ASSESSMENTS OF LAND COVER /USE AND FRACTIONAL COVER ANALYIS IN NORTHERN THAILAND

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1. Abstract

Satellite images are very useful for mapping land cover/use at regional and global scales. This study employed multitemporal Landsat images for obtaining the information on broad land cover/use types over Thailand during 1999-2000. It focuses on the use of Landsat scene 131/47 for: (1) obtaining forest and non-forest areas and other land cover types; (2) mapping the forest fractional cover (*fc*), and (3) obtaining the biophysical properties in the forest areas based on field measurements and the Gap Light Analyzer Software. Results shows that forest areas occupied 74 % of the total area, and the non forest areas account for about 16 %. The remaining areas (10 %) consisted of water, cloud and cloud shadows, respectively. The percentage of fractional cover shows the spatial variation of forest and vegetation density across the image scene. The gap light analysis of fish eye photographs offers the information on biophysical properties from forest areas, which can be used to compare with fractional cover in the image data for assessing degradation, recovery and biophysical properties in the tropical forests.

2. Introduction

This research has been conducted as part of the Asia Pacific Network (APN) and Southeast Asia Research Regional Information Network (SEARRIN) activities. The overall goal of APN/SEARRIN is to develop and provide access to accurate geospatial land use and land cover data, current conditions and forecasting trends of Land Use and Land Cover Change (LUCC) to the various responsible agencies (e.g. resource managers and policy makers) in order to improve their understandings on the processes that link LUCC to the global change issues (e.g. impacts of biodiversity, climate change, urbanization) (http://www.bsrsi.msu.edu/trfic/APN2001-09/). Three activities were conducted to meet the project goal: (1) to develop the L0 land cover database (expert assessment), whereby the land cover/use has been mapped into five main categories: Forest, Non-forest, Water, Cloud and Cloud shadows; and (2) to map the forest fractional cover from the satellite data, which is useful for assessing forest quality; and (3) to document the precise location of specific land use and land cover types by a GPS, and use a digital camera with a fish-eye lens to capture field-level forest canopy (fractional cover) data (analyzed with Gap Light Analyzer Software, GLA_V2).

3. Research sites and Data sources

The research sites are represented by five Landsat TM scenes (Figure1), which were supplied by the Center for Global Change and Earth Observations, Michigan State University (2003). Detailed information on these data is shown in Table 1**.** They were rectified and registered into a UTM coordinate system. The image processing was mainly conducted on ERDAS Imagine software version 8.5 (ESRI, 2003) on a PC -based microcomputer.

Figure 1: Landsat scenes (in rectangles) covering research sites in Thailand

Source: Center for Global Change and Earth Observations, Michigan State University (2003)

Table 1: Landsat Data Description

Landsat Scene Path/Row	Acquisition Date	Vector File Name	Regional coverage
130 / 50	25-Dec-99	V130050_f.e00	Central
129 /54	04-Dec-00	V129054_f.e00	South
128 /48	27-Dec-99	V128048_f.e00	North-East
127 / 50	25-Mar-00	V127050_f.e00	southeast
131 /47	18-Dec-00	V131047_f.e00	North -Chiang Mai

Source: Center for Global Change and Earth Observations, Michigan State University (2003)

4. Methods

Remote sensing techniques were employed, including atmospheric corrections, image classification and the forest fractional cover *(fc)* analysis. The supervised and unsupervised classification methods were used for classifying all Landsat scenes into five major categories. Then, the forest *fc* was calculated for the entire image scene of P131/47. Field survey was conducted to get the fish-eye photographs from 91 sample sites, consisting of hill evergreen, mixed deciduous, dipterocarp and some non-forest areas. Description on methodologies are summarized as follows:

4.1 Expert assessment (Level 0 Analysis)

The version L0 land cover analysis does not involve field surveys, except field data of some areas from the time period of the data acquisition are involved. Spectral enhancement was firstly conducted to increase the quality of the image data. This procedure allows the operator to adjust the image data by different means, such as stretching, compressing of image channels into major components (PCA), and calculation of vegetation index. The L0 analysis of P131/47 was based on the supervised and unsupervised classification methods. The supervised classification requires enough training areas as inputs into the process. Training areas are identified as the homogeneous areas, which have a similar spectral reflectance on the ground. The unsupervised classification is based on a statistical analysis of the pixels within the image data, which are being grouped into a number of discrete spectral classes, according to the degree of similarity of their spectral reflectance values (Verbyla, 1995). Thus, the unsupervised classification requires no knowledge of existing cover types prior to a classification.

A total number of 46 training areas, including 13 forest areas, 14 non-forest areas, 7 water bodies, 4 cloud areas and 8 cloud shadow areas were digitized from the color composite image (354/BGR) using a visual interpretation for a supervised classification on Landsat scene P131/47. In order to increase the classification accuracy, variance values from each training area are controlled within a minimum bound to avoid having mixed reflectance between classes. Four input image channels, including PC1-PC3 images and NDVI were used for the supervised classification by Minimum Distance to Means and Maximum Likelihood algorithms (Lillesand & Kiefer, 1994) to get forest, non-forest, water, clouds and cloud shadow categories. Forest areas are characterized by hill evergreen, mixed-deciduous and dipterocarpus types. Non-forest areas consist of agricultural land, grassland, shrubs and built-up areas. The unsupervised ISODATA was performed on six input TM bands, including three original bands (3, 4, 5), two haze removal bands (band 1 and band 2) and NDVI image channel for classifying scene P131/47 into 100 spectral classes. Supplementary data such as vegetation map, topographic map and ground information were used for labeling all these values into the same categories as did by the supervised classification.

4.2 Forest Fractional Cover Analysis

Fractional cover (*fc*) is an indicator of the integrity of a tropical forest. This newly developed technique provides a mechanism for mapping continuous fields of forest density rather than discrete classes of cover types (Qi, 2002). Estimation of forest *fc* can be obtained by field measurements, but with a limitation of time and budget over large areas. Satellite images offer advantages for *fc* assessments because of their ability to cover large areas. An approach to this analysis is based on the macroscopic mixture modeling theory (Zeng, et al., 2000). For a surface area consisting of multiple components, the measured spectral response can be expressed as the linear summation of individual contributions, and can be expressed as:

$$S_i = \sum_{J=1}^{n} r_{ij} c_j + e_i \qquad (1)$$

Where, Si is the measured response signal in spectral band i, rij is the response of component j in spectral band i, cj is the contribution of component j within a pixel, ei is the error term, n is the total number of independent reflecting features in a pixel. Unmixing approach assuming each component contributes to the overall observed signals independently at macro scale. Before the equation is applied, a number of components within a pixel are determined. For this analysis, a two-component system was considered (only soils and forest/vegetation). Let Rt be the total spectral response from the surface, Rveg the response from vegetation, Rsoil the response from bare soil, and *fc* the fractional cover of forest, then, the total response from these two components is:

$$Rt = Rveg\, fc + Rsoil\,(1-fc) \quad (2)$$

Equation (2) suggests that the total radiation of pixel is the linear combination of radiation from its vegetation and bare soil, weighted by the vegetation fractional cover *fc*. The reflectance of surface targets changes greatly at different wavelengths, so it is difficult to select the optimal wavelengths for Rveg and Rsoil. At certain wavelengths, Rveg and Rsoil are highly affected by the vegetation wetness, structure, soil moisture and texture. A spectral vegetation index (VI) has been successfully used to suppress these external effects (Qi et al., 2002). Replacing the spectral response R with VI in equation (2) yields:

$$VIt = VIveg\, fc + VIsoil\,(1-fc) \quad (3)$$

Where VIveg is the vegetation index value of the vegetation component, VIsoil is VI value of bare soil component. Then, the *fc* can be expressed as:

$$fc = (VI- VIsoil / VIveg – VIsoil) * 100 \% \quad (4)$$

The *fc* of each pixel can be calculated and the forest density of the whole image can be mapped. This equation was used as a demonstration on the forest and non-forest estimation with satellite and ground measurements in L1 analysis. It is noted that the image data acquired during leaf-on is suitable for mapping forest *fc* than those acquired during leaf-off, because the linear unmixing approach was designed to be sensitive to green vegetation only (Qi, 2002). Thus, seasonal factor needs to be taken into account.

4.3 Field based accuracy assessment (Level 1 Analysis)

The goal for this analysis is to calibrate and validate the fractional cover products derived from Landsat image. This analysis involved with ground survey to take canopy photographs using a fish-eye len camera, and the use of gap light analyzer software to derive the information on the biophysical properties from a range of forest cover types. It is noted that not all of the photograph are in forest cover of 100 %. Some photos in areas with 10-30%, 30-50%, and 50-70% forest cover can be taken from the field. Some non-fish-eye plain digital pictures in non-forest areas were collected as well, with GPS points. This information can be used to validate the non-forest classes (Samek, 2004-personal communication).

For these field measurements, 77 samples from three forest types were chosen (Table 2). Only 19 samples were taken from non-forest areas. Three criteria were considered for conducting field survey: (1) *fc* values from the satellite image; (2) accessibility to the selected sites; and (3) ratio of forest land use on the classified satellite image of the same scene at a finer level of information (Sangawongse et. al., 2004).

Table 2: Ratio of forest land use and the selected sample sites

Land Use	Area (sq.km)	Percent	Number of samples
Hill evergreen forest	6833	26.862	23
Mixed deciduous forest	8741	34.362	29
Dipterocarp forest	9863	38.776	25
Total	25437	100.00	77

Source: Sangawongse et. al. APN final report (2004)

Field measurements of *fc* and other biophysical variables were taken between March-May 2004 to cover 91 sample sites in Chiang Mai, Lumpang and Lumphun Provinces. Forest biophysical properties from each site are characterized by tree height, stem height, canopy density, DBH, LAI, and fractional cover. It is noted that the ground survey period does not correspond with the time of image data acquisition, which may underestimate *fc values* in some forest areas. Chiang Mai sampling sites include Doi Suthep area, area around Maekwang reservoir, Khun Wang area in Maechaem district, Maegat and Huai Num Dung in Mae Taeng district. The Thung Kwien and Doi Khun Tan areas were chosen as sampling sites from Lumpang Province.

Field equipment consisted of digital fish-eye len camera, hand level, compass, handheld GPS, notebook computer, GPS transmitter, field survey form and a measuring tape. The compass was used to orient the upper part of the photos to the north direction. The hand level was used for adjusting the camera in the horizontal level. The photographs can be taken in north, east, south and west directions after adjusting the camera to the horizontal level. Photographs taken from all sample sites were used as an input to the Gap Light Analyzer Software, GLA_V2. More details on steps for analyzing data by this software can be seen in Sangawongse et. al., (2004).

5. Results

5.1 Lo Analysis

The result from a supervised classification of P131/47 scene reveals that forest is the main category, which covers 25,437 square kilometers or about 74 % of the total area (34,032 square kilometers). The non forest area accounts for 5389 square kilometers or about 16 % of the total area. Water accounts for 111 square kilometers or 0.33 % of the total area. Cloud and cloud shadow account for about 1,455 square kilometers (4.28%) and 1,640 square kilometers (4.8 %), respectively. The result of ISODATA classification overestimated area of non-forest (66934 square kilometers), so it did not use for a further analysis. The classification result obtained from all Landsat scenes is shown in Table 3.

Table 3: A summary of land cover classification result of Landsat scenes over Thailand

Scene	Forest	Non-forest	Water	Cloud	Cloud Shadow	Total Area (sq.km)	Remark
130 / 50	5182.47	27967.8	1149.755	-	-	34300.03	Supervised classification
129 /54	25,437.00	5,389.00	111.00	1,455.00	1,640.00	34032.00	Supervised classification
128 /48	7474.93	25695.75	539.06	519.38	-	34229.12	ISODATA
127 / 50	11834.54	9146.72	9234.62	2827.93	1136.14	34179.95	ISODATA
131 /47	25,437	5389	111	1,455.00	1,640.00	34,032.0	Supervised classification

5.2. Fractional cover and L1 Analyses

The database was developed in microsoft access as a result of gap light analysis. Forest biophysical properties such as average of canopy open, average LAI, and average of site open from different land use types were recorded. This digital data base includes photos from fish-eye camera at all survey locations from a GPS measurement. They can be linked into a GIS data layers such as soil, geology, and other interesting attributes for more studies. Table 4 represents result of gap light analysis from Hill evergreen forest, Mixed deciduous forest and dipterocarp forest and non-forest areas. It was found that the average canopy open from hill evergreen forest (25 %) is lower than those obtaining from other forest types, whilst the average of LAI is higher than the others. As was expected, Avg. of % Canopy Open from non-forest areas such as paddy filed is nearly 97 %, with an average site open of about 71 %. These figures correspond with the fractional cover image at the same location.

Table 4: Example of gap light analysis from forest and non-forest areas

Landuse	Avg. Of % Cnpy Open	Avg. Of LAI 5Ring	Avg. Of Trans Dif	Avg. Of % Site Open	Avg. Of % Trans Tot
Field crops	71.59	0.41	11.16	71.53	77.86
Dipterocarp forest	41.35	0.82	7.90	41.35	54.84
Hill evergreen forest	25.34	1.45	4.53	25.33	30.47
Mixed deciduous forest	31.73	1.17	5.75	31.73	39.49
Orchard	38.98	1.05	6.76	38.96	46.18
Paddy field	96.81	0.04	14.11	96.74	96.67
Shrubs	43.61	0.85	7.75	43.60	40.73

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