Analysis of forest types and stand structures over Korean peninsula using NOAA/AVHRR data

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ABSTRACT

In this study, visible and near infrared channels of NOAA/AVHRR data were used to classify land use and vegetation types over Korean peninsula. Analyzing forest stand structures and prediction of forest productivity using satellite data were also reviewed.

Land use and land cover classification was made by unsupervised clustering methods. After monthly Normalized Difference Vegetation Index (NDVI) composite images were derived from April to November 1998, the derived composite images were used as temporal feature vectors in this clustering analysis. Visually interpreted, the classification result was satisfactory in overall for it matched well with the general land cover patterns. But subclassification of forests into coniferous, deciduous, and mixed forests were much confused due to the effects of low ground resolution of AVHRR data and without defined classification scheme.

To investigate into the forest stand structures, digital forest type maps were used as an ancillary data. Forest type maps, which were compiled and digitalized by Forestry Research Institute, were registered to AVHRR image coordinates. Two data sets were compared and percent forest cover over whole region was estimated by multiple regression analysis. Using this method, other forest stand structure characteristics within the primary data pixels are expected to be extracted and estimated.

INTRODUCTION

The primary mission of OSMI is worldwide ocean color monitoring for the study of biological oceanography. It will generate 6 band ocean color images with 800km swath width and 1km GSD by whiskbroom scanning. Though originally designed to be used in oceanographic applications, OSMI will be used in monitoring vegetation greenness on the landscape like AVHRR data on the NOAA satellite.

In this study, visible and near infrared channels of NOAA/AVHRR, which are equivalent to band B5 and B6 of OSMI respectively, were used to classify land use and vegetation type mapping over Korean peninsula. Prediction of forest productivity and analyzing forest stand structure were also reviewed.

METHODS AND PROCEDURES

AVHRR Data

The NOAA AVHRR data used in this study were acquired from the Korea Ocean Research and Development Institute, Korea. Because this study was intended to get information on the distribution of forest vegetation over the Korean peninsula, daily AVHRR data from April to November 1998 were selected for the analysis. These multitemporal data are expected to contain phenological information about vegetation which can be valuable for separating different types of vegetation in a large area. The spatial resolution of the AVHRR is 1.1km

NDVI composite image

Using the channel 1 and channel 2 of AVHRR data, Normalized Difference Vegetation Index(NDVI) was extracted on the daily basis. The NDVI is the difference of near-infrared and visible red reflectance values normalized over total reflectance. That is

$$NDVI = \frac{\text{Near } IR \text{ (Ch 2)} - \text{Red (Ch 1)}}{\text{Near } IR \text{ (Ch 2)} + \text{Red (Ch 1)}}$$

This equation produces NDVI values in the range of -1.0 to 1.0, where negative values generally represent clouds, snow, water, and other nonvegetated surfaces. Positive values represent vegetated surfaces.

Cloud-free observations of the land surface are necessary for monitoring vegetation with satellites. The likelihood for a single AVHRR overpass being completely cloud free is minimal. Holben(1986) showed that compositing AVHRR data acquired over several days can produce spatially continuous cloud-free imagery over large areas. According to Holben's MVC(Maximum Value Composite) method, monthly NDVI composites were produced for the study. Eight monthly NDVI composite images were produced for each month and these images were used as phenological feature vectors in total composite data set. The MVC technique is also useful to minimize the effects of different sun angles, shadows, and atmospheric conditions existing among multiple data set.

Modeling percent forest cover

For individual pixels, the level of detail and the limit of accuracy are compound functions of the sensor's spatial, spectral, and radiometric resolutions. When spatial resolution is coarse, such as that of AVHRR, pixels covering small objects or edges of large objects become mixed. In this respect, if the objects under consideration are mixed features with forest and nonforest lands, the measure of the amount of pure forest per unit area (one pixel in this case) can be used to solve the mixed-pixel components.

Solutions for pixel mixture are often derived by calibrating the coarse resolution satellite data with reference data that are based on accurate subpixel measurement. The regression analysis is adopted between two data sources. One is to regard the low-cost, coarse resolution data for the entire study area(i.e., AVHRR) as multiple independent variables, the other is expensive ancillary data with fine resolution and detailed ground information as the dependent variable. Several studies describe applications of the multisource approach involving AVHRR and Landsat data(Cross *et al.*, 1991; Iverson *et al.*, 1989; Nelson and Holben, 1986; Zhu, 1994; Zhu and Evans, 1994). In this study digital forest type maps were used instead of Landsat data to get actual forest stand information.

RESULTS AND DISCUSSIONS

Before classifying land use and forest types over Korean peninsula using the NDVI composite data, the temporal changes of NDVI values on several sites which maintain typical land use types were extracted. Figure 1 shows the overall patterns of temporal changes from urban area, paddy field, and

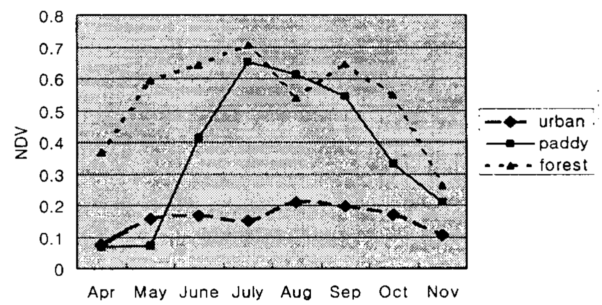

Fig. 1. Temporal changes of NDVI values in urban area, paddy field, and forest land.

forest land. Pyongyang city in North Korea representing the urban area shows the lowest NDVI values throughout the year. A slight high up in May compared to April seems due to the effects of shooting new leaves in spring from the trees in streets and urban parks. Paddy fields show low NDVI value in April and May. Then it comes to its peak on July and lowers till November. This pattern typically represent the lives of rice. The site of forest land is Seorak mountain area in Kwangwon province. These signatures showing different profile patterns according to their land cover types are useful in a classification process.

The classification result of primary land cover types using the eight monthly NDVI composite images is shown in Figure 2. For this, ISODATA unsupervised classification method was used and each spectral clusters was merged into one of seven land use type categories. When visually interpreted, the classification result was satisfactory in overall for it matched well with the general land cover patterns. Though waterbody had several clusters with different spectral levels, it was well distinguished with the other land use categories. Urban areas including exploited sites and barelands, which have scarce greenness that represent low NDVI values through all seasons as shown in Figure 1, were categorized into one easily. Paddy and cultivated farm field were also separated well between them according to their geographical positions and phenological characteristics.

But subclassification of forests into coniferous, deciduous, and mixed forests were much confused. An AVHRR pixel size is 1.1km×1.1km and diverse kinds of forests can exist within a pixel. Korea's land area is about 220,000km^2 in total and the peninsula is laid relatively long from north to south. The terrain is rugged. And with high population pressure the land use type is inevitably intensive. So are the forests. It is almost hard to find a vast forest land with mono or homogeneous tree species. They are spread in patches adapting themselves to the environments. Therefore, a defined classification scheme coincident with the varying scale or resolution is required to meet this problem.

The areas occupied by each classification categories are not presented here. One reason is that it is difficult to find reliable ground data to validate

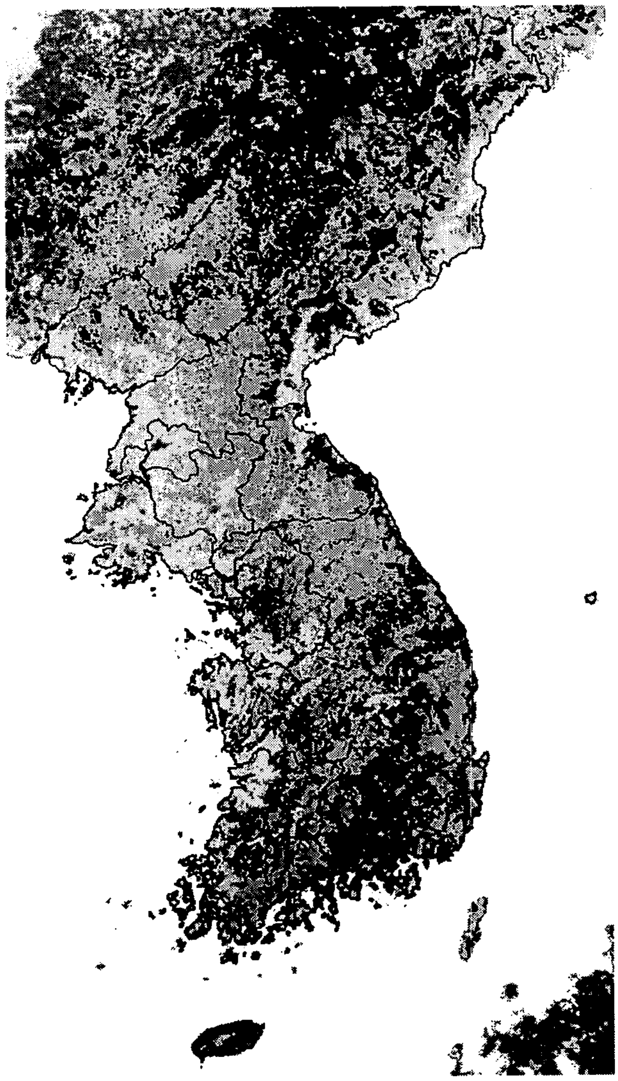

Fig. 2. Unsupervised classification result over Korean peninsula using NDVI composite image

the classification result, and the other reason is that the results statistics differ case by case. There are a few attempts to classify and to map vegetation cover types over Korean peninsula using AVHRR data in recent years(Lee, 1994; Kim and Lee, 1996; Suh *et al.*, 1997). The result statistics are different according to the date they selected, the classification methods used, and the numbers and kinds of categories adapted. To pile up one more statistics backed up with weak validation is not important in this study.

Figure 3 shows the percent forest cover derived from multiple regression model. As stated, forest type maps, which were compiled and digitalized by Forestry Research Institute, were used as a reference data to predict the percentage of forest cover within pixels of AVHRR data. After digital forest type

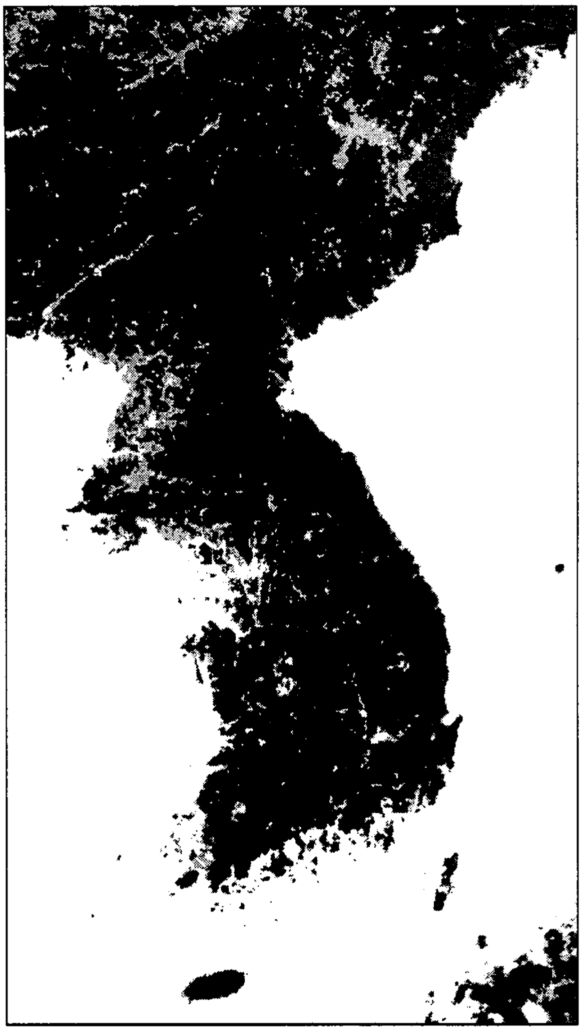

Fig. 3. Predicted percent forest cover derived from multiple regression analysis

maps and AVHRR data were coregistered to the same coordinate system, percent forest cover were identified within sample AVHRR pixels. The linear multiple regression model between the map-determined forest percentage (the dependent variable) and corresponding AVHRR NDVI values (independent variables) was fitted and determined to construct this map. In this case, about 170 AVHRR pixels were sampled around the South Korea where the forest type map covers, and multiple correlation coefficient was 0.47. Though the coefficient value was not high and insufficient to explain fully extrapolating to the whole country, the method is much promising. Besides the percentages of forest and nonforest components in pixels, percentages of coniferous, deciduous, and/or mixed forests, percentages of each stand age classes, and other forest stand structure components can be extracted. Comparing the data sets, any stand structure characteristics including productivity within the primary data pixels will be estimated by regression analysis for the whole study area.

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