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東亞地區植生指標之空間與時間分析：1982-2000

A Spatial and Temporal Analysis of East Asian Normalized Difference Vegetation Index: 1982-2000

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中文摘要

監測植物分佈變化是自然環境資源管理之重要方法，本文目標是分析東亞地區植生指標(1982-1993, 1995-2000)之空間與時間變化，研究結果顯示有6主成份因子解釋大於1%之東亞地區植生指標變異，主成份因子1，2及3分別解釋59.5%，9.8%及4.2%之東亞地區植生指標變異，本文認為主成份因子1是“氣候”，主成份因子2及主成份因子3是“季節”，本文使用群落分析方法研究東亞地區植生指標，研究結果顯示有32個主要群落。

關鍵字：植生指標，主成份因子，群落分析方法，東亞

Abstract

Detection of changes in vegetation patterns is an important key to natural resource assessment. The aim of this research is to analysis spatial and temporal variations in East Asian monthly maximum NDVI data for the period of 1982-2000, excluding 1994. There are 6 components that explain higher than 1% of the variance in the original 216 East Asian monthly maximum NDVI time series images. Principal components 1, 2, and 3 explain 59.5%, 9.8%, and 4.2% of the variance in the original 216 East Asian NDVI data. Principal component 1 was interpreted as the “climate” component. Principal components 2 and 3 were interpreted as the “season” components. Thirty-two East Asian vegetation clusters were generated in this research.

Key words: Normalized Difference Vegetation Index, Principal Components, Cluster Analysis, East Asia

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Introduction

Vegetation, both native and cultivated, covers much of the earth and strongly influences the environment (Sabins, 1996). Until recently adequate data were lacking for mapping the composition, concentration, and dynamics of the world's vegetation. Sabins (1996) stated that remote sensing from satellites provide our first opportunity to inventory the surface resources of the earth in a systematic repetitive manner. Campbell (2002) also indicated that remote sensing provides the only practical means of mapping and monitoring changes in major ecological regions that, although not directly used for production of food, have great long-term significance for mankind. Campbell (2002) stated that the tropical forests that cover significant areas of the earth's surface have never been mapped or studied except in local regions. Yet these regions are of critical importance to mankind due to their role in maintaining the earth's climate and as a source of genetic diversity. Humans are rapidly destroying large areas of tropical forests; it is only by means of remote sensing that we are ever likely to understand the nature and locations of these changes (Campbell, 2002).

Healthy canopies of green vegetation have a distinctive interaction with energy in the visible and near-infrared regions of the electromagnetic spectrum (*IDRISI32 Release 2 Guide to GIS and Image Processing Volume 2*). In the visible regions, plant pigments cause strong absorption of energy, primarily for the purpose of photosynthesis. This absorption peaks in the red and blue areas of the visible spectrum, thus leading to the characteristic green appearance of most leaves. In the near-infrared, however, a very different interaction occurs, energy in this region is not used in photosynthesis, and it is strongly scattered by the internal structure of most leaves, leading to a very high apparent reflectance in the near-infrared. It is this strong contrast, then, most particularly between the amount of reflected energy in the red and near-infrared regions of the electromagnetic spectrum, that has been the focus of a large variety of attempts to develop quantitative indices of vegetation condition using remotely sensed imagery (*IDRISI32 Release 2 Guide to GIS and Image Processing Volume 2*).

During the 1980s, pioneering research was conducted to map and monitor vegetation on continental scales using data acquired by the U.S. National Oceanographic and Atmospheric Administration's (NOAA) meteorological satellite, the Advanced Very High Resolution Radiometer (AVHRR). Liu et al. (2002) applied NOAA AVHRR data, roughly 200 days from 1998 to 1999, in delineating normalized difference vegetation index (NDVI) maps of Taiwan. Lee et al. (2002) used a 9-year dataset (1982-1990) of biweekly composites of NOAA AVHRR maximum NDVI values to examine the variation in the date of onset of green-up in Inner Mongolia. Li et al. (2002) used monthly NOAA AVHRR maximum NDVI data of China for the year 1982-1992 to investigate the relationships that exist between NDVI, vegetation type and various climatic parameters in China. Pan et al. (2003) used 1 km NOAA AVHRR NDVI data, spanning a 12-month period (April 1992 – March 1993) to carry out a vegetation classification of China. They produced a map with 47 vegetation types. Previous studies indicated that NOAA AVHRR NDVI images are useful to examine vegetation types.

The aim of this research is to use principal components analysis to analyze spatial and temporal variations in East Asian monthly maximum NDVI images for the period of 1982-2000, excluding 1994. Also this research classified East Asian NDVI composite map into major significant clusters. NDVI is an index derived from reflectance measurements in the red and infrared portions of the electromagnetic spectrum to describe the relative amount of green biomass from one area to the next. Values of NDVI ranged from 1.0 to -1.0 (Sabins, 1996). Higher values indicate higher concentrations of green vegetation. Lower values indicate non-vegetated features, such as water, barren land, ice, snow, or clouds.

Methods

This research used *IDRISI32 Release 2* to analyze NOAA Advanced Very High Resolution Radiometers (AVHRR) Normalized Difference Vegetation Index (NDVI) data of East Asia for the period of 1982-2000, excluding 1994. *IDRISI32 Release 2* is a geographic information and image processing software system developed by the Clark Labs, a not-for-profit organization within the Graduate School of Geography at Clark University, USA. This research applied Time Series Analysis of *IDRISI32 Release 2* to explore spatial and temporal variations in East Asian NDVI data. Cluster Analysis in *IDRISI32 Release 2* was used to classify NDVI composite map of East Asia.

(1) East Asian Normalized Difference Vegetation Index Data

This research used the *Global Change Data Archive Vol. 4: 0.1 Degree Global Monthly Vegetation Index (NDVI) 1981-2000* CD made by the Clark Labs, Clark University, USA. The CD contains monthly NDVI maximum value composite images, 1981-2000, with the exception of September-December 1994 (*Global Change Data Archive Vol. 4*). The spatial resolution for the NDVI images is 0.1 degree. Each image has 3600 columns and 1800 rows. Monthly NDVI maximum value composite images were originally downloaded from the NASA ftp site. The original data set was produced as part of the NOAA/NASA Pathfinder AVHRR Land Program. NASA’s Mission to Planet Earth Program funded its production and distribution. The Pathfinder Program produces long-term data sets derived from the observations made by AVHRR on the NOAA operational meteorological satellites (NOAA-7, NOAA-9, NOAA-11) and processed in a consistent manner for global change. NOAA AVHRR NDVI data are created by the steps described in *Vegetation Index from AVHRR NDVI.* Calibration and atmospheric corrections are applied and stated in *Vegetation Index* from AVHRR NDVI. On the NOAA-7, NOAA-9, and NOAA-11 satellites, the AVHRR sensor measures emitted and reflected radiation in five bands of the electromagnetic spectrum: a visible (0.58 to 0.68 micrometer) band that is used for daytime cloud and surface mapping; a near-infrared (0.725 to 1.1 micrometer) band used for surface water delineation and vegetation cover mapping; a mid-infrared (3.55 to 3.93 micrometer) band used for sea surface temperature and nighttime cloud mapping; a thermal infrared (10.5 to 11.5 micrometer) band used for surface temperature and day and night cloud mapping; and another thermal infrared (11.5 to 12.5

micrometer) band used for surface temperature mapping (*Vegetation Index from AVHRR NDVI*). The first AVHRR channel is in a part of the spectrum where chlorophyll causes considerable absorption of incoming radiation, and the second channel is in a spectral region where spongy mesophyll leaf structure leads to considerable reflectance. NOAA AVHRR NDVI values are derived from the visible and near-infrared channel reflectances (0.58 to 0.68 micrometer and 0.73 to 1.10 micrometer, respectively). NDVI is derived from: (Band2 reflectance - Band1 reflectance) /(Band2 reflectance + Band1 reflectance) Figure 1 shows East Asian maximum NDVI images of January and July of 2000.

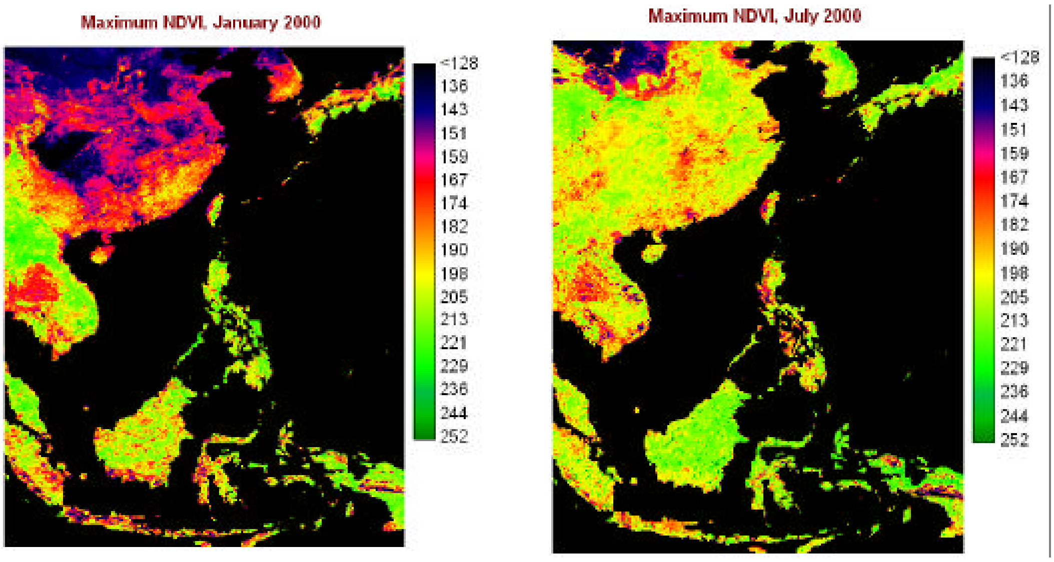

Figure 1. Maximum NDVI Maps of East Asia, January and July, 2000.

(2) Time Series Analysis

Time Series Analysis (TSA) in *IDRISI32 Release 2* is used for the analysis of long time series of image data (*IDRISI32 Release 2 Guide to GIS and Image Processing Volume 2*). TSA analyzes the series as a whole based on a standardized principal components analysis. At present, up to 256 images may be analyzed simultaneously. The output from TSA includes both temporal and spatial patterns that should be interpreted together. TSA produced a set of principal component images, each expressing underlying themes (trends, shifts, periodicities, and so on) in the original series. Principal components are uncorrelated with one another and are ordered in terms of the amount of variance they explain from the original data set. The standardized principal component images indicate the spatial patterns of major elements of variability over the series. The temporal output consists of a set of loadings graphs. Loadings graphs are produced for each component and show the correlation between that component image and each of the original images.

(3) Cluster Analysis

Cluster Analysis (CA) in *IDRISI32 Release 2* provides an unsupervised classification of an image based on the information in a color composite image (*IDRISI32 Release 2 Guide to GIS and Image Processing Volume 2*). The aim of unsupervised classification is to uncover the major land cover classes that exist in the image without prior knowledge of what they might be. Unsupervised classification techniques search for clusters of pixels with similar reflectance characteristics in a multi-band image. They are concerned with uncovering the major land cover classes, and thus tend to ignore those that have very low frequencies of occurrence. CA uses a histogram peak technique (*IDRISI32 Release 2 Guide to GIS and Image Processing Volume 2*). This is equivalent to looking for the peaks in a one-dimensional histogram, where a peak is defined as a value with a greater frequency than its neighbors on either side. Once the peaks have been identified, all possible values are assigned to the nearest peak and the divisions between classes fall at the midpoints between peaks. Here a three-dimensional histogram is used because the composite is derived from three bands. A peak is thus a class where the frequency is higher than all of its neighbors. Once the peaks have been located, each pixel in the image can then be assigned to its closest peak, with each such class being labeled as a cluster.

Results

(1) Principal Components

Time Series Analysis was used to analyze East Asian monthly maximum NDVI images for the period of January 1982 to December 2000, excluding 1994. Table 1 lists the percentages of variance explained by components in East Asian monthly maximum NDVI images. There are 6 components that explain higher than 1% of the variance in the original 216 images. The components 1, 2, and 3 explain 59.5%, 9.8%, and 4.2% of the variance in the original 216 East Asian monthly maximum NDVI data. Table 1 indicated that the first 6 components explain 78% of the variance.

Table 1. Results for the Extraction of Principal Components.

Components	Percentage of Variance	Cumulative Percentage of Variance	Components	Percentage of Variance	Cumulative Percentage of Variance
1	59.54	59.54	6	1.14	78.25
2	9.78	69.32	7	0.88	79.13
3	4.18	73.50	8	0.83	79.96
4	1.91	75.41	9	0.65	80.61
5	1.70	77.11	10-216		100.00

(2) Spatial Variability of East Asian NDVI

Time Series Analysis of the 216 East Asian monthly maximum NDVI images generates a set of standardized principal component images. Figure 2 shows components 1, 2, and 3. The range of the component image 1 is from –39.1 to 22.1. Mid-latitude regions have negative values and equatorial regions have positive values. Principal component 1 was interpreted as the “climate” component.

The range of the component image 2 is from –17.2 to 18.3. Central China, Korea, and northern Japan have the most positive values, indicating the higher concentrations of green vegetation. Principal component 2 was interpreted as the “season” component. The range of the component image 3 is from –9.5 to 10.7. Southern China and Indochina Peninsula have the most positive values, indicating the higher concentrations of vegetation. Central China and Indonesia have the most negative values, indicating the lower concentrations of vegetation. Principal component 3 was also interpreted as the “season” component. These principal components show the major spatial variability over the original East Asian monthly maximum NDVI time series data.

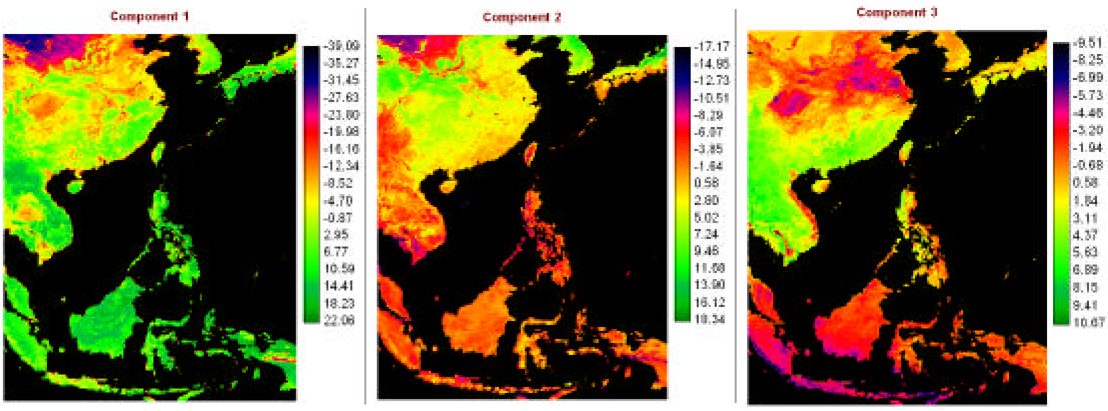

Figure 2. Spatial Maps of Components 1, 2, and 3 of East Asia Maximum

(3) Temporal Variability of East Asian NDVI

The temporal outputs of Time Series Analysis consist of a set of loading plots. Loading plots are generated for the first 3 components. These graphs show the correlation between the principal component image and each of the original East Asian monthly maximum NDVI images.

The temporal loadings of components 1, 2, and 3 are plotted in Figure 3. The range of the loadings of component 1 is from 0.34 (September 1991) to 0.89 (December 1989). The range of the loadings of component 2 is from –0.44 (March 1992) to 0.73 (August 1991). The July-August-September (Northern Hemisphere hot season) months have positive values. The January-February-March (Northern Hemisphere cold season) months have negative values. The range of the loadings of component 3 is from –0.38 (April 1992) to 0.47 (October 1991). The October-November-December (Northern

Hemisphere cool season) months have positive values. The April-May-June (Northern Hemisphere warm season) months have negative values. These loadings of principal component show the temporal variability over the original East Asian monthly maximum NDVI time series data.

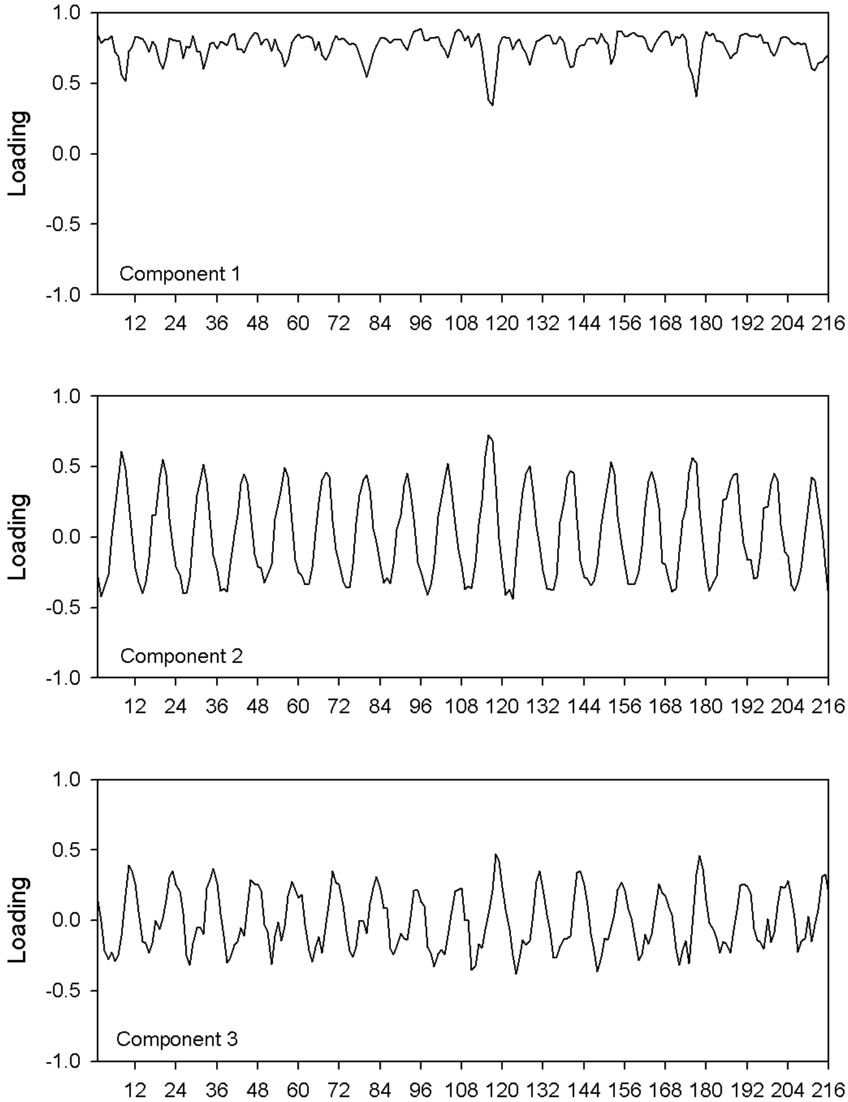

Figure 3. Temporal Loadings of Components 1, 2, and 3 (1=January 1982, 144=December 1993, 145=January 1995, and 216=December, 2000).

(4) Clusters of East Asian NDVI Composite Map

This research used Cluster Analysis to classify East Asian NDVI composite image. East Asian NDVI composite image was produced from combining components 1, 2, and 3 images (Figure 4). Fine clustering of Cluster Analysis in *IDRISI32 Release 2* generated 32 clusters with dropping least significant clusters (<1% of all area) (Figure 5). Then, we could identify the land cover class of each cluster. This research did not identify all the clusters because more data (e.g., topographic maps, remote sensing images, and aerial photographs) is needed to identify the clusters. The result could be useful in the future to improve East Asian land cover classification.

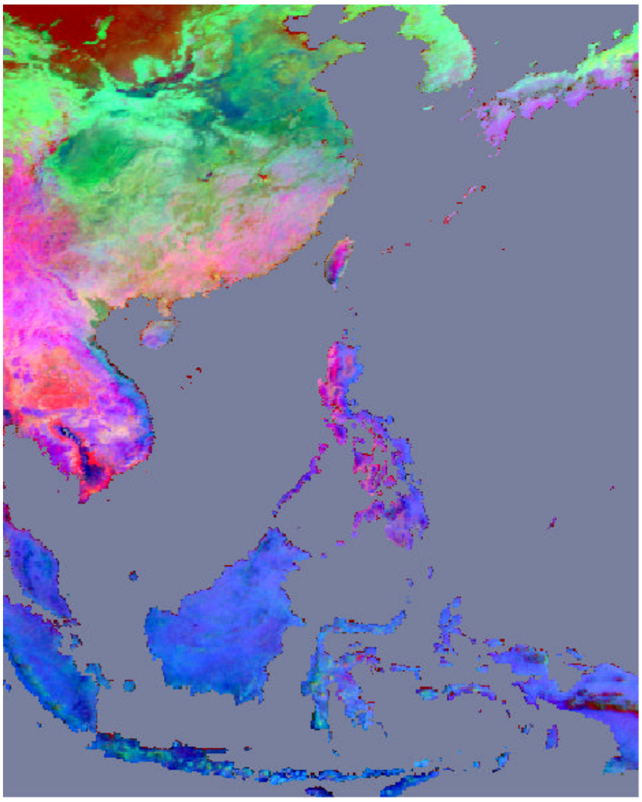

Figure 4. Composite Map of Components 1, 2, and 3

(B-G-R=Component 1, Component 2, Component 3).

Conclusions

This study analyzed spatial and temporal variations in East Asian monthly maximum NDVI images for the period of 1982-2000, excluding 1994. The components 1, 2, and 3 explain 59.5%, 9.8%, and 4.2% of the variance in the original 216 East Asian monthly maximum NDVI data. Component 1 was interpreted as the "climate" component. Components 2 and 3 were interpreted as the "season" components. Thirty-two East Asian vegetation clusters were generated in this research. The result is useful in the future to improve East Asian land cover classification.

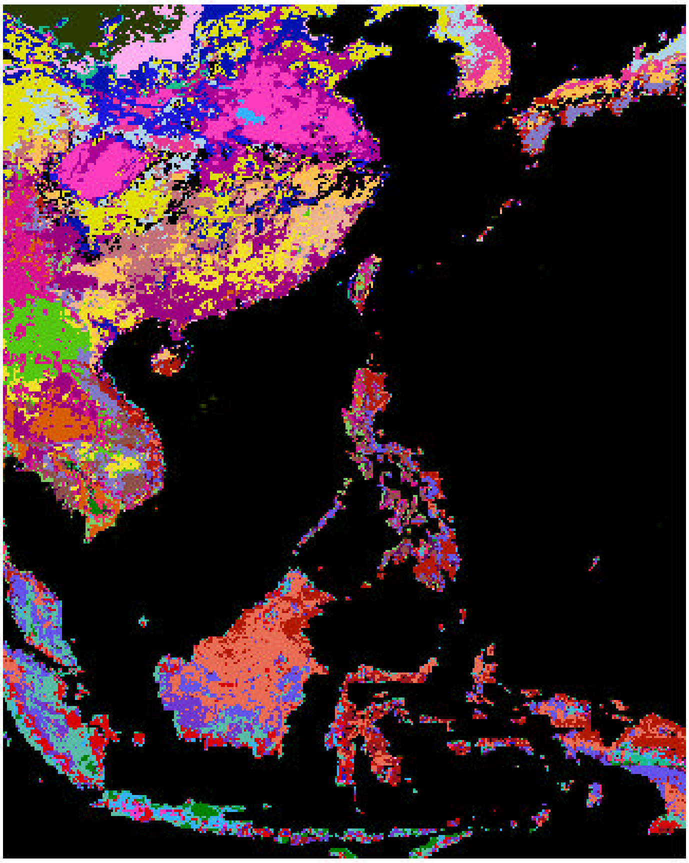

Figure 5. Cluster Map of East Asian Vegetation (32 Clusters).

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