E-5 Mapping of Vegetation Distribution and Vegetation Index Distribution in South East Asia Region Using NOAA AVHRR (LAC) Imageries

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Abstract Several methodological developments, eg., geometric and radiometric corrections, were made for deriving accurate vegetation distribution and vegetation index distribution maps of South East Asia from NOAA AVHRR (LAC) imageries, and for revealing their temporal changes.

The geometrical improvement was achieved by applying colinearity condition in photogrammetry and data of ground control points (GCPs) to estimation of parameters which determines a correct position and attitude of a satellite. The method enables to correct distortion of imageries with fewer numbers of GCPs than those required in conventional methods. An additional geometric correction was incorporated by referring to the digital elevation model.

The radiometric intensity of imageries acquired at different time was adjusted in terms of the zenith angle of the sun and atmospheric condition such as precipitable water content to mosaic them without discontinuity. A new algorithm was, moreover, developed to locate a corresponding point of two images automatically by comparing their spectral characteristics.

Mosaiced satellite images and vegetation index images of 1985, 1989 and 1992 were produced from NOAA AVHRR (LAC) imageries covering South East Asian region with 1 km spatial resolution. Differences between two of the vegetation index images were mapped to evaluate landcover changes during the periods.

Key Words Remote Sensing, Vegetation Index, Mosaic, NOAA, South East Asia

1. Introduction

In south East Asian countries there have been serious natural disasters such as typhoon or flooding, and also in summer seasons there have been observed unusual high values of air temperature. As one of the reasons for those natural phenomena, regional scale or meso-scale climate changes due to deforestation are pointed out. Deforestation, desertification and land degradation have been very critical global environmental problems during the past decade. Monitoring of earth surface conditions and their changes is essential to the management of the environmental problems in both global and regional scales. Remote sensing from space can provide an efficient tool for continuously and broadly monitoring a wide range of environmental variables because of its potential advantages.

2. Objectives

The objective is to make methodological developments such as geometric and radiometric corrections for deriving accurate vegetation distribution and vegetation index distribution maps of South East Asia from NOAA AVHRR (LAC) imageries and for evaluating their temporal changes. The product image should be smooth, cloud-free and of 1 km resolution as well as original NOAA images.

3. Geometric Correction

A geometric correction, so called the system correction, of NOAA AVHRR imagery has been carried out by using the satellite ephemeris data or the orbital element data which are transmitted every day from NOAA. There remain some distortions in the corrected image, since the ephemeris data have some errors and the variation of satellite attitude is not compensated. GCPs are, thus, usually applied to the resultant image to eliminate the remained distortions and attain more accurate product. The authors have developed a method to directly correct the orbital elements and the satellite attitude from NOAA accurately utilizing colinearity condition in photogrammetry and GCPs. One of the most important advantage of the new method is that it is possible to make a precise geometric correction even if only few GCPs are available in the open ocean or on the cloudy image.

Negligible difference in altitude varies with the scan angle, shown in Fig. 1. The '1.1 km mesh' in the figure represents the case when an original image is resampled into the regular grid size of 1.1 km. Figure 2 shows how many pixels the point of 8,000 m in altitude are distorted in the image with ground resolution of 1.1 km. The image is so distorted that the terrain effect is not negligible in a high altitude area even when the only sub-satellite region of images are used. The conventional method of geometric correction of AVHRR imagery hardly take the terrain effect into consideration and sometimes causes misregistration. The method above-mentioned can easily involve a digital terrain model within its part of resampling, that is, conversion from the latitude-longitude to the earth rotation coordinates. The ETOPO5 supplied by UNEP/GRID-Tsukuba was used here as the data source for altitude.

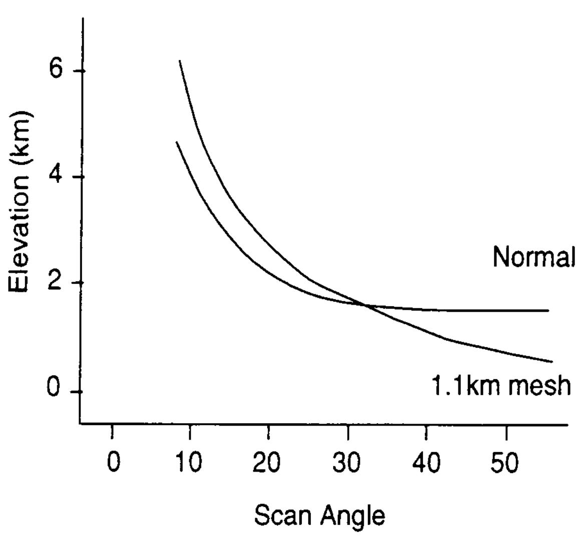

Fig 1 Relationship between Scan Angle and Negligible Elevation

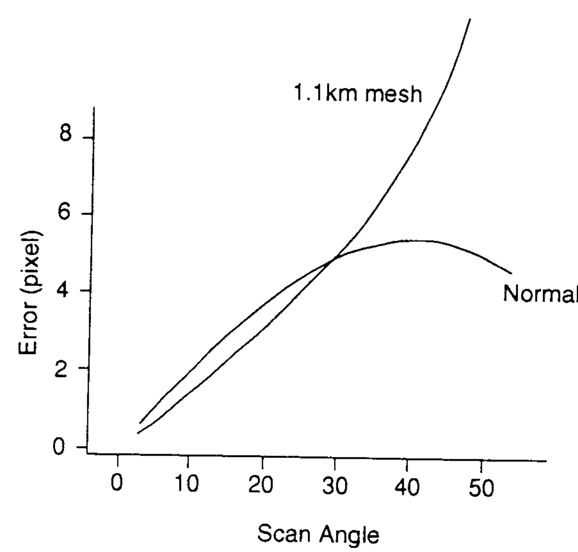

Fig 2 Distortion Error on the point of 8000m in the Altitude

4. Radiometric Correction

The radiometric intensity of imageries acquired at different time should be adjusted in terms of the zenith angle of the sun. Provided that the earth has a Lambertian surface, the following correction was applied to make a mosaiced image and vegetation index map more

Fig. 3 Image mosaiced from 4 NOAA AVHRR images

accurate.

$$A = (S \cdot C + I) / \cos Z$$

where A is a corrected reflectance, C and Z are an AVHRR image value and the zenith angle of the sun, respectively, and S and I are coefficients for converting C to albedo. It is also assumed that the curvature of the surface effects equally over the area of interest. A new algorithm was, moreover, developed to locate a corresponding point of two images automatically by comparing their spectral characteristics for realizing efficient and accurate mosaicing. Figure 3 is the image covering India and South East Asia which was mosaiced from 4 AVHRR images after the above correction. There was not founded any discontinuity in not only coastal but also inland areas in the image.

5. Atmospheric Effects

An amount of the atmospheric effect depends upon the atmospheric model and the sun-target-sensor-geometry. The former is characterized by precipitable and aerosol water contents of the air. The tropical standard atmospheric model of LOWTRAN is applicable for the water contents in lower altitude areas. The region of South East Asia is, however, wide enough and covering a variety of climate areas. The water contents in highland or subtropic areas might be different from the model, and necessary to be modified.

By using LOWTRAN 7 code, the atmospheric effects were simulated thoroughly for a wide range of vegetation index, precipitable and aerosol water contents, and sun-target-sensor-geometries. The simulation depicted that the effects cause somewhat underestimation of NDVI under any circumstances. The extent of the underestimation is greater under conditions of higher NDVI, more turbid atmosphere and larger scanning angle of the sensor.

An algorithm was developed to estimate the atmospheric effects and correct the radiances of Band 1 and 2 of AVHRR imageries by use of LOWTRAN 7 code with an assumed atmospheric model. Two water contents, precipitable and aerosol, determine the appropriate assumption of the atmospheric model. The precipitable water content can be estimated by referring to the brightness temperatures of Band 4 and 5 of AVHRR. As for the aerosol content, there is so far no effective method to estimate from the AVHRR data, and thus necessity to assign some reasonable value a priori.

6. Satellite Mosaic Image and Vegetation Index Image

Mosaiced satellite images and vegetation index images were produced from NOAA AVHRR (LAC) imageries covering South East Asia regions with 1 km spatial resolution. First AVHRR original images were geometrically and radiometrically corrected, and then the corrected images were mosaiced after cloud removal.

The calibrated Normalized Difference Vegetation Index (CVI) was calculated for each pixel of the mosaiced image as follows:

$$CVI = 260 \times (A2 - A1) / (A2 + A1) + 15$$

where A1 and A2 are the reflectance of Band 1 and 2 of the AVHRR data, respectively, after radiometric correction.

The upper line of Fig. 4 shows the CVI images produced from the AVHRR imageries obtained during the periods of December 1985 to March 1986, December 1989 to March 1990, and December 1992 to March 1993. The last two of the CVI images were produced as a part of the global environmental monitoring project funded by the Center for Global Environmental Research (CGER).

7. Evaluation of Landcover Change Based on the CVI Images

The CVI change maps were produced from three CVI images by subtracting one from each other to evaluate the landcover changes during the period of 1985-1993. First, the CVI values of each image was normalized to fall between the specified highest and lowest CVI values for eliminating effects of multi-temporal scanning on CVI. Tarr Desert in West India and the original tropical forest in Miyammer were selected as common standard areas to be assigned the lowest and highest CVI, respectively.

One normalized CVI image was subtracted from each other to evaluate changes in CVI value. The lower line of Fig. 4 shows the CVI change maps between 1985&86-1989&90, 1985&86-1992&93 and 1990&91-1992&93.

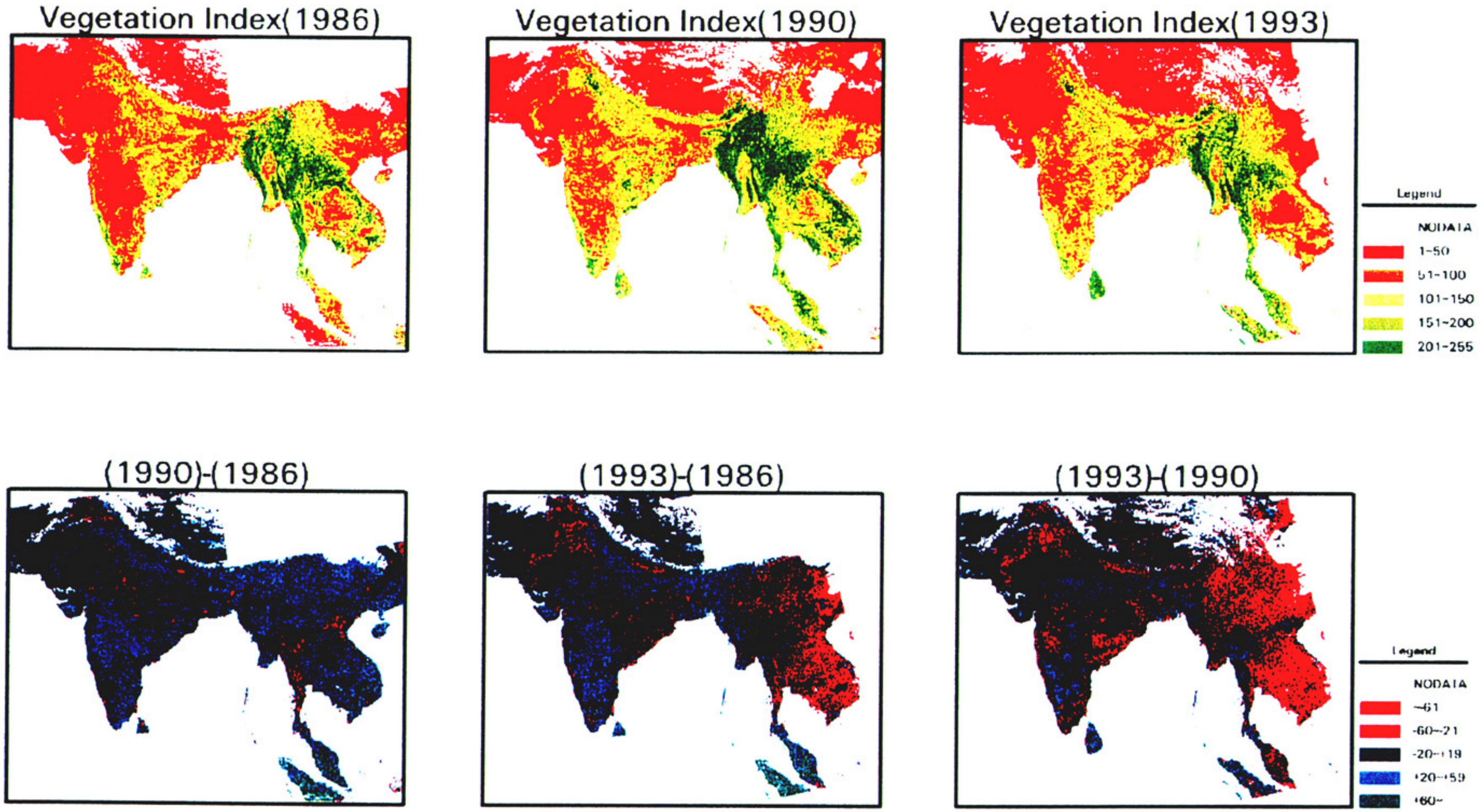

Fig. 4 Vegetation Index (CVI) maps and their change maps in South East Asia.
(Upper line : Vegetation Index maps of 1985&86, 1989&90 and 1992&93.
Lower line : CVI change maps of 1985&86-1989&90,1985&86-1992&93, 1989&90-1992&93)