Chapter 2

Slope Failure Analysis Using Chromaticity Variables

Rashidi Othman and Mohd Shah Irani Hasni

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.71248

Abstract

Slope failure has become a major concern in Malaysia due to the rapid development and urbanisation in the country. It poses severe threats to any highway construction industry, residential areas, natural resources, as well as tourism activities. Thus, this study aims to characterise the relationship between chromaticity variables to be manipulated as indicators to forecast slope failure. The concentration of each soil property in slope soil was evaluated from two different localities that consist of 120 soil samples from stable and unstable slopes located along North South Highway and East West Highway. Indicators that could be used to predict shallow slope failure were high value of variable L*(62), low values of variables c* (20) and h* (66). Furthermore, the hues that indicate stable slope based on Munsell Soil Colour Chart are between 2.5YR and 5YR while the hues that indicate unstable slope are between 5YR and 10YR. The overall analysis leads to the conclusion that the reactions and distinctive changes of chromaticity variables between stable and unstable slopes were emphasised as results of significant differences between soil properties, the locations, slope stability and combinations of all interactions.

Keywords: chromaticity, CIELAB, Munsell Soil Colour Chart, soil properties, shallow slope failure, early warning system, key indicator assessment, Oxisols

1. Introduction

The slope failure trend has increased significantly owing to improper changes in land usage and ranked 10th among the most devastating natural disasters in the world occurring across almost all terrains with steep slopes singled out as the most susceptible to sliding [1]. Marques et al. [2] reported an annual rate of soil erosion of 30–40 ton/ha in developed countries of Asia, Africa and South America. On a global scale, the annual loss of 75 billion tons of soil costs the world about US$400 billion per year or approximately US$70 per person per year [3]. Soil erosion from catchments with natural forests is minimal, but levels of soil erosion tend to increase when natural forest is changed to tree crop plantations.

There were many incidents of slope failure occurring both at constructed and natural slopes that caused huge number of deaths especially in tropical countries which received high temperatures and yearly precipitation that brought a large amount of water and consequently triggered extreme effects on the slopes [4]. With these geological factors and climate condition, added with other contributing aspects, slope failure can be considered as one of the crucial threats of environmental catastrophe in Malaysia that requires a serious attention. For example, the slope failures in Hulu Kelang areas have been studied by a number of local researchers and practicing engineers. Ashaari et al. [5] had carried out a field survey work at Hulu Kelang area. A total of 152 slope failures scars of both soil and rock slopes were identified as the potential catastrophe sites. Gue and Cheah [6] investigated the slope failure motions at Kampung Pasir, Hulu Kelang using continuous monitoring approach. They found that the ground had moved from 2 to 17 mm during the monitoring period of 10 days. Hua-xi and Kun-long [7] had performed a detailed investigation on one of the major slope failures occurred in Hulu Kelang area, known as Bukit Antarabangsa 2008 landslide. They concluded that prolonged rainfall during the monsoon season was one of the main factors triggering the failure.

The issue of slope failure in the highway construction industry is closely related to the soil factors [8]. The weakening of soil properties that causes slope failures is resulted from physiochemical activities. It is generated by natural phenomena and human activities through excessive developments which lead to disturbance and destruction of soil surface which are hazardous to slopes. There are many indicators of soil qualities such as organic matters and nutrient deficiency resulted from leachate showing a decline in soil chemical properties while erosion and water infiltration are examples of physical degradation processes [9]. Soil chemical indicators can be identified through specified considerations based on the existence of certain amount of soil colloids whereas physical indicators can be determined by exploring on certain physical appearances and water-holding capacity of the soils. Biological indicators are determined by identifying the amount and mass of microorganisms through concentrations of biogeochemical responses or determining the populations of microorganisms in slope soil.

The soils of the humid tropic such as highly weathered soil (Oxisols) and sandy soil have been observed to be problematic, especially with regard to their fertility. Reviews of research work on current slope soil development in Malaysia, Thailand and Indonesia have significantly shown that such fertility constraints could be improved. Poor fertility of the saprolite is more complex and should be imposed with serious enhancement and management activities. Furthermore, like all acid soils of the humid tropics, Oxisols soils are low in pH value which causes many potential associating problems, including H, Al, and Mn toxicity, Ca deficiency, low CEC, P fixation and low microbial activities [9]. The shallow topsoil is highly vulnerable to erosion and if it is not managed properly especially after the process of clearing the vegetation on top of soil surface, it can slowly lose its original fertility and beneficial physical properties which finally will cause shallow slope failure. Several reviews on the characteristics and management of these soils did not take into account the effect of terracing in exposing

http://dx.doi.org/10.5772/intechopen.71248

saprolites or C horizon. With the surface soils and subsoils already being considered problematic, one could only imagine what kind of impact the saprolites pose to soil fertility.

2. Experimental design

2.1. Description of site selection and soil sampling

Two different localities that were chosen as sampling sites are North South Highway (PLUS) and East Coast Highway (LPT). The whole samples were taken from the slopes that have the gradient lower than 35°. As for unstable soil sample, only slope that collapsed abruptly were collected whereas for stable sample collected from the slope that fully covered by vegetation (**Figure 1**). At North South Highway, 30 soil samples of stable and 30 soil samples of unstable slopes were collected randomly from two sections which were at Section C2 (Tanjung Malim to Bidor) and Section C3 (Sungai Buloh to Tanjung Malim); whereas, in East West Highway (LPT), 30 soil samples of stable and 30 soil samples of unstable slopes were collected from Section 1 (Karak to Jengka) and Section 2 (Jengka to Kuantan). Therefore, a total of 120 soils samplings were collected from those two different localities in Peninsular Malaysia. Auger set was used to collect soil sample at the designated area and soil samples were collected in the depth of 30 cm from the surface. Then, the soil samples were stored in plastic bag and labelled for further analysis.

2.2. Method of data analysis

The collected samples were air-dried, homogenised and sieved to pass a 2 mm mesh sieve for chromaticity variables analysis by CIELAB spectrophotometer. By using a CIELAB spectrophotometer analysis, 10 g of samples were accurately weighed by using analytical balance and was transferred into polystyrene cell and was placed horizontally under spectrophotometer. During the measurement, each sample was measured at three points randomly in order to obtain the mean colour and the variability between different points. When the measurement

Figure 1. Condition and appearance of stable and unstable slopes soil.

was completed, the variables L*a*b*, c* and h* values were displayed on the built by graphical display following each reading. Readings were entered by hand into an Excel spreadsheet.

For analysis, all data gathered were inserted in Microsoft Excel. The mean and standard deviation for each concentration of every experiment was calculated. One-way ANOVA were conducted to measure the validity of the data and the significance of the variation in the results between the stable slope and unstable slope for each soil property.

3. Results

Soil colours give valuable clues in regard to soil properties, soil classification and interpretation. Through this study, the results have been discussed in such a way that it is possible to relate between the Munsell and CIELAB system. It is because, Munsell and CIELAB system has a similar cylindrical structure, and the colour parameters L*, C * [over] ab (CIELAB) as hue, value, chroma (Munsell) represent the same colour perception attributes (hue, lightness, chroma) [10].

3.1. Analysis of soil colour intensity by using Munsell Soil Colour Chart

Scoring with Munsell relies upon human perceived assessment of the three colour attributes: hue, value and chroma. These attributes give valuable clues in soil properties, soil classification and interpretation. Hue is identified as the basic spectral colour or wavelength (Red, Yellow, Blue, or in between, such as Yellow-Red). Value refers to measurement of soil organic matter (OM) in relation to the lightness or darkness of a colour and the range is from 0 (pure black) to 10 (pure white); while chroma is a measurement of colouring agents like Iron or Manganese and the range is from 0 (no colour) to 8 (most coloured).

For this study, the analyses by using Munsell Soil Colour Chart showed a slight difference in stable and unstable slopes. The hues for overall samples were YR (Yellow-Red) and the hues indicating the stable slopes were between 2.5YR and 5YR while the range of hues that indicated the unstable slope was between 5YR and 10YR (**Table 1**). Within each letter range, hue became more Yellow and less Red as the numbers increased. Based on the result, 2.5YR is redder than 5YR and 7.5YR is less yellow than 10YR. This result is consistent with Fontes and Carvallho [11] that reported hue 2.5YR indicates hematite predominate (reddish black), hue 10YR indicates that the soil has goethite (yellowish brown) but does not have hematite whereas hues 7.5YR and 5YR indicate that the soil contains a mixture of goethite and hematite. It is generally believed that hematite, goethite and probably maghemite are the main pigmenting agents in the soil systems [12]. Thus, the different Oxisols variant studied for all sites could be categorised into two main groups which are hematitic or red soil comprising most of the samples from stable slope, and goethite or yellow soils made up most of samples from unstable slope. Therefore, the Munsell chroma combined with the hue value was also used to predict the relative amount of Iron oxides in highly weathered soils [11]. Iron oxides are reddish, yellow and orange in colour [13] and showed in a very small particle size in soils in comparison with other soil minerals which favour their capacity for pigmentation.

No	Munsell soil colour	Hue	Value	Chroma	Colour chips
Stable slopes					
1	Dark reddish grey	2.5YR	3	1	
2	Dusky red	2.5YR	3	2	
3	Dark reddish brown	2.5YR	3	3	
4	Dark red	2.5YR	3	6	
5	Dark reddish grey	2.5YR	4	1	
6	Reddish brown	2.5YR	4	4	
7	Weak red	2.5YR	5	2	
8	Reddish brown	2.5YR	5	3	
9	Reddish brown	2.5YR	5	4	
10	Reddish grey	2.5YR	6	1	
11	Light reddish brown	2.5YR	6	3	
12	Light red	2.5YR	6	6	
13	Very dark grey	5YR	3	1	

No	Munsell soil colour	Hue	Value	Chroma	Colour chips
14	Dark reddish grey	5YR	4	2	
15	Reddish brown	5YR	4	3	
16	Yellowish red	5YR	4	6	
17	Reddish brown	5YR	5	3	
18	Yellowish red	5YR	5	6	
19	Yellowish red	5YR	5	8	
20	Reddish yellow	5YR	7	6	
21	Brown	7.5YR	4	4	
22	Reddish yellow	7.5YR	6	6	
23	Light brown	7.5YR	7	4	
24	Dark brown	10YR	3	3	
25	Dark yellowish brown	10YR	4	4	
26	Brown	10YR	5	3	

No	Munsell soil colour	Hue	Value	Chroma	Colour chips
Unstable slopes					
1	Pale brown	2.5YR	8	4	
2	Light reddish brown	2.5YR	7	3	
3	Pinkish white	2.5YR	8	2	
4	Reddish brown	5YR	5	4	
5	Light reddish brown	5YR	6	3	
6	Light reddish brown	5YR	6	4	
7	Pink	5YR	7	4	
8	Reddish yellow	5YR	7	8	
9	Pinkish white	5YR	8	2	
10	Brown	7.5YR	5	3	
11	Light brown	7.5YR	6	4	
12	Reddish yellow	7.5YR 6/6	6	6	

No	Munsell soil colour	Hue	Value	Chroma	Colour chips
13	Pinkish grey	7.5YR	7	2	
14	Reddish yellow	7.5YR	7	6	
15	Reddish yellow	7.5YR	7	8	
16	Yellowish brown	10YR	5	6	
17	Light grey	10YR	7	2	
18	Very pale brown	10YR	8	4	
19	Yellow	10YR	8	6	
20	Yellow	10YR	8	8	

Table 1. Summary of overall soil colour analysis by using Munsell Soil Colour Chart in response to stable and unstable slope conditions.

Ibáñez-Asensio et al. [14] stated that the dark colour of the soil organic matter is caused by the humid acid fraction and a huge amount of calcium carbonate that is also influencing organic matter on lightness. Carbonates of Calcium and Magnesium contribute to the white colour of the soils. Moreover, in terms of the differences in the regression equations, Schulze et al. [15] pointed out that the relationship between the organic matter content and the Munsell value of soils was strongly influenced by soil texture, parent material and vegetation. High contents of clay and sand affects the soil colour to become yellowish, reddish and whitish. Clay is the smallest particle in soils and exhibits colloidal properties. Some of the clays, like Iron oxide clay, play an important role in soil aggregation and in addition impart red to yellow colours to soils. Embrapa [16] stated that most minerals are not highly coloured and when they are coated with humus and Iron oxides, they take on the colours of humus (black or brown), Iron oxides and hydroxides (red and yellow). **Table 1** showing summary of overall colour analysis by using Munsell Soil Colour Chart for 120 soil samples in response to stable and unstable slopes.

http://dx.doi.org/10.5772/intechopen.71248

3.2. Analysis of reflectance colorimeter measurement by using CIELAB spectrophotometer

3.2.1. Analysis of CIELAB L (lightness) value*

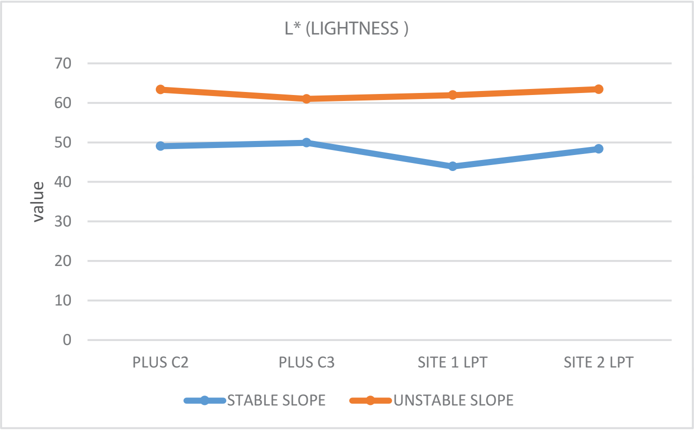
Statistical analysis showed that there was a significant difference for Oxisols colour variable L* between stable and unstable slopes. The value of colour variable L* was the lowest in stable slopes for each study area compared to unstable slopes. The value of variables L* in stable slopes ranged from 44 to 50 whereas in unstable slopes, from 61 to 63 (**Figure 2**).

3.2.2. Analysis of CIELAB a (red-green axis) value*

Statistical analysis showed that there was a significant difference for Oxisols colour variable a* between stable and unstable slopes. The values of colour variable a* were higher in stable slopes from sites, Plus C2 and Site 2 LPT in comparison to unstable slopes. However, the results also revealed that the values of variable a* in stable slopes from sites, Plus C3 and Site 1 LPT were lower compared to unstable slope respectively. The level of variable a* in stable slopes ranged from 7.2 to 11.8 whereas in unstable slopes, from 5.4 to 10.5 (**Figure 3**).

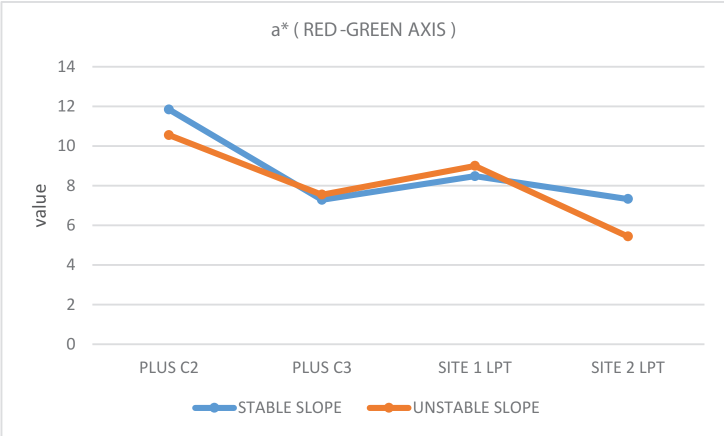
3.2.3. Analysis of CIELAB b (yellow-blue axis) value*

Statistical analysis showed that there was a significant difference for Oxisols colour variable b* between stable and unstable slopes. The values of colour variables b* were higher in unstable slopes for each study area compared to stable slopes. The values of variable b* in unstable slopes ranged from 19 to 22.7 whereas in stable slopes, from 16.5 to 19.8 (**Figure 4**).



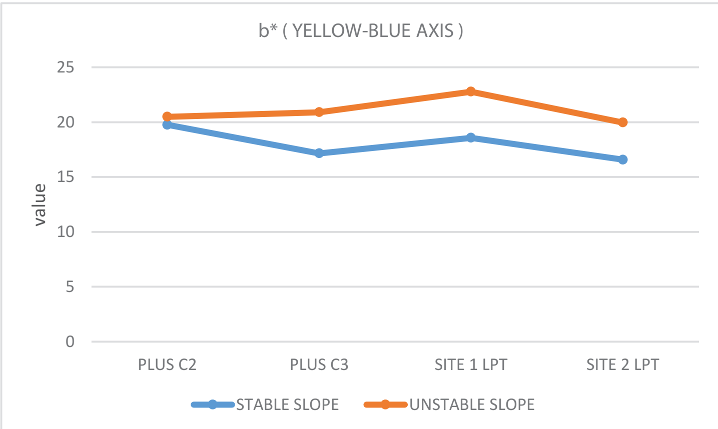
SITE	PLUS C2	PLUS C3	SITE 1 LPT	SITE 2 LPT
STABLE SLOPE	49	50	44	48
UNSTABLE SLOPE	63	61	62	63

Figure 2. The average of variable L* in Oxisols for stable and unstable slopes.



SITE	PLUS C2	PLUS C3	SITE 1 LPT	SITE 2 LPT
STABLE SLOPE	11.8	7.2	8.5	7.3
UNSTABLE SLOPE	10.5	7.5	8.9	5.4

Figure 3. The average of variable a* in Oxisols for stable and unstable slopes.



SITE	PLUS C2	PLUS C3	SITE 1 LPT	SITE 2 LPT
STABLE SLOPE	19.8	17	18.5	16.5
UNSTABLE SLOPE	20.4	20.9	22.7	19

Figure 4. The average of variable b* in Oxisols for stable and unstable slopes.

3.2.4. Analysis of CIELAB c (chroma) value*

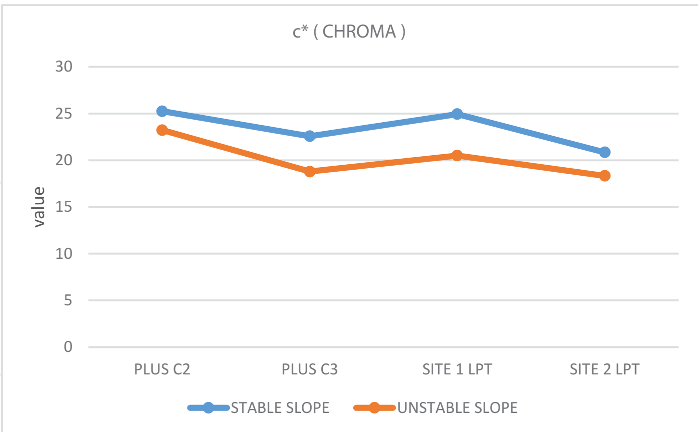
Statistical analysis showed that there was a significant difference Oxisols colour variable c* between stable and unstable slopes. The values of colour variable c* were higher in stable slopes for each study area compared to unstable slopes. The values of variable c* in stable slopes ranged from 21 to 25 whereas in unstable slopes, from 18 to 23 (**Figure 5**).

3.2.5. Analysis of CIELAB h (hue) value*

Statistical analysis showed that there was a significant difference for Oxisols colour variable h* between stable and unstable slopes. The values of colour variable h* were higher in stable slopes for each study area in comparison to unstable slopes. The values of variable h* in stable slopes ranged from 65 to 76 whereas in unstable slopes, from 60 to 69 (**Figure 6**).

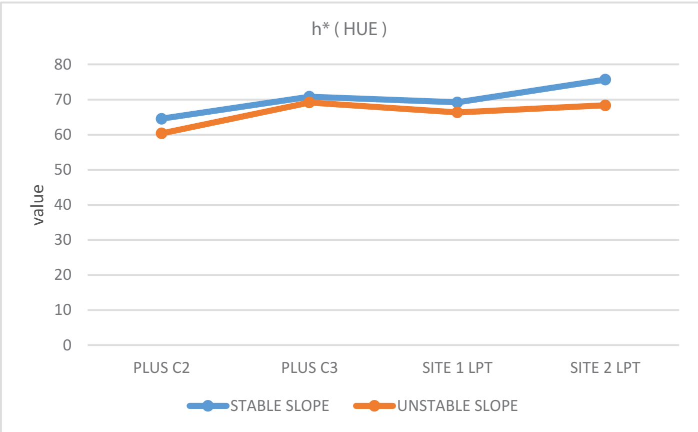
3.2.6. Overall CIELAB soil colour value analysis

Statistical analysis showed that there was a highly significant difference ($P < 0.0001$) in overall CIELAB soil colour variables analysis between stable and unstable slopes. The results of the quantitative measurements of soil colour performed in the laboratory are summarised in **Table 2**. The value of variables L* was higher in unstable slopes rather than stable slopes with the values of 62 and 48, whereas the value of variables a* was slightly lower in unstable slope with the value of 8.1 compared to the stable slope with 8.7 in value. The value of variables b* was slightly higher in unstable slope in comparison to stable slope with the value of 21 and 18. Finally, the value of variables c* and h* were lower in unstable slopes as compared to the stable slopes. In conclusion, the unstable slopes for overall sites consist of higher value of colour variables L*, b* and lower value of colour variables a*, c* and h*, respectively. Since there is a significant difference of colour variables in the comparison of different slope condition, it is possible to conclude the soil colour can be an indicator for early warning of shallow slope failure.



SITE	PLUS C2	PLUS C3	SITE 1 LPT	SITE 2 LPT
STABLE SLOPE	25	23	25	21
UNSTABLE SLOPE	23	19	21	18

Figure 5. The average of variable c* in Oxisols for stable and unstable slopes.



SITE	PLUS C2	PLUS C3	SITE 1 LPT	SITE 2 LPT
STABLE SLOPE	65	71	69	76
UNSTABLE SLOPE	60	69	66	68

Figure 6. The average of variable h* in Oxisols for stable and unstable slopes.

Colour variables	Slope condition	
	Stable slope	Unstable slope
L* (lightness)	48 ± 6	62 ± 6
a* (red-green)	8.7 ± 2	8.1 ± 1.5
b* (yellow - blue)	18 ± 4	21 ± 4
C* (Chroma)	23 ± 4	20 ± 4
h* (hue)	70 ± 6	66 ± 6

Table 2. Mean values for overall soil colour variables in stable and unstable slopes.

4. Discussion

4.1. Relationships between CIELAB spectrometer and Munsell Soil Colour Chart

Munsell Soil Colour Charts are develop for colour identification of an object by direct comparison by using set of colour palettes with a sequence of colour samples on each page in it. CIELAB, is the methods that operated without relying on human eye. It works by scanning an object via spectrophotometer and the outcomes were recorded in graph in three dimensional colour space. This equipment is very effective as supporter to the Munsell colour system. Some complications that make the outcomes an alternative and attractive prospect are inherent to the Munsell colour system for example, a great degree of subjectivity and unpredictability between researchers. CIELAB spectrophotometer able to capture more colour data than Munsell colour charts because the level of precision by CIELAB spectrophotometer is available in colour description.

Through the result and analysis using CIELAB spectrometer, variation of soil colours became apparent at different slope conditions. The soil samples collected from the unstable slopes were characterised by the high values of variables L*, b* and slightly lower values of variables a*, C* and h* (**Table 2**). The difference was also detectable by the soil colour reader using the Munsell colour system, where the findings indicated that the hues for overall samples were classified as YR (Yellow-Red), with the stable 2.5YR to 5YR whereas unstable slope 5YR to 10YR, respectively. The positive value CIELAB variables a* and b* are the indication that this soil sample of Oxisols are dominance by the Iron oxide which influencing the soil colour and also can detected directly through the Munsell Soil Colour Chart. This difference can be measured through the b* value where a strong positive value indicates a strong yellow colour and a strong negative value indicates a strong blue colour whereas a* value where a positive value indicates a red colour and negative value indicates green colour [17].

Moreover, the high value of variables L* in unstable slope in comparison to stable slope is the indication that the unstable slope consist low amount of organic matter content which have a great influencing as among the colouring agent for Oxisols soil. These observations also suggest that the colour of the slope soil samples, particularly the variable L* as soil colour that attributes lightness (similar to Munsell value) provides the most information about the relationship with soil properties which accounted to the ranges of 61–63. Since there was a significant difference for colour variables in the comparison of different slope conditions, it is possible to conclude the soil colour can be an indicator for early warning of shallow slope failure.

4.2. Relationship between chromaticity variables and soil properties

The study on the relationship between chromaticity variables and other soil properties was initiated by investigating the response of soil colour, in stable and unstable slopes samples, in relation to some general properties of the slope soils. CIELAB analysis and Munsell Soil Colour Chart tests revealed important relationships between chromaticity variables and soil properties. These observations suggest that the variable L* provides marked indicator about the relationship with most of the soil properties. Colour variable L* is closely correlated with soil texture including clay and sand contents, soil organic carbon, Iron oxide and Aluminium concentrations. The relationships between L*, Iron oxide and Aluminium which contributed to the darkening of the soils, either individually or associated with other organic materials; also had been revealed by Ibáñez-Asensio et al. [14]. Furthermore, colour variable L* was found strongly affected by differences in climate and vegetation as well as soil moisture regime. The L* variable was the lowest (darker) in stable slope soils which covered by vegetation particularly with fern species in comparison with those unstable slope soils without vegetation. This attributed to the effect on the soil colour of the variations in the composition and quantity of soil humus [17].

Therefore, based on the results, it can be pointed out that unstable slope higher value of variable L* (lightness), which was the evidence that soil properties have strong influence on the weakly developed soils. Several researchers found the lightness value decreased when the number of clay sized particles increased and also indicated the presence of Iron oxides [15]. Most of Iron oxides are seen in small particle size so that very small quantities would be adequate in influencing soil colour since some of those particles had remained on the negatively charged surface of clay grains [15]. The correlation of L* with clay content, may be caused by the relationship of free oxides and humid compounds with phyllosilicates, favoured by their superficial activities. The phyllosilicates act as a support for the other pigments as the increase in phyllosilicates content (white or greyish pigments) would also cause an increase in L* [17].

Iron oxide and soil total organic carbon have a combined influence on L*, and this effect is closely linked to the soil particle sizes. Schulze et al. [15] had found that soil organic carbon and Iron influence on the spectral reaction of soils interrelates with particle size. The results of the present research are consistent with their findings as it is confirmed that interactions between texture and Iron exist. It also showed a positive relationship between soil lightness and soil texture. Sawada et al. [17] also had found low values for soil colour variables particularly L* in stable slope soils with high clay content, high organic carbon and high concentration of Iron oxide. On the contrary, unstable slope contains high values of colour variables, high sand contents, low organic carbon and less concentration of iron oxide. Soil with coarse textures and low levels of organic carbon, consequently, generated greater lightness values than in soils with finer textures and higher contents of organic matter. The analysis used in this study confirms the multivariate relationships and the outcomes pointing to this direction. Finally, in relation to soil organic carbon content effects on lightness, this research had discovered the same relationship found by Konen et al. [18].

Moreover, in this study, it was found that variable h* (Hue) of the stable slope was slightly higher in comparison to unstable slope. This could be caused by the joint migration of the clay and Iron formed in the slope soils. The higher duration of the annual dry period at altitudes of less than 1000 m, higher temperatures with the consequent rising in dehydration of the Iron forms, could be the factors of this greater reddening [13]. This result is also consistent with the finding through the Munsell Soil Colour Chart that indicates the hues for overall samples were YR (Yellow-Red) which were influenced by high concentration of Iron oxides in studied area. Iron oxides can reflect the surrounding of the environments in which they are formed and are considered as colouring agents for most of slope soil samples. Curi [12] stated that in the soil systems, hematite, goethite and probably maghemite which are classified under Iron oxides are the main pigmenting agents in influencing soil colour. The hues that indicate stable slope are between 2.5YR and 5YR and unstable slope are between 5YR and 10YR. 10YR hue shows that the soil contains goethite predominance while 2.5YR hue is hematite predominate, whereas hues 7.5YR, and 5YR show a combination of goethite and hematite. From the findings it can be concluded that the yellowish colour for most of the unstable slope soil samples are caused by a yellow to brown iron oxide mineral called goethite. Generally, these soils have lower iron contents extracted by the sulphuric acid digestion than the other. That occurs either because the parent material had a low iron content or because iron was removed from the soil by percolating water.

Due to the yellower colour, it is relatively easy to distinguish the horizons for instance the red colour dominance for most of the stable slope soil samples are due to hematite and a dark red due to iron oxide. The content of iron oxides extracted by Non-ferric Red Oxisols are quite variable in texture, which ranges from medium to very clayey. The parent material for these soils is very variable and ranges from sandstones to pelitic rocks, with the major requirement being relatively high iron content. Similar to the variable a* value in stable slopes which is slightly higher and this means that the soils are slightly redder in comparison to unstable slopes which contain high sand fraction and slightly higher b* values, it means that the soil is dominantly yellowish in colour [18].

In addition, with respect to the overall soil samples, the conditions of slope are essential in influencing the chroma values in such a way that the stable slopes has a slightly high chromatic value than the unstable slopes. As was stated before, this is interrelated to the larger amount of Iron formed in the stable slopes which might be caused by modification and illuviation of slope structure. Chroma C* is also correlated with total organic carbon content, which has also been described for other soils [19] and most strongly associated with soil texture content. This means that the colour of the texture becomes more uniform as the contents of these minerals increases, which may be attributable to the processes of reduction and enlargement.

5. Conclusion

The overall soil colour analyses lead to the findings that the CIELAB variables L* (lightness), c* (chroma) and h* (hue) with significant values of colour variables measured at different slope conditions, provide the most information in relation to soil properties. Regarding to the relationship between soil properties, the study had identified that soil texture, total organic carbon (TOC), Iron oxide and Aluminium concentration were strongly interrelated with soil colour variables at the studied areas. It is also recommended that in order to explain and detect the colour of slope soils, the function and availability of lightness-darkness as an analytical factor should be highlighted, together with the amount of Iron oxides. To sum up, indicators that can be used to predict shallow slope failure based on chromaticity variables are high value of variable L*, low values of variables c* and h* and the Munsell Soil Colour Chart were between 2.5YR and 5YR (hematite predominance). The correlative relationships between chromaticity variables and soil erosion suggest that all these properties may potentially be used as an indicator of slope failure.

These findings should be used to trigger further investigation of the reasons or sources for the failure of the slope soil and an assessment made of the potential risks to humans or the environment if the failure continues. Through this study it showed that the weakening of the slope soil properties occurred mostly due to erosion effect towards the existing soil properties. Consequently, serious attention should be emphasised on each slope along the highways particularly the unstable slopes in order to reduce harmful effects. Most of the landslides occurred during the rainy days when the soil is relatively wet. It would require special preventing strategies such as slope levelling, terracing and practicing in planting suitable vegetation in slope areas.

Vegetation and slope stability are interrelated by the ability of the plant life growing on slopes to both promote and hinder the stability of the slope. The relationship is a complex combination of the type of soil, the rainfall regime, the plant species present, the slope aspect, and the steepness of the slope. Any study of soil properties should take serious attention towards any vegetation above the slope area as this factor is crucial in influencing the loss of several nutrients. Planting vegetation will increase the organic carbon in soil thus the ions of organic carbon will bind with ion in clay and hydrogen in soil. These reactions will strengthen the soil structure. Knowledge of the underlying slope stability as a function of the soil type, its age, horizon development, compaction, and other impacts are the major underlying aspect of understanding how vegetation can alter the stability of the slope. Our study did take note of vegetation, but for future studies, a more thorough study with regard to the vegetation of the areas in conjunction with certain soil properties would be interesting to be highlighted. The research findings showed that unstable slope was more likely to occur if there is no plant life growing on the top of soil. The less vegetation growing in the soil the more likely that erosion will happened. Vegetation can protect the soil from the impact of the rain and slows down the infiltration process. Plants with deeper roots are better at holding the soil together and protect it from erosion.

Finally, an efficient management on landslide risk, the coordination between regions, departments concerned, universities, research centres, non-governmental organisations and local peoples in landslide-prone would be helpful in order to obtain the better risk management. This coordination and communication would minimise the wasting budget, man power, time allocation and miscommunication of decisions taken in future. Additionally, the findings of this research can be integrated with the various components of landslide risk in risk information and management systems which should be developed as spatial decision support systems for local authorities dealing with risk management. The availability and quality of historic landslide database cannot be overemphasised since they constitute the basis for all components of landslide. Modern technologies, such as geographic information system (GIS) and remote communications, should have a wider application in landslide risk assessment and management.

Acknowledgements

The authors would like to thanks Ministry of Education (MOE) and International Islamic University Malaysia (IIUM) for the Research Grant NRGS13-002-0002.

Author details

Rashidi Othman* and Mohd Shah Irani Hasni

*Address all correspondence to: rashidi@iium.edu.my

International Institute for Halal Research and Training (INHART), Herbarium Unit,
Department of Landscape Architecture, Kulliyyah of Architecture and Environmental Design,
International Islamic University Malaysia, Kuala Lumpur, Malaysia

References

[1] Leroy SA, Gracheva R. Historical events. In: Encyclopedia of Natural Hazards. Netherlands: Springer; 2013. p. 452-471

[2] Marques AMJ, Bienes R, Jimenez L, Perez-Rodríguez R. Effect of vegetal cover on runoff and soil erosion under light intensity events. Rainfall simulation over USLE plots. Science of the Total Environment. 25 May 2007;**378**(1–2):161-165

[3] Eswaran H, Lal R, Reich PF. Land degradation: An overview. In: Bridges EM, Hannam ID, Oldeman LR, Pening de Vries FWT, Scherr SJ, Sompatpanit S, editors. Responses to Land Degradation. Proc. 2nd. International Conference on Land Degradation and Desertification; Khon Kaen, Thailand. New Delhi, India: Oxford Press; 2008

[4] Jordán A, Martínez-Zavala L. Soil loss and runoff rates on unpaved forest roads in southern Spain after simulated rainfall. Forest Ecology and Management. 2008;**255**(3–4):913-919

[5] Ashaari M, Shabri S, Mahadzer M, Nik Ramalan NH, Fadlee MB, Mariappan S, Low TH, Chong S, Zaini MM, Wan Mohd RWI. Slope field mapping and finding at Ulu Klang area, Malaysia. In: Proceeding of the International Conference on Slopes Malaysia; Kuala Lumpur, Malaysia. 4–6 November 2008

[6] Gue SS, Cheah SW. Geotechnical challenges in slope engineering of infrastructures. In: International Conference on Infrastructure Development. Malaysia: Putrajaya Mariott Hotel. 2008; 7–9 May 2008

[7] Hua-xi G, Kun-long Y. Study on spatial prediction and time forecast of landslide. Natural Hazards. 2014;**70**:1-14

[8] Harwant S. Slope Assessment Systems: A Review and Evaluation of Current Techniques Used for Cut Slopes in the Mountainous Terrain of West Malaysia. Faculty of Resource Science and Technology. Kuching, Sarawak, Malaysia: University Malaysia Sarawak; 2006

[9] Shakilah N. Studies on chemical properties of stable and unstable slope of highly weathered soil (oxisols) [Dissertation]. Kuala Lumpur, Malaysia: International Islamic University Malaysia; 2014

[10] Sanchez-Mara NM, Delgado G, Melgosa M, Hita E, Delgado R. Cielab colour parameters and their relationship to soil characteristics in mediterranean red soils. Soil Science. 1997;**162**:833-842

[11] Fontes MPF, Carvallho AI Jr. Colour attributes and mineralogy characteristics, evaluated by radiometry of highly weathered tropical soils. Soil Science Society of America Journal. 2005;**69**:1162-1172

[12] Curi N. Lithosequence and toposequence of oxisols from Goiás and Minas Gerais States, Brazil [Unpublished PhD's dissertation]. Indianapolis, USA: Purdue University; 1983

[13] Schwertmann U. Relations between iron oxides, soil colour and soil formation. In: Bigham JM, Ciolkosz EJ, editors. Soil Color. Madison: Soil Society of America; 1993. p. 51-70. SSSA Special Publication No 31

[14] Ibáñez-Asensio S, Marqués-Mateu A, Moreno-Ramón H, Balasch S. Statistical relationships between soil colour and soil attributes in semiarid soils. Biosystems Engineering. 2013;**116**:120-129

[15] Schulze DG, Nagel JL, Van Scoyoc GE, Henderson TL, Baumgardner MF. Significance of organic matter in determining soil colors. In: Bigham JM, Ciolkosz EJ, editors. Soil Color. Madison: Soil Society of America; 1993. p. 71-90. SSSA Special Publication No 31

[16] Embrapa. Manual de métodos de análise de solos. Rio de Janeiro: Centro Nacional de Pesquisas de Solos; 1997. p. 212

[17] Sawada K, Wakimoto T, Hata N, Taguchi S, Tanaka S, Tafu M, Kuramitz H. The evaluation of forest fire severity and effect on soil organic matter based on the L*, a*, b* color reading system. Analytical Methods. 2013;**5**:2660-2665

[18] Konen ME, Burras CL, Sandor JA. Organic carbon, texture, and quantitative color measurement relationships for cultivated soils in North Central Iowa. Soil Science Society of America Journal. 2003;**67**(6):1823-1830

[19] Dobos RR, Ciolkosz EJ, Waltman WJ. The effect of organic carbon, temperature, time, and redox conditions on soil color. Soil Science. 1990;**150**:506-512