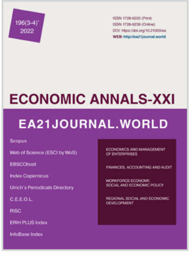

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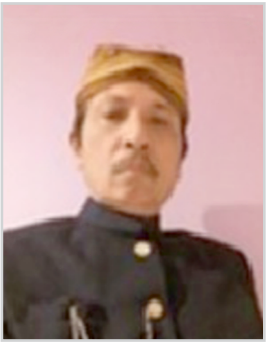

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Using scoring techniques to assess the landslide events and the level of hazard and socio-economic impact in the Sub-Watershed Samin Upstream of Karanganyar District of Indonesia

Abstract
Landslide is a type of mass transfer of soil or rock and a mixture of the two to a lower area due to disruption of slope stability, causing economic and environmental damage to property and human life. This study aimed to assess the landslide events and the level of landslide vulnerability and its economic impact using scoring techniques. The scoring is determined by the sum of the weight's multiplication and the factor that started the landslide. Nine factors causing landslides have been evaluated using the statistical methods. The results showed that the scoring technique could be used as a guideline (tool) to analyze the relationship between landslide events and the level of vulnerability and also assess the socio-economic impact in

the Samin Hulu sub-watershed. The survey and mapping results found that the distribution of landslide-prone areas in the Sub-watershed Samin Upstream can be divided into five landslide-prone levels, namely: extraordinarily prone, very prone, prone, somewhat prone, and not prone. The Samin Sub-watershed area can be categorized as an area classified as prone to landslides.
To lessen the socio-economic damage to the area, a number of programmes and cooperation initiatives between authorities and local communities have been introduced. For that purpose, a reforestation and agroforestry mechanism is applied which means planting teak forests combined with multiple cropping such as coffee, guava, cashew and other local plants.
Keywords: Economic Impact; Prone Level; Level of Hazard; Watershed; Assessment Technique
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1. Introduction

Landslides, known as the movement of soil masses, rocks or a combination thereof, often occur on natural or artificial slopes and are natural phenomena in which nature seeks a new balance due to disturbances or factors that influence it. Landslides arise due to sliding a soil volume over a saturated, somewhat impermeable layer (Aristizábal & Sánchez, 2020). This layer contains high clay content (Klei), and once saturated with water, it will function as a launcher. However, there is also a waterproof layer consisting of rock (Alonso, 2021). Rocks that are impermeable to water can create sliding fields against the ground. Water that enters the soil cannot penetrate the rock layers and flow laterally. When it rains, the water will fill the slip's surface so that there will be landslides above the rock (Xiao et al., 2020).

Indicators of landslide vulnerability can be seen from the following factors: rainfall, slope, land use, geology, the presence of fractures/ slickenside, soil depth, infrastructure, and settlement density (Nguyen et al., 2020). Furthermore, the results of this identification can be compiled (synthesis) of something important concerning. The level of vulnerability/vulnerability of land to landslides (Pollock & Wartman, 2020). The level of landslide threat to human settlements (Jiang et al., 2020). The responsibility of the leader towards land use in landslide-prone areas. Proposed control activities (models) suitable for landslides (Rabby et al., 2022). The classification of landslides is based on. There are four types of maximum depth of material landslides: surface landslides, shallow landslides, deep landslides, and very deep landslides. Based on the activities, namely: active (wound and broken/cracked) and resting / dormant (very slow / very long / hidden: the result of modification of the physical weathering process, erosion, and vegetation growth) (Shafique, 2020). Landslide susceptibility indicators can be seen from rainfall, slope, land use, geology, the presence of cracks/cracks/slickensides, soil depth, infrastructure, and settlement density. Based on these factors, the level of vulnerability to landslides, the level of landslide threat to human settlements, the responsibility of the leader for land use in landslide-prone areas, proposed control activities (models) that are suitable for landslides (Aristizábal & Sánchez, 2020; Mo et al., 2019).

The variation in the level of vulnerability of a landslide-prone area can be divided into three levels. Areas with a high vulnerability level are areas with great potential for land movement and are moderately densely populated. This area often experiences ground movement (landslides), especially during the rainy season or earthquakes (Ma et al., 2020). Areas with a moderate level of vulnerability are areas with a high potential for movement. Areas with a low vulnerability level are areas with a high potential for ground movement. However, there is no risk of human or building casualties. Areas that are less likely to experience landslides but contain important settlers or construction. The level of landslide vulnerability can be calculated from the sum of the factor values (weights and scores) that affect landslides/observation variables. The results can be very high, high, medium, low, very low (Reyes-Carmona et al., 2020).

The Samin Sub-watershed (a subsidiary of the Upper Solo watershed), including the Katena Lawu, mainly in the Karangayar Regency area and a small part in the Sukoharjo Regency, has an area of 27,830 hectares (or 4.22% of the Upper Solo Watershed), including climate type C (Schmidt and Ferguson) with a Q value of 0.473, namely ten wet months and two dry months. This value is the average of all sub-watersheds, but if you look closely, there are three rain classes, namely 1500 mm (<600 masl), 1500 - 2000 (600 masl - 1200 masl), and 2000 mm - 3000 mm

(1200 masl - 2000 masl). This shows that the Samin Hulu sub-watershed is one of the essential sub-watersheds contributing to floods and disasters (landslides) in the Solo watershed area. Especially for landslides, its characteristics are: being in an area with high slope classes, moderate to high rainfall, without up to a little vegetation, large population, and soil conditions with low aggregate stability value, so that the combination of characteristics of the land will be prone to causing landslides (Fan et al., 2020).

If we pay close attention to landslides, it is caused by uncontrolled and increasing soil erosion, resulting in landslides that have the potential for landslides and rock/soil collapse from the upper slopes. Natural events cannot be predicted with certainty and cannot be changed by humans (Gamble & Hogan, 2019). The estuary of landslides has a significant impact. It is a cycle of natural events that must continue to occur periodically and periodically. So a relevant approach is needed to anticipate landslides. This research is intended to provide a model of landslide disaster management through a scoring system of landslide incidents to the level of landslide vulnerability

2. Research Methodology

This research was carried out at 46 points/locations of landslide-prone areas in the Samin Hulu sub-watershed, Karanganyar Regency, which is spread over five sub-districts, namely Jatiyoso, Tawangmangu, Matesih, Karangpandan, and Jumantono through 3 steps (map, field, and geomorphology) which are interrelated and complementary, and each area was taken 2 locations as representatives based on the category of hazard level/weight so that all ten sampling locations (very high/high = 2 locations, medium = 2 locations, and low/shallow = 2 locations). Prefield activities include literature studies, data collection from related agencies such as rainfall data, administrative data, slope maps, village administration maps, soil type maps, river maps, land use maps, and geological maps continue to be analyzed, map interpretation and overlays with the GIS system. at Pusdatt Yogyakarta. Field activities in field surveys, observations, soil descriptions, soil sampling, and interviews with residents. Further actions in the form of laboratory analysis and statistical analysis (physics, morphology, and environment: height, rainfall, slope, land use, lithology, surface rock, water depth, solid/hard soil layer, landslide type, soil solum, moisture content, weight Volume, Soil Color, Soil Texture and Soil Permeability; chemical properties: Potential pH and Actual pH; a combination of physical properties, chemical properties, biological properties: soil type).

Furthermore, to determine the level of landslide vulnerability, the data from the statistical analysis of each component of each biophysical land factor are scored according to their weight (Gädeke et al., 2020). These results can be used as material for drawing conclusions/recommendations, especially about strategies for handling landslide mitigation. In determining the class of each factor causing landslides, a scoring system is carried out. Each class is guided by the UGM Center for Natural Disaster Studies (2005); Minister of Public Works Regulation No. 22 of 2007; Technical Guidelines for Preparation of Condition Maps and Status of Environmental Damage by the Ministry of Environment (2009).

3. Results and Discussion

The level of landslide hazard is determined from the overlay of eighteen thematic maps of the factors causing landslides, including Altitude, Rainfall, Slope, Land Use, Lithology, Surface Rocks, Water Depth, Solid / Hard Soil, Landslide Type, Type of Soil, Soil Solum, Moisture Content, Soil Volume Weight, Soil Colour, Soil Texture, Permeability, Potential pH and Actual pH. From the overlay results, the eighteen factors that cause landslides are obtained 5 (five) classes of landslide-prone levels, including; extraordinarily vulnerable, very prone, prone, somewhat prone, not prone. In general, the Samin Hulu Sub-watershed of Karanganyar Regency is very prone to landslides, with details of which are unusually prone to 40.1 ha or 4.35 percent, very prone to 1,229.3 ha or 21.74 percent, and areas prone to landslides covering an area of 1,901.4 ha. or 32.61 percent. The somewhat prone areas were 1,600.6 ha or 23.91 percent, while non-prone areas were 737.3 ha or 17.39 percent. For more details, see the following Table 1.

To determine the level of landslide vulnerability in the Samin Hulu Sub-watershed. It was determined through a map overlay process based on scoring which resulted in 5 (five) landslide susceptibility classes, namely extraordinarily prone, very prone, prone, somewhat prone, and not prone.

Table 1:
Relationship between Landslide Hazard Level and Landslide Incidence in Sub-watershed Samin

Landslide Hazard Class	Landslide incident		Area (ha)
	Lots of Events	Percentage (%)	
Extraordinary Prone	21	4.35	40.1
Very Prone	10	21.74	1,229.3
Prone	15	32.61	1,901.4
A little prone	11	23.91	1,600.6
Not prone	8	17.39	737.3
Amount	46	100	5,508.3

Source: Compiled by the authors using public data available as of 2020

3.1. The Altitude Factors

In higher areas, landslide susceptibility is more significant than in lower regions (Rengers et al., 2020). At an altitude of > 1500 m above sea level, there is still a lot of forest vegetation as land cover compared to the height below (500 m - 1500 m asl). The foliage is small because there has been many land conversions from forest to especially roads, seasonal agricultural land, and housing. Driven by the nature of andosol soil prone to landslides, the slope is still high (Li et al., 2019). Whereas at an altitude of < 500 m asl, the incidence of landslides is the least. This is because the area is relatively stable (it is in an old residential area and has a low slope) (Table 2).

Table 2:
Effect of Site Height on Landslide Vulnerability

Factor	Category	Instrument	Σ Incident	Scoring			Prone Level
				Rating (R)	Weight (W)	Score (R X W)	
Height	<500 m asl (low)	Using GPS (Global Positioning System)	1	1	3	3	Not prone
	500 - 1000 m asl (moderate)		28	2	3	6	Very prone
	1000 - 1500 m asl (high)		12	2	3	6	Prone
	> 1500 m asl (very high)		5	3	3	9	A little prone

Source: Compiled by the authors using public data available as of 2020

3.2. Rainfall Factor

The rainfall in the Samin sub-watershed, dominant with landslides, is between 2000 - 3000 mm / year. In the Samin sub-watershed, the largest landslides were experienced in areas with 2000 - 3000 mm. This is because the area has often experienced soil excavation/land conversion into production agriculture, housing, roads, and other similar types, as well as rainfall of that size, is strong enough to cause landslides and is supported by the unstable nature of the soil (primary material comes from volcanoes) (Nguyen et al., 2020; Bezak et al., 2019) (Table 3).

Table 3:
Effect of Rainfall on Landslide Hazard

Factor	Category mm/years	Instrument	Σ Incident	Scoring			Prone Level
				Rating (R)	Weight (W)	Score (R X W)	
Rainfall	0 – 2000	Documentation	3	2	3	6	Not Prone
	2000 – 3000		26	3	3	9	Very prone
	> 3000		17	4	3	12	Prone

Source: Compiled by the authors using public data available as of 2020

3.3. Slope Factor

In the Samin sub-watershed, which dominantly experiences landslides on a slightly steep sloping area. This is due to many open spaces due to land conversion such as forests into roads, settlements, food crop farming. When the rainy season arrives, the area is prone to landslides. However, in a slope of > 40% (Very Steep), landslides do not occur, so they are not prone (Ahmed & Akram, 2018) (Table 4).

3.4. Land Use Factor

In the Samin sub-watershed, the largest landslides are experienced in dry areas. This is because dry land use is less well maintained than the management of mixed gardens, paddy fields, and settlements. In mixed gardens, the incidence of landslides is more than in settlements and paddy fields, caused by frequent agricultural activities even though the soil's nature is prone to landslides (Gädeke et al., 2020) (Table 5).

Table 4:
Effect of Slope on Landslide Hazard

Factor	Category	Instrument	Σ Incident	Scoring			Prone Level
				Rating (R)	Weight (W)	Score (R X W)	
Slope	0-8% (flat)	Using GPS (Global Positioning System)	3	1	3	3	Not prone
	(8-15% (ramps)		15	2	3	6	Prone
	(16-25% (Slightly Steep)		18	3	3	9	Very prone
	25-40% (Steep)		10	4	3	12	A little prone
	> 40% (very steep)		0	5	3	0	Not prone

Source: Compiled by the authors using public data available as of 2020

Table 5:
Effect of Land Use on Landslide Hazard

Factor	Category	Instrument	Σ Incident	Scoring			Prone Level
				Rating (R)	Weight (W)	Score (R X W)	
Land use	Forest	Field observation Description of soil surface morphology	1	3	2	6	Not prone
	Mixed Garden		14	2	2	4	Prone
	Settlement		6	5	2	10	A little prone
	Rice fields		5	1	2	2	A little prone
	Moor		20	4	2	8	Very prone

Source: Compiled by the authors using public data available as of 2020

3.5. Lithological Factors

In the Samin sub-watershed, the largest landslides were experienced in areas with andesite lithology (source rock). Meanwhile, other locations are of the Napal source rock type. This is because the andesite source rock material came from the eruption of the Lawu Volcano. The rock's nature is light and brittle, so it is prone to landslides (Regmi & Walter, 2020) (Table 6).

Table 6:
Effect of Land lithology on Landslide Hazard

Factor	Category	Instrument	Σ Incident	Scoring			Prone Level
				Rating (R)	Weight (W)	Score (R X W)	
Lithology	Napal	Profile Description	2	3	3	27	Not prone
	Andesite		44	5	3	15	Very prone

Source: Compiled by the authors using public data available as of 2020

3.6. Soil Type Factor

In the Sub-Watershed Samin Upstream, landslides are dominant in areas with the type of soil such as Latosol, Reddish Brown, and Andosol (Table 7).

This is because both of them come from the main andesite material of Mount Lawu, which is light and brittle, often used for agricultural activities without paying attention to environmental conservation aspects (food plants on sloping to steep land, land conversion from the forest on sloping land until it is very very sloping to become highways and settlements (Li et al., 2019).

Table 7:
Effect of Soil Types on Landslide Vulnerability

Factor	Category	Instrument	Σ Incident	Scoring			Prone Level
				Rating (R)	Weight (W)	Score (R X W)	
Type of soil	Rendzina	Soil type map	3	3	2	6	Not prone
	Alluvial		8	4	2	8	Little prone
	Regosol		1	4	2	8	Not prone
	Reddish-brown Latosol		18	4	2	8	Very prone
	Andosol		13	5	2	10	Prone
	Litosol		2	4	2	8	Prone
	Red Yellow Mediterranean		1	2	2	4	Not prone

Source: Compiled by the authors using public data available as of 2020

3.7. Soil Solum Factor

In the Sub-Watershed Samin Upstream, areas with shallow soil solum have poor drainage, very fine or coarse soil texture, steep clamps, high levels of erosion, and poorly managed of many obstacles. Solum is divided into two, namely the upper layer and the lower layer. The topsoil layer has two horizons (O horizon and A horizon). The lower soil layer has two horizons, namely (E & B horizon) or solum consisting of the OAEB horizon. However, a complete soil profile has many horizons with unique or distinctive properties and characteristics. Generally, the soil layer from top to bottom consists of horizons O, A, E, B, C, and R. Horizon O is divided into two, namely horizon O1, formed from plant debris that is still a visible form of falling flowers and leaves or branches. Tree. Meanwhile, the O2 horizon is located below O1, formed from the remains of plant parts that have undergone further weathering. If the organic horizon is > 20 cm thick, it includes or is called peat soil. With dense soil, solum means it is relatively resistant to landslides (Samia et al., 2017). Meanwhile, thin or shallow soil solum is prone to landslides (Table 8).

Table 8:
Effect of Soil Types on Landslide Vulnerability

Factor	Category	Instrument	Σ Incident	Scoring			Prone Level
				Rating (R)	Weight (W)	Score (R X W)	
Solum Soil	0 - 30 cm (low)	Descriptions of profiles and measuring instruments (meters) and MSC	31	1	2	2	Very prone
	31 - 81 cm (deep)		13	3	2	6	prone

Source: Compiled by the authors using public data available as of 2020

3.8. Soil Texture Factors

In the Sub-watershed Samin Upstream, the predominant landslides are textured from Clay loam until Loam. Loam means the coarser the texture of the landslide event, the lower/less. This soft/light texture is unstable due to solid particle bonds (high stability). However, it cracks easily, significantly when the rainy season is easily eroded and washed away, causing landslides to occur (Van Liew & Mittelstet, 2018) (Table 9).

Table 9:
Effect of Soil Texture on Landslide Vulnerability

Factor	Category	Instrument	Σ Incident	Scoring			Prone Level
				Rating (R)	Weight (W)	Score (R X W)	
Soil Texture	Loam	Profile description and lab analysis (pipette method)	10	1	2	2	Prone
	Clay loam		19	2	2	4	Very prone
	Silty loam		9	2	2	4	Little prone
	Sandy loam		7	3	2	6	Little prone
	Clay		1	4	2	8	Not prone

Source: Compiled by the authors using public data available as of 2020

3.9. Permeability Factor

In the Sub-watershed Samin Upstream, the dominant landslide is in the medium to swift permeability class. This is due to the soil's nature, which is easy to pass and absorbs water, especially during the rainy season, so that the land is prone to landslides (Alonso, 2021) (Table 10).

Table 10:
Effect of Permeability on Landslide Vulnerability

Factor	Category	Instrument	Σ Incident	Scoring			Prone Level
				Rating (R)	Weight (W)	Score (R X W)	
Permeability	Very slow	Permeameter	2	1	2	2	Not prone
	Slow		1	2	2	4	Little prone
	Moderate		8	3	2	6	Prone
	Rather fast		4	4	2	8	Little prone
	Fast		7	5	2	10	Very prone
	Very fast		24	6	2	12	

Source: Compiled by the authors using public data available as of 2020

3.10. Determination of landslide hazard class scores by the Ministry of the Environment in 2006

Determination of landslide hazard class scores by the Ministry of the Environment in 2006, land in the Samin Sub-watershed Samin Upstream are the level of landslide vulnerability here occurs in all research areas except in Sukosari Village, Jumantono Subdistrict, where landslides are not found because this area of forest areas is regularly good if seen as mitigation by the community is running well, i.e., non-structurally it is good, marked by community communication with the government and between community members, hitting voice kentongan as a warning sign of landslide (4 times) and sounding the siren (Table 11).

To lessen the socio-economic damage to the area, a number of programmes and cooperation initiatives between authorities and local communities have been introduced. Practically it is done with Reforestation and Agroforestry Mechanism which means planting teak forests combined with multiple cropping such as coffee, guava, cashew, Thai papaya, kencur, turmeric, ginger, durian, rambutan, petai, long beans, laos, ganyong, and arrowroot (Li et al., 2019).

Table 11:
Landslide Hazard Class Based on The Last Score

No.	Symbol	Landslide Hazard Level	Final Score Weighting
1	Landslide Hazard Level I	Not prone	< 8
2	Landslide Hazard Level II	Little prone	8 - 19
3	Landslide Hazard Level III	prone	19 - 30
4	Landslide Hazard Level IV	Very prone	30 - 41
5	Landslide Hazard Level V	Extraordinary Prone	41 – 52

Source: Compiled by the authors based on regulations introduced by the Ministry of the Environment of Indonesia (2006)

4. Conclusion

The scoring technique can be used as a guide (tool) to analyze the relationship between landslide events and their vulnerability level in the sub-watershed Samin Upstream. From the survey and mapping results, it is found that the distribution of landslide-prone areas in the Sub-watershed Samin Upstream can be divided into five landslide-prone levels, namely: severe landslides, very prone, prone, somewhat prone, and not prone.

The Sub-watershed Samin Upstream area can be categorized as an area classified as prone to landslides due to:
1) High altitude, 500 - 1500 m above sea level (moderate to high);
2) Rainfall, from 2000 to > 3000 mm / year;
3) The land's slope gently ramps up;
4) land use (land use) in the form of the moor;
5) Lithology, andesite;
6) Soil Type, Andosols and Brown Latosols;
7) Soil solum, 0 - 81 cm;
8) Soil texture Loam to Clay loam;
9) Medium to very fast permeability.

Land in the Sub-watershed Samin Upstream area is potentially still possible to be used as limited agricultural land. However, it must still pay attention to environmental aspects.

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