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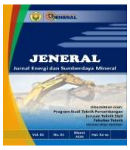

Ekstraksi Parameter Topografi sebagai Survei Pragmatik untuk Analisis Potensi Longsoran Lereng[1]

Extracting the Topographic Features as a Pragmatic Survey for Landslide Susceptibility Analysis

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ABSTRACT

Landslide susceptibility mapping in the mountainous area has become crucial for taking any precautions and imperative for any disaster management. As safety factor is currently widely used to indicate the ratio of strength to stress in a unit column, it lacks what matters to the disaster response unit – the probability in which a landslide can occur in a place. A value of safety factor shows whether a unit column will fail (SF >1) but does not lead to which unit column will be prioritized for monitoring and prevention measures. Therefore, unit slopes are generated based on the watersheds to part the study area. Before evaluating the landslide movement, and types, slope analyses is required. Several references of slope classification are chosen to gain the descriptive characteristics of a certain unit column and its correlation to other topography parameters. This research paper is a step before limit equilibrium analysis where the ratio of strength-to-stress calculation cannot disregard the slope behavior and soil thickness.

Keywords: landslide, topography, slope

INTRODUCTION

The physical geological conditions of each area vary widely, but often areas with a relatively high level of danger and susceptibility to natural disasters remain to build a dwelling. this is due to the need for land which continues to increase along with the increase in human population. It is known that natural disasters are one of the results of the interaction of natural hazards with their vulnerable situations. A mountain slope is a frequent occurrence for natural disasters, especially floods and landslides. This is due to mountainous conditions, soil conditions, and rainfall levels, so that the climate and geology in this area need to be thoroughly studied for the vulnerability of the area. Therefore, it is necessary to conduct research to solve these problems.

The purpose of this research activity is to make a map of the location of areas that have a priority risk of landslides, as well as to assess the risk of simulation results and the impact of landslide frequency. The target of this research activity is to provide a detailed slope maps

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with the spatial correlation to other topography parameters that is demonstrated by unit slopes generated from the watershed. This study will give recommendations in the application of a form of aerial photography-based planning in two mountain slopes in West Java. In addition, the results of this study can become a reference for stakeholders in continuing the movement type of a potential landslide, and compiling disaster-based spatial planning using aerial photography technology in this area.

In previous research, namely "Shallow Hazard Assessment Using a Three-Dimensional Deterministic" Using 143 drill holes in the area which are useful as sample points so that the depth of the soil can be ascertained. However, data for a wider area cannot be obtained from direct / field measurements. These predictions cannot be as accurate as direct / field measurements. From a financial point of view, the number of drill holes made is less efficient due to the amount of funds spent on field measurements [1].

If seen from the results of the previous research, only the safety factor was issued and it was obtained 32 units of dangerous slopes with a safety factor <1. The safety factor shown was not easily understood by the general public. In addition, the map results from this method do not prove the priority of the intended disaster because the distance from the safety factor is too wide.

The safety factor in this method is considered safer because it is able to provide a high level of geometric accuracy and resolution, photos are operated from the air so that areas covered with fog and high rain intensity can still be obtained, data can be acquired more quickly, practically and efficiently because many of the jobs are Photogrammetry work can be automated as well as more economical in terms of cost. By using the aerial photography method, disaster maps (landslides) are easy to read and have a priority scale because the data is stored in a concise form.

METHODS

Description of the Observed Location

The research locations as the subjects to this research paper are Guntur and Pangalengan areas (Figure 1). Both locations are considered as well represented morphology types, located in mountainous areas, having landslide historical records and adequately vast for analyses. The Guntur area is located in Garut, West Java Province, Indonesia and the Pangalengan area is located in South Bandung Regency, West Java Province, Indonesia. Both areas are located in the same province and have a history of landslides so they deserve to be analyzed.

Aerial Photograph

Data Aquisition

Aerial photos are photos obtained from aerial surveys, namely taking aerial photography in certain areas with certain photography rules. Then a flight path design is made so that the resulting photos are of good quality. The process of taking the flight path is usually taken the longest distance to do the recording, this is to obtain the stability of the aircraft when shooting. Then, there is a ground control point (GCP), which is a field tie point that directs the image to the actual location in the field. Aerial photo processing was carried out using

Agisoft Photoscan software with a total of 407 photos. The results of the aerial photo data processing are in the form of DEM data from the Guntur and Pangalengan areas (***Error! Reference source not found.***).

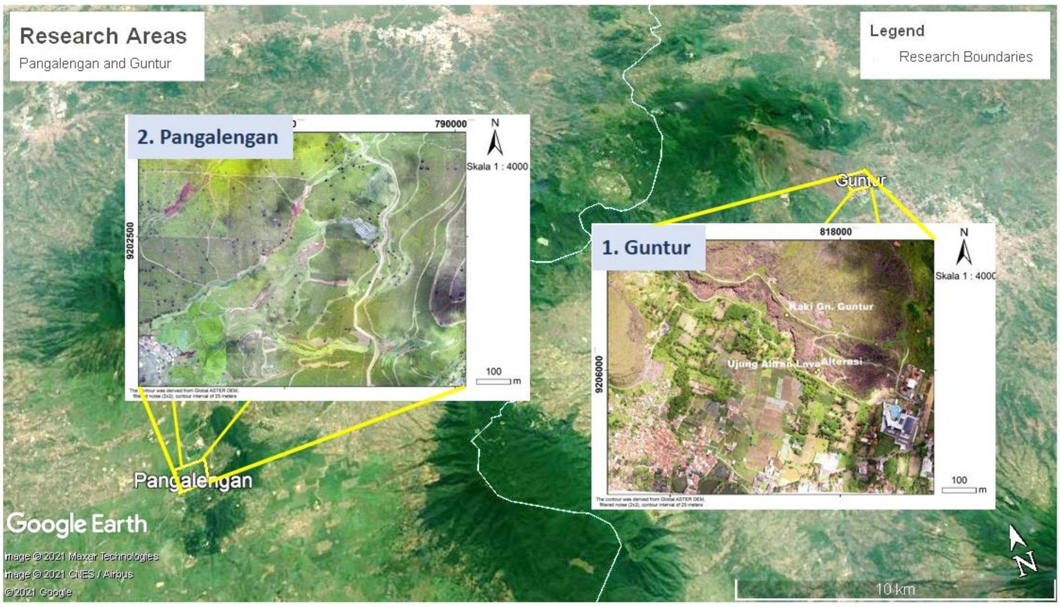

Figure 1. Research areas in West Java Province; orthophoto models of 1) Guntur area and 2) Pangalengan Area

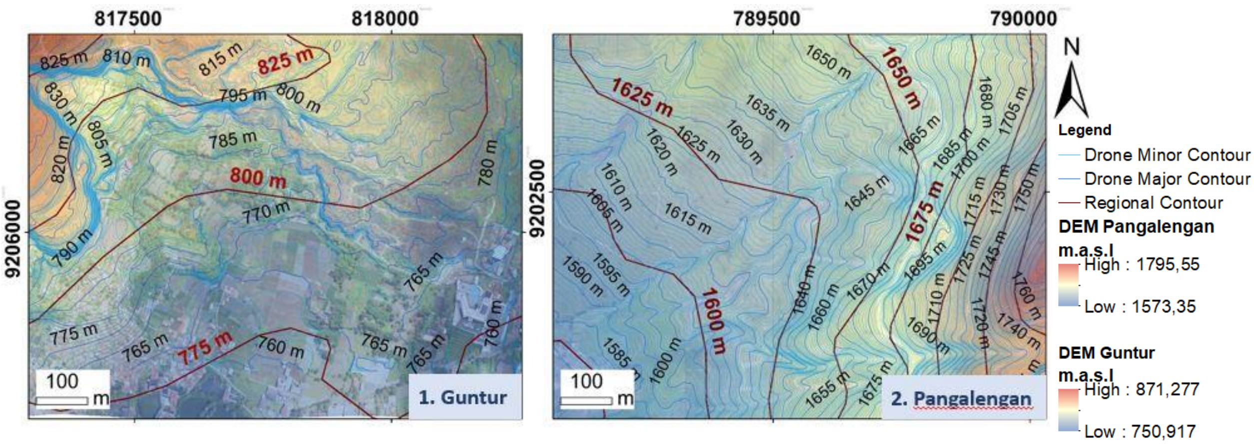

Figure 2. DEMs from 1) Guntur and 2) Pangalengan; Detailed contour maps constructed from UAV Drone DEMs compared to regional contour map from Global ASTER DEM.

Photometry

Photometry is used to generate far more detailed Digital Elevation Model (DEM) to be used as the database. The DEM is obtained through UAV Drone and filtered by its land use to derive only the terrain model; this extraction was examined carefully by filtering out the vegetation, building, cloud, and other disturbed lands (except for old landslides) (***Error! Reference source not found.***). A landslide study requires sufficient resolution of DEM down to centimetre order to look at micro displacements.

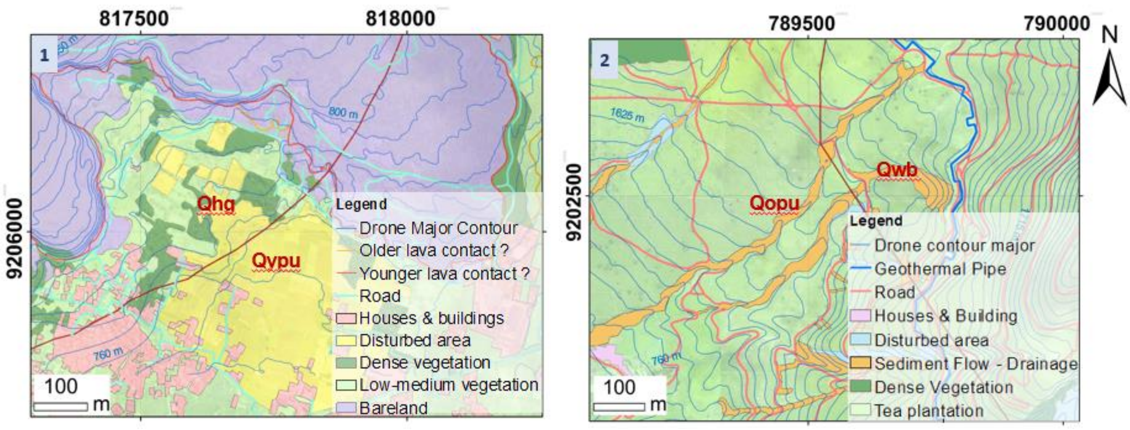

Figure 3. Landuses as filters when constructing DEMs for both research areas; 1) Guntur, and 2) Pangalengan.

Slope Classification

A landslide does not necessarily occur when the slope is steep. However, slope classification can indicate the possible land movement type related to its morphology. Several references are listed to compare the slope descriptions (Table 1). The land movement will be further classified by its rock type and consolidation.

Table 1. Slope description comparisons over the years.

Reference	*Description*	*Unit*	*Slope*	*Class*
CDA (1974)	Simple topography, single slope (regular surface)	Percent (… %)	0 - 0.5	depressional to level (A)
			>0.5 - 2	very gently sloping (B)
			>2 - 5	gently sloping (C)
			>5 - 9	moderately sloping (D)
			>9 - 15	strongly sloping (E)
			>15 - 30	steeply sloping (F)
			>30 - 60	very steeply sloping (G)
			>60	extremely sloping (H)
	Complex topography, multiple slopes (irregular surface)	Percent (… %)	0 - 0.5	nearly level (a)
			>0.5 - 2	gently undulating (b)
			>2 - 5	undulating (c)
			>5 - 9	gently rolling (d)
			>9 - 15	moderately rolling (e)
			>15 - 30	strongly rolling (f)
			>30 - 60	hilly (g)
			>60	very hilly (h)
Zuidam (1985) [2][3], [4]	Comprises character process ang field condition (erossion, mass movement, creep, denudasional process)	Degree (… °) [Δh]	0 – 2 [<5]	flat
			>2 – 4 [5 – 50]	gently sloping
			>4 – 8 [50 – 75]	sloping
			>8 – 16 [75 – 200]	moderately sloping
			>16 – 35 [200 – 500]	steep
			>35 – 55 [500 – 1000]	very steep
			>55 [>1000]	extremely steep

Reference	*Description*	*Unit*	*Slope*	*Class*
Sikdar et al (2004) [5]		Degree (… °)	0 - 5	very gentle
			>5 - 10	gentle
			>10 - 15	moderate
			>15 - 25	moderately steep
			>25 - 35	steep
			>35	very steep
Listyanti (2019) [6]	Critics to Zuidam's slope classification, proposed subclasses from the seven main division	Percent (… %) $[\Delta h]$	0 - 2 [<5]	Flat or almost flat
			3 - 7 [5 – 50]	Gently undulating
			3 - 7 [5 – 75]	Undulating
			8 – 13 [5 – 25]	Sloping undulating
			8 – 13 [25 – 75]	Undulating – rolling
			8 – 13 [75 – 200]	Rolling
			14 – 20 [25 – 50]	Moderately steep rolling
			14 – 20 [50 – 200]	Rolling – hilly
			14 – 20 [200 – 500]	Hilly
			21 – 55 [50 – 200]	Steep hilly
			21 – 55 [200 – 500]	Hilly – steeply dissected
			21 – 55 [500 – 1000]	Steeply dissected
			56 – 140 [200 – 500]	Very steeply dissected
			56 – 140 [500 – 1000]	Steeply dissected mountainous
			56 – 140 [>1000]	Moderately steep mountainous
			>140 [500 - 1000]	Mountainous
			>140 [>1000]	Extremely steep mountainous

The landslide classification is consistently a consequence of two important factors; the movement type and the material. However, in the earlier research, the terms for 'material' were divided into rock, debris, and earth, which are compatible neither in geological or geotechnical terms [7]. Later on, an updated Varnes landslide classification was introduced [8]. Going to that direction, this research will provide sufficient data before analysing the sliding plane and the type of movement. All these analyses will come to conclusion about the potential landslide occurrence in an area.

Other Topographic Parameter

The direction of each slope or aspect is represented in its azimuth value (N 0-360^0 E) and the curvature of the slope is represented in integers. These values will be evaluated to inform the relationship between parameters through bivariate statistics analyses.

DISCUSSION

Detailed Contour Maps

The original pixel size of the Pangalengan DEM is 0.46m x 0.46m, an even smaller pixel size is possible because the Guntur DEM resolution is 6cm x 6cm. However, creating slope gradient map in centimetre order seems unnecessary since no detailed equipment for soil displacement to be found. Therefore, the Guntur DEM resolution was resampled to match the Pangalengan DEM resolution. Contour generations for both locations were conducted and show that high-resolution-DEM (raster) can provide more detailed elevation information that are imperative for the landslide monitoring aspect. The comparison of regional contour and aerial-photograph-derived-contour is already shown in (Figure 2).

The Guntur research area, having a range of 750 – 871 meters above sea level elevation, shows a noticeable gap in regional contour and drone contour. A similar situation is found on the Pangalengan research area (1573 – 1795 m.a.s.l), where regional contour cannot possibly show smaller drainage or catchment areas. The elevation difference is required in the slope classification process, especially in Zuidam and modified Zuidam slope classification, to further classify the sub-unit of the morphological features.

Slope Gradient Maps

The slope gradient values (α) are divided into classes at every 1 standard deviation intervals; fixed interval was inappropriate as some classes will be packed while the others are empty because of the outliers. Fixed class has a subjective decision into it and default (jenks) can be too much number of classes (up to 9 classes). Therefore, the whole slope data are divided into 5 classes at every standard deviation values, named $\alpha \leq 5.29^0$ (green), $5.29^0 < \alpha \leq 14.08^0$ (light green), $14.08^0 < \alpha \leq 22.86^0$ (yellow), $22.86^0 < \alpha \leq 31.65^0$ (orange), and $\alpha > 31.65^0$ (red) for Guntur area; and $\alpha \leq 7.62^0$ (green), $7.62^0 < \alpha \leq 15.50^0$ (light green), $15.50^0 < \alpha \leq 23.38^0$ (yellow), $23.38^0 < \alpha \leq 31.26^0$ (orange), and $\alpha > 31.26^0$ (red) for Pangalengan area. These classes at every area is shown in Figure 4. Table 2 shows each slope class percentage to better understand the slope gradient distribution in Guntur.

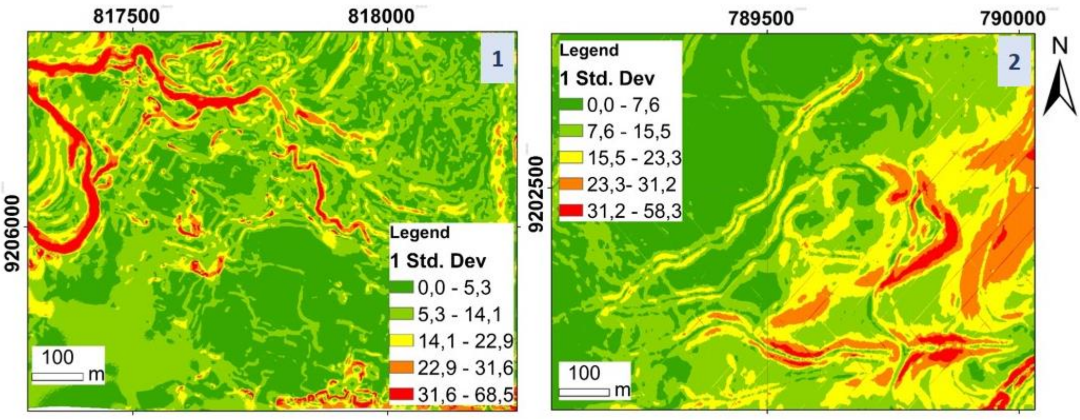

Figure 4. Slopes at a) Guntur & b) Pangalengan; classified into 5 groups by its standard deviation (in degree).

Table 2. Slope class percentage throughout Guntur area.

No.	***Classes***		***Coverage***	
	Degree (°)	*Percent (%)*	*Area (ha)*	*Percentage (%)*
1	0 – 5.29	0 – 9.26	36.61	35.18
2	5.29 – 14.08	9.26 – 25.08	46.30	44.48
3	14.08 – 22.86	25.08 – 42.16	13.03	12.52
4	22.86 – 31.65	42.16 – 61.64	4.43	4.25
5	31.65 – 68.52	61.64 – 254.11	3.71	3.56

The maximum value of slope is compromised due the resolution of raster was made smaller through resampling. The range of slope could have been 0^0 – 86.8^0 if calculated with the original resolution of 6 cm x 6cm. Because of the resampling, the range became shorter. This happened because the overall slope value at 0.46m x 0.46m is the averaged value; the 'individual' slope values can be various. The slope coverage in Pangalengan area was not compromised as the resolution was kept original (shown in Table 3).

Table 3. Slope class percentage throughout Pangalengan area.

No.	***Classes***		***Coverage***	
	Degree (°)	*Percent (%)*	*Area (ha)*	*Percentage (%)*
1	0 – 7.62	0 – 13.38	59.85	38.69
2	7.62 – 15.50	13.38 – 27.73	54.20	35.03
3	15.50 – 23.38	27.73 – 43.23	26.13	16.89
4	23.38 – 31.27	43.23 – 60.73	11.00	7.22
5	31.27 – 58.36	60.73 – 162.29	3.53	2.28

The majority of slope in both areas are different. Table 4 and

Table 5 show the morphology classes of Guntur and Pangalengan across many references, respectively. In the earlier classification, a slope can be defined and single, multiple slopes, or combined. The capital letter depicts the form of single slope.

Table 4. Guntur slope classes (… ^{0}) and its morphology description.

From	***To***	***1974***	***1985***	***2004***	***2019***
0	***5.29***	ae – multiple slopes from nearly level to moderately relling	Flat to sloping	Very gentle	Flat or almost flat – gently undulating
5.29	***14.08***	ef – multiple slopes, moderately rolling to strongly rolling	Moderatel y sloping	Gentle – moderate	Undulating – moderately steep rolling
14.08	***22.86***	fg – multiple slopes from strongly rolling to hilly	Steep with hints of moderate slopes	Moderatel y steep	Moderately steep rolling – steep hilly
22.86	***31.65***	Gh – very steeply sloping for single slope & very hilly for multiple slopes	Steep	Steep	Steep hilly
31.65	***68.52***	Hh – extremely sloping for single slope & very hilly for multiple slopes	Extremely steep	Very steep	Steep hilly – very steeply dissected

Table 5. Pangalengan slope classes (… ^{0}) and its morphology description.

From	*To*	*1974*	*1985*	*2004*	*2019*
0.01	**7.62**	ae – multiple slopes from nearly level to moderately relling	Flat to sloping	Very gentle	Flat or almost flat – Sloping undulating
7.62	**15.50**	ef – multiple slopes, moderately rolling to strongly rolling	Moderately sloping	Gentle – moderate	Undulating – moderately steep rolling
15.50	**23.38**	fg – multiple slopes from strongly rolling to hilly	Steep with hints of moderate slopes	Moderatel y steep	Hilly – steep hilly
23.38	**31.27**	Gh – very steeply sloping for single slope & very hilly for multiple slopes	Steep	Steep	Steep hilly – steeply dissected
31.27	**58.36**	Hh – extremely sloping for single slope & very hilly for multiple slopes	Extremely steep	Very steep	Steeply dissected – very steeply dissected

Landslide Material

Figure 3 provides information about the material or the lithology types. There are two kinds of geological formation both in Guntur and Pangalengan areas. Guntur area comprises of a) labradiorite basaltic lava, that came from Guntur Lava (symbolized by Qhg), and b) undifferentiated efflata deposits of young volcanics (volcanic ash and lapilli, sandy tuff, blocks of andesite-basalt, laharic breccia and efflata; symbolized by Qypu). Pangalengan area consists of different formations, named a) undifferentiated efflata deposits of old volcanics (fine to coarse dacitic crystalline tuff, tuffaceous breccia contains pumices and old andesitic-basaltic laharic deposits; Qopu) and b) Waringin-Bedil Andesite, old Malabar (alternation of lava breccia and tuffs, pyroxene andesitic & hornblende andesitic composition; Qwb). From the geological information above, the Guntur area has more loose materials than that of Pangalengan area (tuffs). Therefore, the different landslide material can be helpful in determining the landslide type.

Watersheds as Unit Slopes

A demonstration of how a unit slope is simulated will be shown through a unit slope 4 of Guntur and unit 29 of Pangalengan that are suspected to be the most likely to fail based on its extreme slopes only. A unit slope is created based on watershed generation at a unit area. The watershed's accuracy for both areas is at 1 hectare to create sufficient number of units; 48 units at Guntur (Figure 5) and 51 units at Pangalengan (Figure 6). Conducting a simulation of a unit requires a grid generation that is shown in Table 6 to discreet each unit.

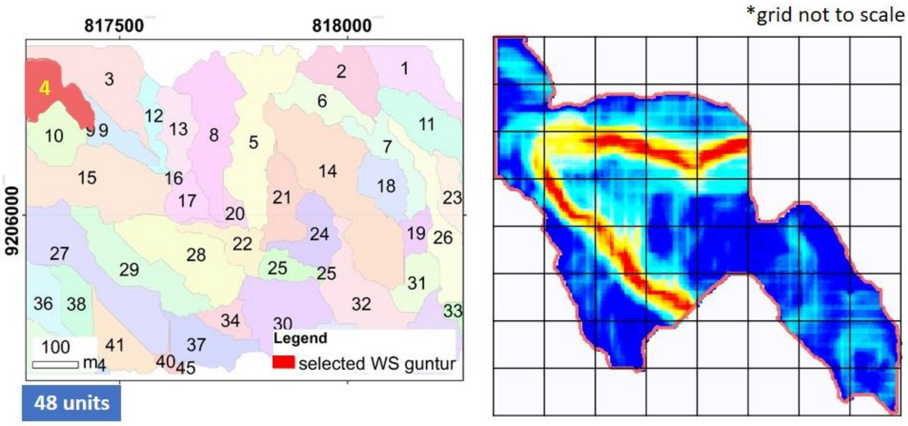

Figure 5. Watersheds of Guntur at 1 ha resolution and the selected/demonstrated unit slope (unit 4); data displayed in the right hand-side figure is slope (degree).

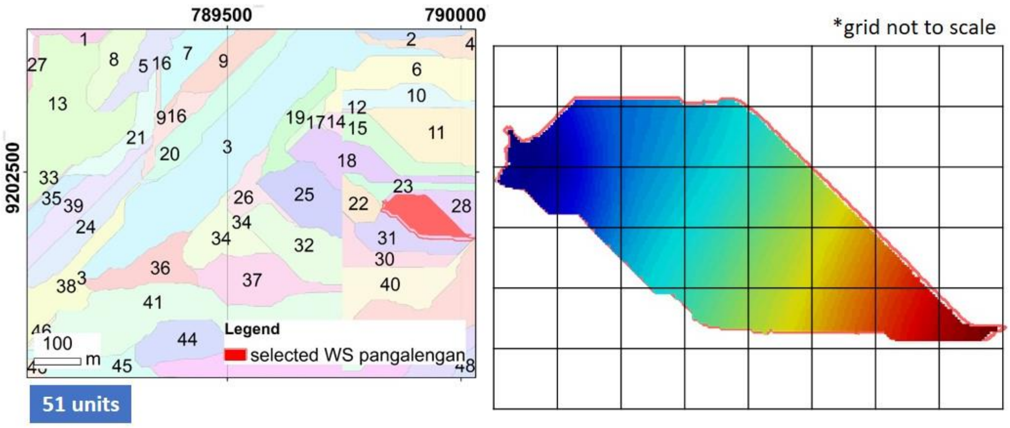

Figure 6. Watersheds of Pangalengan at 1 ha resolution and the selected/demonstrated unit slope (unit 29); data displayed in the right hand-side figure is DEM (masl).

Table 6. A cartesian grid for simulation at each subunits.

Grid Parameters	*Guntur – Unit 4*	*Pangalengan – Unit 29*
Easting (min)	817242.17 meter	789828.32 meter
Northing (min)	9206181.79 meter	9202352.85 meter
Cell size (X)	1 meter	1 meter
Cell size (Y)	1 meter	1 meter
Number of cells (X)	202	201
Number of cells (Y)	188	97

An overall look into the watersheds show a significant difference of the shapes. Watersheds generated throughout Guntur area are less elongated than those in Pangalengan area. Although further calculations in shape ratio, circularity ratio, elongation ratio, and aspect ratio are needed. An initial look into these shapes tells that different tectonic activities are incorporated into both locations.

Correlations of the Topography Parameters

A Gaussian simulation will be conducted in the selected unit slopes. The simulation is aimed to search the topography parameter pairs to enhance the spatial relationship (if any), and compared to the bivariate statistics relationship of the raw data. All data will be transformed into the Gaussian distribution to obtain the normal "bell-shaped" data distribution that is ideal for the simulation. In the following research, this simulation will provide several realizations that will be selectively analysed (mean).

The built raster will be based on the grid parameter stated in previous sub-section. The raster will contain many parameters on a single cell, including geological information, elevation, slope, aspect and curvature (Figure 7). The figure below only represent one slope unit for each areas. With all informations gathered, the spatial correlation amongst variables in these units can be easily obtained; Table 7A for topography parameter correlation in Guntur area unit 4, while Table 7 for Pangalengan area unit 29).

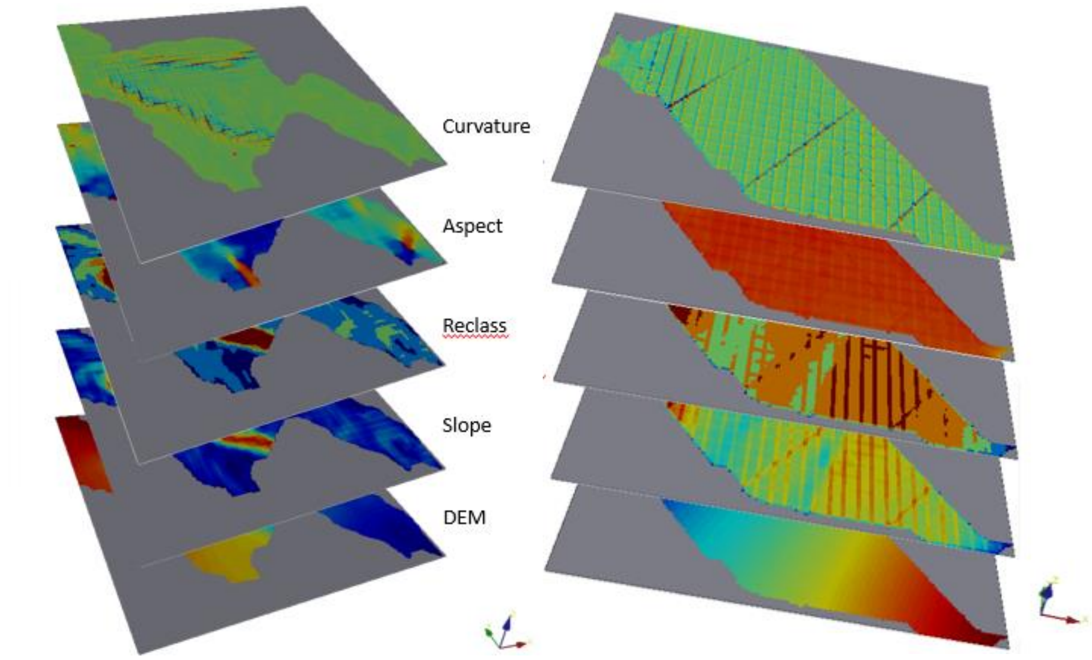

Figure 7. Built raster of Guntur (left) and Pangalengan (right)

Table 7. Spatial correlations.

A.Guntur

Raster	*Elevation*	*Slope*	*Class*	*Aspect*	*Curvature*
Elevation	1				
Slope	0.25	1			
Class	0.28	0.93	1		
Aspect	0.04	-0.09	-0.09	1	
Curvature	0.10	-0.015	-0.01	-0.003	1

B.Pangalengan

Raster	***Elevation***	***Slope***	***Class***	***Aspect***	***Curvature***
Elevation	1				
Slope	0.15	1			
Class	0.18	0.93	1		
Aspect	0.32	0.17	0.19	1	
Curvature	0.074	-0.003	-0.007	0.006	1

Every parameter will be the subject of random variables to predict the slip surface(s) of the landslide. The form of the surface, curvature, or the nature of the slope's crest (flat, concave, or convex) will also determine how the burden fall. The parameter that is as important is aspect that shows the direction to which a weak plane/slip surface will likely to occur. Moreover, the burden can be the material's weight itself, which is very dependent to elevation. The variables (before clipping) selected to proceed are those who have the highest correlation coefficient among others. A Monte Carlo simulation will be the tool to model the possibility of slip surface shapes.

The remaining task for landslide susceptibility analysis is to calculate the equilibrium of each unit slope. This process requires the previous analysis to compare the weigh or burden 'on' the weak plane to the retaining force existing. This will be called equilibrium analysis. Guntur and Pangalengan have a very distinct features and so is its topography emphasis. The sub-watersheds, as the unit slopes, alone will tell the tectonic activitiy handprints just by their shapes.

CONCLUSION

Unit slopes are generated based on the watersheds to part the study area. A slope in Guntur (unit 4) and a slope in Pangalengan (unit 29) are chosen to gain the descriptive characteristics of a certain unit column and its correlation to other topography parameters. The building of every unit slope raster is based on 1m x 1m pixel that consists of elevation, slope, class, aspect, and curvature. The correlation between parameters shows that the slope and its class have the higher correlation coefficient. This is due to reclassification of the slope is based on the slope values. The topographic parameters that are not correlated to each other is curvature to others. There is a significant difference of aspect-elevation correlation in both areas; that in Pangalengan has 0.32 while Guntur has only 0.04 coefficient correlations. However, the elevation to slope and class in Guntur is higher than the coefficient Pangalengan has. This leads to different random variables to be put into Monte Carlo simulation to predict the slip surface.

ACKNOWLEDGEMENT

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