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SLOPE OBSERVATION OF THE PADANG SOLOK ROAD AREA BASED ON RADAR DATA

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ABSTRACT
The Padang Solok route topographically has a geological structure that is prone to steep slopes, so it has a high level of disaster risk, one of which is shifting soil and causing landslides. Slope is one of the factors that cause landslides, the purpose of this study is to determine the slope that is prone to landslides. However, slope information needs to be known the slope, and we can know the percentage and degree by mapping using satellite radar SAR (Syntetic Aperture Radar) technology, which is an effective choice for detecting the earth's surface in the Padang-Solok area with SRTM data taken in the area. Processed by observing the slope of the area and then analyzing the landslide area. SAR radar satellite technology allows monitoring of landslide-prone areas with high accuracy, and wide area coverage, operating day and night. This slope is a comparison of height in the form of the vertical distance of a land with its horizontal distance. The amount of slope can be expressed in several units, including percent and degree. Spatial information on slope describes the condition of the land surface, such as a flat, gentle, or steep slope. The Padang-Solok route includes steep slope areas with the highest slope of 7,9° to 40,8° and in percentage 13,80% to 90,10%, classified as steep and steep slope. Areas with steep slopes have a greater potential for landslides than those with moderate slopes, in addition to increasing the amount of surface flow. So the steeper the slope, the greater the velocity of surface flow, and thus the greater the water transport energy.

INDEX TERMS ***Slope, Landslide, Padang-Solok, Satellite Radar SAR***

I. INTRODUCTION

The Padang-Solok route, which is often called Sitinjau Lauik, includes Lubuk Kilangan sub-district in Padang City, which is a busy route that connects between cities, most of which are hilly areas with steep slopes. In addition, the tropical climate resulting in high rainfall in some areas is also one of the factors causing landslides [1]. This pathway is an area that has a high potential for natural disasters, especially landslides, because this area has steep slopes. Supported by the tectonic conditions of this path that form morphology, faults, volcanic rocks, climate thus increasing its potential. Slope and slope length are topographic elements that have the most influence on surface flow, slope is expressed in degrees or percent. A 100% slope steepness equals a 45° steepness [2]. Mapping of landslide prone areas can be done by using Synthetic Aperture Radar (SAR) Satellite technology. Some of the advantages of SAR Radar Satellite technology that are taken into consideration in monitoring landslide prone areas are high level of accuracy, wide area coverage, ability to operate day and night without being affected by weather conditions, and lower cost. Radar data is also easily accessible and available in large quantities with short temporal and normal baselines that allow periodic monitoring with good spatial resolution [3]. SAR is one of the special methods that can be applied in remote sensing which consists of a transmitter, antenna, receiver sensor, and electronic system used to record data, and has an active sensor that is able to emit its own energy without relying on sunlight, this method is widely used for regional conditions

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and mapping [4][5]. The utilization of remote sensing technology can be used to determine the slope of the area on the Padang-Solok route so that a mapping of landslide-prone areas based on the slope of the area on this route can be produced, thus facilitating the analysis [6]. This technology is an advanced solution that can help in the prevention and mitigation of landslides with high accuracy and easier data access, and facilitate the analysis of the area without direct contact with the object or phenomenon to be studied in reference to disaster management in potential lands. In this mapping, two radar images are required to have the same nominal geometry to develop SAR interferometry by using phase as a wave fraction, which is then converted into distance [7][8][9].

Data from the SRTM satellite that is processed using ArcGis and Global Mapper software is processed and can show steep areas. This research aims to utilize remote sensing technology on the importance of knowing the slope in the highlands to do mapping.

II. STUDY AREA AND SATELLITE DATASET

The study area is located at latitude 0º58'4"LS-100º 21'11"BT, Sitinjau Lauik hill forest area is a protected forest area located ± 30 KM from the center of Padang City. Sitinjau Lauik Hill has an altitude of about 300-1100 meters above sea level with an area of ± 150 ha [10]. Solok Average rainfall is 384.80 mm/month. Sitinjau Lauik is located on the Cross Sumatra Road with the route Padang City-Arosuka-Solok.

The observation area in this study is located between trees and even the river on the roadside, although it is small but quite heavy during the rainy season, so there are dozens of points that have the potential for landslides, especially during high rainfall.

Figure 1. Observation Area

The Padang Solok route which has the topography of the Sitinjau Lauik road section is in the hills with its physical form consisting of climbs, descents, and sharp turns. The location of this research is along the Padang-Solok Road, Padang-Solok City Route, Indarung, Lubuk Kilangan District, Padang City, West Sumatra Province with a road length of 6.11 KM. This path is the only national link in the Sumatra region, landslide material that covers the road at four points in the sitinjau lauik area, two landslide points are right on the border path and panorama two, and often causes this path to be temporarily closed, causing congestion.

A. TOPOGRAPHY AND GEOMORPHOLOGY

Basically, Indonesia is prone to landslides, especially along the southern coast of Java. This is due to the direct influence of the location of the two islands in the subduction zone of two continental plates that extend from the Andaman sea, the west coast of Sumatra to the south of Java island to the south of the Nusa Tenggara islands.

Subduction formed due to the collision of the Eurasian plate and the Indo-Australian plate where the Indo-Australian plate from the south and west moves more actively. The subduction of the Indo-Australian plate that occurs causes magma under the belly of the island of Sumatra to be trapped and presses the surface layer above it to form mountains and active volcanoes along the side of the direction of the island of Sumatra. These mountains are known as the Bukit Barisan mountain range with the highest peak being Mount Kerinci [11].

Areas with steep slopes have a greater potential for landslides compared to moderate ones, in addition to increasing the amount of surface flow, the steeper the slope also increases

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the speed of surface flow thereby increasing the water transport energy [12].

Figure 2 shows the topographic structure of the study area and its contours. The study area in the black box in Figure 2 covers the area positive terrain slope: blue color and negative terrain slope yellow-green color. The positive terrain slope in the study area represents the shortening of the line of sight (LOS) of a satellite with a high-resolution cell in the direction of coverage. Contrary to the positive slope, the western side has good coherence but with minimum resolution. This is because the terrain of the region is parallel to the satellite LOS [13][14]. The cell coherence and resolution of terrain area images are greatly affected by the topography of the area of interest.

B. GEOLOGICAL STRUCTURE

An overview of the geology of an area, which includes the existing relief structure and the structural forms of each rock. There are types of Quaternary volcanic rocks consisting of volcanic breccia, tuff, lava, agglomerate, and lahar. Volcano breccia, gray, black, and brown in color, angular-bundled and andesite in composition caused by the subduction of the Indian-Australian Ocean plate under the Sumatra plate. Geological conditions are also a factor in the occurrence of land shifts such as how many areas where the soil contains sand, sand mixed with clay and loam, clay soil types with a thickness of 2.5 meters and a slope angle of more than 22 °, have the potential for landslides [15][16].

The hillside rocks are dominated by volcanic weathering in the form of passive clay loam with pebble-sized rock fragments to large boulders. It can be seen in Figure 3 that the Padang Solok line is at the red level with high land movement. Padang City is one of the cities located on the west coast of Sumatra. The topography of Padang city has an altitude of 0 m above sea level to 1853 m above sea level. The varied topography and subduction zone of tectonic plates make Padang City prone to landslides and land movement.

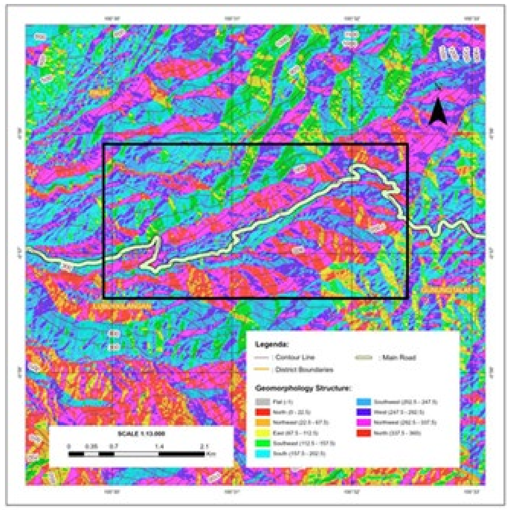

Figure 2. Topographic structure and geomorphology of Padang-Solok area, West Sumatra, Indonesia represented by DEM SRTM data with 30 M resolution. The black box marks the study area. The inset image on the bottom right shows the surface aspect of the Padang-Solok area.

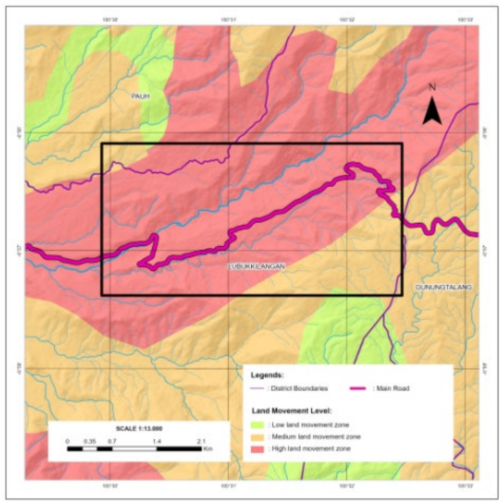

Figure 3. Geologic structure of land movement level of Padang-Solok Line, Padang City, West Sumatra, Indonesia.

It is categorized as a landslide-prone area. The Bukit Barisan mountain range tends to narrow to the west, forming a steep coastline along the west coast of Sumatra, from Aceh to Bandar Lampung. On the east coast, there are more gentle slopes. The mountainous areas and steep coastline in the west are prone to landslides and land movement. This complex geological environment in the Padang-Solok area is the main cause of severe ground shifts and the higher the fault, the more landslide prone the area.

C. RAINFALL AND TEMPERATURE

The intensity of rainfall can cause surface flow which can cause erosion at the foot of the slope, leading to potential

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landslides. The cause of landslides is triggered by sudden heavy rains, so that the soil cannot withstand the impact of rainwater and slips downward. [17]. Rainfall plays a major role in landslides, rainfall has the potential to cause landslides if the intensity is high enough and for a long period of time. This diagram is made based on rainfall data using rainfall data from Maritime and Bayur Meteorological Stations which can be seen in Figure 4. The rain that falls in the Padang-Solok route area throughout 2022 with high intensity. Figure 4 presents the intensity of rainfall on the Padang-Solok route, West Sumatra. Based on this diagram the average rainfall intensity is high.

Figure 4. Rainfall intensity distribution of Padang Solok lane area in 2022 after landslide.

The peak is at the end of the year in September-November when high rainfall occurs, while there is low rainfall caused by local rainfall that occurs in the area that causes landslides in the same place. The rainfall diagram above shows the maximum monthly rainfall based on the date of the landslide in 2022 in July 38.5 mm, August 0.70 mm, September 106 mm, October 93.5 mm and November 186.4 mm.

III. METHODS

The research method used is a survey which includes observation of the research area. The research used several supporting tools including laptops, computers, Global Mapper software with DEM (Digital Elevation Model) data processing materials.

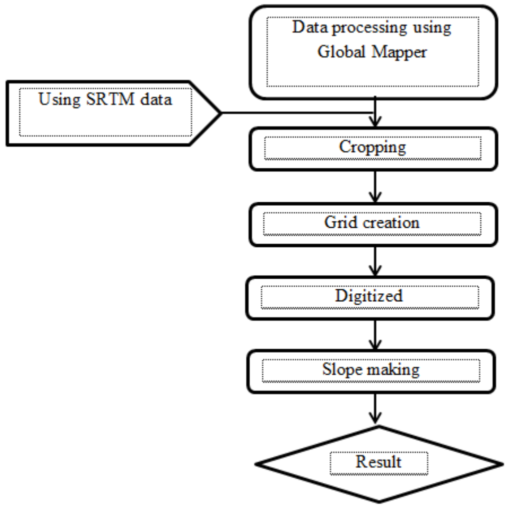

Figure 5. Research Diagram.

The analysis used is to know the higher the total value of an area, the steeper the slope in that area. The data used is SRTM (Shuttle Radar Topography Mission) data to obtain digital elevation using Global Mapper data processing specification 20.0 on SRTM DEM data in two-dimensional and three-dimensional forms to obtain the slope of the area.

2.1 Data Analysis

The analysis used in this research is by observing the slope of the area on the Padang-Solok route, West Sumatra.

2.1.1 Slope

The slope of the area refers to the classification of Van Zuidam (1985).

Classification	Slope		Height Difference (m)
	Percent (%)	Degrees (°)	
Flat	0-2%	0-2°	<5 m
Slightly Sloping	2-7%	2-4°	5-25 m
Ramps	7-15%	4-8°	25-75 m
Somewhat Steep	15-30%	8-16°	75-200 m
Steep	30-70%	16-35°	200-500 m
Rugged	70-140%	35-55°	500-200 m
Very steep	>140%	>55°	>1000 m

Table 1. Slope Classification.

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2.1.2 Synthetic Aperture Radar (SAR)

The data used is Digital Elevation Model (DEM) which describes the topographic shape visualized into a 3D view. SAR interferometry is one of the algorithms for DEM data with a resolution of 30 × 30 for area mapping.

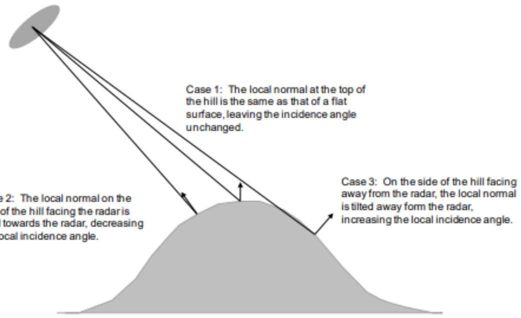

Figure 6. The local angle of incidence differs from that expected for a flat surface with no relief, causing topographical variations in the image.

The hill illuminated by the radar system, as shown in figure 5 for the local normal to the surface for several positions on the hill. With respect to a flat surface, it is apparent that for points on the hill facing the radar, the local normal will be more inclined towards the radar, therefore, the local angle of incidence will be smaller than for a point on the same ground range, but on a flat surface [18]. SAR is one of the special methods that can be applied in remote sensing which consists of a transmitter, antenna, receiving sensor, and electronic system used to record data, and has an active sensor that is able to emit its own energy without relying on sunlight.

$$\phi_1 = \frac{4\pi R}{\lambda} \quad (1)$$

$$\phi_1 = \frac{4\pi(R+\Delta R)}{\lambda} \quad (2)$$

$$\Delta\phi = \phi_2 - \phi_1 = \frac{4\pi\Delta R}{\lambda} \quad (3)$$

$$\Delta\varphi_{m,s}(T) = \Delta\varphi_{m,s}^{flat}(T) + \Delta\varphi_{m,s}^{topo}(T) + \Delta\varphi_{m,s}^{disp}(T) + \Delta\varphi_{m,s}^{atm}(T) + \Delta\varphi_{m,s}^{atm}(T) + \Delta_{m,s}^{noise}(T) \quad (4)$$

SAR method with an external Digital Elevation Model (DEM) and image pairs with different image acquisition times. In this processing, some components are estimated, then filtered and removed and only
Ground deformation is calculated based on the phase of the Interferogram between two different time acquisitions. This technique can be used when the baseline for two pairs of data is not possible, or no DEM is available in the study area. By using the method of topographic pair and deformation pair are independent [19].
The technology of this radar is different from conventional radar which only detects and presents location or distance information and presents information in the form of an image. Estimated, then filtered and removed then only the displacement component $\Delta\varphi_{m,s}^{disp}$ that remains. SAR has wide applications in remote sensing and mapping of the earth's surface. Obtained results in the form of slope areas that occur in the study area, including landslide-prone areas.

IV. RESULT AND DISCUSSION

This research uses SRTM data as radar data used in data processing to produce a map of the slope area along the Padang-Solok route. The slope of this area is one of the triggers of landslides, it is a comparison between the height difference (vertical distance) of a land with its horizontal distance. The amount of slope can be expressed with several units, including percent (%) and degree, and can be seen more clearly in Figure 5. Spatial information of slope describes the condition of the land surface, such as flat, sloping, as shown in the figure, this research area includes steep slope. In terms of slope and elevation, a spatial method accompanied by contour correction was used. Figure 1 with a distance of 10 km is colored red with an elevation of 1,750 m, this triggers landslides. Areas with steep slopes have a greater potential for landslides compared to moderate ones, in addition to increasing the amount of surface flow, so the steeper the slope also increases the speed of surface flow, thus the water transport energy is greater. The image used in the data downloaded by DEMNAS in 2022 which can be seen in Figure 7 at an altitude of 1,060 m, 1,040 m, 1,250 m, 1,000 m, 985 m, 960m, 940 m. Path profile to display the vertical profile along the specified path using the elevation dataset loaded along the Padang-Solok area path can be seen in Figure 8.

Based on the above image, the path profile of the slope area in Figure 8 is useful for the path profile at an altitude of 1,060 m by providing the optimal azimuth angle for antenna alignment to match the elevation scale.

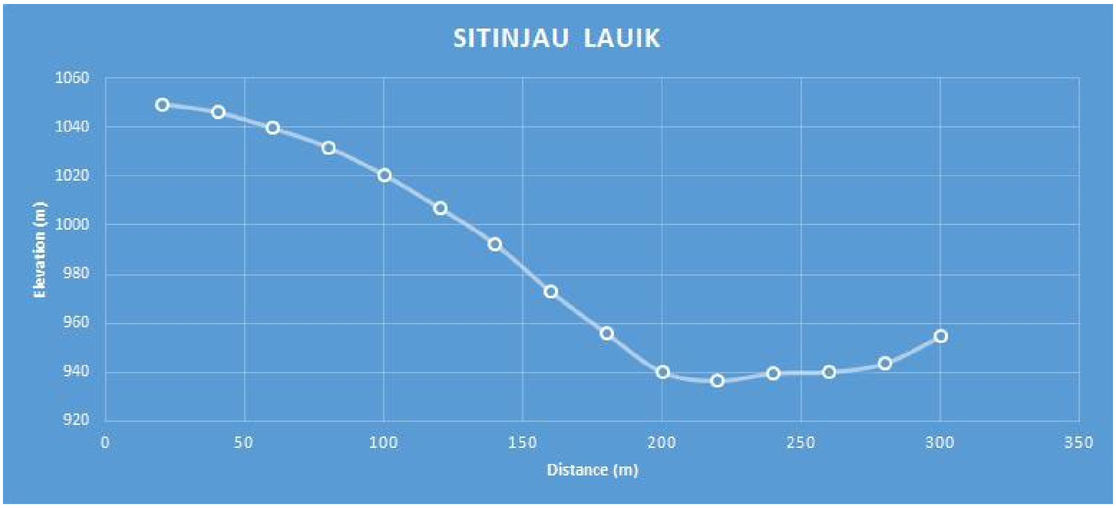

Figure 7. Sitinjau Lauik Track.

The slope classification for ease in explaining the topographic differences of the Padang-Solok area includes steep and steep slope classes. Steep slopes of 13-50% with a slope of 7º-26º. It can be seen in Figure 7 that the highest area is at an altitude of 880 m and the lowest slope area is 960 m if the area is enlarged to 3 km.The slope of the area with a distance of 3 km as seen in Figure 7 with heights from 1,060 m to 920 m and the lowest point of 940 m. Furthermore, the profile path is extracted to Microsoft excel can be seen in table 2.

No	X	Y	Elevation	Distance (Total)	Slope (Degrees)	Slope (Percent)
1.	100,5397	-0,93894	1049,492	20,228	7,9	13,80%
2.	100,5396	-0,9391	1046,137	40,158	15,8	28,40%
3.	100,5396	-0,03926	1039,678	60,088	19,5	35,30%
4.	100,5395	-0,93942	1031,816	80,018	25,8	48.30%
5.	100,5394	-0,93958	1020,576	100,25	32,1	62,70%
6.	100,5393	-0,93974	1007,046	120,18	34	67,40%
7.	100,5392	-0,9399	992,428	140,11	40,3	84,90%
8.	100,5391	-0,94006	973,045	160,04	42	90,10%
9.	100,5391	-0,94023	955,9	180,26	40,8	86,30%
10.	100,539	-0,94039	940,135	200,19	28,9	55,30%
11.	100,5389	-0,94055	936,557	220,12	10,1	17,90%
12.	100,5388	-0.94071	939,618	240,05	4,4	7,70%
13.	100,5387	-0,94087	940,233	260,28	2,9	5,10%
14.	100,5387	-0,94103	943,647	280,21	20,5	37,40%
15.	100,5386	-0,94119	954,561	300,14	26,7	50,20%

Table 2. Slope of Padang-Solok Road Area.

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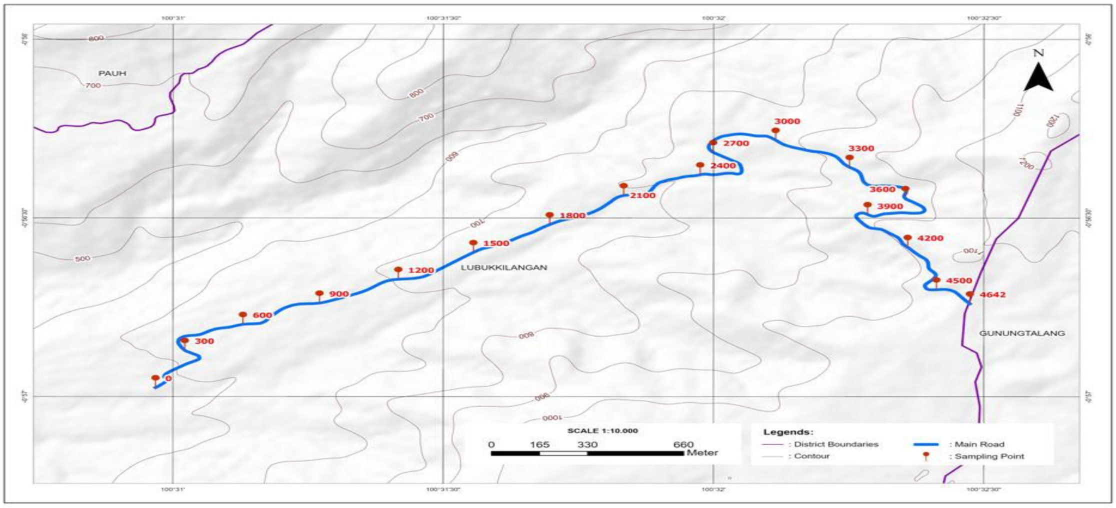

Figure 8. Slope Area.

Based on the Padang-Solok slope area map figure 8 Line 1 to 17 each distance to 4,642 m with x,y angle at x angle 100.539 to 100.5397 with y angle -0.9399 to -0.93894 obtained slope 7,9° 15,8° 19,5° 25,8° 32,1° 34° 40,3 42° 40,8° 28,9° 10,1° 4,4° 2,9° 20,5° 26,7° with a percent of 13,80% 28,40% 35,30% 48.30% 62,70% 67,40% 84,90% 90,10% 86,30% 55,30% 17,90% 7,70% 5,10% 37,40% 50,20% and 9.85%.The higher the slope the lower the percentage of soil pore space causing damage to the soil so that on large slopes of the risk of landslides is higher.The topography of the Padang-Solok area is hilly with very steep slopes >45º. On slopes that have a high level of slope will result in areas of great potential other things also support the causal factors including rainfall, geological structure and soil types in the area. Based on the data processing, it can be seen that the slope of table 2 percentage of Padang-Solok route. as shown in table 2 in 6 km area with the highest area which is one of the causes of landslide. The slope data extracted from Global Mapper and Arcgis can be found in the table. This area to the east shows the ground movement factor due to high slope and becomes a frequent landslide location when triggered by heavy rain. Large land movement values have steep and steep slopes. The classification of slope areas in the soil threat criteria includes flat, gentle, to slightly steep hilly slopes with very steep and steep slopes. The slope area of Sitinjau Lauik is very steep part of its 50%. The 0-15% area will be stable against the possibility of landslides, while the 50% will be prone to landslides. In addition to the factors that support this research area, the topographic structure and geology are the internal causes that come from the body of the slope itself because of the participation of water in the body of the slope, this condition is due to the climate in the form of rainfall and Other causes include soil type.

Classification	Slope		Height Difference (m)
	Percent (%)	Degrees (°)	
Flat	1,1-3,5%	0,7-2°	<5 m
Slightly Sloping	3,7-7,1%	2,1-4,1°	5-25 m
Ramps	7,1-14,4%	4,1-8, 2°	25-75 m
Somewhat Steep	14,4-28,4%	8,2-16, 1°	75-200 m
Rugged	28,40-70,4%	16,1-35, 1°	200-500 m
Steep	70,4-101,3%	35,1-45,4°	500-890 m

Table 3. Classification of Slope Classes.

Based on the classification data that has been obtained from the info table from the DEM extraction to Microsoft excel to show the values, the Padang-Solok area includes a varied slope area so that it is divided into flat classes 5,10%, rather gentle and sloping ranges 37,40%, rather steep 17,90%, and rugged 19,5% to 34%, and the most dominating area is the central part of the area which includes steep 13% to 90%.

V. CONCLUSION

Based on the data processing, it can be concluded that the slope area on the Padang-Solok route is steep and steep from 13,80% to 90,10%, then the results of the post landslide rain analysis and the geological and topographic maps of the area show that this area has the potential for landslides. SAR radar satellite technology allows monitoring of landslide-prone areas with high accuracy, wide area coverage, operating day and night. With this information, it is expected that the government and related agencies can take more effective preventive measures in dealing with potential landslides in the Padang-Solok route area and minimize the impact that may occur. SAR radar satellite technology can be a valuable tool in this endeavor.

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