

## **Evaluation of Alternative Simple Band Ratios**

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### **ABSTRACT**

Vegetation indices are commonly applied to remote sensing data and their application is based upon well established image processing theory and methodology. Simple band ratio vegetation indices allow for consistent and uniform data processing and analysis. However, it was hypothesized that many of these standard vegetation indices (e.g., SR, NDVI and SAVI) may not produce results any different from other simple ratios calculated from any pair of spectral bands in a given image. To test this, all possible combinations of simple band ratios were created with SPOT 5 imagery using Idrisi software. The resulting simple ratio indices were then correlated against each other and further examined. Results of this study indicate that all simple band ratio combinations are highly correlated with one another and tend to describe the same land surface phenomena.

**KEYWORDS:** *vegetation indices, NDVI, SPOT*

## INTRODUCTION

Processing digital imagery and the subsequent interpretation of these data can provide valuable information and results in savings in both time and money. The use of vegetation indices to interpret satellite imagery and validate these interpretations with *in situ* data further increases these benefits. However, the effectiveness of vegetation indices is the subject of much scrutiny as scientists continue to experiment with various combinations of band ratios, often times adjusting indices to optimize outcomes under specific soil or vegetation conditions. It is believed that isolating one vegetation index versus another as a single effective derivation of vegetation for all digital images may sacrifice data integrity. Yet, the Normalized Difference Vegetation Index (NDVI) was established for the purpose offering a standardized product that could be uniformly applied worldwide. The NDVI ratio was created using the following calculation (Jensen, 2000):

$$\text{NDVI} = \frac{\text{NIR} - \text{RED}}{\text{NIR} + \text{RED}}$$

As a simple band ratio (SBR) (meaning that only two bands are involved in the algorithm and that the index is a result of the quotient of the difference over the sum), consistent in its results, this formula provides uniform vegetation analysis across a variety of data collection scenarios and is applicable to a large number of satellite platforms. Its success and comparative simplicity suggests equally effective indices may be formed with other combinations of spectral bands which may produce similar results.

## MATERIALS AND METHODS

To test this, all combinations of SBR indices were calculated using the spectral bands available within SPOT 5 imagery. Once calculated, results were analyzed for each pair of SBR's for correlation (using adjusted  $R^2$ ) and for their pixel dispersion from the line of best fit (i.e., end members). Results were also analyzed to determine whether a significant difference exists between the derived SBR's. It is noted that other equally well known indices such as the Simple Ratio (SR) and Soil Adjusted Vegetation Index (SAVI) warrant further research as alternative spectral band combinations. However, for the purposes of this evaluation, SBR's were calculated following the standard NDVI equation (i.e., the difference of band A and band B, divided by the sum of band A and band B).

### *Imagery*

Image selection was based on knowledge of the area and vegetation for *in situ* data verification. SPOT 5 satellite imagery was acquired for the U.S. Sheep Experiment Station near DuBois, Idaho on August 5, 2005. The imagery was georectified using nearest neighbor resampling (RMSE = 3.48) and then corrected for atmospheric effects using the Cos(t) algorithm in Idrisi (Chavez 1996). The imagery was then projected into Idaho Transverse Mercator (NAD 83). Vegetation studies of the area indicate the dominant plant species are Mountain Big Sagebrush (*Artemisia tridentata* Nutt. ssp. *vaseyana* (Rydb.) Beetle.), threetip sagebrush (*Artemisia tripartita* Rydb.), Antelope bitterbrush (*Purshia tridentata* (Pursh) DC.), bluebunch wheatgrass (*Pseudoroegneria spicata* (Pursh) A. Löve), thickspike wheatgrass (*Elymus lanceolatus* (Scribn. & J.G. Sm.) Gould), Sandberg bluegrass (*Poa secunda* J. Presl), arrowleaf balsamroot (*Balsamorhiza sagittata* (Pursh) Nutt.), and tapertip hawksbeard (*Crepis acuminata* Nutt. ssp. *acuminata*) (West and Young, 2000, Wright and Bailey, 2004, Weber, et al 2007).

### *Image Processing and Analysis*

Using Idrisi Kilimanjaro's image calculator and the imagery described above, SBR's were systematically determined for all possible combinations of Green, Red, NIR and SWIR bands (Table 1). Regression analysis (REGRESS) was then used to determine the correlation coefficient between all pairs of SBR's (Table 2) and from these analyses the coefficient of determination ( $R^2$ ) was calculated and used for subsequent comparison.

**Table 1. Simple Band Ratios (gray areas indicate SBR's that were not calculated)**

	Green	Red	NIR	SWIR
Green		<u>red-grn</u> <u>red+grn</u>	<u>nir-grn</u> <u>nir+grn</u>	<u>swir-grn</u> <u>swir+grn</u>
Red	<u>grn-red</u> <u>grn+red</u>		<u>nir-red</u> <u>nir+red</u>	<u>swir-red</u> <u>swir+red</u>
NIR	<u>grn-nir</u> <u>grn+nir</u>	<u>red-nir</u> <u>red+nir</u>		<u>swir-nir</u> <u>swir+nir</u>
SWIR	<u>grn-swir</u> <u>grn+swir</u>	<u>red-swir</u> <u>red+swir</u>	<u>nir-swir</u> <u>nir+swir</u>	

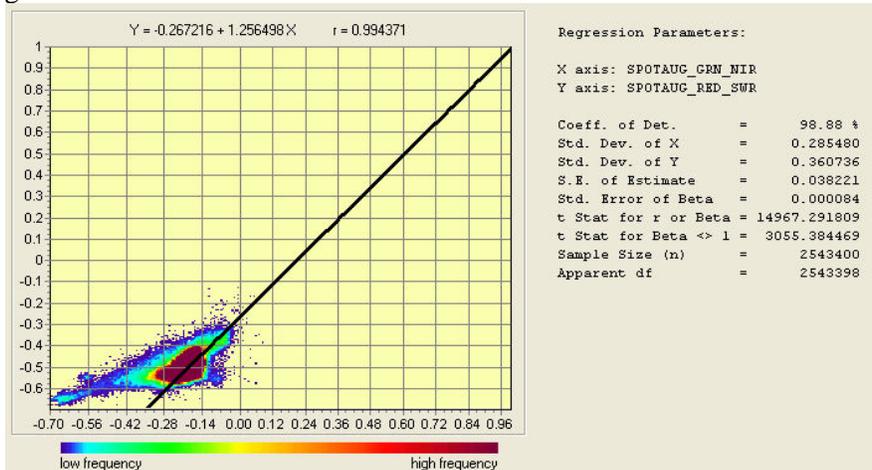
- a. GNDVI (Hunt et al. 2007)
- b. NDVI (Tucker 1979)
- c. NDII or NDWI (Gao 1996, Hunt and Yilmaz 2007)
- d. NDSI (Riggs et. al., 1994, Dozier 1989)

**Table 2. All Possible SBR Combinations compared in this study (gray areas indicate redundant combinations)**

	Grn_Red	Grn_Nir	Grn_Swir	Red_Grn	Red_Nir	Red_Swir	Nir_Grn	Nir_Red	Nir_Swir	Swr_Grn	Swr_Red	Swr_Nir
Grn_Red												
Grn_Nir												
Grn_Swir												
Red_Grn												
Red_Nir												
Red_Swir												
Nir_Grn												
Nir_Red												
Nir_Swir												
Swr_Grn												
Swr_Red												
Swr_Nir												

**RESULTS AND DISCUSSION**

The resulting statistical information (r-values and coefficients of determination [R<sup>2</sup>]) and pixel scatter plot distributions were analyzed for variation and similarities between SBRs. Three examples of these results are shown in Figures 1-3.



**Figure. 1 GRN NIR and RED SWIR pair-wise comparison.**

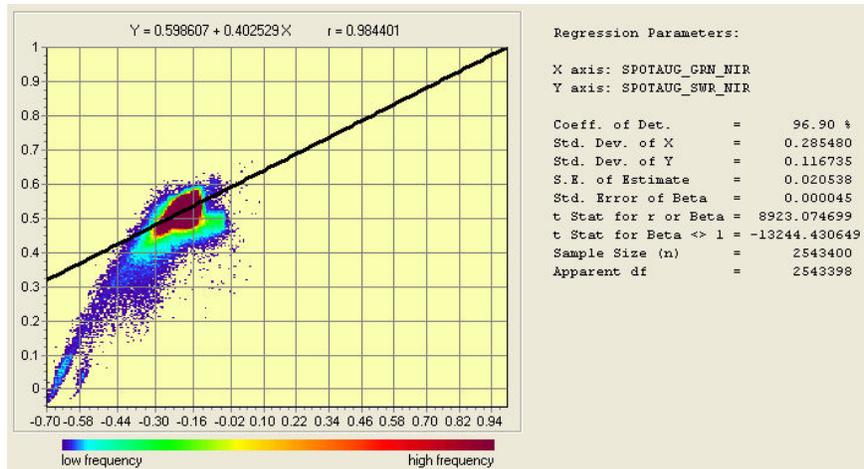


Figure 2. GRN NIR and SWR NIR pair-wise comparison.

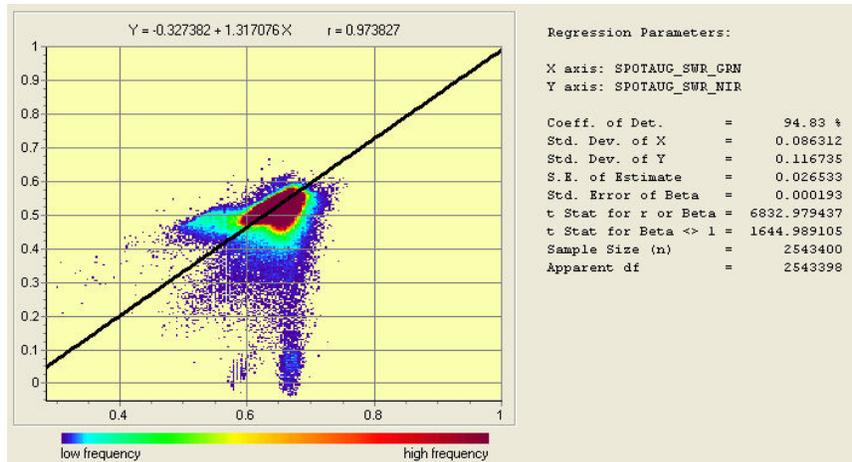


Figure 3. SWIR GRN and SWR NIR pair-wise comparison.

Regression analysis and the resulting  $R^2$  values indicated high correlation between all SBR pairs (Table 3) with coefficients of determination ranging from a low of 0.88 to a high of 0.99.

Table 3 – The  $R^2$  value for all SBR correlation calculations

	Grn_Red	Grn_Nir	Grn_Swr	Red_Grn	Red_Nir	Red_Swr	Nir_Grn	Nir_Red	Nir_Swr	Swr_Grn	Swr_Red	Swr_Nir
Grn_Red												
Grn_Nir	0.98											
Grn_Swr	0.99	0.99										
Red_Grn	0.96	0.97	0.98									
Red_Nir	0.94	0.98	0.97	0.98								
Red_Swr	0.97	0.98	0.99	0.99	0.98							
Nir_Grn	0.97	0.93	0.96	0.95	0.89	0.95						
Nir_Red	0.98	0.92	0.96	0.93	0.88	0.94	0.99					
Nir_Swr	0.98	0.97	0.99	0.98	0.95	0.99	0.98	0.97				
Swr_Grn	0.96	0.92	0.93	0.93	0.89	0.92	0.96	0.99	0.94			
Swr_Red	0.95	0.90	0.91	0.88	0.84	0.88	0.94	0.96	0.91	0.98		
Swr_Nir	0.94	0.96	0.94	0.93	0.95	0.93	0.89	0.89	0.91	0.94	0.92	

A review of paired-SBR plots revealed some emergent characteristics within the majority of pair-wise SBR comparisons. Among the most notable was an isolated segment of pixels (end-members) extending from the central cluster and appearing as a tail (Figure 4).

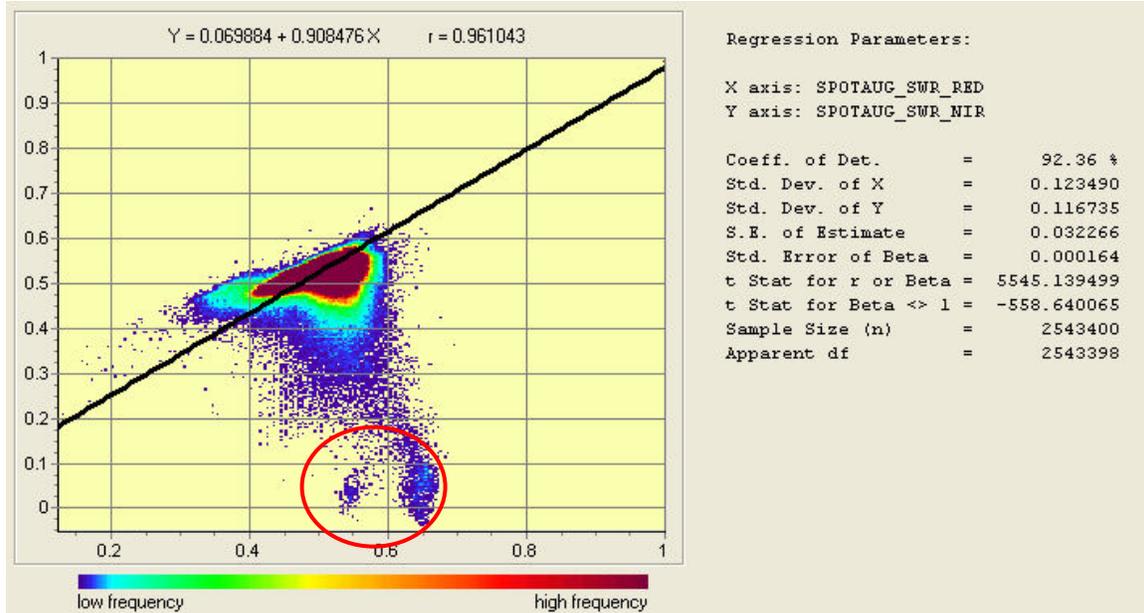


Figure 4. An isolated end-member tail revealed during pair-wise SBR comparisons.

It was hypothesized that some unique land surface characteristic was most likely the cause of the end member tail. To investigate this, the geographic features representing the end member tail needed to be identified and so logical expression was calculated in Idrisi Kilimanjaro to isolate these pixels. To accomplish this (cf. Figure 4) all pixels in the SWR\_NIR SBR (cf. Y-axis in the figure 4) with values  $\leq 0.10$  were identified using the Idrisi raster calculator. Next, all pixels in the SWR\_RED SBR (cf. X-axis in the figure 4) with values  $\geq 0.60$  were similarly selected. Next, a Boolean AND process was calculated using the results of the first two logical expressions resulting in a new raster layer which isolated the end member tail of interest. The boolean image that was returned had pixel values of one in all areas corresponding to the end member tail and zero's elsewhere.

The resulting boolean image did not appear as a salt-and-pepper scatter of pixels but rather a tight cluster of pixels within the northwest quadrant of the imagery. The raster layer was opened in ArcGIS along with National Agricultural Imagery Program (NAIP) ortho-imagery (acquired in 2004). From this visual analysis it was apparent that the cluster of pixels representing the end-member tail was an irrigated farm field. This was validated in the field by visiting the site and speaking with the land owner about the condition of the field on or around August of 2005 who informed us that the field is (and was) irrigated alfalfa.

## CONCLUSIONS

Close and repeated review of image processing results revealed that SBR's derived from combinations of the green, red, NIR, and SWIR bands did not significantly differ from one another regardless of the specific SBR calculated. However, there appears to be some promise of improved land cover differentiation through the use of differenced-SBR's or SBR-quotients. Applying the former to the end-member tail discussed in this paper would yield pixel values near zero for all well correlated pixels (those closest to the line of best fit) and increasing larger values for those pixels representing the end-member tail. Applying the latter (SBR-quotients) would result in pixel values near one for all well correlated pixels and increasingly larger values for the pixels representing the end-member tail. Using the example described in this paper, SBR-quotient values would have a maximum of 31 which, in contrast to the well-correlated pixels ( $\sim 1.0$ ), is quite different. Additional research appears to be merited into the applicability of SBR-quotients as a means of identifying unique land features.

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