

Analysis of Vegetation and Atmospheric Correction Indices for Landsat Images

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ABSTRACT

Vegetation and Atmospheric Indices are mathematical combinations of remote sensing bands which are useful in distinguishing the various values of the spectral reflectance. In this paper we study how the applications of various atmospherically corrected indices and vegetation indices can aide in retrieving the amount of surface reflectance from a remotely sensed image. Specifically, this paper studies and compares three vegetation indices and one atmospherically resistant index. These indices include the Normalized Difference Vegetation Index (NDVI), the Soil Adjusted Vegetation Index (SAVI), the Green Vegetation Index (GVI), and the Atmospherically Resistant Vegetation Index (ARVI), respectively. The algorithms attempt to estimate the optical characteristics of Thematic Mapper (TM) imagery. It will be shown that the NDVI algorithm followed by the ARVI correcting algorithm provided significant improvements in the tonal qualities of the retrieved images. The results are presented on 1987 TM images over the Kennedy Space Center (KSC) and are compared with a set of United States Geological Survey (U. S.G.S) maps.

L INTRODUCTION

The calculation of vegetation densities from remotely sensed imagery has been used for developing and validating various studies regarding land cover dynamics such as global carbon modeling, biogeochemical cycling, hydrological modeling, and classification response modeling [1]. However, the remote imagery collected by satellites are often contaminated by the effects of absorption and scattering of radiation from the earth's surface by surrounding atmospheric particles. This scattering effectively reduces the amount of radiation in a given scene, and therefore reduces the amount of surface reflectance from the scene. For any given material, the amount of radiation that is reflected from a substance will vary with wavelength [6]. This important property of matter allows for the possibility that different substances or classes can be identified and separated by their spectral signatures. Therefore at certain wavelengths, green vegetation may reflect more light than water or sands, however at another wavelength it absorbs more light and therefore has a reduced reflection. One method that is useful in differentiating the various values of spectral reflectance in a remote image is the application of vegetation and atmospherically resistant indices [5].

The purpose of this paper is to investigate the usefulness of three basic vegetation indices for KSC images and one atmospherically resistant index: the Normalized Vegetation Index (NDVI), the Soil Adjusted Vegetation Index (SAVI), the Green Vegetation Index (GVI), and the Atmospherically Resistant Vegetation Index (ARVI) in the mapping of various vegetation around the Kennedy Space Center. The images are of dimensions of 512 rows by 512 columns.

The resulting vegetation maps were compared with a set of United States Geological Survey (U. S.G.S) maps, in order to determine how effective each algorithm proved in determining the amount of vegetation that actually resided in the geographic structures. The

U. S.G.S. map serves as the ground truth and displays the regions of vegetation and other landcover materials.

The Normalized Difference Vegetation Index (NDVI) was found using the following equation[4]:

$$NDVI = (TM4-TM3)/(TM4+TM3),$$

where TM3 and TM4 represent the reflectance **values** of a pixel in the TM band 3 and the TM band 4 images, respectively. In the image bands, the numerical pixel value (0 to 255) was taken to be the corresponding reflectance value. The NDVI algorithm was applied on a pixel by pixel basis to the TM bands in order to obtain the resulting set of TM data. When evaluating the NDVI results, a large reflectance value is represented by a high concentration of vegetation in the corresponding geographic area. Therefore, the higher the pixel intensity value, the more vegetation coverage was found to exist within that individual pixel.

The Soil Adjusted Vegetation Index (SAVI) was applied to the TM bands in a similar fashion. The SAVI images were based on the following equation[1]-[2]:

$$SAVI = \frac{(TM4 - TM3)(1+L)}{(TM4 + TM3 + L)},$$

where L is a correction factor which ranges from 0 for very high vegetation coverage to 1 for very low vegetation coverage [1]. The (1 + L) multiplicative term is used in order for the range of the vegetation index to be from 1 to -1. This is done so that SAVI reduces to NDVI when the adjustment factor goes to zero. A value of 0.5 was used for this research since it was considered typical for intermediate vegetation coverage.

The Green Vegetation Index (GVI) was also applied to the various TM 1, TM2, TM3, TM4, TM5, and TM7 bands. The Green Vegetation Index is an algebraic function combining the previously listed TM bands. The equation for evaluating the resulting GVI data set is given by[1]:

$$GVI = (-0.2848*TM1) - (0.2435 *TM2) - (0.5436 *TM3) + (0.7243 *TM4) + (0.0840 *TM5) - (0.180*TM7).$$

The Atmospherically Resistant Vegetation Index (ARVI) is one of a family of built-in atmospheric correcting indices. The form of the equation for ARVI is similar to that of NDVI with the exception that the TM band 3, the red reflectance band, in NDVI is replaced with a term combining TM 1, TM3, and γ . The ARVI images were found in a corresponding fashion based on the following equation [4]:

$$ARVI = (TM4 - rb)/(TM4 + rb),$$

with rb defined as:

$$rb = TM3 - \gamma(TM3 - TM1).$$

The value of γ was varied between 0.5 and 1.0. However, only the results using $\gamma=1.0$ are presented here.

II. NDVI RESULTS

The water covered areas of the NDVI image were generally represented by low reflectance values, near black in color. The NDVI image revealed that some parts of the water contained some amount of vegetation within the pixels. Possible reasons for the lighter areas are due to shallow waters consisting of underwater vegetation or floating vegetation. Also, some of areas mapped as water by the U.S.G.S. were only inundated part of the year. The vegetated areas of the NDVI image are represented by the medium gray levels. The areas of high vegetation on the NDVI image did correspond well to the mapped vegetation of the U.S.G.S. map. The highest

intensity of pixels, near white in color. represent areas of scarce or zero vegetation. These areas of zero vegetation include sands, highways, and buildings, see Figure 1.

The SAVI image contained similar comparisons to that of the NDVI image. The SAVI corrected image again represents water coverage with low intensity pixels (near black). In some of the water areas, the SAVI image was not able to discern the neighboring land pixel intensities. However, unlike the NDVI image, the vegetated areas of the SAVI image indicated intensity levels where less vegetation occurred. These intensity levels of the SAVI image could be closely matched to that of the U.S.G.S. maps which indicate that these areas contain more soil and are less vegetated, see Figure 2.

The GVI image resulted in pixel intensity values in which some of the areas of water could not be discerned with that of neighboring land pixels. The GVI image was not useful in determining the highly vegetated areas from areas which contained medium vegetation coverage, see Figure 3.

The ARVI results with a gamma (γ) representation of 1.0 showed vegetation and water coverage areas similar to that of the NDVI image. The areas of zero vegetation exhibits higher pixel values similar to NDVI. However, errors did occur in the water areas. The water areas of the ARVI image tend to have higher intensity levels than that of the NDVI image, see Figure 4.

VI. CONCLUSIONS

In general, this project accomplished its goal of using vegetation and atmospherically resistant indices as a unit of measure for recovering and examining the reflectance values of vegetation in the geographic region of interest. NDVI appeared to distinguish vegetation, sands, and water areas fairly well. This study also determined that ARVI also proved well in determining vegetated and water areas. SAVI was useful in determining the less vegetated lands, however, some of the water areas and the neighboring land areas had similar pixel intensities and were difficult to discern between the two. The GVI image appeared not to be useful for this geographical area under study.

ACKNOWLEDGMENTS

This project was partially funded by a grant from NASA, Project #NAG10-0 155.

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Figure 1: NDVI Image



Figure 2: SAVI Image ($L=0.5$)



Figure 3: GVI Image



Figure 4: ARVI Image ($\gamma=1.0$)