A NEW VEGETATION INDEX FOR REMOTE SENSING

JOJI IISAKA and TAKAKO SAKURAI-AMANO*

Pacific Forestry Centre, Natural Resources Canada
506 West Burnside Road, Victoria, BC., Canada V8Z 1M5
Jiisaka@pfc.forestry.ca
Phone. +250-363-0625
Fax +250-363-0797

* Earth Observation Research Center/NASDA
Roppongi First Bldg., 13F
1-9-9 Roppongi, Minato-ku, Tokyo, Japan 106-0032
Email: takako@eorc.nasda.go.jp
TEL：+03－3224－7021
Fax：+03－3224－7052

Abstract:

Global vegetation change is one of major global concerns. Remote sensing images provide an efficient and useful data source to estimate global vegetation covers, and a number of methods have been proposed to estimate them. Among them, the NDVI is one of the most popular indices, and it is_easy to calculate with simple image computing. However, this index is very much affected by the radiometric environment of sensing such as atmospheric conditions and the sun illumination angle. Therefore, it is not appropriate to apply the NDVI to investigate seasonal changes. This paper discusses these problems and proposes an alternative index, MODVI(Modified Vegetation Index) , that is less affected by radiometric environment changes. An experiment was conducted to compare these two indices using temporal Landsat TM sub-scenes.

1. INTRODUCTION.

There are two major approaches to evaluate vegetation covers from remote sensing data: the one is to classify the observed data into the categories of discrete pre-defined ground cover types. The other is to use indices of continuos parameters, and this approach is used more with remote sensing data of coarse spatial resolution such as AVHRR data and TM data. The latter methods are widely used to monitor the global vegetation , as the methods are easy to process remote sensing images and could extract biological information such as biomass- related information

2. A NEW VEGETATION INDEX.

2.1 LIMITATION OF THE NDVI.

Among various vegetation indices, the NDVI is most popular index, because the algorithm to derive the NDVI is simple and easy to generate global vegetation maps .

The NDVI is defined as a ratio between spectral red band and near -infrared band(Tucker, Jim, 1979)

$$NDVI = \frac{(Ch4 - Cch3)}{(Ch4 + Ch3)} \qquad (1)$$

Here, $Ch4$ and $Ch3$ are the data of band 4(Near-infrared) and band 3(Red), respectively.

Most of other types of vegetation indices are also defined as functions based on this ratio or include additive terms between the band 4 and 3 data.

2. 2 NDVI AND MODVI

As seen in the equation (1), the NDVI is an alternative presentation of spectral data. Ordinary, every multi-spectral data is presented in a Cartesian spectral space using the spectral data as Cartesian coordinates(for an example, (*Ch*3, *Ch*4)). This data point can be presented in different values , if a different coordinate system is used

Let's rotate the spectral axis's to 45 degree with anti-clockwise, as shown in Figure 1. These axis's represent lines of *Ch*4-*Ch*3=0and *Ch*3+ *Ch*4=0. The data point can be presented as (a, b), using the new Cartesian coordinates.

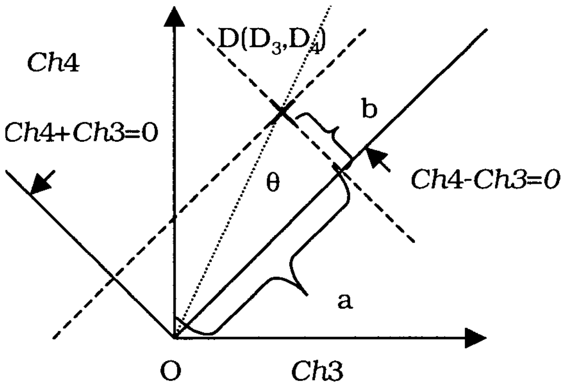


Figure 1. Data Presentation in a scatter plot and coordinate system

Here,$a\sqrt{2}=(D_4-D_3)$, and $b\sqrt{2}=(D_4+D_3)$,

and , D_4 and D_3 are the spectral components of the data point D($D_3^2+D_4^2=a^2+b^2$).

However, as seen in the definition of the NDVI, the numerator corresponds to the distance of a line, Ch4-Ch3=a, from the line, Ch4-Ch3=0, and the denominator corresponds to the distance of a line, Ch4+Ch3= b, from the line, Ch4+Ch3=0.

Therefore, the NDVI is the tangent of the angle θ between a line from the origin of spectral space O to the data point D and the diagonal line of *Ch*4-*Ch*3=0, as illustrated in Figure 1. In other words, the data points which reside along the line $\overline{OD}$ have same NDVI. As the angle is limited between 45° and -45° , the range of the NDVI is between 1 and -1.

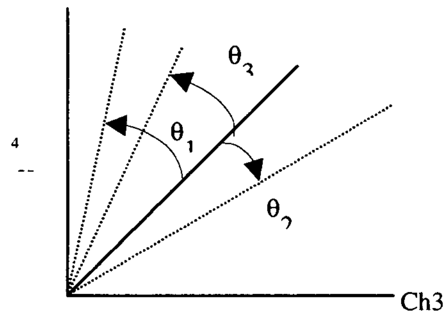


Figure 2. The NDVI presentation in a scatter plot. Each dashed line corresponds to a specific NDVI value.

In other words, the vegetation cover presentation with the NDVI is equivalent to divide the spectral space into fun-shape regions based on a range of the angles.

Figure 3 illustrates an actual scatter plot derived from the TM image of band 4 and band 3 of the study area. Unfortunately, actual scatter plot does not support this assumption. The vegetation data distribute along a line , but it does not intersect the origin of the spectral space , rather intersect with the spectral point of the very dark object such as water class.

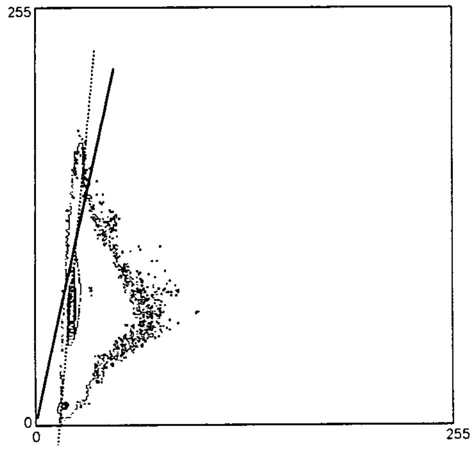


Figure 3. Actual Scatter Plot derived from a sub-image of the study area between TM band 4 and 3.

Another problem of NDVI is the stability against radiometric variation such as seasonal changes of sun illumination and variability of path radiance in the atmosphere.

In general, the energy D detected by the sensor can be approximated as:

$$D=\alpha IR+\beta \qquad (2)$$

Here, α is attenuation coefficient of the atmosphere along the path from the sun to the terrain objects and the path from the objects to the sensor. The I denotes the intensity of the sun illumination reached to the earth, R is the reflectance of the objects of interest, and β is the contribution of path radiance. The β is very much affected by the quality of the atmosphere such as the amount of water vapor, water drops and dust contents., and varies at every moment and every pixel locations.

Therefore, the denominator of the NDVI is not stable enough to investigate temporal and seasonal changes of vegetation covers, because the denominator includes an additive term of the two spectral bands.

It is also difficult to expect that practical and operational atmospheric correction methods will be available in near future, because conventional atmospheric correction methods require extensive parameter values, and the behavior of atmosphere is basically chaotic phenomena.

Therefore, it is required to develop a new vegetation index or other indices to analyze the vegetation covers and those indices should be stable against radiometric environment changes and have better back ground rationales with acceptable computational loads.

The author is proposing an alternative vegetation index that is less effected by radiometric changes such as atmospheric conditions and sun illumination angle differences named as a modified vegetation index (MODVI).

The original bands images are offset by the spectral values of the dark spectral end member class such as water bodies. The MODVI is defined as a ration between the two band sifted images.

$$MODVI=\frac{(Ch4-W_4)}{(Ch3-W_3)} \qquad (3)$$

Although the attenuation coefficients ↦'s are spectral band dependent, the ratio between ↦'s of each bands can assumed as a constant. Therefore, the equation of the MODVI is more stable against radiometric variations as long as the values of the darkest objects can be estimated .

3. EXPERIMENTS

3-1-: STUDY AREA

The study area of this experiment is the watershed area of Greater Victoria, District on Vancouver Island , BC., Canada. The size of the sub-image is 800x 800 pixels. This area is located in the suburban area of Victoria, and protected from public access, but a lot of logging activities is observed.

3.2 DATA SETS.

In this study, two images of Landsat TM data were investigated. The one is acquired in September 4, 1990, and the other is acquired in August 4, 1993.
The months of these data acquisition were ones of best months in terms of local climate.

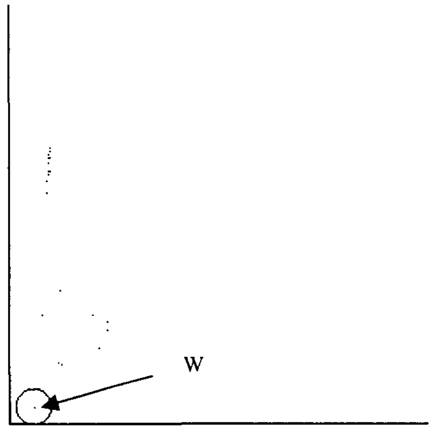
3.3 W VALUE ESTIMATION

The key to estimate the MODVI is to estimate reliable spectral values of the darkest objects in a scene.

In general, water class shows specific spectral characteristics in TM band 4 (near infrared band) as typical darkest objects. Water pixels include mostly only single material, water, and their spectral values can be considered as darkest objects in a scene. Generally, the location of this value can be derived from the bounds of spectral histogram of TM band 4, but the response from water class is usually small enough comparable with sensor noise level.

In this study, a local peaks from the scatter plot between TM band 3 and 4 are to be detected . At first , an image smoothing operation was applied to remove minor peaks. Small peaks(less frequent pixels) are also are removed , because they would be minor objects in the scene. Then a peak closest to the origin is selected to present the darkness end point value in this study.

Figure 4 illustrates the location of local peals and the location of the darkest object W.
With this approach, the values of W class are determined as (17,12) for the scene of 1993, and (10,4) for the 1990 scene.



location of local peaks:

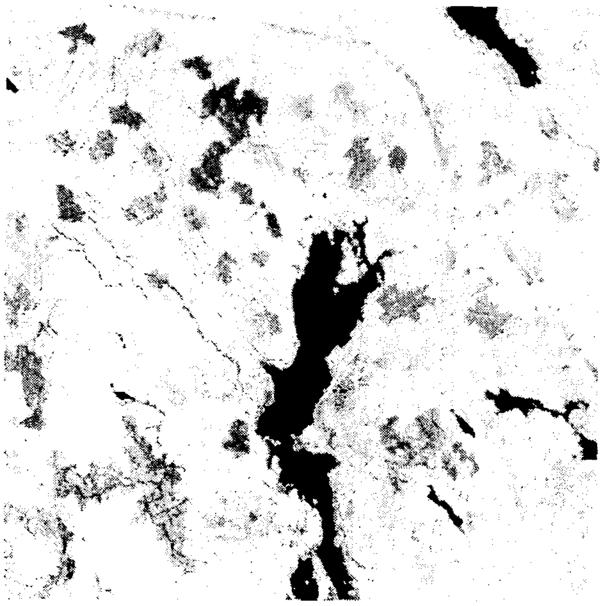
Figure 4. The darkest point (Water point)estimation from TM band 3 and 4 scatter plot.
(each point indicates the location of local peaks of the scatter-plot (see Figure 3) .
W indicates the water class selected.

3.3 NDVI AND MODVI

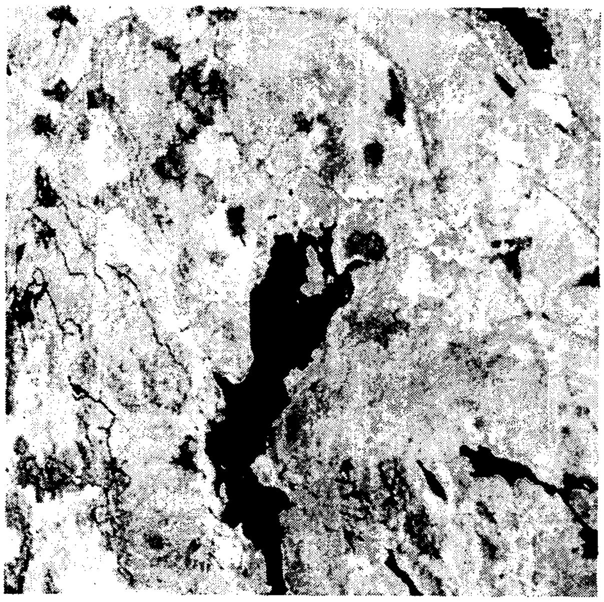
An experiment was conducted to compare the results derived from conventional methods and the new method using a sub-scene of the study area.

Figure 5(a) and 5(b) illustrate the images of NDVI, and Figure 6(a) and 6(b) show the images of MODVI.

It has been identified that the MODVII images provided more details of forest covers and other features through field survey and air-photo interpretation. The blob-like features in the MODVI are bare rocks and small communities of deciduous trees mixed in the forest of coniferous trees.

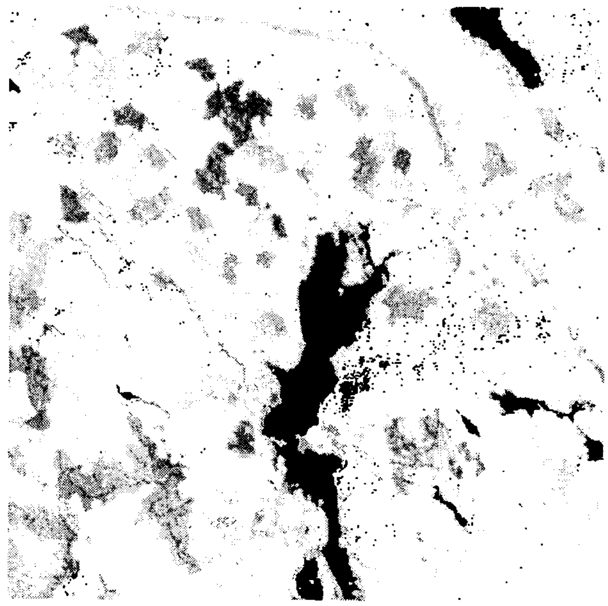


(a) NDVI of 1990

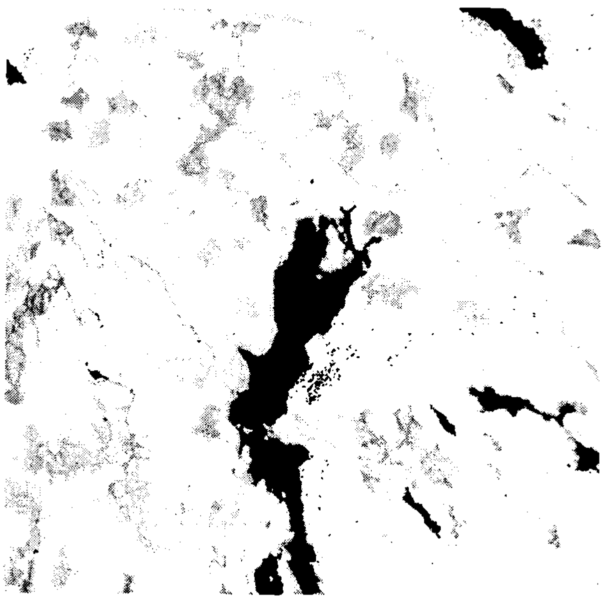


(b) NDVI of 1993

Figure 5. The NDVI images derived from the Landsat TM data.



(a) MODVI of 1990



(b) MODVI of 1993

Figure 6. The MODVI images derived from the Landsat TM data.

In order to clarify the differences between the NDVI and MODVI, histograms of NDVI and MODVI were estimated as shown in Figure 7(a) and (b).

Although there is a three-year difference between the two data sets and some ground cover changes are observed, it can be assumed that the major ground cover types in a scene should be same and ground cove changes might appear as minor features in the histogram.

As seen in the Figure 7(a) for the NDVI, the locations of peaks are different between the data set of 1990 and 1993. The patterns of the histogram distribution are very close, but some differences are observed. The figure 7(b) illustrates the histograms of MODVI for 1990 and 1993.

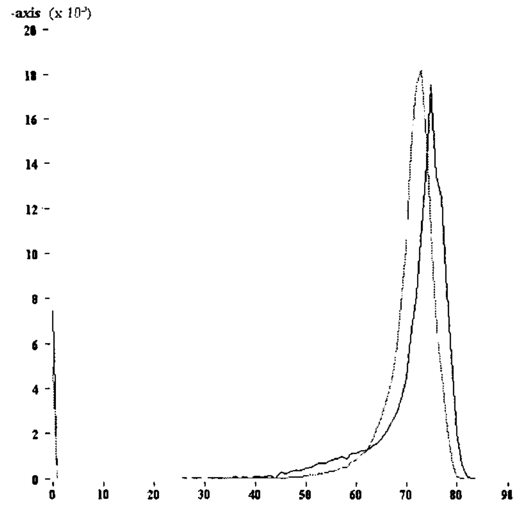


Figure 7(a) The histogram of NDVI for 1990 and 1993

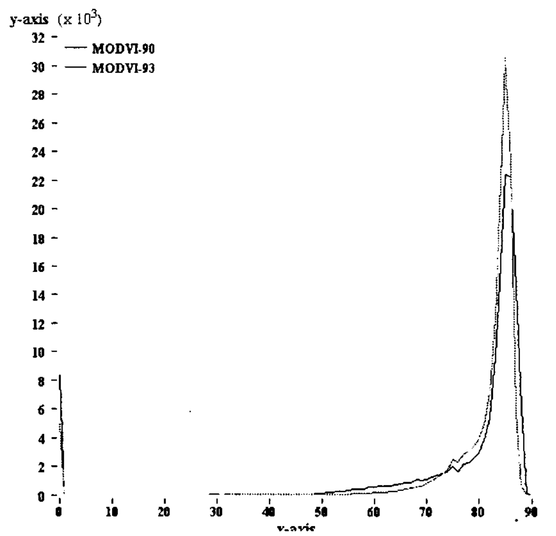


Figure 7(b). Histograms of MODVI for 1990 and 1993.

As seen in Figure 7(b), the histograms of MODVI are well matched for temporally different data sets.

4. CONCLUSIONS

In this paper, some weakness of current vegetation indices for remote sensing is discussed. An alternative method MODVI was proposed, which is less affected by the radiometric and atmospheric environment differences.

The usefulness of this index is examined using Landsat TM data sets of different dates , and it was demonstrated that the MODVI is more stable against temporal changes.

Reference

1) Joji Iisaka, H.Yoshimura, Y.Yasuda, Y.Emori, "Phenomena modeling of remotely sensed data by image rationing", Proc. The 15th International Symposium of Remote Sensing of Environment, Ann Arbor, Michigan , USA, pp.1127-1140,1981.

2) Joji Iisaka, Etsuko Amano and Takako Amano, " Automated forest clear cut detection from TM data ".In Proceeding of the 26th Annual Symposium of Remote Sensing of Environment, Vancouver , Canada, p.67-70,March 1996.

4) Compton J. Tucker, "Red and Photographic infrared Linear combinations for monitoring vegetation" , Remote sensing of Environment, Vol.8(2) pp.127-150(May 1979).

5) John A. Richards, Remote Sensing Digital Image Analysis : An Introduction, Springer Verlag, New York, USA; ISBN: 0387582193, edition September 1994.