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An Analysis of the Collapse Potential of Slope using the Rom Scale: A Case Study of Sultan Azlan Shah Campus, Sultan Idris Education University, Malaysia

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Abstract
Slope failure is a geological process that is closely related to the agents of erosion, such as water, wind, temperature and vegetation cover in the vicinity of the slope. Therefore, this study was conducted to analyse the current status of the slope stability within the new Sultan Idris Education University campus using the ROM scale. A total of 20 slopes or soil sampling points were included in this study. The results obtained from the ROM scale shows that about 16 of the 20 slopes with critical status have experienced landslides. This is due to the land fragility, lack of binder (clay) between the rocks, sand and silt. In fact, the proportion of sand in the soil exceeded 90%. Thus, additional protective measures should be taken to increase the level of soil moisture and improve the bond between soil compositions and, ultimately, the slope stability in Sultan Azlan Shah Campus can be improved. This is due the soil moisture of the critical slopes is only at 25% to 30%. And with the implementation of slope protection measures by engineering and bioengineering techniques, landslide occurrence can be avoided and reduced in the future.
Keywords: UPSI, Slope Failures, ROM Scale, Slope Control

Introduction
A slope is a structure of soil with certain angles. In general, Malaysia has sloped and hilly natural terrain and receives a high amount of rainfall throughout the year. Steep slopes as well as abundant and continuous rainfall cause an increase in surface runoff and groundwater flow, making the slopes more susceptible to landslides or slope failures. Studies conducted by Lal

(1976), Azman and Fauziah (2003), Mohamad Suhaily Yusri *et al*. (2013) and Mohmadisa (2014) clearly show that the amount of rainfall is high in Malaysia and may lead to the occurrence of landslides. Zulfahmi *et al*. (2007), Huat *et al.* (2008), Roslan *et al.* (2009), Lawrence and Aaron (2013) also stress that landslide occurrence in Malaysia has become the norm, especially during the wet season of the Northeast Monsoon.

Slope failure or landslide is a geological event that involves large movements of land, falling of rock, or a combination of both. Most landslides start on downhill slopes and are often caused by surface runoff (Syers & Rimmer, 1994; Bujang *et al*., 2008; Bujang & Sina, 2010; Mohamad Suhaily Yusri *et al*., 2013; Kokutse *et al.,* 2016). A landslide is likely to occur gradually unnoticed or rapidly during heavy rainfall and move downslope with earth materials under the pull of gravity (Fitzpatrick, 1994). According to Muhammad Barzani *et al*. (2011), the physical characteristics of the soil will also affect the slope's stability: sandy soil structure will improve soil porosity and increase the infiltration rate during heavy rainfall, thus contributing to slope failure. Other than that, various weak zones that exist in rocks, such as *granis* and *skis*, also cause slope movement in the form of plane, wedge and toppling failures (Tan & Tajul, 2000; Sidle & Ochiai, 2006; Stanley, 2013; Kumar *et al.,* 2016).

Marhana (2006) stresses that slope failure that is often associated with steep slopes is not actually true, as there are many cases where slope failures occurred on gentle slopes. Therefore, slope stability depends on many other physical and mechanical factors other than the degree of the slope gradient. According to Herbel and Gile (1973), the effects of rainfall on soil water content are influenced by several factors; soil characteristics, topography, amount and intensity of rainfall, vegetation cover and the existing soil water content before rainfall.

The implications of slope failure that affect human beings and nature are in many forms. Loss of properties and lives are commonplace after the occurrence of a landslide (Ibrahim & Lim, 2003; Muhammad Barzani *et al*., 2011). Debris from the landslide, which consists of rocks, soil and other materials, will affect the environment in terms of the transported sediment (Mohd Ekhwan *et al*., 2009; Ibrahim, 1987; Mohamad Suhaily Yusri *et al*., 2013; Mohmadisa *et al*., 2012) and change the natural view of the surrounding slope area (Morgan, 2005). Eroded material on the surface of the slope will flow into river basins and consequently increase the cost of managing the river basin.

Based on previous studies, this study was undertaken to reduce the larger implications that may arise on slopes in Sultan Azlan Shah Campus (KSAS). The ROM scale approach was used in the study in order to determine the landslide status of the slopes in KSAS, although there are many other methods that can be used to determine slope stability (Johari *et al*., 2013). The results obtained from this study can be used as a benchmark for repairing and improving the slopes in KSAS.

Johari *et al*. (2013) explain that there are five possible methods that can be used for the slope stability analysis: random sampling (Monte Carlo simulation), analytic method (analytic), approximation method (estimation), response surface method and stochastic finite element method. However, the Monte Carlo simulation method is more efficient and faster (Low, 2007; Husein Malkawi *et al*., 2000; Ishii & Suzuki, 1987; Tan *et al*., 2013).

Case Study Area

The new campus of Sultan Idris Education University (UPSI), Sultan Azlan Shah Campus (KSAS) covers an area of 324.36 hectares. KSAS is situated in the basin of Keroh river and Salak river, where rainwater will flow into the basin and into Behrang river before streaming into Bernam river. The height of the surrounding KSAS area is between 60 to 120 metres above sea level. The eastern area, which is close to the mountain range, is a higher area (120 m). The centre of the area is at an elevation of 80 m and both the west and north are at elevations of 60 m (Mohamad Suhaily Yusri *et al*., 2013). Meanwhile, the green area (natural plants) of the campus covers merely 61.11 hectares, which is only 19% of the entire KSAS area.

According to Figure 1, the amount of rainfall in KSAS in 2015 was 2396.6 mm. The highest amount of rainfall recorded was in May, which was 498.1 mm, while the lowest amount of rainfall was in February, which was 11.9 mm. In the study area, the amount of rainfall during the Southwest Monsoon (SWM) season was higher compared with the Northeast Monsoon (NEM) season in 2015. This may be due to the fact that KSAS is protected by the Titiwangsa Range. Based on Figure 1, the amount of rainfall during the SWM season, which spans from May to September, was 1210.7 mm. On the other hand, NEM season, which spans from November to March, brought 832.4mm of rainfall.

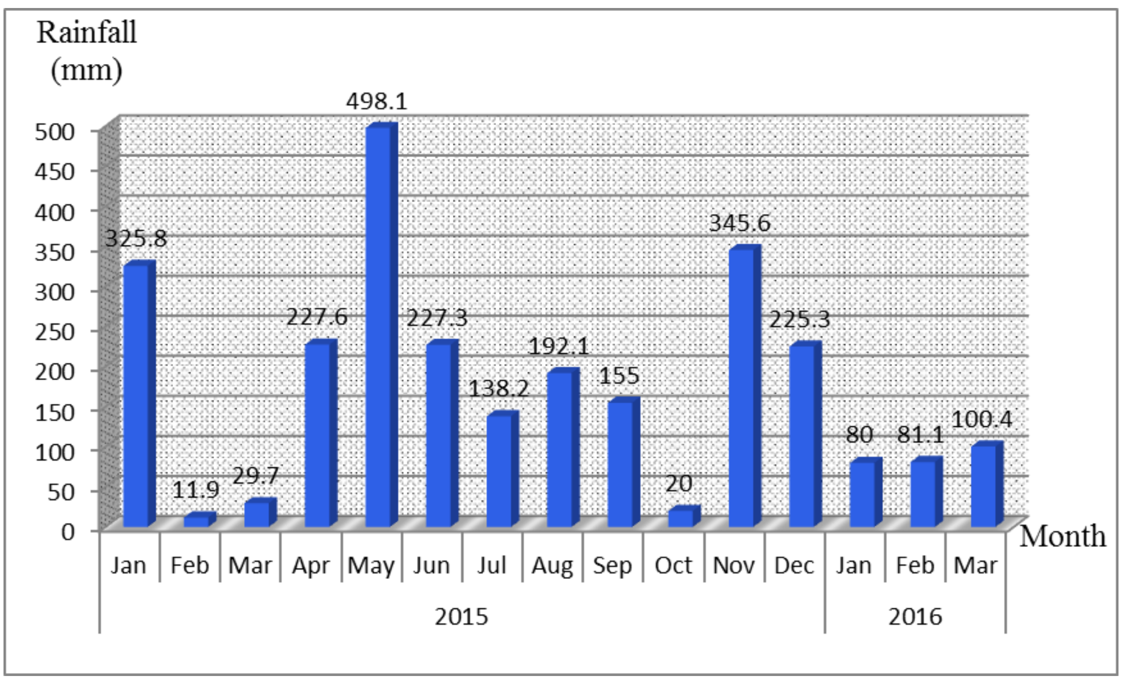

Figure 1: The amount of rainfall recorded at UPSI Meteorological Station

The physical characteristics of the slopes in the study area reflect to the current state of the slopes, which involve various geomorphological aspects. Among the aspects that can be seen in the vicinity of the slopes are those that are open and exposed to erosion agents, such as rain, wind, heat and human intervention, including hillside terracing and various other development activities. The study area of Tanjong Malim, Perak receives a high amount of rainfall (over 2400 mm per year). The rate of rainfall is very high compared to the east coast and south of Peninsular Malaysia (Mohamad Suhaily Yusri *et al*., 2010, 2013). Thus, it is not surprising that erosion by rainwater plays a dominant role in the process of erosion in the study area.

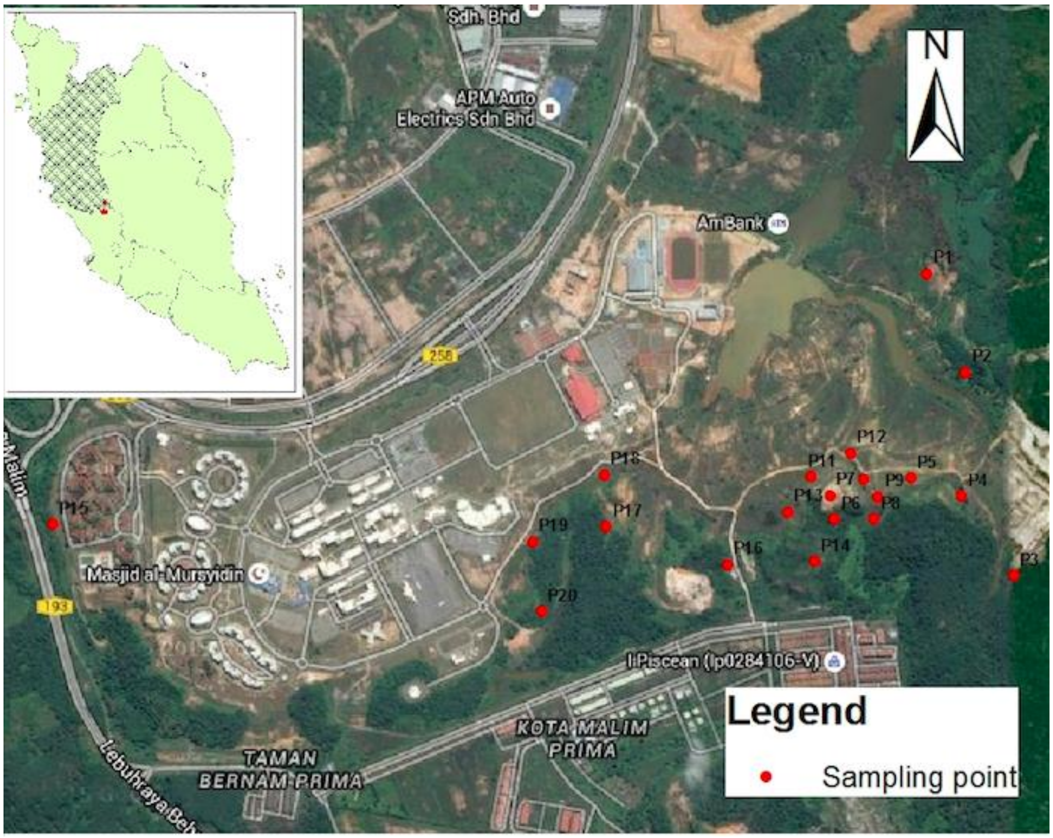

Figure 2: Sampling points in the Sultan Azlan Shah Campus (KSAS), UPSI

Methodology

This study used field methods in which a total of 20 soil samples were taken from every slope to identify the stability status of the slopes in KSAS area (Figure 3). Soil sampling was performed according to the guidelines of the ROM scale measuring method, whereby soil samples should be taken during the hottest hours. The hottest hours refer to the day before rainfall or when there is no rainfall in the area. In addition, soil samples should also be taken from a depth of 30–50cm and dried at room temperature before the sieving process. The process of sieving the soil samples was carried out in the Physical Geography Laboratory, UPSI, using a soil sieving machine (Figure 4) for 20 minutes on each soil sample.

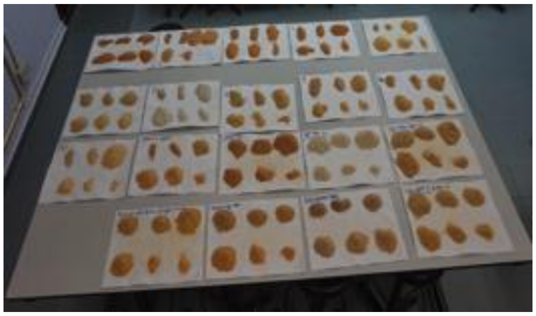


Figure 3: Soil sample Figure 4: Sieving machine

Determination of the particles size of the sand, silt and clay are the foundation to identify the collapse potential of a slope via the ROM scale. The size of the sand particles was determined using a sieve size of 1.0 µm, 500 µm, 250 µm and 125 µm. Meanwhile, a size 63 µm sieve was used to determine the particle size of silt and pan size < 63 µm was used to determine the size of the clay particles (Figure 5). After the results of the laboratory work were obtained, the data were analysed using the ROM formula in order to determine the stage of the slope collapse potential. The ROM formula is as follows:

Figure 5: Layers of sieve size

$$EI_{ROM} = \frac{\%\ \text{sand} + \%\ \text{silt}}{2(\%\ \text{silt})}$$

The ROM formula is a method of measuring the risk of landslide based on the natural properties of the soils found on the slopes. This formula was developed by Roslan and Mazidah in 2004, in which the function of clay content in the soil is given most emphasis (Roslan & Zulkifli (2005). This is because clay is capable of holding greater water content, has a high level of resistance towards the actions of raindrops and surface runoff, and is capable of binding soil particles (Mokhtar *et al.,* 2011). Therefore, clay plays an important role in strengthening and stabilising the slope, compared to sand and silt. There are four scales of slope collapse potential based on ROM scale: low, medium, high and critical.

Table 1: The categories of slope's collapse potential based on ROM Scale

ROM Scale	Level of Collapse Potential
< 1.5	Low
1.5 – 4.0	Moderate
4.0 – 8.0	High
> 8.0	Critical

Source: Roslan & Zulkifli (2005)

Results

Soil composition of the slopes based on the sieve test

Based on the sieving test of soil particle size, the average percentage of sand is the highest (84.37%), with minimum and maximum percentages of 56% and 96%, respectively. A total of eight sand samples displayed a particle size that exceeded 90%: P4, P5, P14, P16, P17, P18, P19 and P20 (Figure 6).

The results of the sieving for the size of silt particles recorded an average value of 11.07%, with minimum and maximum values of 2.5% and 25.5%, respectively. Meanwhile, the average percentage of clay particles was the lowest at 5.47% and each slope recorded a low percentage of clay, except in P1, which recorded the highest percentage of clay at 37%.

The findings of this study indicate that all the slopes in KSAS are at high risk of erosion and landslides. It can be concluded that the high risk of slope failure and soil erosion in KSAS is closely related to the soil texture, which exhibits a lack of clay content in the soil. This is because clay particles play an important role as a binder between the sand, rock and silt particles. When the sand, rock and silt particles are indirectly bound by clay particles the slope will be more intact and stable. Therefore, when the percentage of clay content in the soil is low, the slopes in KSAS are more prone to landslide and erosion. Based on the results, the mean of the particle size percentage of clay is only 1%.

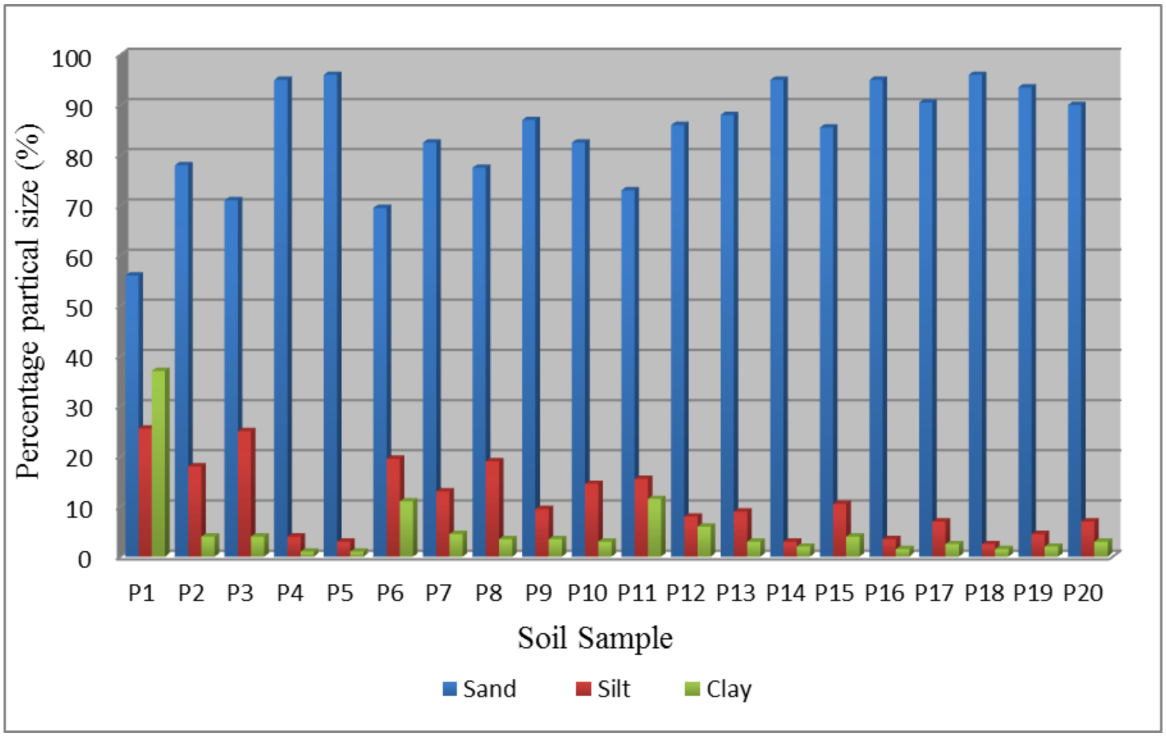

Figure 6: The percentages of soil particle size based on the sieve test

Types of soil based on the soil texture test

The pipette test was used to determine the soil texture of the slopes in KSAS. This test can determine three main compositions of soil: sand, silt and clay. Based on the findings, the soil texture of the slopes in KSAS is sandy type, except for P1, which is sandy loam. The results of this study clearly indicate a high level of porosity and brittleness of the slopes in KSAS (Table 2). The high content of sand in the compositions of the soil will cause instability of the slopes (Muhammad Barzani *et al*., 2011; Stanley, 2013; Kokutse *et al.,* 2016). Based on the study by Richter and Negendank (1977), land with sandy texture of more than 40% can be easily eroded.

Table 2: Types of soil texture in the slopes in KSAS

Sample	Sand (%)	Silt (%)	Clay (%)	Types of soil texture
P1	56	25.5	37	Sandy loam
P2	78	18	4	Sandy
P3	71	25	4	Sandy
P4	95	4	1	Sandy
P5	96	3	1	Sandy
P6	69.5	19.5	11	Sandy
P7	82.5	13	4.5	Sandy
P8	77.5	19	3.5	Sandy
P9	87	9.5	3.5	Sandy
P10	82.5	14.5	3	Sandy
P11	73	15.5	11.5	Sandy
P12	86	6	8	Sandy
P13	88	9	3	Sandy
P14	95	3	2	Sandy
P15	85.5	10.5	4	Sandy
P16	95	3.5	1.5	Sandy
P17	90.5	7	2.5	Sandy
P18	96	2.5	1.5	Sandy
P19	93.5	4.5	2	Sandy
P20	90	7	3	Sandy

Analysis of slope collapse potential level based on ROM scale

The ROM scale emphasizes three main compositions of soil: sand, silt and clay. Based on the results, 2 slopes are at moderate stage of collapse potential (P1 and P11); 2 slopes are at a high stage of collapse potential (P6 and P12) and 16 slopes are at a critical stage of collapse potential (P2, P3, P4, P5, P7, P8, P9, P10, P13, P14, P15, P16, P17, P18, P19 and P20) (Table 3). Based on the ROM scale analysis, the slopes in KSAS campus are very prone to landslide if no protection control measures are taken. Figure 7 shows the variety of slopes in KSAS and Table 3 lists the statuses of collapse potential.

Table 3: The statuses of slope collapse potential level in KSAS

Sample	Calculated value based on ROM formula	Collapse potential status
P1	2.2	Moderate
P2	12	Critical
P3	12	Critical
P4	49.5	Critical
P5	49.5	Critical
P6	4.1	High
P7	10.6	Critical
P8	13.78	Critical
P9	13.8	Critical
P10	16.16	Critical
P11	3.84	Moderate
P12	7.83	High
P13	16.17	Critical
P14	24.5	Critical
P15	12	Critical
P16	32.83	Critical
P17	19.5	Critical
P18	32.83	Critical
P19	24.5	Critical
P20	16.16	Critical


a) P1 Moderately


b) P6 High

c) P14 Critical

d) P17 Critical

e)P18 Critical

f)P19 Critical

g)P20 Critical

h) P15 Critical

Figure 7: The level of collapse potential in variety of the slopes in KSAS

Factors of soil moisture, slope gradient and cover crops in influencing the collapse potential level of the slopes in KSAS

Suitable soil moisture is one of the important elements in stabilising slopes. Soils with low moisture levels are susceptible to slope failure. This was proven by the P2, which experienced failure and where the soil moisture was only 11.3%. In addition, this failed slope is categorised under critical status as based on the ROM scale. This clearly shows that soil moisture and collapse potential status of slopes, as based on ROM scale, are strongly connected. In support of this theory, the slopes with moderate status, the P1 and P11, have a relatively high moisture level of 35% and 42%, respectively, which are the highest compared to other slopes.

In addition to the soil moisture, the gradient of slope also plays a role in slope stability. Slope failure is primarily associated with erosion triggered by surface runoff. Thus, the gradient of the area plays an important role in influencing the rate of erosion and slope stability. Slopes with higher gradients are at higher risk of experiencing erosion (Lawrence & Aaron, 2013; Mohamad Suhaily Yusri *et al*., 2013; Kokutse *et al.,* 2016). This can be proven by the failure of the slope in P2, which has an angle of 41°. This is because the high gradient will produce high water velocity and increase the rate of erosion. When the surface runoff has high velocity, the water flow will carry sediments easily and rapidly via the erosion and transportation processes.

Cover crops have various functions in stabilising slopes. This can be seen when the tree canopy prevents and reduces direct drops of water eroding the ground surface. Tree roots also play a role in reducing the water level (content) of the soil, provide vital nutrients for plant growth, anchor plants, store/absorb water and contribute to the process of photosynthesis (Baets *et al*., 2008; Danjon *et al*., 2008; Normaniza & Barakabah, 2006; Pierret *et al.,* 2007; Kumar *et al.,* 2016). The growth of plant roots will encourage significant changes in the physical and chemical properties of the soil and will indirectly strengthen the soil structure (Wang *et al*., 2003; Garg *et al.,* 2012; Gao *et al.,* 2014; Garg & Ng, 2015).

Table 4: Soil moisture, gradient and estimated cover crops on studied slope in the KSAS campus

Sample	Moisture (%)	Gradient(°)	Estimated cover crops (%)
P1	35	31	70
P2	11.3	41	90
P3	21	33	30
P4	27	33	35
P5	18.9	4	20
P6	23.5	34	40
P7	17.2	35	40
P8	21.4	34	35
P9	11.8	35	40
P10	33.4	31	35
P11	42.4	32	20
P12	17.5	28	20
P13	11.4	34	25
P14	11.7	33	25
P15	14.8	34	35
P16	20.4	32	60
P17	25	33	70
P18	27.3	34	65
P19	19.7	31	40
P20	22	31	35

Conclusion

All slopes in the KSAS campus are prone to failure or landslide in the future, as the terrain in the KSAS area is hilly and the area receives a high intensity of annual rain. High amounts of rainfall will worsen the situation as the rainwater infiltrates into the soil and undermines the soil structure. Erosion and weathering processes that constantly occur in the KSAS area also cause the soil to become sandy and easily eroded. Furthermore, sandy soils on the slopes will trigger landslides.

Overall, all slopes in the KSAS are currently of high and critical status, as based on 20 soil samples analysed using the ROM scale. The high average percentage of sand particles (84.37%) in the soil is the main reason for the high and critical statuses. However, further studies should be conducted to determine whether the slopes in KSAS are stable or not.

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