USING REMOTE SENSING INDICES TO REDUCE EFFECTS OF HILLSHADE ON LANDSAT 8 IMAGERY

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SUMMARY
This paper presents the effects of hillshade on the spectral values of Landsat and application of remote sensing image indices to reduce the influence of topography. This research uses the calibrated Landsat 8 images that are provided by the Center for Science and Earth Observation, known as the Earth Resources Observation and Science (EROS), the United States Geological Survey (USGS). The research has conducted in three typical areas of mountainous terrain in Vietnam and has used 22 remote sensing indices, including NDVI, NBR, NBR2, NDMI, SAVI, MSAVI, EVI, RATIO, TVI, CTVI, TTVI, DVI, IRVI, NLI, OSAVI, RDVI, VARI, MSR, LAI, GNDVI, GRVI and RVI to assess the levels of each hillshade- adjusted index. The results showed that in the same forest type, the values of spectral band image on the hillshade side are lower than those on the sunshine side. The more pronounced the hillshade is, the greater the difference is. In the case of light hillsade, indices of NDMI, NBR, NBR2 and VARI are more likely to minimize the most effects of mountain hillsade, followed by the group of indices, namely NDVI, RVI, GRVI, MSR, OSAVI, IPVI, RATIO, GNDVI, CTVI, TTVI and TVI. The remaining group of indices including MSAVI, SAVI, EVI, LAI, RDVI, NLI and DVI are strongly affected by the terrain even in the case of light hillsade. The findings of this research are useful for selecting the remote sensing indices in relation to management of natural resources and environment where there is an existence of complex mountainous terrain.
Keywords: Hillshade effects, Landsat 8, minimisation, remote sensing indices.

I. INTRODUCTION

Hilly terrain causes the appearance of the hillshade, which would affect the reflection values of the state on the earth's surface. Mountain shadows may reduce reflected energy of the sun, leading to the noise of object reflector, so reflected energy is weaker than the solar area with normal lighting. In the process of studying the surface cover, this research particularly uses remote sensing indices, namely NDVI (Normalised Difference Vegetation Index), NBR (Normalised Burn Ratio), NBR2 (Normalised Burn Ratio 2), NDMI (Normalised Difference Moisture Index), SAVI (Soil Adjusted Vegetation Index), MSAVI (Modified Soil Adjusted Vegetation Index), EVI (Enhanced Vegetation Index), RATIO (Ratio Vegetation Index), TVI (Transformed Vegetation Index), CTVI (The Corrected Transformed Vegetation Index), TTVI (Thiam's Transformed Vegetation Index), DVI (Difference Vegetation Index), IRVI (Infrared Percentage Vegetation Index), NLI (Non-linear Index), OSAVI (Optimised Soil Adjusted Vegetation Index), RDVI (Renormalised Difference Vegetation Index), VARI (Visible Atmospherically Resistant Index), MSR (Modified Simple Ratio), LAI (Leaf Area Vegetation Index), GNDVI (Green Normalised Difference Vegetation Index), GRVI (Green Ratio Vegetation Index) and RVI (The simple Ratio Vegetation Index) as a basis of interpreting the object. In normal conditions, results of remote sensing indices assessed are relatively accurate. However, for the hilly and plateaus areas, where the information is disturbed by mountain shadows, the question is whether the remote sensing indices may reduce the effects of the complexity of the terrain or not. Therefore, this paper examines the effects of the mountainous shadow on the spectral band values of Landsat 8 and then evaluates the possibility of hillshade calibration of remote sensing indices.

II. METHODOLOGY

2.1. Scope of research

This research has been conducted at 4 sites where there is the existence of typical mountains from medium to high terrain condition. The mountainous range belongs to three Southern provincial territories, namely Khanh Hoa, Lam Dong and Ninh Thuan, for short name as three Southern provinces; Fansipan mountain range; Tam Đao mountain in Vinh Phuc province; and mountainous range of Bac Kan province, including Bach Thong district, Cho Moi and Ba Be.

Table 01. The research sites

ID	Territory	Peak on the left corner		Peak on the bottom- right corner	
		X	Y	X	Y
1	Fansipan	373429.0788	2465416.139	399662.0297	2443320.6
2	Southern provinces	888268.0634	1359597.141	921192.4844	1332878.92
3	Tam Dao	545894.207	2395259.132	569819.1061	2370417.755
4	Bac Kan	565547.0072	2477981.802	600554.244	2442696.177

Coordiate system: WGS84, Zone48, Unit: metter.

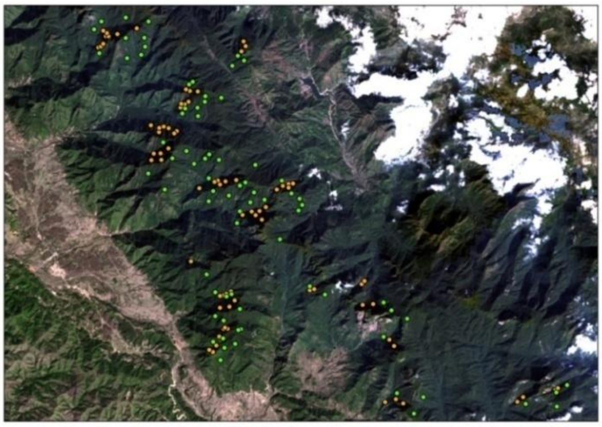

Figure 01. Fansipan range site

2.2. Research data

A dataset of Landsat 8 images is used this research, which are calibrated and provided by the Center for Science and Earth Observation, known as the Earth Observation and Science Resouces (EROS) and by the United States Geological Survey (USGS). The digital number values of images have been converted into the surface reflectance values, 30m spatial resolution and 16 bit radiometric resolution with the projection UTM, Zone 48, hydraulic system.

Table 02. Landsat 8 data

Zones	Image codes	Date	Path/Row	Sun elevation	Hillshade assessments
Fansipan	LC81280452015029-SC20160216211739	29/1/2015	128/045	42.5	Pronounced hillshade
Tam Dao	LC81270452014019-SC20160213222605	19/1/2014	127/045	41.0	Pronounced hillshade
Bac Kan	LC81270452014019-SC20160213222605	19/1/2014	127/045	41.0	Pronounced hillshade
Three southern provinces	LC81240522014062-SC20160215095722	3/3/2014	124/045	56.6	Light hillshade

Source: http://earthexplorer.usgs.gov

2.3. *Selection of sample points*

The sample points are selected based on the topographic features where they are are taken in two sides. One side is the directional side with the hillshade while the opposite side is without the hillshade. The state of forest land had been selected and tested on the Google Earth and SAS Planet.

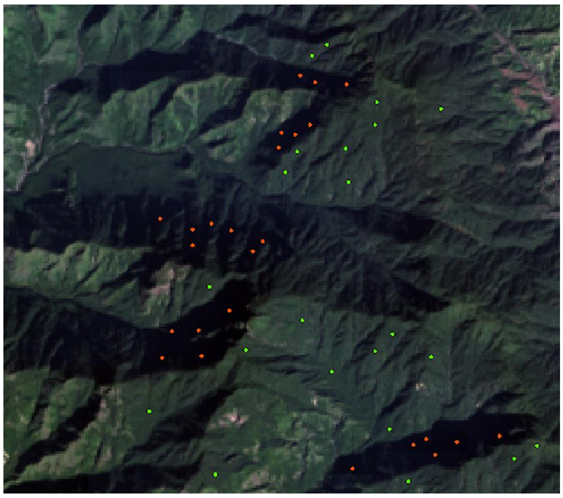

Figure 02. Pronounced hillshade and clear

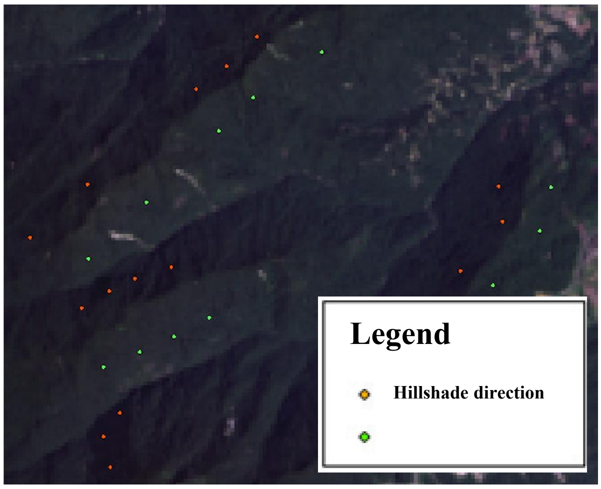

Figure 03. Blurred hillshade and unclear

2.4. Mapping remote sensing indices

The calculation of remote sensing indices on study sites have been conducted using the ArcGIS 10.1 software with the following formula as shown in table 03.

Table 03. Remote sensing indices used this research

ID	Remote sensing indices	Formula	References
1	NDVI: Normalized Difference Vegetation Index	$NDVI = \frac{NIR - RED}{NIR + RED}$	Rouse et at., (1973)
2	NBR: Normalized Burn Ratio	$NBR = \frac{NIR - SWIR2}{NIR + SWIR2}$	USGS
3	NBR2: Normalized Burn Ratio 2	$NBR2 = \frac{SWIR1 - SWIR2}{SWIR1 + SWIR2}$	USGS
4	NDMI: Normalized Difference Moisture Index	$NDMI = \frac{NIR - SWIR1}{NIR + SWIR1}$	Gao (1996), Shaun et al. (2003)
5	SAVI: Soil Adjusted Vegetation Index	$SAVI = \frac{(NIR - RED)(1 + L1)}{(NIR + RED + L1)}$	Huete (1988)
6	MSAVI: Modified Soil Adjusted Vegetation Index.	$MSAVI = \frac{2 * NIR + 1 - \sqrt{(2 * NIR + 1)^2 - 8 * (NIR - RED)}}{2}$	Qi et al. (1994)
7	EVI: Enhanced Vegetation Index	$EVI = \frac{NIR - RED}{NIR + C1 * RED - C2 * BLUE + L}$	Huete et al. (1999)
8	RATIO : Ratio Vegetation Index	RATIO = NIR/RED	Jordan (1969)
9	TVI: Transformed Vegetation Index	TVI = SQRT(NDVI+0.5)	Deering et al. (1975)
10	CTVI: The Corrected Transformed Vegetation Index	CTVI = ((NDVI+0.5).SQRT(|NDVI + 0.5|))/ |NDVI + 0.5|	Perry and Lautenschlager (1984)

11	TTVI: Thiam's Transformed Vegetation index	TTVI = SQRT(|NDVI + 0.5|)	Thiam (1997)
12	DVI: Difference Vegetation Index	DVI = NIR – RED	Richardson and Wiegand (1977)
13	IPVI: Infrared Percentage Vegetation Index	IPVI = NIR/(NIR + RED)	Crippen (1990),
14	NLI : Non-Linear Index	NLI =(NIR^2 – RED)/(NIR^2 + RED)	Goel and Qin (1994)
15	OSAVI: Optimized Soil Adjusted Vegetation Index	OSAVI = 1,5*(NIR – RED)/(NIR + RED + 0.16)	Rondeaus et al., (1996)
16	RDVI: Renormalized Difference Vegetation Index	RDVI = (NIR – RED)/SQRT(NIR + RED	Roujean and Breon (1995)
17	VARI: Visible Atmospherically Resistant Index	VARI = (GREEN – RED)/ (GREEN + RED – BLUE)	Gitelson (2002)
18	MSR: Modified Simple Ratio	MSR = [(NIR/RED) - 1]/[SQRT(NIR/RED) + 1]	Chen (1996)
19	LAI: Leaf Area Vegetation Index	LAI = (3.618*EVI – 0.118)	Boegh et al., (2002)
20	GNDVI: Green Normalized Difference Vegetation Index	GNDVI = (NIR – Green)/ (NIR + Green)	Busch mann and Nagel (1993)
21	GRVI: Green Ratio Vegetation Index	GRVI = NIR/Green	Sripada et at. (2006)
22	RVI: The Simple Ratio Vegetation Index	RVI = RED/NIR	Richardson and Wiegand (1977)

Where: NIR is the Near infrared, spectral reflectance of near-infrared wavelength region (0.7 ÷1.3µm); RED is the Spectral reflectance of Red wavelength; BLUE is the Spectral reflectance of blue wavelength region; GREEN is the Spectral reflectance of green wavelength region; SWIR1 is the Shortwave infrared 1, spectral reflectance of shortwave infrared region 1 (1.3 ÷ 1.9µm); SWIR2 is the Reflectance of shortwave infrared region 2 (1.9 ÷ 2.6 µm);

L1 is the Brightness correction factor (Brightness) ground, L1 = 0.5;

L, C1 and C2 are Atmospheric correction factor, L = 1; C1 = 6; C2 = 7.5.

2.5. Analysis of differences between brighteness-directed and hillshade-directed sample values

This research used non-parametric Mann-Whitney test to assess the effects of the hillshade on image bands.

To analyze and examine whether the influence of the hillshade on the spectral band values and the calibration of remote sensing indices, the research has used the chart box analysis (Box plot) that is established in R software.

III. RESULTS AND DISCUSSION

3.1. Effects of the terrain on the spectral band values

The materials or objects absorb the solar energy, then reflects back to the wavelength in that each object is capable of spectral radiation. However, in the same climatic conditions and time, the terrain becomes as an important factor that may change the ability of the spectral reflectance of objects. The areas with complex terrain, especially mountainous areas usually appear the shadow of the mountains, which prevents the ability to absorb and the solar reflectance of vegetation. Therefore, the values of spectral reflectance of the same object in cases where the shadow of the mountains and the sun lighting are different. The values of "P-value" are statistically calculated through accreditation statistical Mann-whiney recorded in table 03.

Table 03. Mann – Whitney test results of comparing hillshade sides to sunshine sides of Landsat 8 bands

ID	Band	Bac Kan	Tam Dao	Fansipan	Three southern province
1	Band 1	1.39330E-124	2.84600E-85	5.95990E-26	5.82970E-28
2	Band 2	1.18370E-127	1.64320E-102	8.93820E-27	3.26820E-37
3	Band 3	2.17030E-129	6.51050E-109	8.89240E-27	3.38050E-46
4	Band 4	2.19620E-129	6.53220E-109	8.85610E-27	9.51120E-46
5	Band 5	2.16850E-129	6.39050E-109	8.98420E-27	1.89580E-45
6	Band 6	2.16700E-129	6.16030E-109	8.94840E-27	2.69240E-46
7	Band 7	2.18000E-129	6.32220E-109	8.83000E-27	4.54980E-46

From the tested results, it is clear that there is a difference between the values of spectral reflectance surfaces (Surface Reflectance) of two topographic status. $P_{value} < 0.05$ in all bands show the heterogeneity of spectral values on the same subject. It can be seen that although there are differences, but the band 1 is the biggest P_{value} (table 03). Thus, all the bands are significantly influenced by the mountain shadow and the band 1 is the band with at least effects compared to the remaining bands.

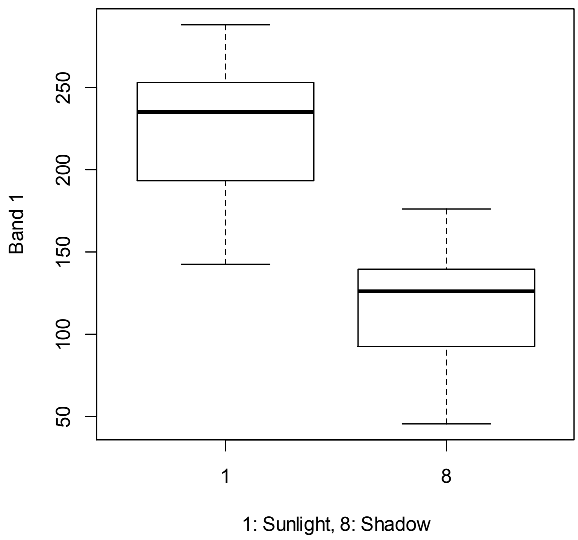

Figure 04. Band 1- Fansipan (more pronounced hillshade)

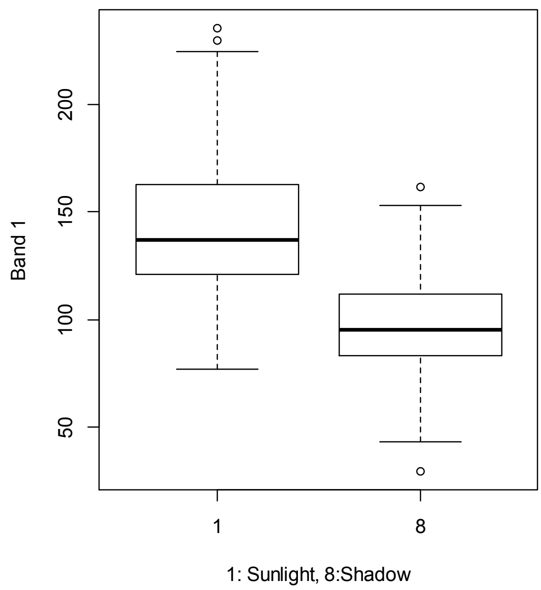

Figure 05. Bands 1 and 3- Southern provinces (lighter hillshade)

As can be seen in figure 04 and figure 05, the image band does not have absolute capabilities in reducing the effects of hillshade. In general, values of the hillshade side are completely lower than those on the sunlight side.

3.2. Effects of hillshade calibration of remote sensing indices

In principle, the remote sensing indices are calculated based on the image bands. However, the calculation formula is a combination of bands with different transformation operations. Therefore, the results of the hillshade calibration may achieve better results than the independent bands. The following table provides the statistical values of the Mann-Whitney remote sensing indices.

Table 04. Mann – Whitney test results on comparing the Landsat 8 indices on the hillsade sides to the sunshine sides in the research sites

ID	Indices	Bac Kan	Tam Dao	Fansipan	Three Southern provinces
1	SAVI	2.1692E-129	6.9417E-109	8.9885E-27	1.5728E-43
2	NDVI	1.8602E-123	1.5326E-94	2.0821E-21	1.9503E-07
3	NDMI	2.5422E-120	4.1001E-97	1.5541E-24	0.872855
4	NBR2	2.3896E-56	6.8122E-27	2.2303E-16	0.011488
5	NBR	4.9545E-119	6.5738E-92	4.2332E-24	0.443877
6	MSAVI	2.1692E-129	6.7542E-109	8.9876E-27	9.0561E-44
7	EVI	2.1694E-129	6.6318E-109	8.9867E-27	6.2621E-44
8	RVI	1.8681E-123	1.514E-94	2.0824E-21	1.8824E-07
9	GRVI	4.495E-127	1.3809E-100	3.3329E-25	1.6321E-10
10	GNDVI	4.4949E-127	1.3809E-100	3.3329E-25	1.6321E-10
11	LAI	2.1694E-129	6.6318E-109	8.9867E-27	6.2621E-44
12	MSR	1.8681E-123	1.514E-94	2.0824E-21	1.8824E-07
13	VARI	6.4121E-77	3.9281E-52	3.495E-26	0.097549
14	RDVI	2.17E-129	7.5392E-109	8.9927E-27	7.6233E-42
15	OSAVI	1.7792E-123	1.4205E-94	2.0822E-21	1.8021E-07
16	NLI	2.2667E-129	1.2881E-108	8.939E-27	1.8409E-33
17	IPVI	1.8681E-123	1.514E-94	2.0824E-21	1.8824E-07
18	DVI	2.1688E-129	6.629E-109	8.9774E-27	2.2618E-44
19	CTVI	1.8602E-123	1.5326E-94	2.0821E-21	1.9503E-07
20	TTVI	1.8602E-123	1.5326E-94	2.0821E-21	1.9503E-07
21	TVI	1.8602E-123	1.5326E-94	2.0821E-21	1.9503E-07
22	RATIO	1.8681E-123	1.514E-94	2.0824E-21	1.8824E-07

P_{values} in the research area with the hillshade and sharply dark mountains are smaller than 0.05. Mountain areas with blurred shadow include the mountain range of 3 provinces of Khanh Hoa, Ninh Thuan and Lam Dong where P_{values} are greater than 0.05, namely NDMI, NBR and VARI with P_{values} are 0.873; 0.444 and 0.098, respectively. With these P_{valeus}, it is concluded that the correction capabilities of hillshades of NDMI, NBR and VARI indices are the best. The following box charts on the analysis levels of the hillshade calibration of remote sensing indices are shown in the below figures.

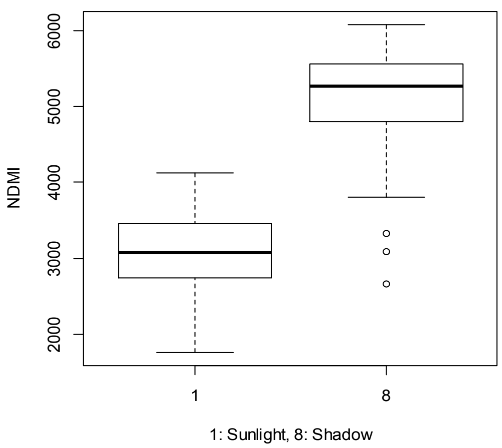

Figure 06. NDMI – Fansipan

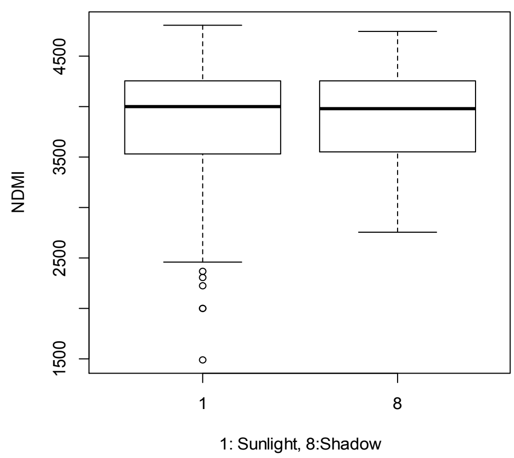

Figure 07. NDMI – three Southern provinces

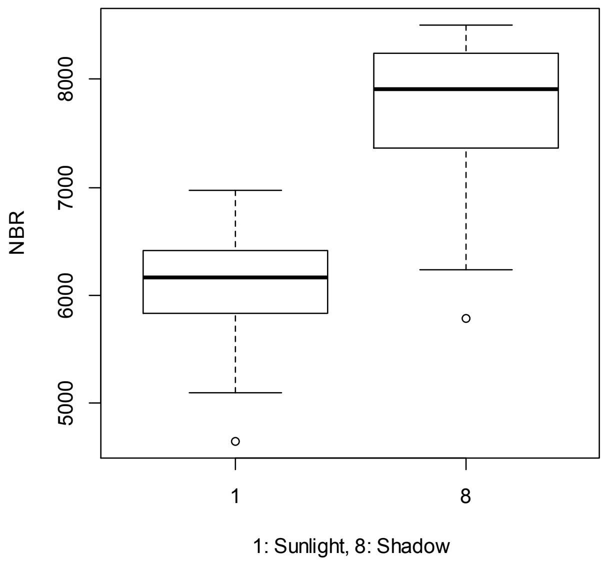

Figure 08. NBR – Fansipan

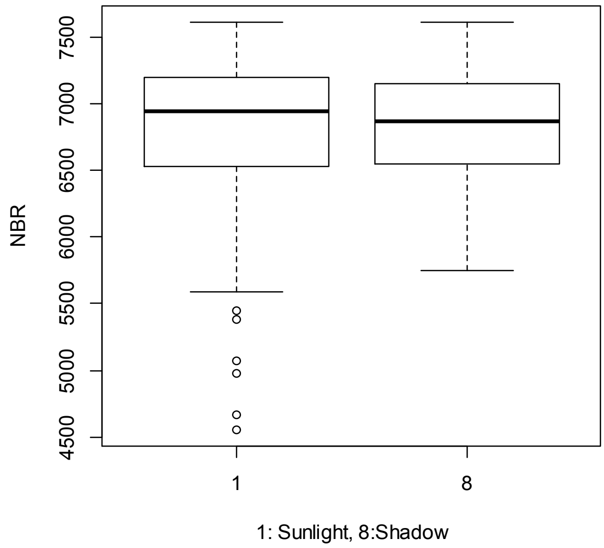

Figure 09. NBR – three Southern provinces

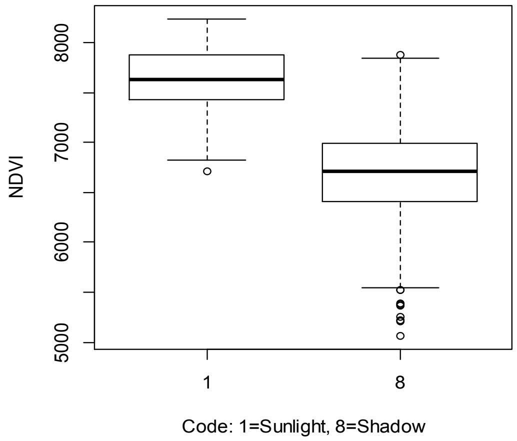

Figure 10. NDVI – Tam Dao

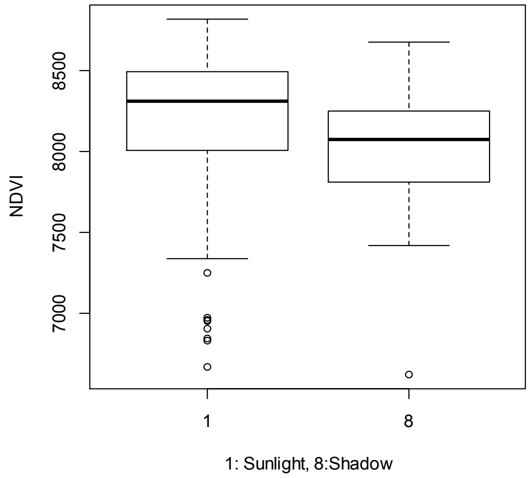

Figure 11. NDVI – Three southern provinces

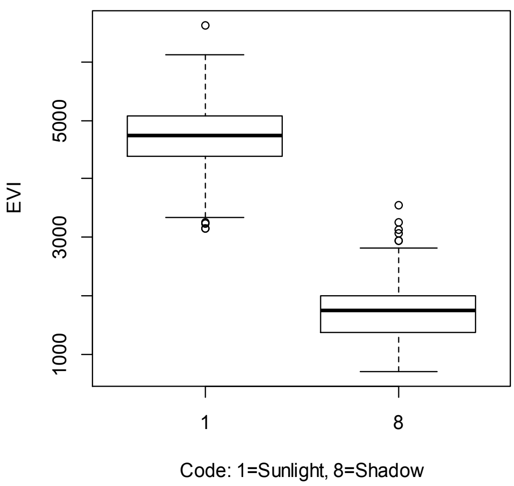

Figure 12. EVI – Tam Dao

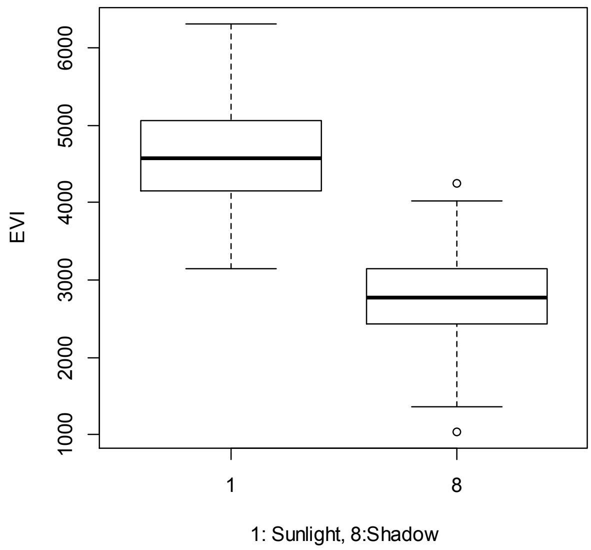

Figure 13. EVI – three Southern provinces

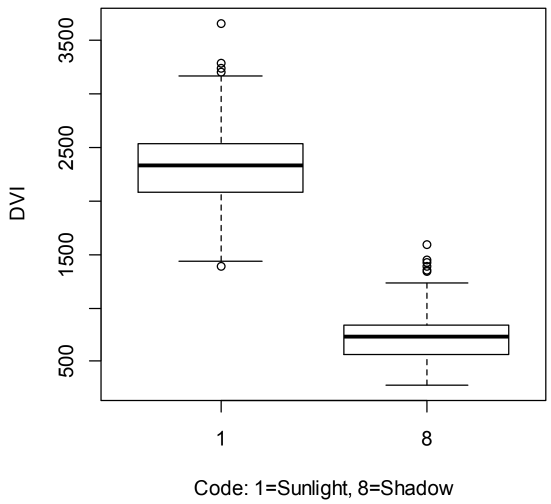

Figure 14. DVI – Tam Dao

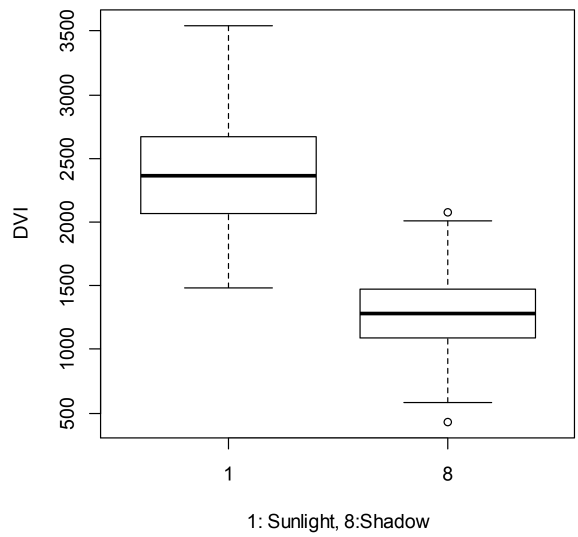

Figure 15. DVI – Three Southern provinces

As shown in the chart boxes, the values of remote sensing indices in the pronounced hillshade areas are significantly different in comparison with sunshine side areas. In particular, in three southern provinces where there are areas with high sun elevation angle, the hillshade effects are relieved. The analysis shows some indices that are capable of remote sensing calibration very well and the charts of NBR and NDMI with the values of the hillshade and without hillshades are the value ranges. There is an absolute difference together both sides. Althought all the remaining indices are the same, the charts and indices of EVI and DVI suggest the calibration levels of the indices is not the same whether weak shadow of the mountains.

IV. CONCLUSIONS

All image bands are valuable in that the values of indices at the hillshade side are lower than that of side without hillshade. All Landsat 8 bands are strongly affected when the shadow of the mountains appears. Remote sensing indices, including NDMI, NBR, NBR2, RVI and VARI, tend to increase the values when the shadow of the mountains appears while other indices, namely NDVI, RVI, GRVI, MSR, OSAVI, IPVI, RATIO, GNDVI, CTVI, TTVI, TVI, MSAVI, SAVI, EVI, LAI, RDVI, NLI and DVI have a tendency to reduce their values as the mountainous shadows appears.

As the pronounced hillshade of the mountains appears in the high and steep mountainous areas, the remote sensing indices are almost unable to calibrate. However, in the case of large azimuth, mountainous shadows appear weak and blurred , then the ability of indices, such as NDMI, NBR, NBR2 and VARI are the best, followed by the group of NDVI, RVI, GRVI, MSR, OSAVI, IPVI, RATIO, GNDVI, CTVI, TTVI and TVI. The eventual group has no ability to calibrate the hillshade, including MSAVI, SAVI, EVI, LAI, RDVI, NLI and DVI.

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ỨNG DỤNG CÁC CHỈ SỐ VIỄN THÁM ĐỂ GIẢM ẢNH HƯỞNG CỦA BÓNG NÚI TRÊN ẢNH VỆ TINH LANDSAT 8

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[3]Công ty Cổ phần Công nghệ Thông tin địa lý EK

TÓM TẮT

Bài báo trình bày kết quả nghiên cứu về ảnh hưởng của địa hình đồi núi đến giá trị các kênh phổ trên ảnh vệ tinh Landsat 8 và ứng dụng các chỉ số ảnh viễn thám trong việc hiệu chỉnh ảnh hưởng của địa hình. Nghiên cứu sử dụng ảnh vệ tinh Landsat 8 đã được hiệu chỉnh và cung cấp bởi Trung tâm Khoa học và Quan sát Trái đất (EROS) và Cục Khảo sát Địa chất Hoa Kỳ (USGS). Nghiên cứu được thực hiện trên ba khu vực điển hình về địa hình đồi núi tại Việt Nam, bài báo sử dụng 22 chỉ số ảnh viễn thám bao gồm NDVI, NBR, NBR2, NDMI, SAVI, MSAVI, EVI, RATIO, TVI, CTVI, TTVI, DVI, IRVI, NLI, OSAVI, RDVI, VARI, MSR, LAI, GNDVI, GRVI và RVI nhằm đánh mức độ hiệu chỉnh bóng núi cho từng chỉ số. Kết quả cho thấy khi có cùng một kiểu trạng thái thì giá trị phổ các kênh ảnh bên bóng núi đều thấp hơn so với bên hướng mặt trời chiếu sáng. Bóng núi càng đậm thì độ chênh càng lớn. Trường hợp bóng núi mờ, các chỉ số NDMI, NBR, NBR2 và VARI có khả năng giảm thiểu được ảnh hưởng của bóng núi là tốt nhất, tiếp theo là nhóm các chỉ số NDVI, RVI, GRVI, MSR, OSAVI, IPVI, RATIO, GNDVI, CTVI, TTVI và TVI. Nhóm các chỉ số còn lại gồm MSAVI, SAVI, EVI, LAI, RDVI, NLI và DVI đều bị ảnh hưởng mạnh mẽ của địa hình ngay cả khi bóng núi xuất hiện mờ nhạt. Kết quả bài báo là tư liệu tham khảo tốt để lựa chọn các chỉ số ảnh viễn thám, phục vụ nghiên cứu trong quản lý tài nguyên và môi trường, tại các khu vực có địa hình đồi núi phức tạp.

Từ khóa: Ảnh hưởng của địa hình, giảm ảnh hưởng chỉ số ảnh viễn thám, hiệu chỉnh, Landsat.

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