Landslide Hazard Analysis In Tuban Regency Using Multilevel Satellite Imagery Processing For Landslide Potential Mapping

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Abstract. Landslide is a kind of land or rock movement, come from a place that has a higher slope as a consequence of disturbed land stability. The landslide can cause huge damage around us, but there are so many ways that can decrease landslide risk assessment, for example, to keep away from landslide area, spread a warning around the people, and apply safety standard when entering a landslide area. This research has purpose to know landslide potential that influences in hazard mitigation strategy in Tuban Regency. This research result is landslide potential map based on the land characteristic, rainfall, slope, and land use. That four parameters pass by an analysis processing an will be sure by remote sensing data that is medium resolution satellite imagery of Landsat 8, high-resolution satellite imagery of SPOT, and very high-resolution satellite imagery of Quickbird. This research result is a map of landslide susceptibility that places Tuban Regency in 5 classifications of it, where Tuban Regency domination in the low stage of susceptibility with 106.618 ha, and for very high of susceptibility with 175.5 ha of areas.

Keywords: Geographic Information System, Landsat 8 Satellite, Quickbird Satellite, Remote Sensing, SPOT Satellite, Tuban Regency.

1. Introduction

Hydro-meteorology hazard which happens in Indonesia frequently is caused by high rainfall and tropical climate. One of hydro-meteorology hazard that can cause other risk and danger to happen is flood and dryness, where National Board for Disaster Management have noted that flood that followed by the landslide is the highest amount of hydro-meteorology hazard in Indonesia.

Tuban Regency is one of the places that have the potency to lose a lot when there is an impact from landslide hazard. Strategy and effort are needed to reduce the amount of landslide hazard that could happen, for example, by issuing the landslide susceptibility area from landslide potential mapping.

The danger of landslides can be identified through geographic information systems and remote sensing by processing the parameters of landslides such as rainfall, soil type, slope, and land use, and then strengthened by using remote sensing data, multilevel satellite imagery. The landslide parameter along with the supporting data is then processed and analyzed using Remote Sensing based technology and Geographic Information System.

This research was conducted with the purpose to know the potential landslide area, as well as the parameters that influence the occurrence of the landslide in Tuban Regency with the output in the form of landslide potential map wherein its preparation refers to some rules of landslide potential map. In its completion, this research is expected to provide information to the government and the public about the area that has the potential of the landslide in Tuban Regency, especially to the people around the area with the potential of landslide.

2. Research Methodology

2.1. Research Sites

The location of this research is in Tuban Regency with an area of about 183,994,562 Ha. Location of astronomy Tuban at coordinates 111°30' - 112°35' longitude and 6°40' - 7°18' Latitude.

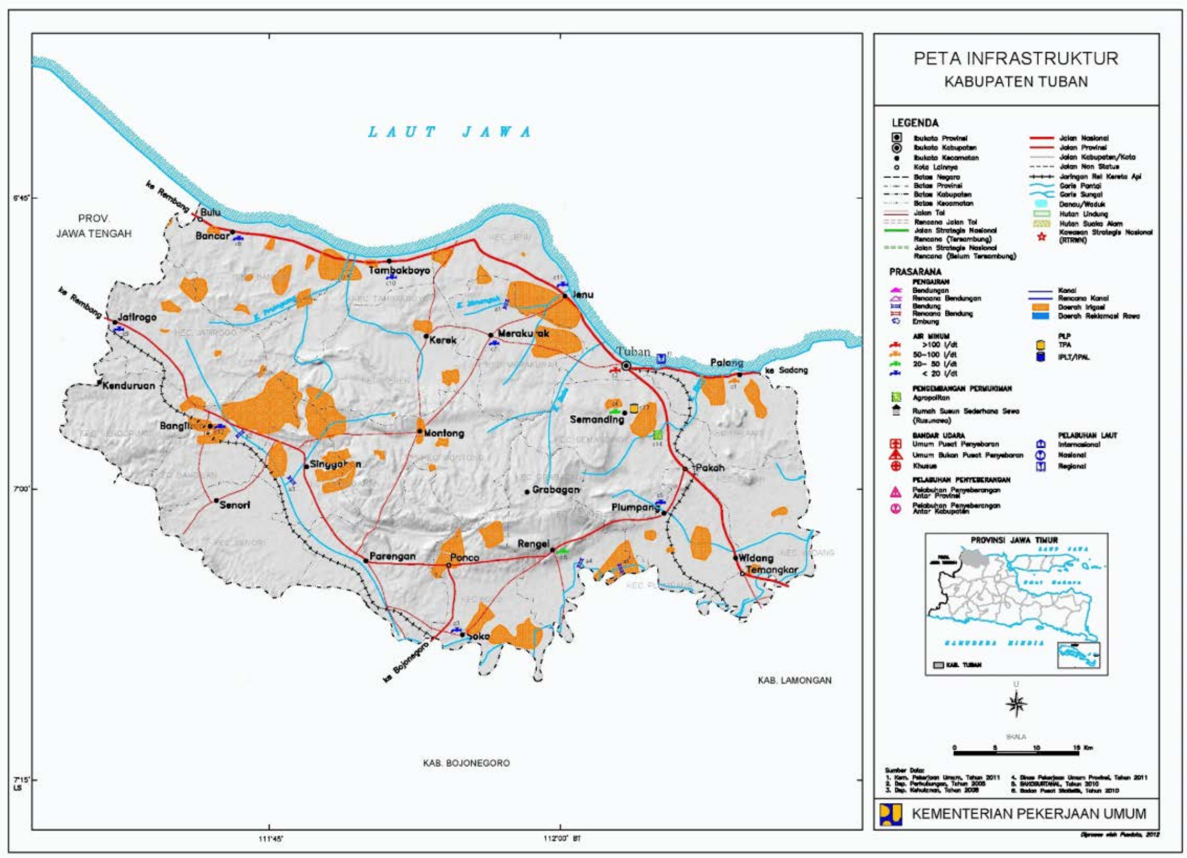

Figure 1. Research Sites Data and Equipment
(Source: PU Tuban)

2.2. Data and Equipment

2.2.1. Data. The data used in this research are:

1. Rainfall data of 2015 (source: Public Works Service Tuban)
2. DEM Satellite Astra Terra SAR X Tuban Regency in 2012 (source: Bappeda Tuban)
3. Soil type data of 2008 (source: Bappeda Tuban)
4. Slope data of 2008 (source: Bappeda Tuban)
5. Medium Resolution Satellite Imagery of Landsat 8 Path 119 Row 65 with acquisition date on 13 October 2015 (source: http://earthexplorer.usgs.gov)
6. High-resolution satellite imagery of SPOT with acquisition on 2016 (source: LAPAN)

7. Very high-resolution satellite imagery of Quickbird with acquisition on 2013 (source: Bappeda Tuban)
8. Administrative boundary (source: RBI Map 1:25.000)
9. Aerial Imagery from UAV (Unmanned Aerial Vehicle)
10. GCP and ICP data from GPS Survey

2.2.2. Stages of Data Processing Equipment. The equipment used in this study include:

1. Hardware
   a. GPS Geodetic dual frequency
   b. Phantom 3 Advance
   c. Laptop
2. Software
   a. Software geospatial processing
   b. Software satellite imagery processing
   c. Software GPS processing
   d. Software orthorectification processing
   e. Software statistic processing

2.3. Stages of data processing in this study are as follows:

1. Making the Rainfall Map
   Interpolation in rainfall data then classification and scoring on the interpolation result.
2. Making the Type of Land Map
   Classifying and scoring on available data
3. Slope Creation
   Classifying and scoring on available data
4. Making the Landuse Map
   Perform radiometric correction and digital classification on Landsat 8 using Supervised Classification: Maximum Likelihood of confusion matrix and calculate the classification results and do the scoring.
5. Overlay, scoring, and reclassification
   Overlay and score on all parameters. The scoring used in this study refers to some references from similar studies as shown in the following table.

Table 1. Parameter Scoring

Score/ Parameter	1	2	3	4	5
Rainfall (mm/year)	<1500	1500-2000	2000-2500	2500-3000	>3000
Soil Type	Alluvial, Glei	Latosol	Brown Foret, Mediteran	Andosol, Grumosol, Podsol	Regosol, Litosol, Organosol
Slope (%)	0 - 8	8 - 15	15 - 25	25 - 45	> 45
Landuse	Water	Forest	Garden	Tackle, rice field, settlement	-

Reclassifications are made up into 5 classes of vulnerability to landslides and then finding the determination of the interval.

6. High and very high-resolution image processing
   Do mosaics and pansharpening so that the image can be seen clearly. Interpolation of GCP and ICP coordinates is required for field measurements to be calculated by the strength of the net by calculating the SoF. Coordinate results that meet GCP and ICP standards are used in orthorectification and accuracy test processes.
7. Vegetation Map Creation

Doing the calculation algorithm Normalized Difference Vegetation Index (NDVI).

8. Wetness Map
   Doing the calculation algorithm Normalized Difference Water Index (NDWI).
9. Groundtruth Parameter Processing
   Comparing the data obtained from the image and obtained from the field.

3. Result and analysis

3.1. Corrected Satellite Imagery

Geometric correction is performed on each image to be able to produce the area corresponding to the situation in the field.

1. Landsat 8
   Geometric correction is performed to produce a rmse of 0.005m which is then continued by radiometric correction using FLAASH method using image data processing software.
2. SPOT
   SPOT Satellite Imagery is rendered using image processing software to obtain a rmse of 0.88 m. It shows that the process of rectification is done can be said to meet the standards, namely <1m as stated in PerkaBIG [1].
3. Quickbird
   Quickbird high-resolution satellite images are used in the manufacture of vegetation maps and wetting maps. Begins with a mosaic and pansharpening followed by interpolating the coordinates of the image of a point GCP and ICP for use in the measurement field.

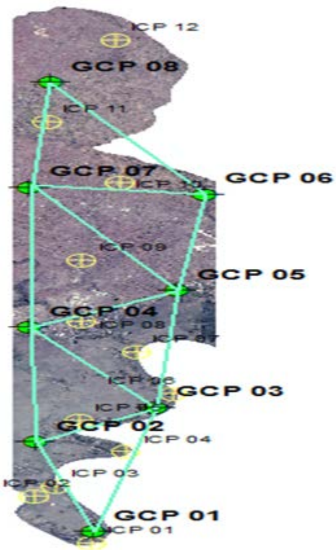

Figure2. Tentative Map

The choice of location and distribution point GCP and ICP Module Validation refers to the Spatial Plan Map BIG [2] where the dot placement must be clearly identified in the image. There are 8 points GCP and 12 ICP points used in this study. SoF value obtained for 0.2115 in accordance with the following calculations.

Σbaseline	: 22	
Σpoint	: 8	
N_u	: Σbaseline x 3	= 66
N_p	: Σtitikpoint x 3	= 24
U	: N_u – N_p	= 42

The smaller the SOF value the better the net configuration, and vice versa. SOF calculations performed have resulted in values <1 so that the design nets that have been made can be considered to be strong [3]. Data collection in the form of coordinate of control point (GCP) and accuracy test point (ICP) is done by using dual frequency geodetic GPS with static method in duration of measurement 30-45 minutes at each point. Measurement data processing is done using GPS data processing software that includes the post-processing and network adjustment.

Coordinates obtained GCP and ICP has been tied with CORS ITS S and has been corrected by SRGI BIG to obtain dx = -4.306m and dy = 0.391m for subsequent use in the process of orthorectification using image processing software to obtain the required RMSE <1.5 Pixel that is equal to 0.7875 pixels. Here is the RMSE of the processed coordinates.

Table 2. RMSE Quickbird Imagery (SRGI)

Point Name	Residual (*pixels*)	X (m)	Y (m)
GCP01	0.493	611415.062	9212055.260
GCP02	0.391	610493.765	9215153.548
GCP03	0.207	612407.164	9216339.387
GCP04	0.644	610388.390	9219113.217
GCP05	0.22	612762.528	9220378.888
GCP06	0.784	613208.440	9223709.584
GCP07	0.597	610415.784	9223937.052
GCP08	0.448	610728.314	9227575.156
ICP01	0.628	611176.463	9211689.356
ICP02	0.222	610453.878	9213282.668
ICP03	0.303	610779.393	9213638.819
ICP04	0.293	611867.692	9214775.977
ICP05	0.216	611103.617	9215903.052
ICP06	0.194	612664.987	9216831.495
ICP07	0.37	612078.452	9218234.885
ICP08	0.439	611217.088	9219342.436
ICP09	0.397	611224.687	9221431.059
ICP10	0.626	611717.011	9224112.681
ICP11	0.381	610678.329	9226189.472
ICP12	0.257	611768.987	9229012.678

Image result from the process of orthorectification is then performed accuracy test to determine the value of accuracy of the image. The accuracy test is performed by calculating the RMSE of all ICP points first then calculated by the formula in accordance with the following Basic Maps Accuracy Technical Guidelines.

The results of test calculations obtained precision horizontal accuracy of 0.9105 so it can be said to meet the standards by including the Class 1 on a scale of 1: 5000.

3.2. Image Data Correlation

The use of multilevel satellite imagery in this research needs to be tested strength / suitability relationship between image data. The relationship is obtained by applying the algorithm NDVI Landsat and QuickBird, as well as the use of the band Blue and Red on SPOT and Aerial Imagery (Foto) from UAV (Unmanned Aerial Vehicle).

Table 3. NDVI on image

Point Name	NDVI			
	Foto	SPOT	Landsat	Quickbird
GT-01	0.04	0.026	0.28	0.4
GT-02	0.063	0.3	0.4	0.51
GT-03	0.056	0.06	0.29	0.62
T-04	0.028	0.06	0.25	0.26
GT-05	0.03	0.26	0.46	0.28

Here is an illustration that shows the relationship between data on the image obtained from NDVI processing of each image with wavelength approach in image and SPOT image.

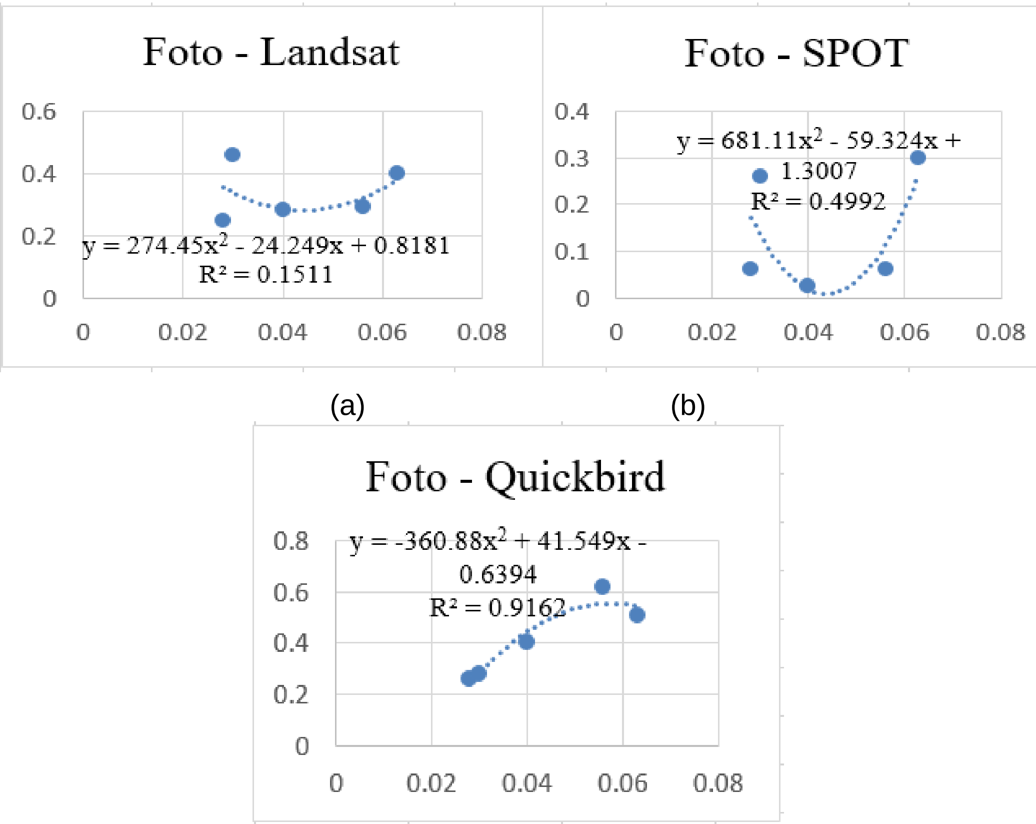

Figure 3. (a) Image Correlation with Landsat (b) Image Correlation with SPOT (c) Image Correlation with Quickbird

From Figure 3 it can be seen that the lowest correlation to the strongest is a photo with Landsat of 0.0945, a photo with a SPOT of 0.2677, and a photo with Quickbird of 0.912. This is possible because of the spatial resolution of each image. Quickbird image has a very high resolution of 0.6m so it has a stronger relationship with the photo when compared with the SPOT of 1.5m and Landsat by 30m.

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Therefore, in this study the parameters of groundtruth are processed by focusing on the use of Quickbird image.

3.3. Rainfall Map
Rainfall data obtained in tabular form includes 26 rainfall stations spread in Tuban Regency. Classification is done with reference to the Puslitbangtanak in Isti [4], followed by a comprehensive layouting to get in each class as follows rainfall.

Table 4. Rainfall

Rainfall	Area (ha)	Percentage (%)
<1500 (mm/year)	173785	87.84
2000-2500 (mm/year)	24056.1	12.16

3.4. Soil Type Map
Data types of soil found in shapefile format (vectors) that include all districts in Tuban. Classification is done with reference to the Sugianti [5] to obtain the area of each class as follows.

Table 5. Soil Type

Soil Type	Area (ha)	Percentage (%)
Mediteran/Rezina	70695.4	35.76
Litosol	22976.4	11.62
Regosol	5273.62	2.67
Grumosol	65923.5	33.35
Alluvial	31773.3	16.07
Rawa	1033.63	0.52

3.5. Slope Map
Slope data in shapefile format (vectors) with classification based on Sugianti [5]. The area of each classification results as follows.

Table 6. Slope Wide

Slope	Area (ha)	Percentage (%)
0 - 8 %	169429	85.71
8 - 15 %	18428.2	9.32
15 - 25 %	6561.86	3.32
25 - 45 %	2824.31	1.43
> 45 %	432.704	0.22

3.6. Landuse Map
Landsat 8 imagery can product a landuse map which processed by radiometric correction as the first, and then followed by a digial interpretation methods called Supervised Classification: Maximum Likelihood with 75,38% of confusion matrix. Classification processed based on Kesaulya and Permen PU No.22 tahun 2007 [6]. The result of landuse area as follows.

Table 7. Landuse Area

Landuse	Area (ha)	Percentage (%)
Water	2054.1	1.04
Forest	138040.0	69.79
Garden	10984.8	5.55
Tackle, rice field, settlement	46700.8	23.61

3.7. *Landslide Hazard Map*

In this study used Storie method that requires rainfall data, soil type, slope inclination, and land cover in the preparation, where the determination of these parameters refers to the Guidelines for Preparation of Spatial Planning of Landslide Disaster Prone Areas of Ministry of Public Works No.22 / PRT / M / 2007 [7].

Data is given a score as shown in Table 1 and then be overlaid and applied tools for dilajutkan intersect the scoring process and the reclassification in accordance with the intervals determined by reference to Susanto [8] as the following formula.

$$\text{Interval} = \frac{\text{maximum score} - \text{minimum score}}{\text{class}} \quad (1)$$

From the calculation of the interval got the range of values of each class along the 2.2 to obtain classification results in 5 classes as follows.

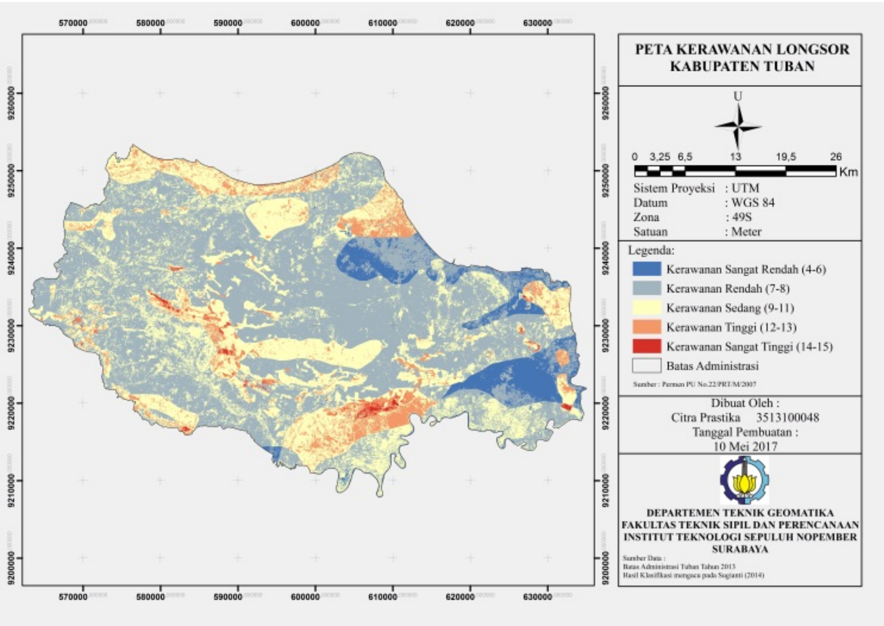

Figure 4. Map of Landslide Hazard

From the result of classification that has been done got wide of each class of landslide vulnerability like following table.

Table 8. Area of Landslide Hazard

Category	Area (ha)	Percentage (%)
Very Low	11,854.200	6.0
Low	104,618.000	53.1
Medium	75,639.300	38.4
High	4,691.870	2.4
Very High	175.502	0.1

3.8 Correlation in Internal Parameters of Landslide Hazard

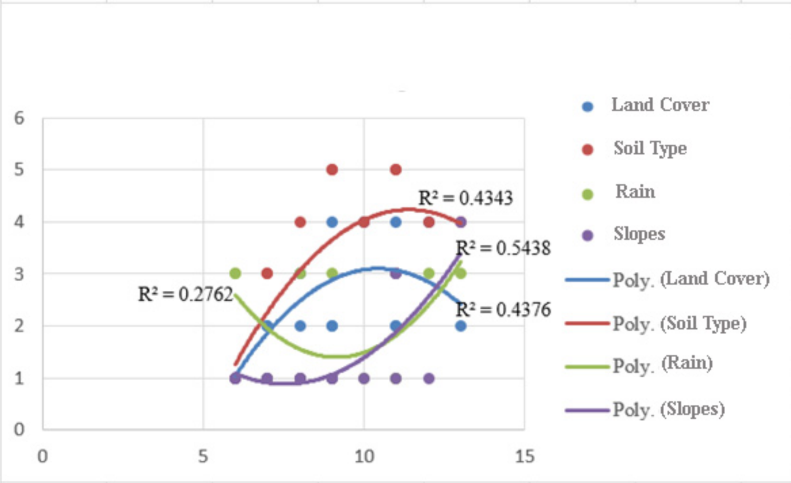

Figure 5. Correlation Parameter of Landslide Hazard

From Figure 5 it can be seen that the magnitude of landslide parameter correlation with landslide vulnerability level from low to high is rainfall of 0.06, land cover is 0.49, land type is 0.59, and slopes is 0.63.

3.9. Groundtruth

Five points of groundtruth are placed on each myander of Bengawan Solo River. The sample soil (for soil moisture content and texture) were done on disturb land (disturbed soil / ground) by using the pipe which is plugged deep around 30cm on land taken about 1kg in order to do the testing on soil samples. Photo image acquisition is done by using Phantom 3 Advance flown around 10-15m above the groundtruth point. It is then being adjusted to the results of the classification and to form such a landslide susceptibility map as shown in figure 4. From table 9 can be seen that Groundtruth point is at a level of vulnerability.

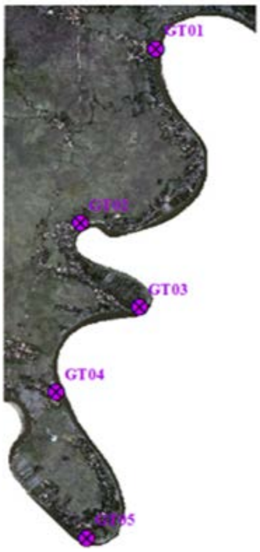

Figure 6. Groundtruth Point

Table 9. Classifixation Groundtruth Points

Point Name	Classification
GT-01	Very High
GT-02	Low
GT-03	Very Low
GT-04	Medium
GT-05	Very Low

3.10. NDVI and NDWI (Quickbird)

Corrected satellite image that has been generated is then processed with the NDVI algorithm for known greenishness. Generated class 5 in accordance with the Regulation of the Minister of Forestry of the Republic of Indonesia No.P.12 / Menhut-II / 2012 [8] to generate a map as follows

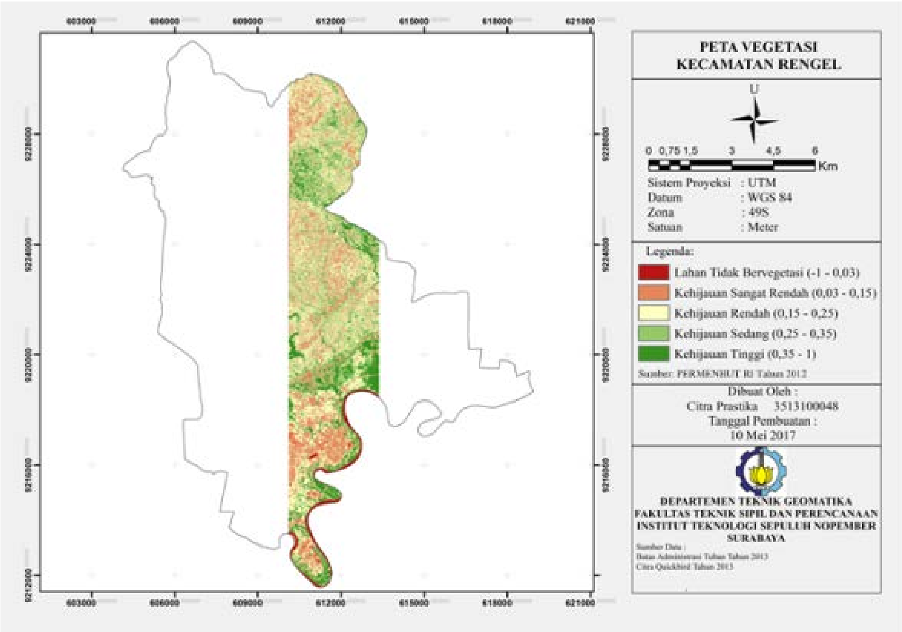

Figure 7. Vegetation Map

Corrected satellite image is further processed by NDWI algorithm. The classification process carried out by referring to Xu (2006, referring to MNDWI) [9] to be produced as follows.

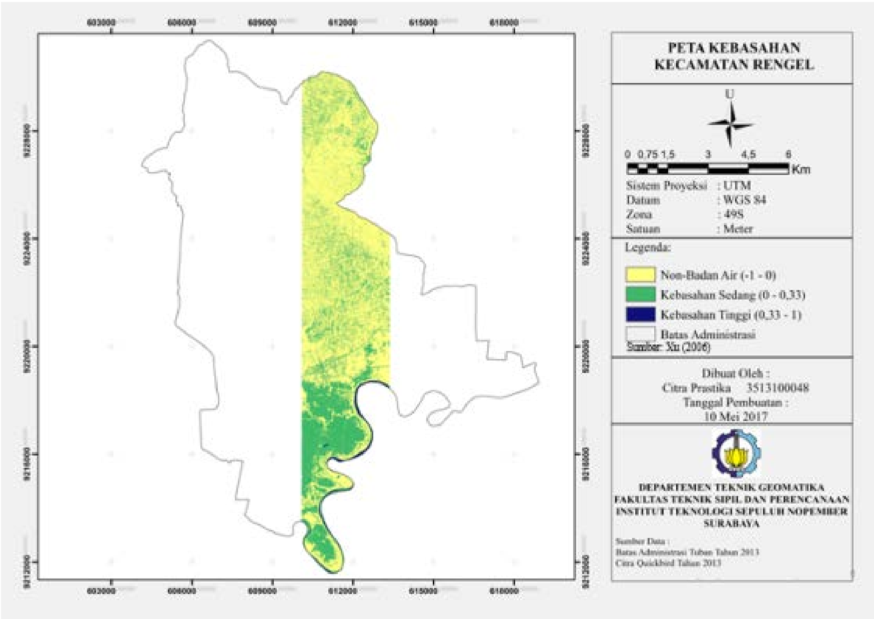

Figure 8. Wetness Map

3.11. Laboratory Tested

Testing the moisture content in the soil was done at the Environmental Service Laboratory of Tuban Regency. Tests carried out on the soil texture Soil and Rock Mechanics Laboratory of Civil Engineering - ITS using a sieve and hydrometer which refers to the Guidelines for Basic Research and Testing Soil for Road Works Department of Public Works No.003-03 / BM / 2006 [10]. The soil testing was conducted based on grain size analysis to find out the fraction of the soil.

The test results of water content and texture of the soil that has been combined with NDVI values and NDWI through Quickbird image processing at each point Groundtruth can be seen in the following table.

Table 10. Results of parameter Groundtruth

Point	NDWI	NDVI	Moisture	Textrure		
				Sand	*Silt*	*Clay*
GT-01	-0.13	0.27	75.22	80.2	13.9	5.9
GT-02	-0.05	0.20	57.17	71.1	11.2	17.6
GT-03	-0.20	0.45	42.55	79.4	14.2	6.4
GT-04	-0.12	0.27	37.17	81.9	12.2	5.9
GT-05	-0.30	0.56	37.67	70.7	15.2	14.1

Soil texture shows the composition of the soil constituents expressed as a ratio of the proportion (%) relative to the sand fraction *(sand)* in diameter from 2.00 to 0.20 mm, dust *(silt)* in diameter from 0.20 to 0.002 mm, and clay *(clay)* (<2 micrometer). Soil sampling is at the *disturb land* (about 20 cm from the soil surface to the inside) so there are some very clear material with sand of different sizes (by naked eye) like a stone / gravel, snails, plant roots, and so on. In soil testing the material is counted in the category> 2.00 mm.

3.12. Correlation of Groundtruth Parameters

The dominance of the sand fraction will cause the formation of few macro pores, so that the grasp of the water is very weak. This condition causes the water easily in and out of the ground and only a few are retained[11]. it is evidenced by the acquisition of a correlation of 0.1 to moisture and sand.

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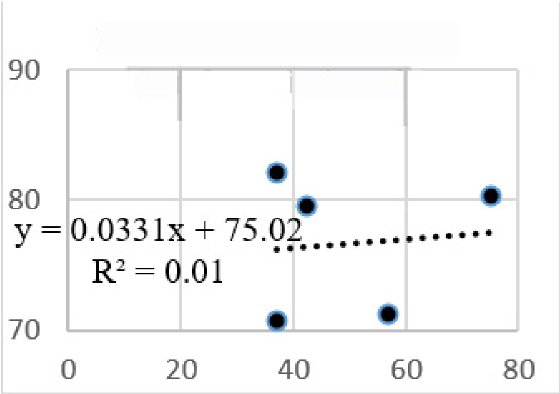

Figure 9. Correlation of Water and Sand Content

The dominance of the clay fraction will lead to the formation of many micro pores, so that the grasp of the water is very strong. This condition causes water to enter as soon trapped, as evidenced by the acquisition of R^2 of 0.95 against water (NDWI) and clay.

The dominance of the dust fraction will lead to the formation of meso pores in moderation, resulting in a strong hold of the water. This causes the water and air quite easily in and out of the ground, some water will be restrained. Dust-textured soils are generally more fertile than sand-textured soils [11].

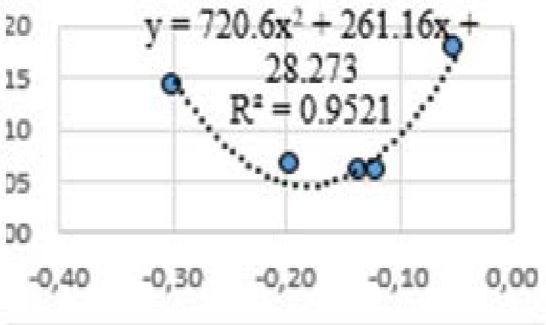

Figure 10. NDWI and Clay Correlation

In addition to soil texture and moisture content in the soil, vegetation also plays an important role in controlling soil stability. The existence of trees along the cliffs are very affected the stability of the cliff through rooting function that protects the soil thus affecting shear resistance *(shear strength)* of land. The presence of organic matter on the soil will affect the increase of water holding capacity, the dissolution of nutrients from minerals, as well as the increasing activity of decomposition of organic matter. This is supported by the acquisition of R^2 of 0.95 to vegetation (NDVI) and water (NDWI)

Figure 11. NDVI and NDWI correlations

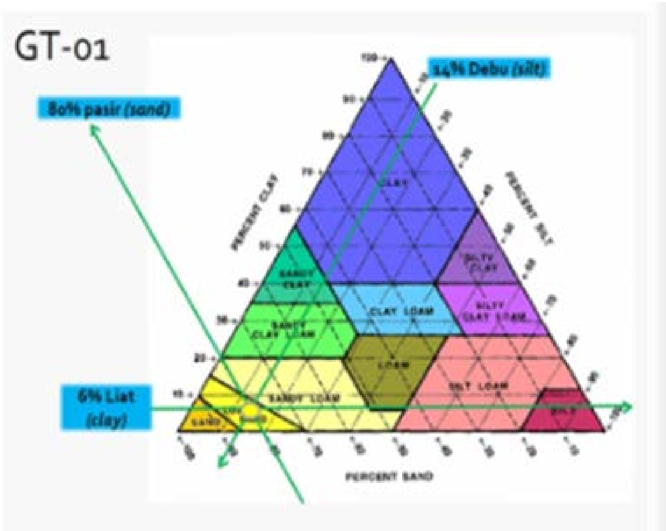

Figure 12. Land Texture According to The USDA Triangle

When viewed from the physical properties of the soil (soil texture and water content) as well as the vegetation on *Groundtruth point,* the GT-01 has the potential of being so large (compared to other *Groundtruth* point) to occur an avalanche. With sand fraction content of 80.2%, 13.9% dust, and clay 5.9%, referring to the USDA (1999) [13], land on the GT-01 has a category of argillaceous sand. With NDWI value of -0.13 which means that there is water content in GT-01 so that there is a possible vegetation growing at that point which is also reinforced with NDVI value of 0.27. Water content in GT-01 has a fairly high category of 75.22% which is a trigger for avalanches. If there is an increase in the water content in the soil (such as the absorption of rainwater, overflowing river water, leaking water / ponds), there will be accumulation of water which further stretches the bonds between grains of soil which will eventually push the soil grains to landslides. Here is the data related parameters that have been obtained.

Table 11. Groundtruth Parameter

Points	NDWI	NDVI	Moisture	Soil Texture				Classification
				Sand	*Silt*	*Clay*	Category (USDA)	
GT-01	-0.13	0.27	75.22	80.2	13.9	5.9	Loamy sand	High
GT-02	-0.05	0.20	57.17	71.1	11.2	17.6	Sandy loamy	Low
GT-03	-0.20	0.45	42.55	79.4	14.2	6.4	Loamy sand	Very Low
GT-04	-0.12	0.27	37.17	81.9	12.2	5.9	Loamy sand	Medium
GT-05	-0.30	0.56	37.67	70.7	15.2	14.1	Sandy loamy	Very Low

4. Conclusion

Based on the processing and data analysis has been done, here are the conclusions that the authors get in completion of this final task.

1. There are 5 classes of landslide vulnerability that is very low, low, medium, high, and very high.
2. Tuban Regency is dominated by low level of vulnerability with an area of 104,618 ha, while for very high level of vulnerability is only 175.5 ha.

3. Of the 5 point *Groundtruth* studied, the point of the GT-01 has a higher avalanche vulnerability compared with other *Groundtruth* point. GT-01 is at a moderate level of vulnerability where it is one to two levels higher than GT-02, GT-03, GT-04, and GT-05.

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