

Rock slope monitoring using drone based multispectral and thermal images

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Abstract. Nowadays, remote sensing compact sensors able to be attached to Unmanned Aerial Vehicle (UAV) platform, which suitable in monitoring and mapping the slope feature at large area. Therefore, this study presents the use of remote sensing compact sensors from visible spectrum (400 nm – 700 nm), Near-Infrared spectrum (700 nm – 1300 nm) and infrared thermography spectrum (1300 nm – 15000nm), respectively in order to produce an efficient technique for monitoring the stability of rock slope. Then, the stability of rock slope is being analyse using vegetation index such as Normalized Difference Vegetation Index (NDVI), water index with emphasizing to the Normalized Difference Water Index (NDWI) for different land type features and radiometry temperature extracted using thermography image. NDVI has been used in analysing the healthiness of vegetation and the healthier vegetation tends to have a stronger root which useful in stabilizing the slope. Meanwhile, the NDWI has the ability to detect the presence of water on the rock slope surface. In addition, the higher index of NDWI indicates the presence of water where at the higher index NDWI potentially be less stable as the water seeps through the crack line of the rock surface. For thermography, by acquiring the thermal data of the rock slope surface, it allows to analyze the damage due to weathering effect. As a summary, this technique is significant to be used as initial indicator to investigate the rock slope failure based on low cost technique and quick data information.

Keywords: Rock slope, drone, multispectral image and thermal image.

1. Introduction

Stability of the rock slope can be identified by numerous of variables where the elements such as vegetation coverage and water content are the major contributor. Vegetation and slope dependability are interrelated by the limit of the vegetation creating on slope to both progress and control the soundness of the slope. Vegetation coverage can sustain the rock slope strength by unequivocally bracing inclines through plant roots, altering soil dampness circulation and pore water pressures, including slope extra charge from the greatness of trees, and turning and wedging soil by roots [5]. In other words, the vegetation coverage contributes more in expanding the steadiness of the rock slope instead of diminishing its security. The effect of water on the slope can be considered into two creases. One is ground water or spring underneath the surface that produce pore water pressure and the other is water entrance that leaks through surface and streams along the incline making water pressure, which implies the presence of water on the slope will give more toward diminishing the strength of the slope. Alongside vegetation and water, stability of the rock slope likewise can be influenced thermally. A few researches recommended that temporal and occasional temperature changes may create thermally provoked burdens adequately high to engender past splits in the rock mass [1]. Taking vegetation, water and thermography factor into thought for dependability of the rock slope might be successful in guaranteeing the supportability of the rock slope by examining the relationship between these three components.

The ever-growing technology of remote sensing nowadays can deliver an analysis of the vegetation, water and temperature of certain territory, for example, a rock slope observation through the multispectral images that captured by the compact sensor mounted on unmanned aerial vehicle (UAV) platform likes drone. UAV as indicated by the unmanned vehicle system (UVS) internationally is characterized as a generic aircraft configuration to work with no human pilot installed. UAV photogrammetry unquestionably will open an assortment of new applications in the close-range photogrammetry, starting a minimal cost option to the customary airborne photogrammetry for large scale topographic mapping or precise 3D recording of ground information and being a legitimate correlative answer for terrestrial acquisitions [6]. While drone is the



platform, compact sensors will take the multispectral images of the feature on the ground. These days, there numerous compact sensors accessible yet on the off chance that the investigation is about vegetation, water and temperature, at that point the sensors required will be visible spectrum (400 nm – 700 nm), Near-Infrared spectrum (700 nm – 1300 nm) and Infrared thermography spectrum (1300 nm – 15000nm) sensors respectively.

Visible spectrum sensor or otherwise called RGB (Red Green Blue) is a sensor that produce a picture with real colour. This sensor additionally comprises of three distinctive band which is Red, Green and Blue. The red and green band is required for the analysis of the vegetation and water. It will be overlay with the Near-Infrared band so that the indexes of vegetation and water able to be extracted. NIR is the part of the electromagnetic range straightforwardly neighbouring the visible range, consequently it can't be seen with the bare eye. vegetation reflectance is high in the NIR area due to leaf density and canopy structure impacts. This sharp distinction in reflectance lead between the red and NIR sections of the range is the inspiration for improvement of spectral indices that depend on proportions of reflectance value in the visible and NIR area [4]. For Infrared Thermography (IRT) sensor, it will gauge the radiations discharged by ground feature to assess the temperature. The radiant temperature of a body which relies upon two variables which is kinetic temperature and emissivity will be given through this measurement [7]. Thus, this study aims to utilize drone based multispectral and thermal images in order to investigate the rock slope stability at North-South expressway from Km 257.5 to Km 258.3.

2. Methodology

2.1 Study area

The area of study for these studies is located at Ipoh, Perak, Malaysia or precisely at KM 257.5 to KM258.3 of North-South expressway facing the south bound of the expressway which is after menora tunnel where approximately 800-meter length of bulging rock slope with highest peak is around 120 meters from ground level (**Figure 1**). Besides that, this rock slope also sited in the Northeast-Southwest Kledang Range. The Kledang Range are enormous granitic plutons and this huge slope of rock are heavily fractured and on top of that, the incline for this slope are very steep. With that being said, the stability of this rock slope needs to be considered and monitored properly as it will affect the safety of the expressway user. Most of the surface of this slope were rock but there is also some vegetation scattered around the slope and the peak also mostly covered with vegetation. Besides that, concrete and soil also appear on this rock slope.

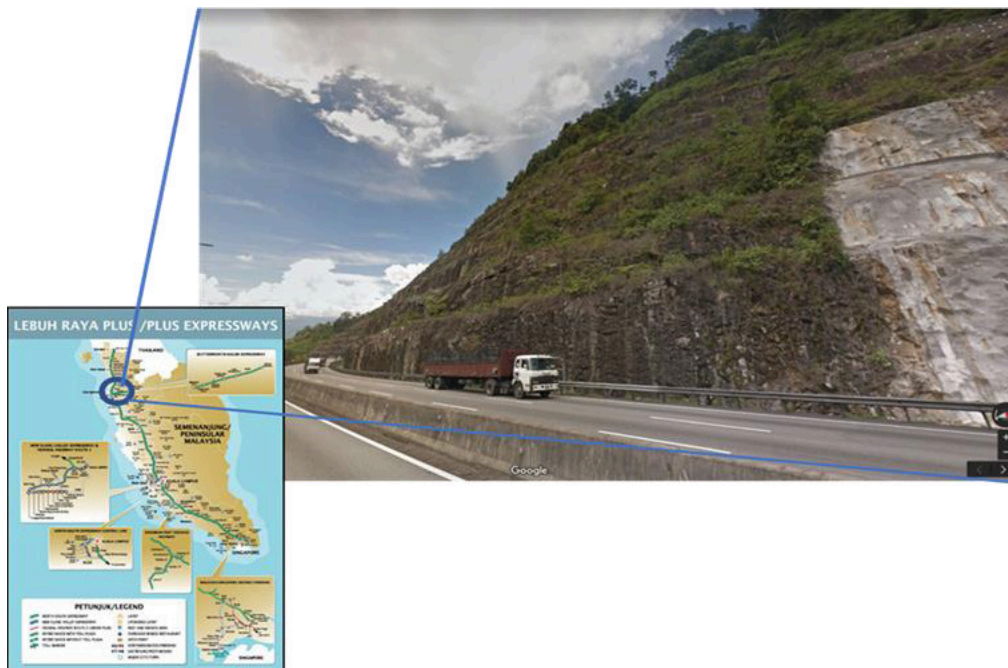


Figure 1. Location of study area

2.2 Dataset

As it been mentioned earlier this study use compact sensor of visible spectrum, near-infrared spectrum and thermography spectrum which indicated that the dataset produces for this study are RGB imagery, NIR imagery and IRT imagery. The RGB and NIR imagery will be used for obtaining the Normalized Difference Vegetation Index (NDVI) and Normalized Difference Water Index (NDWI). Meanwhile, the IRT imagery will be used to extract the temperature of the rock slope.

2.3 Data Acquisition

Data Acquisition phase is where data is collected to do further analysis on the collected data itself so the information can be extracted in order to solve of the issue that have been addressed. For this study, data is gathered where it includes the process of RGB, NIR and IRT image capturing. These images were gathered through the field work that has been conducted using DJI Phantom 4 drone with MAPIR Survey 2 NIR and RGB sensor are attached to it for RGB and NIR data acquisition. As for the IRT images, the drone that being utilized to gather its data is DJI Inspire 2 with FLIR Vue Pro sensor (**Table 1**). Meanwhile, the drone mission is deploying the close-range photogrammetry method which distance about 15 metres from slope surface.

Table 1. The instruments used in this study

Instrument	Specification
 DJI Inspire 2	Payload: 3.2 kg Flight Autonomous: 27 minutes Velocity Range: 10 m/s at height of 2 m Altitude Range: 10 m Operating Range: 10 m Obstacle Sensing Range: 0.7 - 30 m
 DJI Phantom 4	Payload: 1.38 kg Flight Autonomous: 28 minutes Velocity Range: 2 m above ground Altitude Range: 0 - 10 m Operating Range: 0 - 10 m Obstacle Sensory Range: 0.7 - 15 m
 MAPIR Survey2 (NIR and RGB sensors)	Focal length: 35 mm Sensor: 20 megapixels FOV: 60° (horizontal) Capture Speed: RAW+JPG: 3 Seconds / Photo. JPG: 2 Seconds / Photo
 FLIR Zenmuse XT	Lens: 13 mm lens Resolution: 640 × 512 pixels Spatial Resolution: 0.4 cm Spectral Range: 7.5 – 13.5 micrometre Thermal Imager: Uncooled VOx Microbolometer

2.4 Data Pre-processing

Data pre-preparing is an information mining strategy that includes changing raw data into a reasonable configuration. In this study, the raw data experiences the procedure of image stitching to produce an orthophoto and the procedure of layer stacking to overlay two orthophoto together. As earlier mention, the raw data of RGB, NIR and IRT sensors will experience the stitching procedure where all the images taken by every sensor will be consolidate into a single type of image called orthophoto for each RGB, NIR and IRT images. This procedure is conducted with the Pix4D Mapper Software for RGB, NIR and IRT images, respectively (**Figure 2**, **Figure 3** and **Figure 4**)



Figure 2. RGB orthophoto



Figure 3. NIR orthophoto

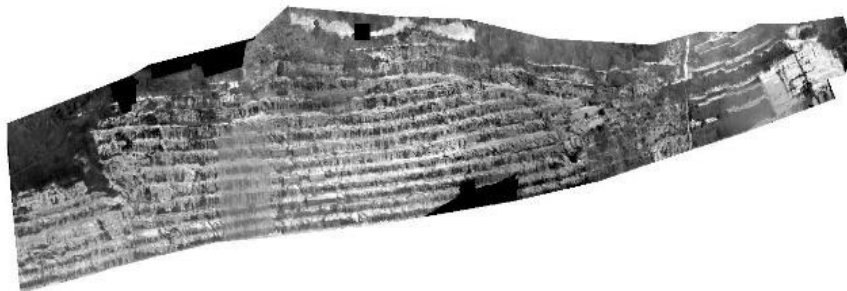


Figure 4. IRT orthophoto

2.5 Data Processing

Data processing is involving the manipulation of the data that carried out by the computer. It incorporates the change of raw data to machine-readable format, stream of data through the CPU and memory to output devices, and arranging or change of output. For this study, the Data processing is conducted to extricate the estimation of NDVI, NDWI and IRT. NDVI extraction process is a basic and reliable measurement parameter, which is used to show the ground surface vegetation coverage [3]. In the mean time, NDWI is proposed to intensify reflectance of water by using green wavelength, limit the low reflectance of NIR by water feature and make use of the high reflectance of NIR by vegetation and surface features [8]. It is along these lines a generally excellent proxy for recognizing water surface. IRT is the analysis of recognizing infrared energy transmitted from a thing, changing over it to obvious temperature, and demonstrating the result as an infrared image. Furthermore, NDVI and NDWI process is performed by using Raster Calculator tool in ArcGIS ArcMap 10.3 software. The algorithm for NDVI and NDWI computation are as appeared in the **Equation 1** and **Equation 2**, respectively. For IRT image the information was collected from the FLIR tool software as the image itself were taken by

FLIR camera. While, **Figure 7**, **Figure 8** and **Figure 9**, respectively show the output after the completion the processing.

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)} \dots\dots\dots (Equation 1) [3]$$

Figure 5. The equation for NDVI

$$NDWI = \frac{Green - NIR}{Green + NIR} \dots\dots\dots (Equation 2) [8]$$

Figure 6. The equation for NDWI

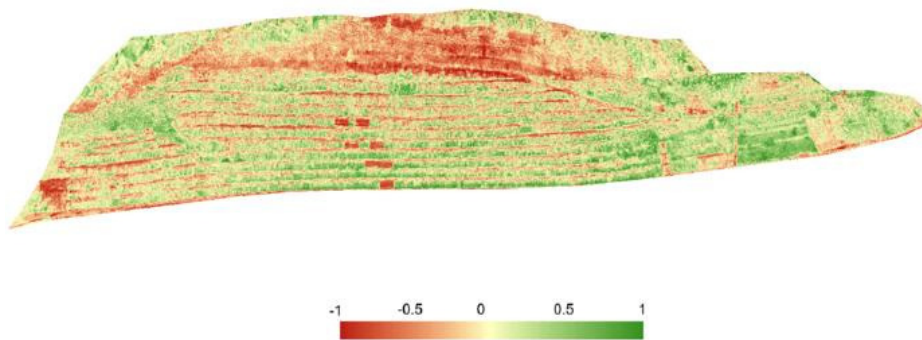


Figure 7. Image of NDVI for rock slope

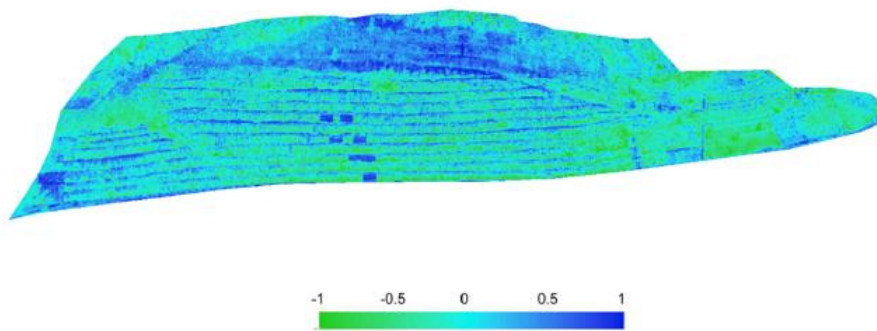


Figure 8. Image of NDWI for rock slope

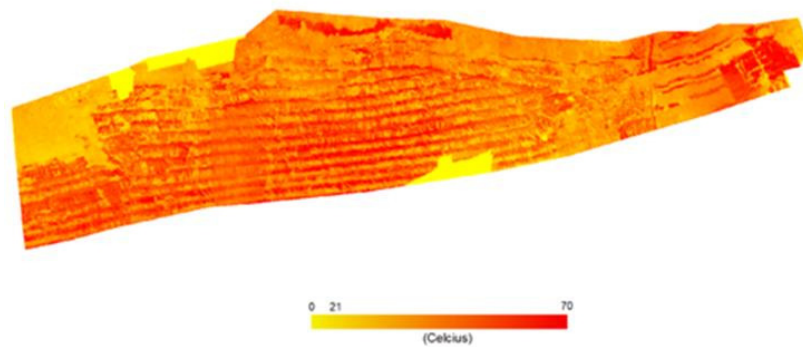


Figure 9. Image of IRT for rock slope

2.6 Data Analysis

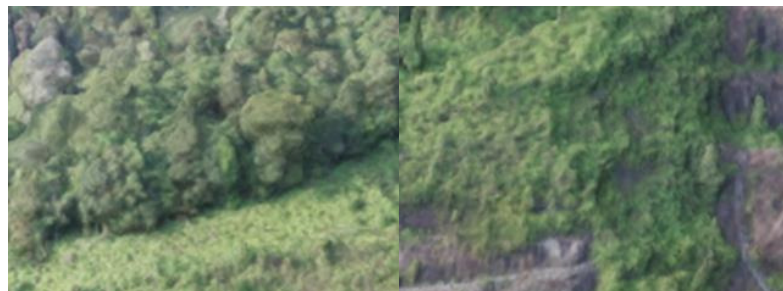
Data Analysis is the procedure of applying logical and statistical method systematically to depict and outline, gather and recap, and assess data. It is a fundamental part of guaranteeing data integrity is the precise and suitable analysis of study finding.

From the output of NDVI, apparently the unhealthy and healthy vegetation were distributed evenly throughout the entire the rock slope while, there are a couple of very healthy vegetation were situated at some region of the rock slope. This mean, there were vegetation with a good health planted all through whole slope that will change soil moisture dispersion and pore water weights of the rock slope which will help its stability.

The NDWI shows that the water for the most part was situated at the concrete and the soil area at the rock slope. There are not many waters was situated at the surface of the rock which implies there is a not many measures of the water that will seeps through the crack of the rock. This also will guarantee the stability of the rock incline.

The IRT data that was extricated from thermography image also showed a very comparative output as they identify a large portion of the high temperature were situated at the rock surface which clarified the few amounts of water were situated at the surface of the rock.

In order to produce a better understanding result of which area of the slope contain more water or vegetation and also which area are appeared to have high temperature which might indicates the stability of the rock slope, each the rock slope dataset of NDVI, NDWI and IRT were divide into five different groups of slope condition sample. Those five groups of samples are, High Dense Vegetation (HDV), Low Dense Vegetation (LDV), Rock Mix Vegetation (RMV), Rock Surface (RS) and Concrete Surface (CS) (**Figure 10**). These five groups of samples were used due to the condition of the rock slope itself. There are three samples were collected for each sample group in order to produce an average value for each sample group.



(a)

(b)

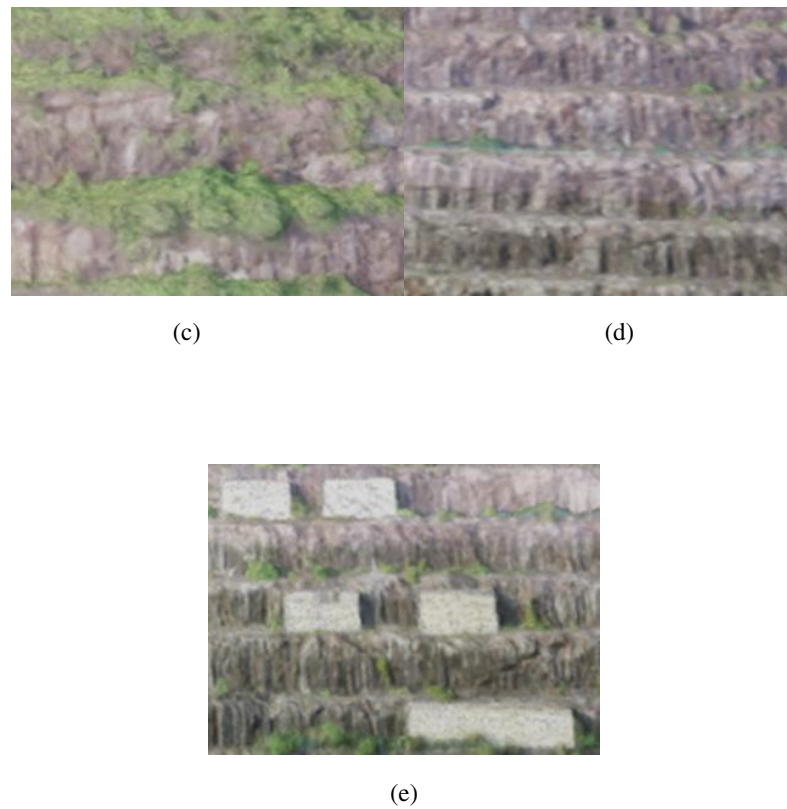


Figure 10. Five group of samples, HDV (a), LDV (b), RMV (c), RS (d) and CS (e).

3. Results and Discussion

This study is performed so as to investigate an analysis on the correlation of vegetation indexes, water indexes and thermography images. Therefore total of 15 samples location have been used for analysis as shown in **Figure 11**, **Figure 12** and **Figure 13**, respectively. Theoretically, NDVI value is high when NDWI value is low and NDWI value is high when NDVI value low. From the observation of this study, it can be seen that at NDVI value and NDWI value are oppose one another which support the theory as stated. For thermography, its value relies upon the feature or surface thermal conductivity. Rock and concrete have higher conductivity than vegetative zone and from this perception it clearly can be see than the temperature of rock and concrete surface is a lot higher than the area with vegetation cover (**Table 2** and **Table 3**). Furthermore, **Figure 14** shows the trend of NDVI, NDWI and IRT according to the five groups of sample which presenting the analysis of the study whereby inline to the given concept and theory.

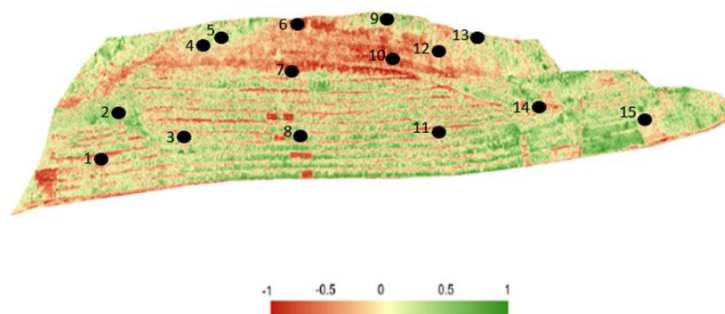


Figure 11. Extraction of sample for NDVI

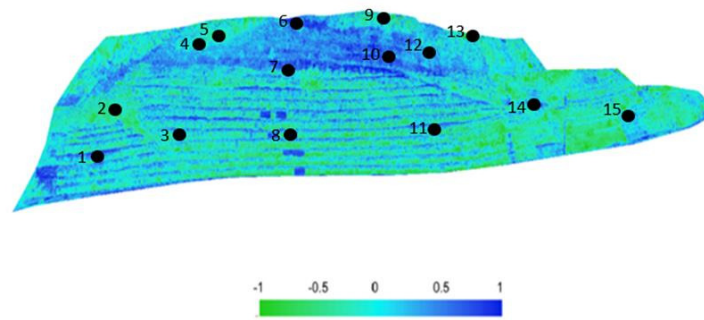


Figure 12. Extraction of sample for NDWI

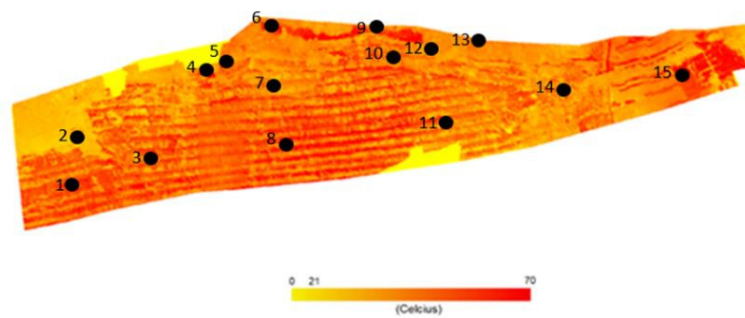


Figure 13. Extraction of sample for 1 IRT

Table 2. Value of sample for Phase 1

Sample	NDVI	NDWI	IRT	Remarks
1	0.148014	-0.154122	37.0	RS
2	0.492958	-0.406593	27.7	LDV
3	0.067138	-0.025271	35.2	RS
4	0.365672	-0.392491	30.9	LDV
5	0.512000	-0.469767	28.5	HDV
6	-0.112500	0.225806	40.5	CS
7	0.150685	-0.226006	32.7	RMV
8	-0.058065	0.089918	39.2	CS
9	0.587302	-0.580247	28.4	HDV
10	0.133550	-0.095082	32.4	RMV
11	-0.053691	-0.111864	34.7	RS
12	0.369176	-0.382456	28.2	LDV
13	0.531915	-0.545455	25.5	HDV
14	0.362205	-0.384615	32.1	RMV
15	-0.108359	0.101796	45.0	CS

Table 3. Correlation between NDVI, NDWI and IRT according to sample group.

Types of sample	NDVI	NDWI	IRT (°c)
LDV	Slightly high (0.36 – 0.49)	Slightly low (-0.4 - -0.38)	Moderate (27.7 – 30.9)
HDV	High (0.51- 0.58)	Low (-0.58 - -0.46)	Moderate (25.5 – 28.5)
RMV	Moderate to slightly high (0.13 – 0.36)	Slightly low to moderate (-0.38 - -0.09)	Moderate (32.1 – 32)
RS	Moderate (-0.05 – 0.1)	Moderate (-0.15 - -0.02)	Slightly high (34.7 – 37.0)
CS	Slightly low (-0.11 – 0.05)	Slightly high (0.09 – 0.23)	Slightly high (36.2– 45.0)

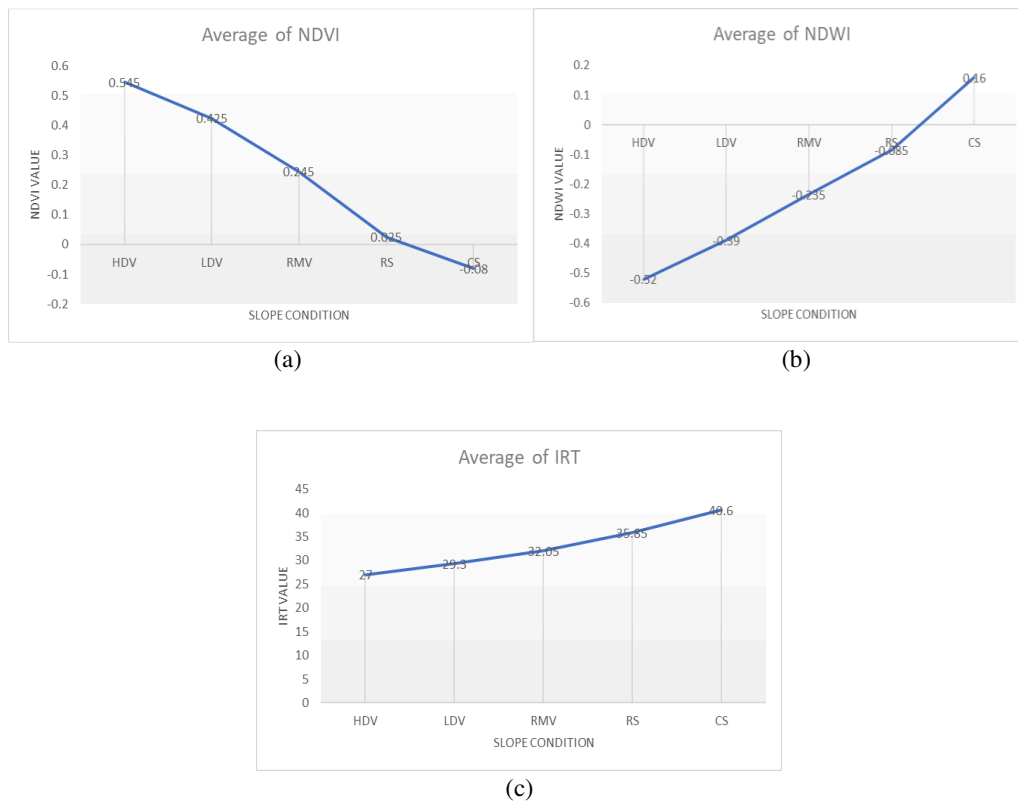


Figure 14. Trend of NDVI (a), NDWI (b) and IRT (c) according to five groups of sample.

4. Conclusion

Refer to the value of NDVI, it seems that the vegetation index is very encouraging as it shows up high at the region with more vegetation which is situated at the peak of the incline and also at the both sides of the slope. The high value of NDVI shows the vegetation at that territory are in good health than the lower value and healthier vegetation will in general have a progressively steady and solid root. The roots of a plant can be useful in stabilizing out the incline through various medium, for example, by grasping on a frail soil mass from fracturing in bedrock, by crossing zones of weakness to more stable soil, and by giving long fibrous binders inside a weak soil mass [5]. The algorithm for distinguishing the vegetation indexes that has being utilized for this study has previously proven useful by numerous different studies. One of the study that consolidate this equation was conducted by Gandhi et al (2015) [3], has demonstrated the unwavering quality of this equation. With respect to NDWI analysis for this study, it generally used to recognize the water feature as it has been conducted by McFeeters (2013) [2] and Xu, H. (2006) [8] and it has been incorporate into this studies so as to discover the existence of water around the rock slope. As it can be already seen from the output of NDWI procedure, water feature are for the most part appear at the concrete and soil area of the slope yet not on the rock slope itself which is a decent outcome as there is less water to seep into the rock that will influence the stability of the rock slope.

From the correlation table, obviously it can be seen that when the vegetation index value is appeared to be high, the value of water index is low and when the vegetation index value is appeared to be low, the value of water index is high. This finding is seemed to has supported the theory of NDVI and NDWI that were mention earlier where it indicates that when the NDVI is high the NDWI is low or other way around. As for the thermography value, it shows that when the temperature is high, the value of vegetation index and water index is at moderate value. The high temperature seemed to be located at the rock and concrete feature of the slope. Lastly, the low cost drone based multispectral and thermal image in this study as considered low altitude remote sensing method as well can be used to develop spatial inventory for the rock slope stability monitoring if it was to be performed continuously. The manipulation of rock slope spatial inventory is then will be able to produce an initial awareness about the rock slope stability.

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