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Applied Small Format Aerial Photograph (SFAP) for Detail Landslide Susceptibility Mapping

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Abstract
Landslide is a disaster which affected by a human and geographic physical condition. Commonly, landslide susceptibility mapping is created by semi-detailed data and direct landslide inventory mapping. It becomes less detailed information and needs more time for data inventory. Small format aerial photograph details remote sensing data for landslide inventory and producing landslide detail mapping. The paper proposes a small format aerial photograph for detailed landslide susceptibility mapping based on landslide inventory. The method for landslide susceptibility mapping is based on landslide detail data produced by interpretation SFAP. We use 2D manual interpretation SFAP to landslide inventory data. This research was conducted in the Bompon micro catchment, Magelang Regency, Central Java. We applied a detailed landslide section and type of landslide to determine the susceptibility landslide area, i.e, crown of landslide, zona depletion, zona accumulation, main body of and toe landslide. Each section of the landslide occurred in different surface morphology. The result shows the landslide susceptibility areas depend on the detailed landslide section. Crown, zona depletion, and the main body of landslide are the unstable zone. They have occurred in the surface morphology such as peak-interfluve, upper slope-shoulder, middle slope-transportation zone, and lower slope-translational zone. Simultaneously, zona accumulation and toe landslide are the stable zone and occurred in the surface morphology such as foot slope-depositional zone and colluvial plain. The accuracy value is 86%; it was done by extensive field check.

Keywords: *Small Format Aerial Photograph, Landslide, Susceptibility map*

I. Introduction

Indonesia is one country that has a lot of volcanic mountains. It can affect the soil weathering, which has a composition characteristic of slightly clayey with little sand and is most fertile and has thick soil conditions. The weathering soil with thick soil conditions and the topography in the mountainous area and no plants with deep and strong roots will be more vulnerable to landslide occur [20; 29; 2]. Landslide is the second-highest disaster that had been occuring in Indonesia after forest and land fire [3]. Landslides occur in hilly or mountainous areas. During January-September 2020 there were 730 landslides occurred in Indonesia. (DIBI, 2020). 74 people died, 391 damaged houses, and 18 public facilities [3]. The landslide occurred is intensively in Indonesia. It is the second-highest disaster that was occuring in Indonesia. The areas with rainfall around 2000 mm/year are the greatest potential for landslides [22]. Bompon micro catchment is located in the Magelang Regency, Central Java, Indonesia. Central Java is the province with the highest number of the landslide in Indonesia. 423 landslides occurred in Central Java [3].

Bompon micro catchment is a hilly and mountainous area. The soil thickness more than 4 meters, with low organic matter, and it was consist of clay and alteration material. The human activities were cultivated mixed garden. There was a lot of cutting the road and opening the land cultivated. Intensively landslide in Bompon micro catchment was also affected by the physical geography condition of Bompon micro catchment.

The landslide susceptibility mapping has done by analyzing each parameter of the landslide. The most important to make landslide mapping is how to make high accuracy. The landslide susceptibility mapping produced by the governor agency uses a heuristic method with the overlay technique. The weakness of this method has a high subjectivity person. Thus, researchers can be a different assumption about landslide susceptibility [30]. The subjectivity of this method is to tend to value each indicator of the landslide. Inappropriate values in each indicator can be affected by to landslide susceptibility map. Besides, the research achievement showed landslide susceptibility mapping uses a small scale for mapping.

The best methods for landslide susceptibility are inventory landslides that use detailed remote sensing data such as small-format aerial photographs and extensive field surveys to measure landslide's morphometry as the accuracy test. Based on [4], remote sensing data can use for landslide identification and landslide susceptibility. Using remote sensing data for landslide identification is an effective way. Detail remote sensing imagery gives detailed information on landslides and produces detailed landslide susceptibility mapping [16; 6; 28; 12; 10; 26].

Photo interpretation has effective ways to the landslide. Inventory map and it plays a very important role, although it needs extensive field check. Small format aerial photographs could be used to identify topography information without an indirect field survey [1; 9]. Several researchers have done research related to this one [4;31;12]. Photo interpretation of Small format aerial photograph gives detailed information. It is one of the detailed remote sensing data. Photo interpretation has obtained by the small format aerial photograph's physical appearance that can use to identify detailed landslides such as object association, pattern, site, hue/color, and shadows. The 2D manual interpretation technique did it.

Detail landslide susceptibility mapping is necessary for determining the mitigation strategy. The landslide susceptibility is related to each section of landslide, i.e., crown, a body of landslide, zona depletion, zona accumulation, and toe landslide. Each section of the landslide has differenced geomorphological processes and neither landslide susceptibility mapping. Each section of landslide could include identification by 2D manual interpretation with spatial resolution 0,7 meter. It will be given high accuracy. The research achievement mostly gives information on identifying the landslide area without specific identification in each section of the landslide. Each section of the landslide represents landslide susceptibility. This study's differences with previous research are that this research tends to apply to small format aerial photograph data for producing detailed landslide susceptibility based on each section of the landslide in the Bompon micro catchment.

Study Area

Bompon micro catchment is part of the Bogowonto catchment system. It is located on Old Mt. Sumbing at the central part of Java Island to the Indian Ocean. The size of the Bompon micro catchment is around 300 ha. This area elevation around 413-539 mdpal (mean sea level) and is dominated by hilly and mountainous areas (Fig.1). The soil thickness more than 4 meters and consists of clay, soil material alteration, unconsolidated landslide material, sedimentation of young Mt. Sumbing, and in the certain area found low organic material and brownish-red soil color. The surface material and the basement material are clay coming from different parent rocks. The surficial clay has been derived from the volcanic ash of Mt. Sumbing. At the same time, the sub-surface clay has been developed from Tertiary volcanic materials of KulonProgo Dome. The landslide might involve the surficial material and both surficial and sub-surface materials. Mostly, the land cover of this area is mixed garden cultivation. The type of landslides has occurred in this area, such as Rotational, Translational, and Topple.

II. Data and Methodology

A small format aerial photograph was used in this research. It was acquired by direct photo using Quadcopter Drone on the 5th October 2015. The drone has specifications such as camera type Powershot 110; focal length 5mm; fly high 300 meters; amount photo 494 photos; the duration of the data is around ± 15 minutes. A small formal aerial photograph orthophoto was produced by combining all the photos using Agisoft photo scan software. The type of data was a 2D multispectral small format aerial photograph. Photo mosaic was only possible for 2D based visual analysis on a computer screen. Since we could not build Digital Surface Model (DSM) from the aerial photos, we used TerraSAR Image to build the Digital Terrain Model (DTM) of the study area even though the DTM had a coarser spatial resolution.

Stepwise 2D manual interpretation method was applied in this research. The technique used for landslide identification is step by step. Its means to identify landslide have to be from general identification to specific identification in each landslide section. Landslide general identification means to identify the area affected by the landslide. Landslide specific identification means to identify each section of a landslide in a landslide area. The stepwise method cannot invert each other based on the object appearance of a small-format aerial photograph. The object appearances used for landslide identification are *i*) land cover, *ii*) escarpment, *iii*) landslide shape, *iv*) Gully erosion, *v*) road association, and *vi*) river association. Each section of the landslide represents landslide susceptibility.

III. Result and Discussion

A. Small Format Aerial Photograph Interpretation

Some research achievements argued that remote sensing data could identify landslides [31; 27; 14; 13]. The aerial photograph is a remote sensing data that has detailed information for producing landslide inventory [16; 6; 31; 26; 15].

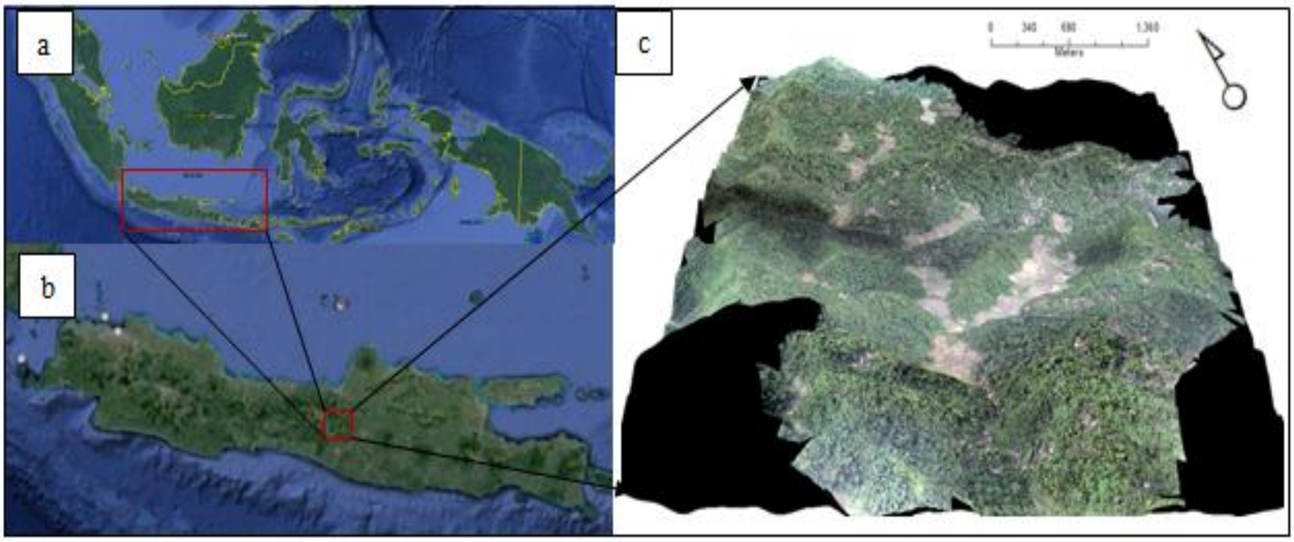


Figure. 1 Study Area: a) Indonesia; b) Java Island; c) Bompon Micro Catchment

There were mostly explained how applied standard aerial photographs and small format aerial photographs to identify landslide, but they were not given detailed information on each landslide section. Standard aerial photograph and small format aerial photograph has each advantage and deficiency. Mostly, a standard aerial photograph that use to identify landslides is stereo and multi-temporal. It makes it easier to identify, but to acquire the data is more difficult and complex than small format aerial photograph. To identify landslides, use a small format aerial photograph done by 2D and 3D interpretation. It depends on the percentages of photo overlays. The acquired small format aerial photograph is simpler than a standard aerial photograph. This research tends to applied small format aerial photographs for landslide susceptibility mapping.

Detail information which obtained from small format aerial photograph depends on the spatial resolution. Thus, the smallest object could be obtained on the special resolution. There are no appropriate basic roles for determining the similarity between spatial resolution, output photo scale, and output mapping scale [24]. For instance, a photo with a spatial resolution of 0,75 meters cannot determine an appropriate output map scale. The researcher uses the *Rule of thumbs* approach to consider between spatial resolution and output map scale [1; 24].

Mapping cannot be separated from cartographic rules. Thus, to produce a landslide susceptibility map, consider the cartographic rules such as the minimum legible area to map digitize. The minimum legible area was influenced by the output scale map (Rossiter, 1999). The zoom out of map digitizes 2D on-screen maximum is 2,5 x output map scale (kennie and Mattews in Sutanto, 2013). Thus, the maximum scale for this research to digitize is 1:4.000. If there were a landslide and it was not less, the maximum legible area will be represented as points. There were several landslides In Bompon micro catchment that represents as points.

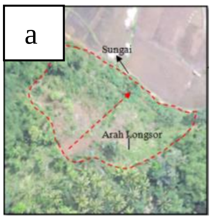
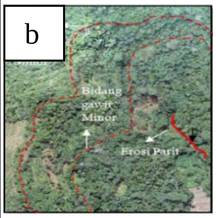
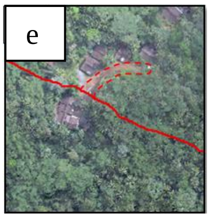
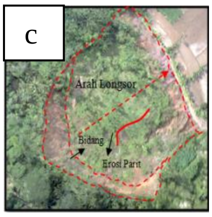
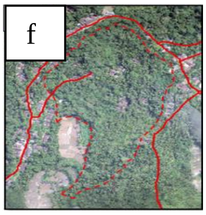
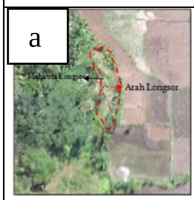
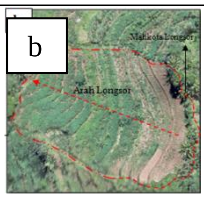
A. *Applied Small Format Aerial Photograph for Detection and Identification Landslide Scale 1:10.000*

The keys of the small-format aerial photograph to identify landslide use the stepwise method. It was done by systematic step general identity to a specific identity. The general identification has identified the area affected landslide and non-affected landslide. Specific identify such identify each section in a landslide (Table 1.1). It was done by interpretation manual on-screen 2D of the object appears in the small format aerial photograph.

Landslide identification based on interpretation of small-format aerial photographs is still rare. Achievement of landslide identification research based on small format aerial photographs only identifies landslide areas and does not explain landslide typology, landslide activity, and landslide units [16; 6; 31; 26]. Based on research achievements, small format aerial photographs and standard format aerial photographs can be used for landslide identification. Small format aerial photographs and standard format aerial photographs have advantages and disadvantages for landslide identification. Most of the standard format aerial photos for landslide identification are stereo and temporal. Thus the process of identifying landslides on standard format aerial photographs is easier. However, the acquisition of standard format aerial photographs for landslide identification has a more complex process.

The identification showed 17 inactive rotational landslides, 14 active rotational landslides, and 4 active translational landslides. The total area affected by a landslide is 44.09% or 1.32 Ha. Landslides distribute in down part Bompon micro catchment. The landslide sections were identified by manual 2D interpretation such as scarp of the landslide, body landslide, toe landslide, zona accumulation, and zona depletion. Detailed information related to the keys of manual information will explain below.

Table 1.1: The Keys Manual Interpretation of Small-Format Aerial Photograph (SFAP) for Landslide Identification

SFAP	Interpretation Description	SFAP	Interpretation Description
	**Shape and Land Cover Identification for Active Landslide** Landslide Body's Tone: Brighter Color: Brown Land Use: Mixed Garden Vegetation Density: Medium to low Vegetation height: Around 5-10 meters Shape of Landslide Perimeter: Curve		**River Association Identification for Active Landslide** Association: river Vegetation type: bush, *Albazia sp*. Vegetation height : 5-10 meters Landslide orientation: toward the river
	**Shape and Land Cover Identification for Inactive Landslide** Landslide Body's Tone: Darker Color : Darkgreen Land use: Mixed Garden Vegetation type: Dominated by Albazia sp, Coconut, Mahogany sp, and bamboo Vegetation height: More than 10 meters Land management: Terrace and showed minor scarp Shape of Landslide Perimeter: Curve		**Road Association for Active Landslide** Landslide orientation: toward the road
	**Scarp and Gully Erosion Identification** Scarp's Tone: Brighter The shape of the Landslide Perimeter: Curve Gully Erosion: Darker (Shadow) Scarp Color: Brown (there is no vegetation) Vegetation density: Medium to low		**Road Association Identification for Inactive Landslide** The high of *Albazia sp*, coconut, Mahogany sp, and bamboo. They have 10-17 meters high There were depletion and accumulation zone
	**Landslide Translational Typology Identification** The shape of the Landslide Perimeter: Relative Planar Landslide Body: not utilized Vegetation: Sprawl Association: Close to River and Road		**Landslide Rotational Typology Identification** The shape of the Landslide Perimeter: Curve Landslide Body : agricultural utilization Association: Close to River and Road

B. Detail Landslide Susceptibility Mapping Based on Inventory Landslide

Landslide is the disaster that occurred by a geomorphological process, the material of landslide, and surface morphology. Inventory landslide could be collected by 2D manual interpretation of small-format aerial photographs as ones. Present and past are the keys to determining the future [19]. Thus, landslide identification obtained from the interpretation of small-format aerial photographs can be used as a reference in determining future landslide susceptibility.

Identify each section of the landslide that could be determined for landslide susceptibility. Each section of landslide will occur in different surface morphology, and the mass movement of the landslide influenced it. The higher percentage of slope in the surface morphology will influence the landslide material movement. The surface morphology is divided into 7 classification systems, i.e., peak-interfluve, upper slope-shoulder, middle slope-transportation zone, lower slope-translational zone, colluvial foot slope-depositional zone, channel bed, and colluvial plain [23]. Each section of landslide occurs in different surface morphology, and it was influenced to susceptible to landslide material movement (Figure. 2).

There are differences in the area of the accumulation zone and the depletion zone based on landslide activity. 0.21% were rotational inactive depletion zones, 3% rotational active depletion zones, 42% rotational inactive depletion zones, 55% translational active depletion zones. The high percentage of landslide bodies in the rotational inactive depletion zone is 42.59% of the Bompon catchment has a slope angle of> 15% -25%. The conditions of the slope angle value cause the soil material to have the potential to move. The part of the landslide body in a depletion zone is spatially distributed on the upper slopes' morphology to the middle slopes. In contrast, the accumulation zone's landslide bodies are distributed to the lower slope morphology, alluvial plains, and colluvial plains.

The unstable zone of landslide susceptible zones occurs in the surface morphology peak-interfluve, upper slope-shoulder, middle slope-transportation zone, and lower slope-translational zone. While the stable zone or insusceptible zone in the surface morphology, colluvial foot slope-depositional zone, channel bed, and colluvial plain. The unstable zone has a higher slope percentage than the stable zone. It will influence the landslide material movement.

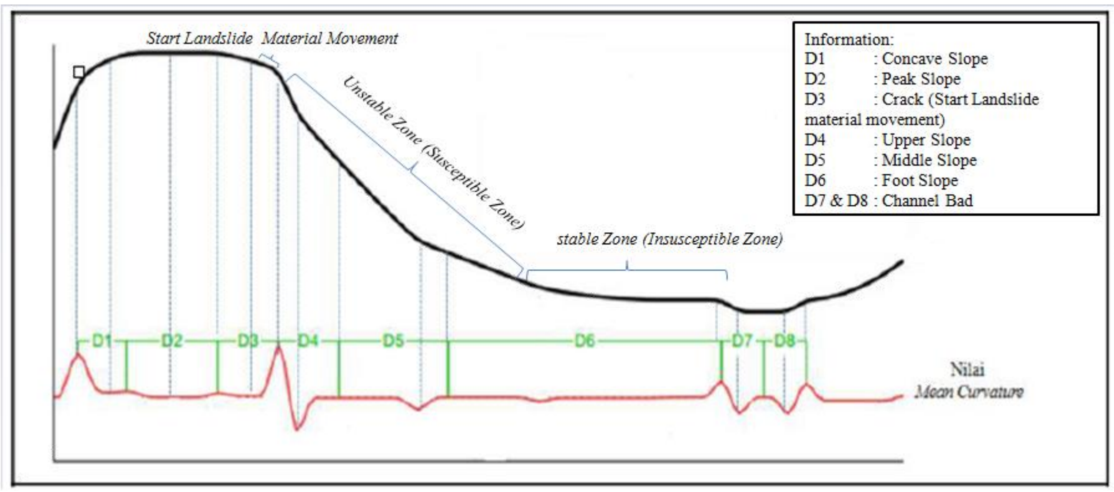


Figure. 2: Illustration the Relationship between Surface Morphology and Landslide Susceptibility [Modified 23]

Landslide identification based on interpretation of small-format aerial photographs using nine elements of interpretation. Landslide identification based on interpretation resulted in 17 inactive landslides with rotational types, 14 active landslides with rotational types, and 4 active landslides with translational types. The total area of landslides that can be identified through the interpretation of small-format aerial photographs of the total area of the Bompon catchment is 44.09% or 1.32 hectares. Each landslide area has a different area of the landslide body in the form of differences in the depletion zone and the accumulation zone.

The mapping result shows that in the Bompon catchment, which is represented using areas and points. The use of areas and points represents the spatial distribution of landslides in the Bompon catchment because several landslides do not reach the minimum standard of the mapping area (Minimum Legible Area). According to [21], the minimum area mapped on a map is 0.25 cm^2. The minimum area that can be mapped based on the 1: 10,000 mapping scale output is 2,500 m^2, so the landslide area whose area does not reach the minimum standard area for mapping is represented on the map using points.

Each section of landslide produced by small format aerial photograph interpretation is a scarp, depletion zone, an accumulation zone. Each section occurs in different surface morphology. Scarp and depletion zone landslide in the Bompon micro catchment occurred in the peak-interfluve, upper slope-shoulder, middle slope transportation zone, and lower slope-translational zone. Thus, we concluded that this area is a susceptible landslide. Simultaneously, the depletion zone occurred in the surface morphology, such as foot slope-depositional zone and colluvial plain. It was an insusceptible zone (Fig., 3). The spatial distribution of the rotational type of inactive landslides is more upstream than downstream, while active landslides with the rotational type are more downstream than upstream.

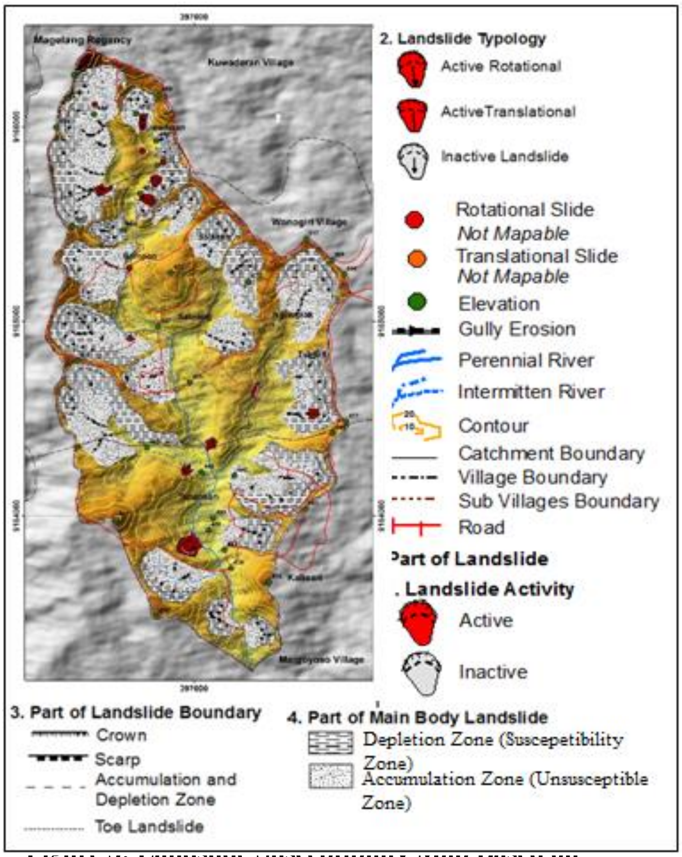


Figure 3. Landslide Susceptibility Map Based on Landslide Inventory Using Small Format Aerial Photograph.

C. *Accuracy Test*

Accuracy test is the most important for displaying interpretation data. It aims to know how accurately applied small format aerial photographs for identification landslide combine with the field's real condition. Accuracy test was done by field check of an active landslide, landslide typology, zona depletion, and zona accumulation. Accuracy test was done at the scale map 1:10.000.

The accuracy technique was done by combining the landslide inventory map from the interpretation and intensive field check. The grid 50mx50m, output map scale, and the smallest polygon were considered accuracy tests [23]. The sample was obtained by Cross Point Grid (CPG) with the grid size 50mx50m. The compare CPG from interpretation small format aerial photograph would be check by intensive field check.

To know the percentage of accuracy use error matrix test [9; 17; 25; 5; 24; 8; 18]. It was produced product accuracy, user accuracy, and all accuracy. Product accuracy is the accuracy produced by omission error, while user accuracy was produced by commission error. Thus, all the accuracy is to calculate amount error omission and commission (Table 1.2)

Table 1.2: Error Matrix

Accuracy Test		Field Check Data			
		X	Y	Z	Amount
Classification Data	X	a	b	c	m
	Y	d	e	f	n
	Z	g	h	i	o
	Amount	p	q	r	t

The Equation:
Error Commission = (d+g)/p x 100%
Error Omission = (b+c) / p x 100%
User Accuracy = a / m x 100%
All the accuracy = (a + e + i) / t x 100%

The accuracy test of this research is 90%. The acceptable minimum test accuracy is 85%. It means that applied small format aerial photograph applies to detailed landslide identification. The accuracy was done by extensive field check of landslide typology, landslide activity, zona depletion, and zona accumulation.

IV. Conclusion

Small format aerial photograph could to the identification of landslide using 2D manual interpretation. The landslide occurrence on the two-dimensional small format aerial photo could be recognized through its characteristics on land cover, scarps, and shape and its association with gully erosion, road, and river. Some interpretation elements applied in landslide identification were tone/color, shape, pattern, association, shadow, and interpretation size. Each section of the landslide was identified by 2D manual interpretation, occurs in the different surface morphology. Thus, it can be determined landslide as susceptible area.

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Reference

[1] Aber, J., Marzolf, I., dan Ries, J. Small Aerial Photography Principles, Technique, and Geoscience Applications. Oxford: Elsevier (2010).

[2] Bera, Somnath., Guru Balamurugan, Ghatterjee, Ranit., Shaw, Rajib. Geographic Variation of Resilience to Landslide Hazard: A Household-Based Comparative Studies in Kalimpong Hilly Region, India. International Journal of Disaster Risk Reduction, (2020) 1-15.

[3] Carrara, A., Cardinali, M., Guzzetti, F., dan Reichenbach, P. GIS Technology in Mapping Landslide Hazard. In: Carrara, A. and Guzzetti, F. (eds.), Geographical Information Systems in Assessing Natural Hazards, (1995) 135–175.

[4] Congalton, R. A Review of Assessing The Accuracy of Classification of Remotely Sensed Data. Remote Sensing, (1991) 35-46.

[5] Fiorucci, C., Rossi., Mondini., Santurri., Ardizzone.,dan Guzzeti.. Seasonal Landslide Mapping and Estimation of Landslide Mobilization Rates Using Aerial and Satellite Images. Geomorphology, (2011) 59-70.

[6] Hadmoko, D. S., Lavigne, F., Sartohadi, J., Hadi, P., dan Winaryo.. Landslide Hazard and Risk Assessment and Their Application in Risk Management and Landuse Planning in Eastern flank of Menoreh Mountains, Yogyakarta Province, Indonesia. Natural Hazard, 54 (2010) 623-642.

[7] Janssen. Accuracy Assessment of Satellite-Derived Land Cover Data: A Review. Photogrammetric Engineering & Remote Sensing, (1994) 419-426.

[8] Lillesand., dan Kiefer. Remote Sensing and Image Interpretation. Third Edition. John Wiley and Sons, New York (1994).

[9] Li, Y., Chen, G., Wang, B., Zheng, Lu., Zhang, Y., Tang, C. A New Approach of CombiningAerial Photography with Satellite Imagery for Landslide Detection. Natural Hazard. (2013) 649-669.

[10] Marfai, M. A., King, Lorenz., Singh, P.L., Mardiatno, D., Sartohadi, J., Hadmoko, D.S., and Dewi, A. Natural Hazards in Central Java Province, Indonesia: an overview. Environmental Geology. (2007) 335-351.

[11] Mantovani, Franco., Soeters, Robert., Van Westen. Remote sensing techniques for LandslideStudies and Hazard Zonation in Europe. Geomorphology. (1996) 213-225.

[12] Metternicht, Graciela., Hurni, Lorenz., Gogu, Radu. Remote Sensing of Landslide: An analysis of the potential contribution to geo-spatial system for hazard assessment in Mountainous Environment. Remote Sensing Environment, (2005). 285-303.

[13] Miyagi, Toyohiko., Prasad, Gyawali., Tanavud, Charchai., Potichan, Anirut, Landslide risk Evaluation and Mapping-Manual of Aerial Photo Interpretation for Landslide Topography and Risk Management. National Research Institute for Earth Science (2004).

[14] Mihai, Bogdan., Sandric, Ionut., Saveloscu, Ionut., Chitu, Zenaida, Detailed Mapping of Landslide Susceptibility for Urban Planning Purposes in Carpathian Subcarpathian Town of Romanis. Cartography. (2010) 418-428.

[15] Nichol, J. S., Shaker, Ahmed., dan Wong, S Application of high-resolution stereo satellite images to detailed landslide hazard assessment. Geomorphology, (2006) 1-8.

[16] Nuarsa. Penggunaan Analisis Citra Digital dan Sistem Informasi Geografi untuk Prediksi Besarnya Erosi di DAS Ayung Bagian Hilir Kabupaten Badung Propinsi Bali. Tesis: Kartografi dan Penginderaan Jauh Universitas Gadjah Mada (Tidak dipublikasikan) (1998).

[17] Olofsson, P., Foody, Giles., Herold, M., Stehman, Stheven.m Woodcock, Curtis., and Wulder, M. Good Practices for Estimating Area and Assessing Accuracy of Land Change. Remote Sensing of Environment, (2014) 42-57.

[18] Panizza, M. (1996). Environmental Geography. The Netherland: Elsevier Science.

[19] Pradhan, Biswajeet. Application of a neuro-fuzzy model to

landslide-susceptibility mapping for Shallow Landslides iin a Tropical Hilly Area. Computers and Geosciences, (2011) 1264-1276.

[20] Rossiter, D. G. Soil Geographic Databases. Lecture Note International Institute for Aerospace Survey & Earth Sciences (ITC), (1999) 1-42.

[21] Sartohadi, J. The landslide Distribution in Loano Sub District Purworejo District, Central Java Province, Indonesia. Forum Geografi, 22(2) (2008) 129-144

[22] Samodra, G. Development of Risk Analysis Technique and Its Application to Geo Disaster Management in Indonesia. Ph.D. Dissertation: Kyusu University, Japan (2015).

[23] Sutanto. Metode Penelitian Penginderaan Jauh. Yogyakarta: Penerbit Ombak. (2013).

[24] Stehman, S., dan Czaplewski, R. Design and Analysis for Thematic Map Accuracy Assessment: Fundamental Principle. Remote Sensing Environment, (1998) 331-344.

[25] Strozzi, T., Ambrozzi, C., dan Raetzo, H. Interpretation of Aerial Photographs and Satellite SAR Interferometry for The Inventory of Landslide. Remote Sensing, (2013) 2554-2570.

[26] Tofani., Segoni., agostini., Catani., Casagli,. Technical Note: Use of Remote Sensing for Landslide Studies in Europe. Natural Hazard System, (2013) 299-209.

[27] Van Westen., Mantovani, Fransco., dan Soeters, R. Remote Sensing Technique for Landslide Studies and Hazard Zonation in Europe. Geomorphology. (1996) 213-255.

[28] Vranken, Liesbet., Turnhout, Van., Eechaut, Den. Economic Valuation of Landslide Damage in Hilly Region: A Case Study from Flanders, Belgium. Science of the Total Environment, (2013) 323-336.

[29] Wahono, B. F. Application of Statistical and Heuristic Method for Landslide susceptibility assessment. Tesis: Geo-Information for Spatial Planning and Disaster Risk Management Graduate School of Universitas Gadjah Mada (Tidak Dipublikasikan) (2010).

[30] Westen, V. Remote Sensing for Natural Disaster Management. Photogrammetry and Remote Sensing, (2000) 1609-161.