E-5 A Study on Landcover Mapping in South-East Asia with Satellite Images (Final Report)

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Total Budget for FY1994-1996 45,071-000 Yen (FY1996; 15,658,000 Yen)

Abstract

The objective of the study is to develop remote sensing methodologies for monitoring landcover/use distribution and its temporal change with satellite images. Landsat TM and MSS images with 30-80m spatial resolution from 1970's - 90's and NOAA AVHRR images with 1km resolution from 1980's - 90's over South-East and East Asia were collected to assess the landcover changes of the area over twenty years. First, an automatic image mosaicing method was developed to composite a large amount of satellite images (TM,MSS) covering the area. Also, an integrated landcover classification and assessment method was developed which utilizes both of TM, MSS and AVHRR data together to take advantages both of high spatial resolution characteristics in TM and MSS and frequent observation characteristics in AVHRR. Further, landcover classification map over East Asia was obtained from the time series monthly AVHRR NDVI images from 1983 to 1990 with 8 km spatial resolution based on classification of the temporal pattern of the NDVI values.

Key Words Land cover, Vegetation distribution, Remote Sensing, Satellite Image, Asia

1. Introduction

Monitoring of earth surface conditions and their changes is essential to the management of the environmental problems in both of regional and global scale. It is, however, not easy to regularly monitor landcover conditions over large areas. The objective of the study is to develop remote sensing methodologies for monitoring landcover/use distribution and its temporal change with satellite data. High spatial resolution LANDSAT TM and MSS images from 1970's - 1990's , and low spatial resolution but wide coverage, frequent observation NOAA AVHRR images from 1980's - 1990's over South-East and East Asia are collected to assess the landcover changes of the area over twenty years.

Data processing methods are devised for landcover classification and assessment with a large amount of satellite images (Fig.1).

(1) Image mosaicing : An automatic image compositing method was developed to mosaic a large amount of satellite images efficiently. TM and MSS images selected from the dateset were geometrically corrected and registered to make a satellite image mosaic (composite) map of the area, and were overlayed on the NOAA AVHRR image covering the whole area to integrate the local data from TM or MSS with the continental scale data from AVHRR.

(2) Landcover classification : An integrated landcover classification method which utilizes both of TM, MSS and AVHRR data together was developed to take advantages both of high spatial resolution characteristics in TM and MSS and high frequent observation characteristics in AVHRR.

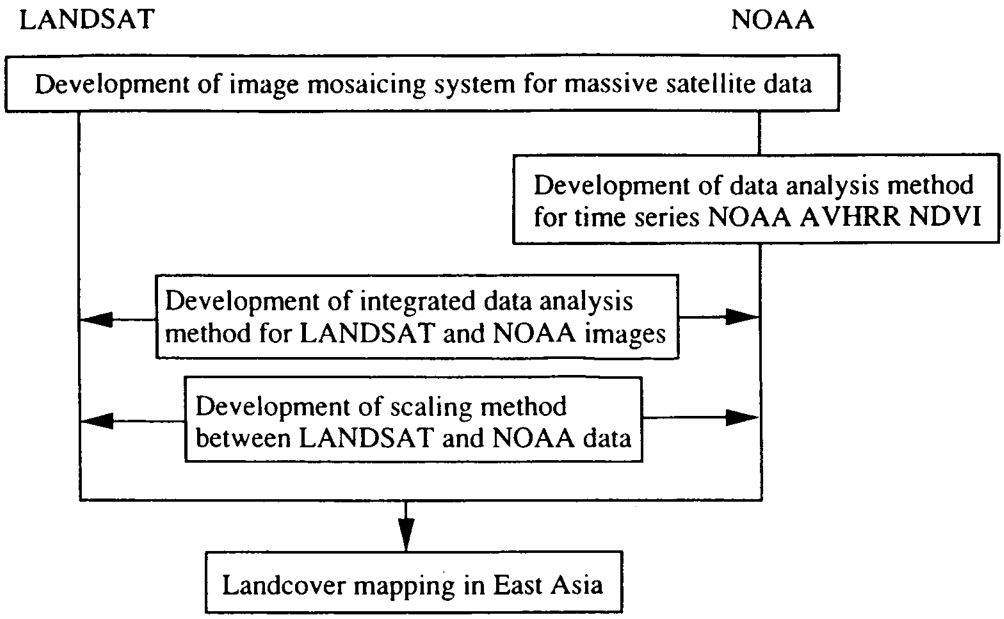

Fig.1 Schematic flow of the study

(3) Extrapolation of information from local to continental : Scaling techniques between the images from TM and AVHRR were investigated to extrapolate the local information based on the high spatial resolution data from TM to more continental/global scale by using low spatial but wide coverage AVHRR data.

(4) Landcover classification with temporal NDVI images : Landcover classification map over East Asia was obtained from the time series monthly AVHRR NDVI images from 1983 to 1990 based on classification of the temporal pattern of the NDVI values.

2. Data collection

Around six hundred Landsat MSS and TM images from 1970's - 90's in South-East Asia were retrieved and collected from Landsat Pathfinder Dateset of US-NASA. Also NOAA AVHRR images covering whole South-East and East Asia were collected. TM and MSS have the advantage in high spatial resolution observation with 30 - 80 m (coverage is 180km in swath and observation cycle is 16 days) whereas NOAA AVHRR data has the advantages in extensive observation (coverage is 2700km in swath and spatial resolution is 1km) and frequent observation (twice/day). TM and MSS images selected from the dateset were geometrically corrected and registered to make a satellite image mosaic (composite) map of the area, and were overlayed on the NOAA AVHRR image covering the whole area to integrate the local data from TM or MSS with the continental scale data from AVHRR.

3. Automatic image mosaicing for a large amount of satellite images [1)]

An automated techniques was developed for linking overlapping neighbor images through "tie point" matching and GCP matching with existing digital maps in order to produce satellite image mosaic map covering a continental scale area. The tie points are a set of common anchor points in the overlapping images and are used to determine relative position of neighboring images. They are small image patches, aligned regularly on a "master" image. Corresponding positions of those tie points in the overlapping "slave" images were determined by image matching techniques with which corresponding positions are given as those giving maximum correlation coefficient values. With the existing image correlation matching techniques, we can not avoid the occurrence of gross errors. In order to remove the gross errors, a limiting correlation coefficient value was introduced to detect the gross error. In addition, large shift of matching position from anticipated position was used for screening. With these screening methods, positional accuracy was approximately one pixel (RMSE maximum error is three pixels).

GCP should be stable against seasonal changes of land cover, and easy for extraction both from satellite image and digital maps. Coastal lines and water-land boundaries of large rivers in existing digital maps such as World Data bank II and Digital Chart of the World were selected for GCP. Satellite images were geo-coded to those digital maps by matching coastal lines and water-land boundaries extracted from satellite images with those in the digital maps. In this study, edges were extracted by wavelet analysis and they were transferred to "one-pixel-width" lines with thinning. In matching the coastal lines etc. of the satellite and the digital maps, ISODATA is applied, where absolute difference of corresponding pixels were accumulated to evaluate the similarity between two images, because the coastal lines and water-land boundary image are represented binary images.

4. Landcover classification using multi-resolution satellite data [2)]

An integrated landcover classification method which utilizes both of TM and AVHRR data together was developed to take advantages both of high spatial resolution characteristics in TM and frequent and extensive observation characteristics in AVHRR. In this scheme, first, seasonal changes of land cover is traced by using NOAA AVHRR images with 1km resolution compiled by USGS EROS data center. At the same time, Landsat TM data and DEM (Digital Elevation Model) are used for the further classification of land covers.

All satellite images are, first, converted to vegetation index (NDVI: Normalized Difference Vegetation Index) images and ordered along seasonal/monthly axis. NDVI images derived from Landsat TM images are adjusted by linear transformation to match the vegetation index images of corresponding month from NOAA AVHRR images. Linear transform functions are determined statistically by comparing the aggregated Landsat TM images with the NOAA AVHRR images. On the other hand, Landsat TM images are converted to edge image with wavelet transform-based edge detection techniques. The edge images are further converted to edge density images through some filtering techniques focusing edge shape and length. Classes of the proposed classification scheme are characterized by seasonal patterns of vegetation index, texture (cultivation pattern) and topographic conditions such as slope gradient.

In computing fitness of individual classes to image data including texture image, spatial resolution of the images have to be taken into account. If the spatial resolution of the image is very high, it can be assumed that each pixel is occupied by a single class. This means the pixel value will fit to the characteristics value of the class within the range of modeling errors. However, when spatial resolution is low, and mixture of the classes is unavoidable, the pixel value will be average over the characteristic values of those mixing classes and may not be equal to any single class characteristic values. Figure 2 demonstrates an example of classification. For checking the classification accuracy, land use map (1990) generated by Department of Land Development, Thailand was used. Classification accuracy was 80% for forest (including evergreen forest and deciduous forest), 70% for paddy and 65% for crop field/grassland.

5. Scaling model between AVHRR data and TM data [3),4)]

Scaling techniques between images from TM and AVHRR were investigated to extrapolate local information on landcover type mixture conditions derived from high spatial resolution data of TM to more continental/global scale by using low spatial but wide coverage AVHRR data. As parameters for scaling the Vegetation-Soil-Water (VSW) index developed in this study and the landcover mixing ratio between vegetation, soil and water were used.

First, TM and AVHRR are overlayed, and several environmental characteristics from satellite data including NDVI and VSW index are compared. Statistical regression analysis shows strong correlation between them. For example, multi-regression analysis between TM VSW index (HV, HS, HW) and CCT counts of AVHRR data (AV_1, AV_2) was resulted in the following equations;

$$AV\_1 = 28.2\ HV + 77.0\ HS + 27.6\ HW \quad (r^2 = 0.90)$$

$$AV\_2 = 73.8\ HV + 89.0\ HS + 21.5\ HW \quad (r^2 = 0.91).$$

From these equations landcover category mixing ratio (HV, HS, HW) was calculated from AVHRR data (AV_1, AV_2) with the equation HV+HS+HW=1. An example of the estimated vegetation coverage ratio, HV, in VSW index, relating to area cover of vegetation in unit area, is shown in Figure 3. It was proved that the mixing ration between vegetation, soil and water derived from TM data in local area has a high correlation with the VSW index derived from AVHRR data, and that the local information from TM data can be extrapolated to more extensive area with AVHRR data.

6. Evaluation of landcover change with time series AVHRR NDVI data

Landcover alteration index was developed with time series AVHRR NDVI data. Ten days composite AVHRR GAC data provided by USGS EROS Data Center was used for the analysis. It covers South-East Asia from 1982 to 1992 with 8 km spatial resolution. Since there are many cloud noise in the original ten days composite data, first, thirty days composite image was produced from ten days composite data by using maximum NDVI values.

The processing is divided into 5 steps for getting alteration index of land cover.

(1) A time sires NDVI data is produced from thirty days cloud free composite data.

(2) An average land cover seasonal change (monthly normal data) of normal year is produced from a time sires NDVI data.

(3) Monthly scattering for 1982 to 1992 is calculated as a standard deviation.

(4) The total amount of the monthly scattering for 1982 to 1992 is calculated.

(5) Finally, alteration index is evaluated by normalizing the total amount of monthly scattering over pixels because it has a pixel-by-pixel difference in an absolute value depending on the landcover categories.

Figure 4 shows an example of alteration index derived evaluated from AVHRR NDVI time series data. In high land areas, there are several overestimated areas with high alteration index. It is due to cloud noise. The north - east part of Thailand are high scattering due to the planted acreage change. Around Hanoi and central Vie - nay, there are high scattering and normalized scattering. In these region, there are big land cover change from forest to agricultural land.

7. Landcover classification using Fourier spectra of time series AVHRR NDVI

Land cover classification over East Asia was also demonstrated using Fourier power spectrum of time series NDVI data which is sampled from 96 months extending from 1982 to 1989. Fourier analysis to time series NDVI data indicates that the power density spectra corresponding to the averaged value (0th order), the 12 months period component and the 6 months period component, respectively, are dominant among all of the components.

Taking these three main spectra as feature vectors of land cover, the monthly NDVI data set is classified into 7 categories (sea, desert, grassland, agriculture, forest1, forest2, and forest3).

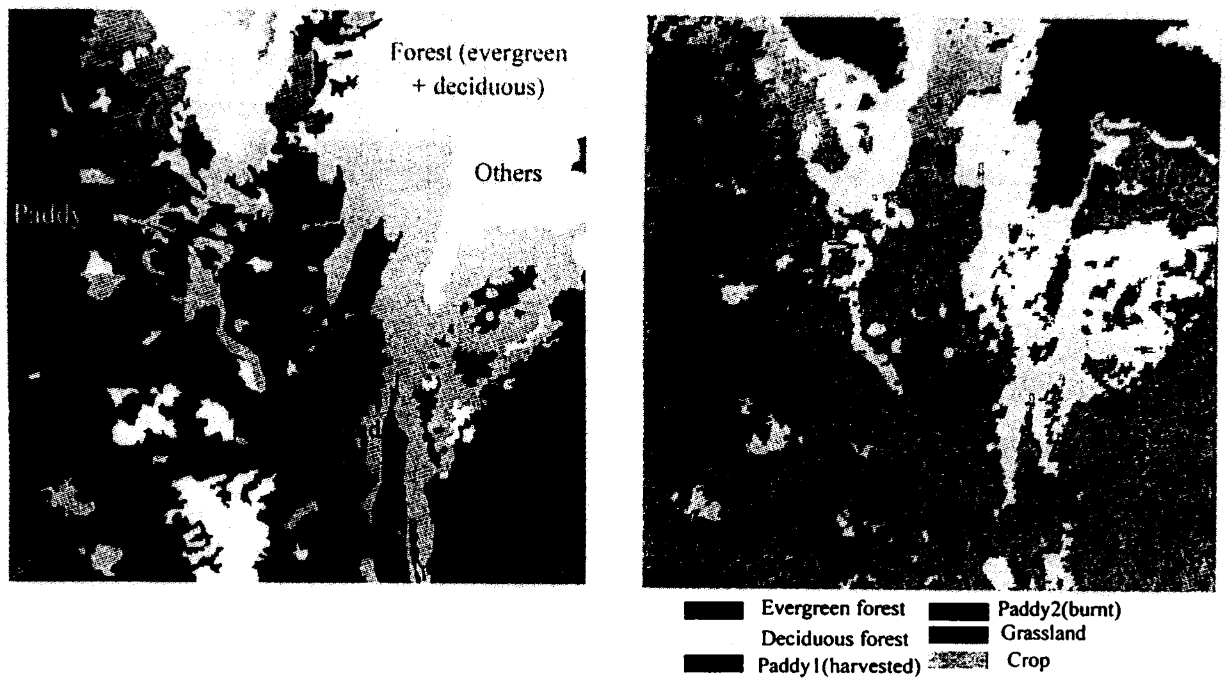

Fig. 2 Landcover classification from TM and AVHRR.

Fig. 3 Estimated vegetation coverage ratio map by scaling model.

First, ISODATA unsupervised classification was operated to the original data and landcover was categorized into 20 clusters, then a maximum likelihood classification was applied after we selected 7 landcover categories (sea, desert, grassland, agriculture, forest1, forest2, and forest3) as training sample data. Figure 5 shows the result of landcover classification over East Asia region. This study demonstrated the possibility to use spectral information as input in a land cover classification of Asia.

8. Conclusions

One of the most serious and direct impact on environment may be land use/cover changes. Monitoring of these rapid and extensive anthropogenic impacts is not easy, and it requires new obsrvation tools besides conventional ground observation. Remote sensing is expected to provide an effective tool to monitor landcover conditions and their changes over extensive area. A large number of satellite images from different sensors are available now, however, new data processing methodologies are needed to extract effective information for environmental management covering from local to global scale.

In this study satellite remote sensing was applied for landcover classification and assessment with new methodological aspects. Landsat TM, MSS and NOAA AVHRR images with different spatial resolution, coverage and with different observation frequency were used in mixed to extrapolate local information to global. An integrated landcover classification and assessment method was developed which utilizes both of TM, MSS and AVHRR data together to take advantages both of high spatial resolution characteristics in TM and MSS and frequent observation characteristics in AVHRR. These new techniques are expected to realize an efficient landcover monitoring system.

References

(1) K.Iwao, R.Shibasaki and M.Takagi(1996): Semi automated geometric correction for mosaicing large number of satellite data, Proc. of 17th Asian Conference on Remote Sensing, pp.F-8-1-F-8-5.

(2) R.Shibasaki, Hua Hu and Elgene.O.Box(1996): Generation of global terrestrial biomass map by integrating satellite data and carbon dynamics model, Proc. of 17th Asian Conference on Remote Sensing, pp.F-8-1-F-8-5.

(3) Y.Yasuoka, M.Sugita, Y.Yamagata, M.Tamura and T.Suhama(1995): Scaling between NOAA AVHRR data and LANDSAT TM data for monitoring and mapping of wetlands, Proc. Int. Symp. on Vegetation Monitoring, pp.131-136.

(4) M.Sugita, Y.Yasuoka, Y.Yamagata and M.Tamura(1996): Scaling of NDVI and VSW index between LANDSAT TM and NOAA AVHRR data, Proc. of 17th Asian Conference on Remote Sensing, pp.L-4-1-L-4-6.