Monitoring Landcover Change in the Mae Chaem catchment Using Time Series Satellite Data: Application for Integrated Water Resource Assessment and Management in the Upper Ping Basin, Northern Thailand

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Abstract Three recent time slices of Landsat satellite data have provided detailed information on land cover change in the Mae Chaem catchment. These time slices acquired in August 1985, February 1990 and February 1995 were analyzed with image processing techniques, including image enhancement, image rectification and registration and image classification. Ancillary data from vegetation maps, soil maps, a Digital Elevation Model (DEM), aerial photographs and ground surveys were used to improve the accuracy of image classification. Land cover was classified into six major types: Forest, Agriculture, Urban/Settlement, Bare land/Openland, Water and Grassland/ Regrowth. Land cover change was determined by using GIS functionalities. Between 1985 and 1995, forest areas have decreased by about 8%, while grassland, agricultural land and bareland have increased by 7%, 0.7 % and 0.6 % respectively. These land cover data are currently employed by the Integrated Water Resource Assessment and Management[1] (IWRAM) project within an interdisciplinary framework. An output of the IWRAM project is to construct a Decision Support System (DSS) to enhance decision-making by key stakeholders for natural resource management in the upper Ping River basin.

Key words: Remote sensing, Landsat, GIS, Decision Support System.

1. Introduction

Land cover is defined by Skole (1994, p. 15) as "The physical attributes of a segment of the Earth's surface, including biota, soil, topography, and human features".

Land cover changes in the Mae Chaem catchment, upper Ping River basin of northern Thailand is caused by physical processes and/or human activities (IGBP, 1997). These changes have had an adverse effect on the environment, and have resulted in the depletion/deterioration of natural resources. The land cover changes in this catchment are much accelerated by shifting cultivation and forest fire. Land use activities are focused on farming of paddy rice, upland rice and cash crops (e.g. soybeans). The combination of shifting cultivation, topography and the expansion of road networks has increased the problem of soil erosion (Schreider, 1999), which is much related to various hydrological processes taking place in the watershed.

Evidence of the rate of change can be found in the three above mentioned time series Landsat imagery and can be documented using image processing techniques. The information on land cover change are useful for Thai agencies, such as the Department of Land Development (DLD), the Royal Project Foundation (RPF) and the Royal Forestry Department (RFD), which are responsible for resource management and planning.

The main objectives of this paper are (1) to provide the statistics of the land cover from analysis of three 1985-1990-1995 time slices of Landsat data; (2) to explore the potential of existing land cover data for deriving model parameters and other input information in sub-catchments used as case studies for developing a decision support tools.

[1] IWRAM is a collaboration between a number of Thai and Australian agencies: Royal Project Foundation of Thailand, Australian Centre for International Agricultural Research; Department of Land Development; Office of Highland Development, Australian National University; Royal Forestry Department; University departments from Chiang Mai, Maejo and Kasetsart.

2. Sources of data

2.1Processed remote sensing database

The International Centre for Agro-Forestry (ICRAF) provided the land cover database for this study. This data is the product of an IGBP-START[2] project which aimed to provide a better understanding of the stages, processes, as well as the forces driving land - cover changes with a focus on changes affecting forest cover. The processed data consisted of one set of geocoded Landsat-MSS and two sets of geocoded Landsat-TM (see Table 1).

The data covers three sub-watersheds: Mae Chaem, Mae Khan, and Mae Klang of the Ping Basin. These areas are parts of the administrative district of Mae Chaem, Samoeng, Hang Dong, Mae Wang, and Chom Thong, Chiang Mai Province, with an approximately extent of 6,692 km^2 (Dietrich and Xuesen, 1999). The principal objective of IGBP-START is to develop a dynamic model for the monitoring of landuse/landcover changes in tropical forest areas as well as to apply this model to predict future trends of landuse/land cover changes (up to 2000).

Table 1: Processed Time series Landsat data (1985, 1990 and 1995)

Database	Path/Raw	Date
1. Landsat MSS	131/047	2/8/85
2. Landsat-TM	131/047	14/2/90
3. Landsat-TM	131/047	28/2/95

Source: IGBP, LUCC Final Report (1997)

2.2 Thematic and processed GIS Data

GIS database was developed from the 1:50,000 scale topographic maps, consisting of spatial data, such as contours and the product of contours (TIN), soil, road network and etc. The Office of Highland Development (OHD) based in Chiang Mai provided streams and road networks coverages of the catchment and sub-catchments in Arc/Info export format. The catchment boundary was used as a frame for cutting/clipping the Mae Chaem catcment. The streams and roads were used for enhancing the landcover information via overlays.

3. Study Area

The Mae Chaem catchment lies between latitudes 18 °-19° N and longitudes 98°-99°E and is located about 100 km to the south-west of Chiang Mai City (Figure 1). The climate is influenced by tropical monsoon. The total catchment area is approximately 3,600 sq.km, covering 15 topographic maps at 1:50,000 scale. The topography of the catchment is mainly mountainous, with slopes of 35% and greater, particularly along the eastern edge. Forest is the major cover type, which is characterized by evergreen, pine, mix deciduous and dry dipterocarp. The human settlement (mostly Karen inhabitants) occurs on small alluvial flats (slope 0 to 4%; altitude 190-500 m) and terraces (slope 4 to 16%, altitude 500-650 m.) along the banks of the Mae Chaem river and its tributaries. The highest point occurs at the summit of Doi Inthanon, the highest mountain in Thailand (approximately 2,700 m ASL). The main source of water consumption is from the Mae Chaem River that flows north - south down the center of the catchment. It turns eastward to join the Ping River at Ban Soota near the bottom of the catchment.

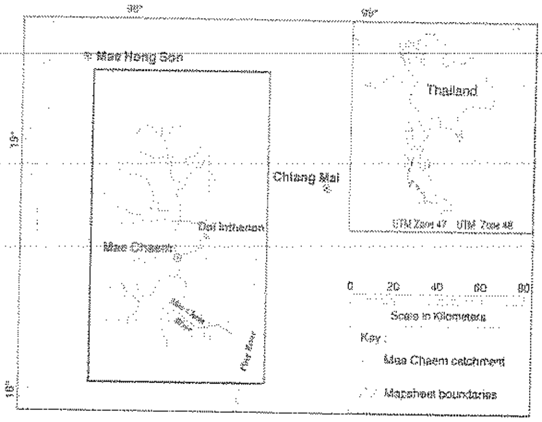

Figure 1: The Study Area in Mae Chaem catchment
Source: Modified from Mullen, et.al.(1999)

4. Methods

4.1 The Digital Image Processing (DIP)

The land cover data for the Mae Chaem catchment were processed by applying DIP (using the MERIDIAN system) on the three available Landsat time slices. The main procedures include of Preprocessing, Image Enhancement, Decision and Classification, Ground Verification and Post-classification (IGBP, 1997).

[2] IGBP stands for International Geosphere-Biosphere; START stands for Global Change System for Research and Training. IGBP/START are programmes supported by GEF/ UNDP to study on the documentation of landuse and landcover change in South East Asian countries.

Preprocessing is usually performed at the start of image processing, which includes radiometric correction and geometric correction. The radiometric correction was performed to remove the atmospheric effects from the raw data, so that interpretation capabilities could be much improved. Geometric correction was performed to relate positions of pixels in the original data to their true ground positions. Geometric correction was firstly performed on the Landsat TM data acquired on 28 February 1995 by registering to a Universal Transverse Mercator (UTM) projection. The *nearest neighbor* resampling which assigns the output pixel value based on the values of the closest pixel in the transformed image (Lillesand & Kiefer, 1994) was chosen for a linear transformation. The image data was resampled from 30×30-meter pixel into 25 x 25-meter pixel size. This rectified image was used as a reference image for co-registering Landsat MSS (2/8/1985) and Landsat TM (14/ 2/1990) by image-to-image registration.

Image Enhancement techniques (i.e. contrast manipulation) were temporarily applied to improve the visual appearance of the image.

Pixels in the raw image data were grouped into land cover classes or "theme", based on their similarities in reflectance, through the classification procedure. *The* supervised classification was chosen, using the *maximum likelihood classifier* that classifies pixels into classes via "Probability density functions" (Richards, 1985). This classifier often yields better result than using other classifiers, except it is a computer intensive. The ancillary data from soil, vegetation and aerial photographs were employed during the classification to improve accuracy.

Ground Verification was conducted using subjective random sampling for checking the accuracy of the classified land cover data. The location of each sample point was collected by using the Global Positioning System (GPS) and ground surveys. *Post-classification* using manual and GIS correction techniques were applied to the classified image after the ground verification (IGBP, 1997).

4.2 Data conversion and derivation

Before the land cover data of the study area can be obtained, much conversion has been done on the processed land cover data, using GIS functionalities. The Northern Remote Sensing and GIS Centre (NRGC), department of Geography, Chiang Mai University provided facilities for this task, as listed below:

- Download the data from the CD onto the hard disk;
- Convert the geocoded Landsat data from PCI EASI/PACE format into ERDAS (LAN) format;
- Import the LAN data into ArcView/ Spatial Analyst as an image;
- Convert the image data into grid data;
- Extract only the Mae Chaem data from the grid data using Map Calculator in ArcView (ESRI, 1996) GIS functions (required GIS data layers, i.e. boundaries of the Mae Chaem catchment and its five sub-catchments)
- Re-calculate the area of each land cover category;
- Checking the accuracy using GIS and ground surveys;
- Produce the time series land cover maps, charts and their attribute tables.

The above stages are computer intensive as raster and grid images data was large (each classified image data took up approximately 15 MB of disk space). The handling of the landcover data requires special storage media such as ZIP disks and CD-rom. A high Computer Processing Unit (CPU) is necessary for a faster processing.

5. Application of land cover data in the Maechaem catchment

The land cover data is currently employed by IWRAM project. For example, Schreider (1999) has employed the landcover data as one of the indicators of potential soil erosion in the Universal Soil Loss Equation (USLE). The preliminary work on soil erosion has been conducted in the Mae Pan sub- catchment. Schreider suggests the use of land cover data as one input among soil and topographic data to derive erosion harzard map.

Department of Land Development (DLD) uses "average crop index" or "C" factor from the land cover data. The "C" factor has been used as one variable in addition to rainfall erosivity (R), slope length (LS), soil erodibility (K) and conservation practice (P) in developing the soil erosion model, based on DLD standard (Tansiri, 1999- pers. Comm). DLD also uses the land cover data with soil maps, land unit maps and soil suitability/capability maps for policy-making on sustainable resources management in the Mae Chaem catchment (Krisadatarn, 1999- pers. comm).

Janekarnkij, Punyawadee and Scoccimarro (1999- pers.comm) have considered the use of the spatial attributes (e.g. village boundaries) from the landcover, for validating a Resource Management Unit (RMU) concept. RMU represents households grouped into homogeneous types based on similarities in biophysical, economic and socio-cultural attributes. RMUs are central to a current catchment project taking place in northern Thailand (Walker and Scoccimarro, 1999).

Suggestions on the development of the land cover data are: (1) use of aerial photographs at approximately 1:15,000 scale for accurate mapping of land cover at village level (2) use of a high resolution of the satellite data with ground surveys for obtaining updated land cover information; and (3) integrate the land cover data with GIS data and terrain attributes, e.g. DEM for obtaining new and useful information in the Mae Chaem catchment.

6. Results and Discussion

Land cover in the Mae Chaem catchment was classified based on IGBP (1997) into six major categories: (1) Forest; (2) Agricultural land; (3) Urban/Settlement; (4) Bare Land/Open Land; (5) Water and (6) Grass/Regrowth. The definition of each of these categories is summarized in Table 2. The extent of land cover in the Mae Chaem catchment was obtained by using the Map Calculation function in ArcView GIS (ESRI, 1996) as presented in Tables 3, 4 and 5 respectively. The time-series landcover maps of the Mae Chaem catchment and its five sub-catchments are shown in figures 2A-2C and figures 3A-3C accordingly.

The four main land cover classes are forest, bareland, grassland and agriculture accordingly. Forest regions dramatically decreased from 87.54 % in 1985 to 76.8 % in 1990 (about 398 sq.km) and slightly increased from 76.8 % in 1990 to 78.83 % in 1995 (about 78 sq.km). The increase of forest area by 2 % from 1990 to 1995 could result from the logging ban policy in 1988. The decrease of forest area between 1985 and 1995 by about 8 % corresponds to the national forest figure (Royal Forest Department, 1996).

Agricultural areas, concentrated in the river basins and the valley floors, steadily increased from 0.93 % in 1985 to 1.6% in 1995 due to the increased demand for cultivation land. Similarly, the urban/settlement (occurred in the valleys) steadily increased from 1985 to 1995 due to the increase of population in Mae Chaem during the period of this study (Chiang Mai Provincial Statistical Office, 1996).

The bare upland fields characterized by fallow fields are found in the mountainous area. Bare land increased from 5.31 % in 1985 to 7.81 % in 1990 (96.07 sq.km), and reduced from 7.81 % in 1990 to 5.89 % in 1995 (72.63 sq.km). Grassland increased from 6.20 % in 1985 to 13.09 % in 1995 (280.87 sq.km), but slightly decreased from 13.45% in 1990 to 13.08 % in 1995 (13.9 sq.km). The land cover change between 1985 and 1995 in the Mae Chaem catchment. is shown in Table 6. The land cover change in the case study sub-catchments has been conducted by Dietrich and Xuesen (1999) using the same method.

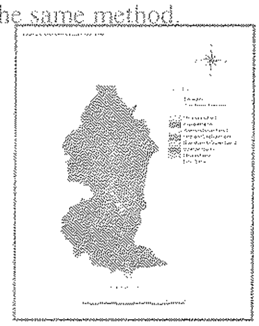

Figure 2A: Land Cover Maps in the Mae Chaem Catchment obtained from the analysis of Landsat MSS data (2/8/1985)

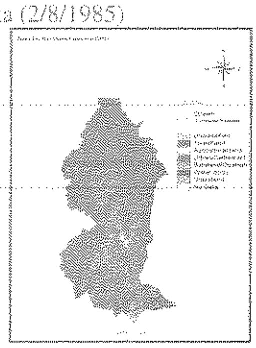

Figure 2B: Land Cover Maps in the Mae Chaem Catchment obtained from the analysis of Landsat LandsatTM data (14/2/1990)

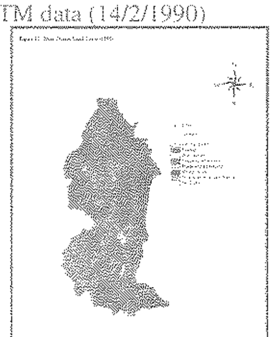

Figure 2C: Land Cover Maps in the Mae Chaem Catchment obtained from the analysis of Landsat
Landsat TM data (28/2/1995)

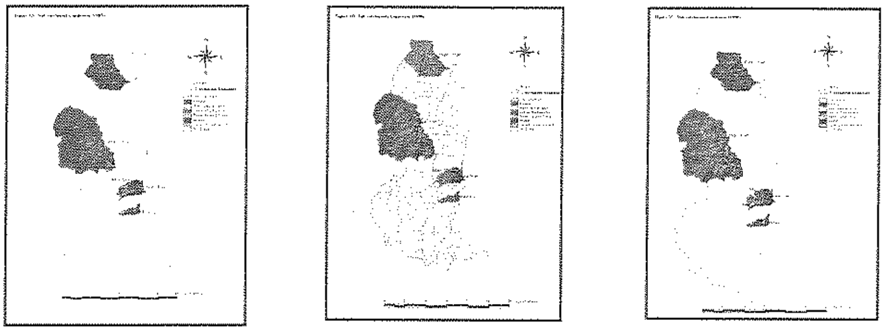

Figure 3: Land Cover Maps in the five Sub-catchments of Mae Chaem obtained from the analysis of Landsat MSS data (2/8/1985), Landsat TM data (14/2/1990) and LandsatTM data (28/2/1995)

Table 2: Description of Land Cover Types in the Mae Chaem Catchment

Category	Land Cover Type	Identification / Description
1.	Forest	Natural forest and reforestation. The main natural forest types are Pine, Mixed Deciduous and Dipterocarps
2.	Agriculture	Permanent or temporary agricultural areas. They mostly occur in the flat plains or lowlands, include active shifting cultivation on the highlands. Agricultural land includes paddy field, upland rainfed fields and cash crops.
3.	Urban/Settlement	built-up area, villages, man-made features along the river banks
4.	Bare Upland Field	New cleared area or prepared highland agricultural area.
5	Water	Natural and man-made reservoirs, moisture surfaces
6.	Grass/ Regrowth	Grassland and secondary growth that develops in deteriorated forest or abandoned agricultural area, including young forest plantation (less than 5 years old) and forest regeneration

Table 3: Land Cover statistics in 1985

	Catchment	Sub-catchment				
Land Cover types/1985	Mae Chaem	Mae Lu	Mae pan	Mae Uam	Mae Yort	Wat Chan
Forest	3361.81	29.26	37.86	33.84	604.24	230.16
Agriculture	35.73	0.93	2.00	2.84	1.91	3.43
Urban/Settlement	0.27	-	-	0.02	0.04	-
Bare Upland Field	203.77	1.12	2.90	-	32.83	2.82
Water	0.42	-	-	-	0.02	0.13
Grass/ Regrowth	238.13	1.74	2.07	2.69	40.99	6.30
Total area	3840.13	33.05	44.83	43.65	680.26	243.04

Table 4: Land Cover statistics in 1990

	Catchment	Case- study Sub-catchment				
Land Cover tpes/1990	Mae Chaem	Mae Lu	Mae Pan	Mae Uam	Mae Yort	Wat chan
Forest	2964.2	27.87	36.51	30.87	517.45	195.88
Agriculture	54.43	1.46	2.64	3.49	3.38	5.17
Urban/Settlement	1.96	0.03	0.04	0.07	0.20	0.18
Bare Upland Field	299.84	1.64	3.88	5.62	48.48	3.90
Water	0.68	-	0.01	0.01	0.03	0.16
Grass /Regrowth	519.00	2.05	1.76	3.57	110.48	37.56
Total	3840.13	33.05	44.84	43.63	680.25	243.05

Table 5: Land Cover statistics in 1995

	Catchment	Case-study Sub-catchments				
Land Cover types/1995	Mae Chaem	Mae Lu	Mae Pan	Mae Uam	Mae Yort	Wat Chan
Forest	3042.68	28.20	36.59	31.18	533.38	210.41
Agriculture	61.75	1.53	3.51	4.72	3.91	5.32
Urban/Settlement	2.67	0.04	0.07	0.08	0.28	0.21
Bare Upland Field	227.21	1.34	2.22	4.03	28.48	1.67
Water	0.72	0.00	0.01	0	0.04	0.17
Grass /Regrowth	505.10	1.95	2.44	3.63	113.93	24.99
Total	3859.61	33.05	44.84	43.64	680.25	242.96

Table 6: Land cover change in the Mae Chaem catchment

Land cover types	1985-1990		1990-1995		1985-1995	
	By area	By %	By area	By %	By area	By %
1. Forest	-397.62	-10.35	+ 78.48	+2.03	-319.13	-8.37
2. Agriculture	+ 18.7	+0.49	+ 7.32	+0.19	+26.02	+0.68
3. Urban/Settlement	+1.42	+0.04	+ 0.98	+0.02	+ 2.4	+0.06
4. Bare Upland Field	+ 96.07	+2.50	- 72.63	-1.89	+ 23.44	+0.61
5. Water	+ 0.26	+0.01	+ 0.04	0	+ 0.30	+0.01
6. Grass/Regrowth	+ 280.90	+7.31	- 13.9	-0.36	+ 266.97	+6.95

N. B. + represents positive change (increase); - represent negative change (decrease)
Unit of measurement is in sq.km. for every table

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Acknowledgment

The authors would like to acknowledge the financial support from the Australian Centre for International Agricultural Research (ACIAR). Many thanks are given to ICRAF for providing the landcover database, especially to Ms. Pornwilai Saipothong for her assistance with this work. Thanks also go to Mr. Wunlop Munnae from Office of Highland Development in Chiang Mai for his help in producing the land cover maps.