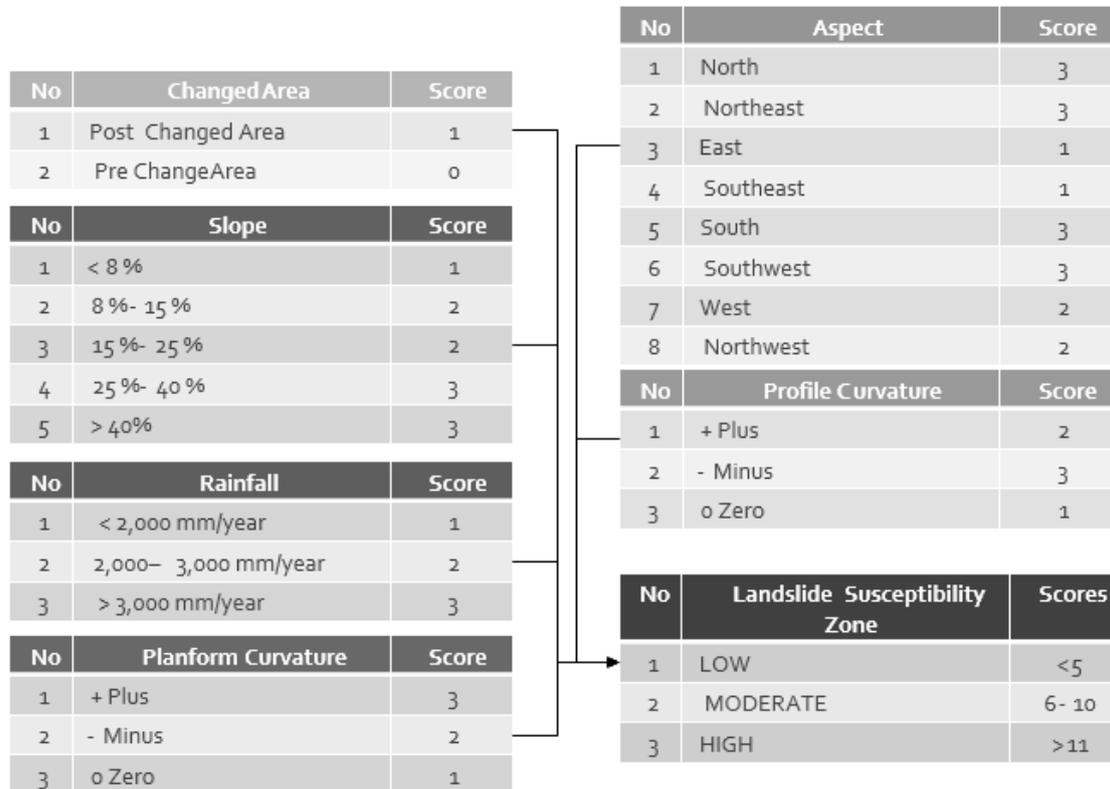


Figure 2. Scoring deployment of detection model

3. Result and Discussion

Landslides, ground settlement and avalanche interfere greatly and persistently with mass activities. It occurs when hill side or valley side slopes falls using to specific geological, climatic and biotic factors. They are bringing about major disruptions of towns and cities, communication systems and large structure including dams and bridges. Mitigation of disasters due to landslides can be successful only with detailed knowledge about the expected frequency, character and magnitude of mass movements in an area. To forecast possibilities of the future landslides in an area, comprehensive knowledge of causative factors of land sliding is necessary. The wide applicability of geospatial technologies are using in solving various environmental tasks. This technology can be used as an effective aid in natural hazard investigation, as well as for the purpose of environmental planning. Drainage map, contour map, digital elevation model, slope angle map, land use / land cover map, relative relief map, thrust (buffer) map, photolineament [11].

According to the analysis (Figure 3), it obtain “big five” district with higher prone landslide susceptibility zone such as Batur district, Pejawaran district, Wanayasa district, Kalibening district and Rakit district. Total susceptibility zone in Banjarnegara regency approximately 604.79 Ha with 15,250 prone point location. Thus, it classified as 14.16 Ha of low zone, 286.41 Ha of moderate zone and 304.22 Ha of high zone. More detailed explanation as shown in Table 1, susceptible zone in Batur district about 117.86 Ha and become the highest susceptible risk contained equal of high zone and moderate zone (49 %) with almost four thousand prone points spreading in all part of the area (Figure 4). Pejawaran district has 101.66 Ha dominant with 62 % of high susceptible zone with two point five thousand prone point spreading in north part, west and east part of the area. Wanayasa district has 93.85 Ha dominant with 66 % of moderate susceptible zone with two point three thousand prone point spreading in center part and

south part of the area. In addition, whole districts of Banjarnegara regency might aware with landslides risk potentially occur further.

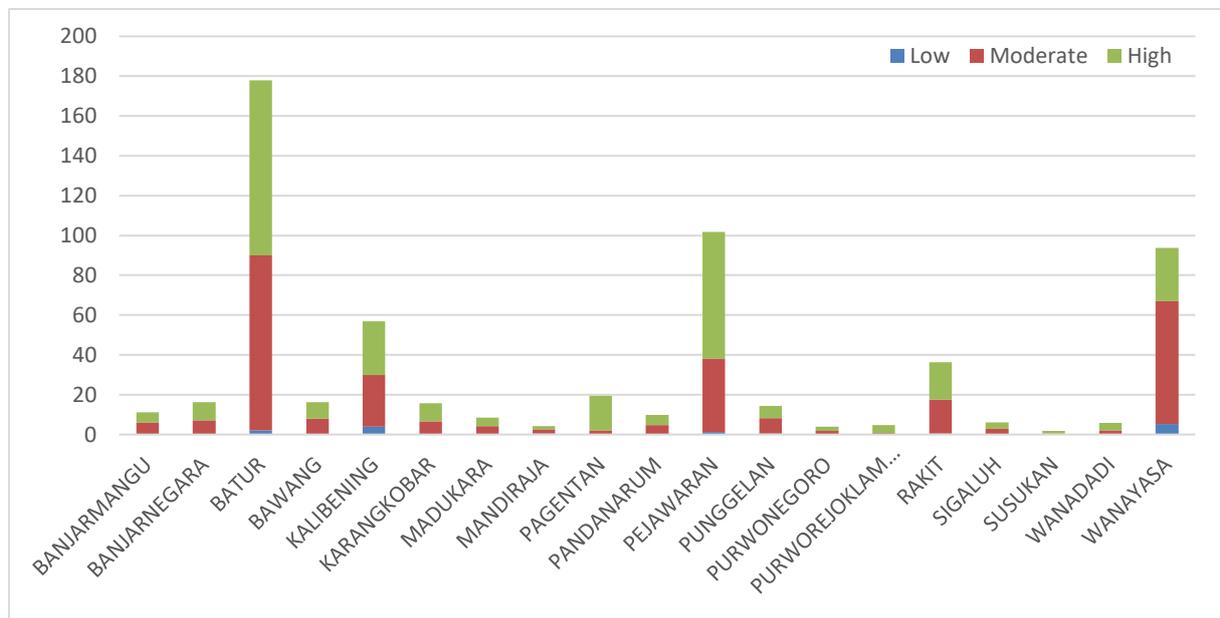


Figure 3. Landslide susceptibility classes in Banjarnegara regency (Ha)

Table 1. Percentage of landslide susceptibility classes in Banjarnegara regency (Ha)

District	Susceptible Area (Ha)	Percentage			Prone Location
		Low	Moderate	High	
Banjarmangu	11.20	1%	54%	45%	359
Banjarnegara	16.35	0%	44%	56%	517
Batur	177.86	1%	49%	49%	3,887
Bawang	16.21	1%	49%	50%	472
Kalibening	56.98	7%	45%	48%	1,314
Karangkoobar	15.66	0%	42%	58%	624
Madukara	8.54	0%	50%	50%	254
Mandiraja	4.10	13%	51%	37%	133
Pagentan	19.53	0%	11%	89%	486
Pandanarum	9.74	0%	49%	51%	293
Pejawaran	101.66	1%	36%	62%	2,449
Punggelan	14.32	3%	55%	42%	578
Purwonegoro	3.89	0%	50%	50%	123
Purworejo Klampok	4.76	0%	17%	83%	132
Rakit	36.20	1%	48%	51%	942
Sigaluh	6.12	0%	45%	55%	171
Susukan	1.86	0%	21%	79%	67
Wanadadi	5.94	0%	34%	65%	176
Wanayasa	93.85	6%	66%	29%	2,273
Total	604.79	2%	47%	50%	15,250

When evaluating the probability of landsliding within a specific period of time and within a certain area, it is of major importance to recognize the conditions that can cause the landslide and the process that could trigger the movement. The correlation between landslide areas and associated factors that cause landslides can be allocated from the connections between areas without past landslides and the landslide-related parameters. In order to prepare the landslide susceptibility map quantitatively, the frequency ratio method was implemented using GIS techniques [12].

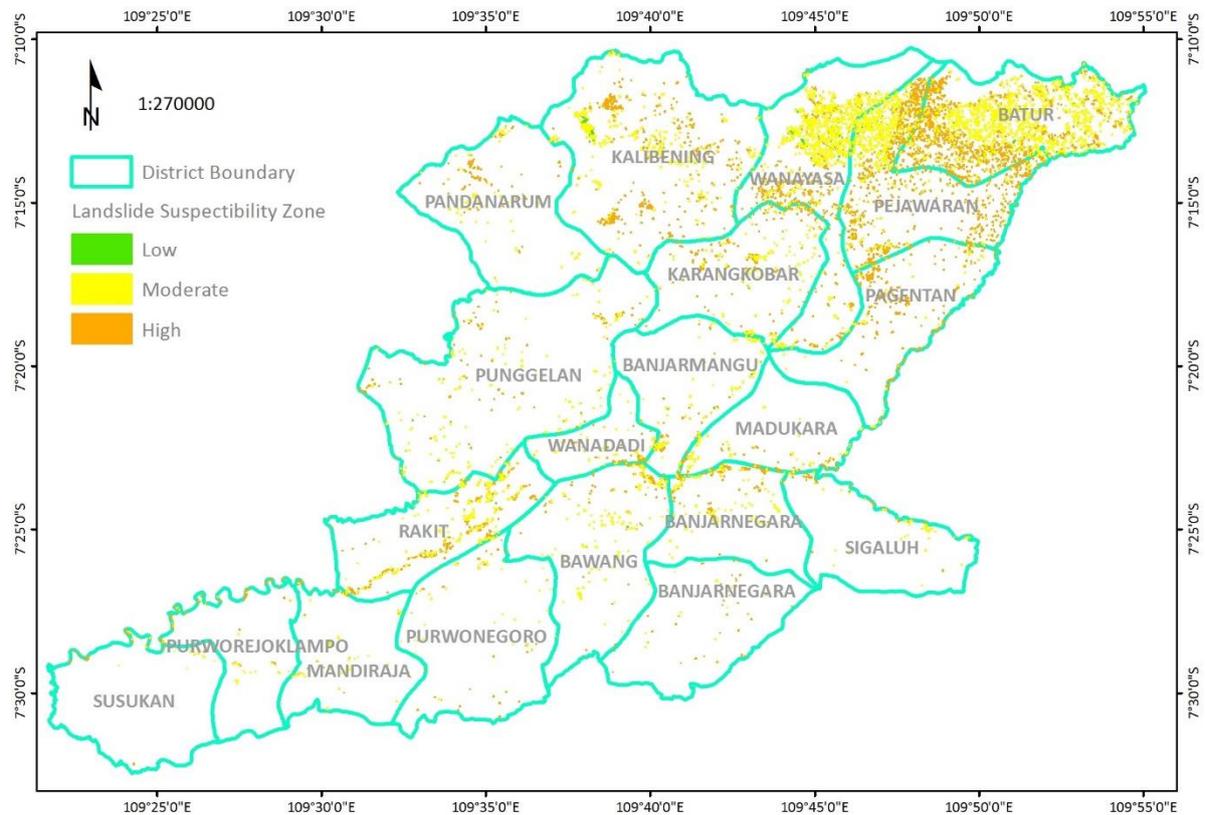


Figure 4. Landslide susceptibility zone Banjarnegara regency

Old landslide motion may still be active again mainly due to the high rainfall in a long time and strong erosion. The ground movement occurs on the slope of a rather steep to steep. Generally, slope formed by rained paddy field and forest cover. On Landsat imagery and SRTM 30 meter DEM, avalanche sightings can be characterized by the shape of a steep escarpment, fracture pattern parallel to the cliff landslides and soil moisture on the slopes below the cliffs. The avalanche shape visually delineated both escarpment avalanches, landslides direction, fracture pattern, and the sliding plane, and the landslide area, and eventually formed a distribution map avalanches [5].

The analysis of this study regarding on the creation of causative parameters and scoring model. Some interpretations might be influenced by the experiences and literature used. As advanced stages, relevant information on additional parameters such as geological factor, weather dynamics, social factors are needed to float a robust model as rapid mapping technique of landslide detection.

4. Conclusion

This study demonstrates as rapid mapping the enormous potential landslide occurrences investigated by susceptibility zone. In term of landslide prone point, the combination optical image and SAR image quite enough to perform post forest cover changes and it also can overlay with another causative parameter. Furthermore, it need to elaborate with quantitative and qualitative parameter in order to obtain the optimal result of landslide susceptibility zone. Eventually, this preliminary study for developing landslide detection model is used as recommendation and part decision support system to local government of Banjarnegara Regency.

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