Land use change in ThapLan National Park, the part of Dong Phra Yayen - Khao Yai Forest Complex World Heritage, Thailand

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Abstract

Land Use and Land Cover Change (LUCC) is a well-recognized agent of ecological change and a prominent interface between human activities and global environmental change. To assess land use classification in ThapLan National Park and the 5 km buffer zone from 1987 to 2006, remote sensing technique was selected. The land use classification in ThapLan National Park and 5 km buffer zone was performed by using 1987, 1997, 2003, and 2006 Landsat-TM data. In this study, ten land use types were 10 land-used types, including Dry Evergreen Forest (DEF), Mixed Deciduous Forest (MDF), Dry Dipterocarp Forest (DDF), paddy field, field crop, perennial and orchard, grassland, water body, urban and built-up area, and other lands (old clearing, uncultivated land, barren land/bare land) based on the classification of Land Development Department (LDD) and the Royal Forest Department (RFD). The maps of land use of ThapLan National Park showed that between 1987 and 2006 the amount of forestland dominantly decreased from 1,948.73 km^2 to 1,890.20 km^2, while those of the 5 km buffer zone decreased from 1,041.35 km^2 to 973.28 km^2. The results quantify the land cover change patterns in the tropical forest area and demonstrate the potential of Landsat data to provide an accurate, economical means to map and analyze changes in land cover over time that can be used as inputs to land management and policy decisions.

Keywords: Land use classification, ThapLan National Park, Remote sensing technique, Landsat-TM data, Buffer zone

Introduction

Tropical forests play a major role in storing large amounts of carbon stocks and in regulating energy and water fluxes. These forests are the center of the plant photosynthesis because the biomass as well as diversity of places is much higher than in other forest types such as temperate or broadleaf forest (Thapa, Shimada, Watanabe, Motohka, & Shiraishi, 2013, pp. 168-178). ThapLan National Park, one of the Dong Phra Yayen - Khao Yai Forest Complex World Heritage (DPKY - FCWH), was inscribed in 2005. This world heritage contains more than 800 fauna species, including 112 species of mammals, 392 species of birds and 200 species of reptiles and amphibians. It is internationally important for the conservation of globally threatened and endangered mammal, bird and reptile species that are recognized as being of outstanding universal value. This includes 1 critically endangered, 4 endangered and 19 vulnerable species. The area contains the last substantial area of globally important tropical forest ecosystems of Thailand Monsoon Forest biogeographic province in Northeast Thailand. Therefore, ThapLan National Park plays an important role in conserving biodiversity and carbon storage in Thailand and Southeast Asia (DNP, 2011). It is now facing serious problems from deforestation and wildlife hunting. Since, there is an expansion of communities into the National Park zone for the tourist attraction in Khon Buri district, Wang Nam Khiaw district, Soeng Sang district in Nakhon Ratchasima province and Na Dee district in Prachin Buri province, the 5 km buffer zone around ThapLan National Park was also taken into account. (Vitousek, Mooney, Lubchenco, & Melillo, 1997, pp. 494-499) have been reported that human population growth represents the primary driving force in land use change. Land use changes in Southeast Asia have been extensive, and less than 50% of the original forest cover remains. The region has experienced one of the highest rates of deforestation in the tropics primarily due to agricultural expansion, logging, and urbanisation (Sodhi, Posa, Lee, Bickford, Koh, & Brook, 2010, pp. 317-328). (Cassidy, Southworth, Gibbes, & Binford, 2013, pp. 26-45) found that land cover change within the lower Mekong River region follow a similar pattern. According to the analytical interpretation by using supervised classification, it was found that most of the areas of Northeast Thailand, i.e., 75%, were made up of cultivated areas, such as rice fields, crop fields in the years 2000-2004 (Ratanopad, & Kainz, 2006, pp. 137-144). The study of the land use classification is one of the most important factors for planning and managing activities concerning the use of land surface. Therefore, the changes of land use in ThapLan National Park and its 5 km buffer zone and carbon sequestration in the forest are greatly of concern. The reason is that the land use change around and in the area would affect carbon sequestration. This matter must be reconsidered and solved to slow down the greenhouse effect and the global climate change at the present time.

Materials and Methods

1. Study Area

The study area covers ThapLan National Park area which is the second largest national park in Thailand after Kaeng Krachan National Park and is the one of Dong Phayayen-Khao Yai-Forest Complex World Heritage. It is situated in Nakhon Ratchasima, Buri Ram and Prachin Buri Provinces. The total study area of 3,824.15 km^2 including the area of 2,219.47 km^2 for the ThapLan National Park and 1,604.68 km^2 for the 5 km buffer zone around the national park. This study area also has 25 sub-districts (Tambol) and consists of 246 villages (Figure 1) (Agricultural Statistics of Thailand, 2004; DNP, 2011)

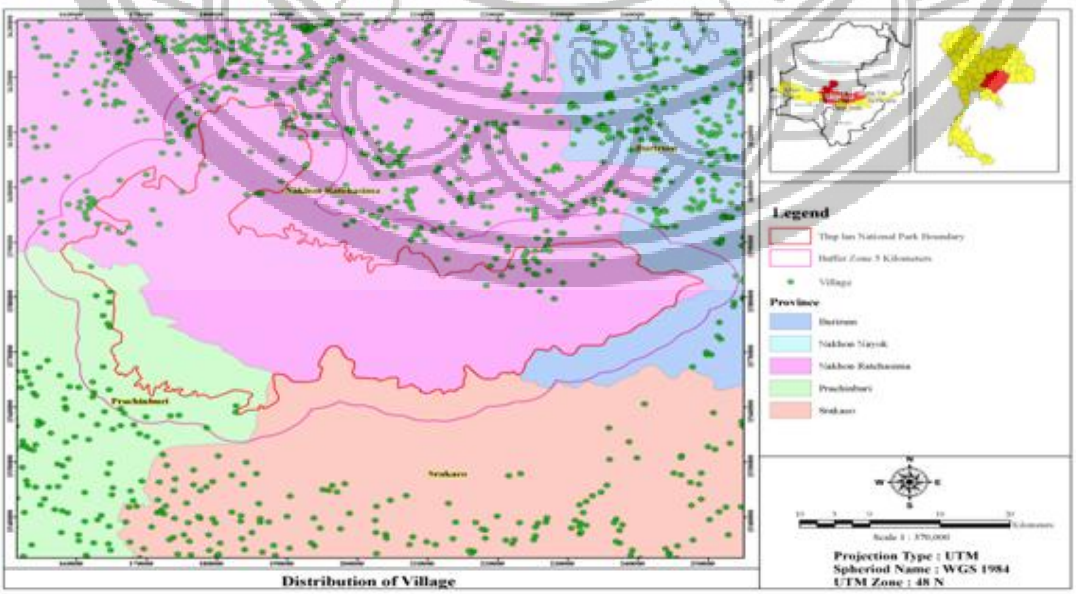

Figure 1 Study Area in ThapLan National Park and its 5 km buffer zone

2. Data and Processing

Landsat-TM data (Path 129 and Row 50) in 1987, 1997, 2003 and 2006 were the major data sources in the study (DNP, 2011; GISTDA, 2012) In addition, land use data in 2006 of Land Development Department, forest cover data in 2000 and 2004 of Royal Forest Department, and field survey data in 2009 were compiled and used as ancillary data in this study (Prayurasiddhi, Chaiwatana, & Naporn, 1999). Major steps in this study were 1) geometric correction of remotely sensed data 2) land use and land cover classification 3) accuracy assessment 4) analysis of prediction. Data used for this research involved spatial data attribute data and Landsat-TM data in 1987, 1997, 2003 and 2006. For equipment, a GPS and a notebook were used as a hardware while GIS ArcGIS 9, and remote sensing Erdas Imagine 8.7 , IDRISI 15.0 soft wares were applied in this study.

2.1 Geometric Correction

Landsat-TM data in 1987, 1997, 2003 and 2006 were geometrically corrected with image to map rectification based on topographic map of the Royal Thai Survey Department. Herein, polynomial second order transformation for spatial interpolation and nearest neighbor resampling for intensity interpolation were conducted with RMS errors less than 0.5 pixel (12.5 m) (Brown, & Masera, 2003, pp. 89-120).

2.2 Land Use and Land Cover Classification

Band 3, 4 and 5 of Landsat-TM data in December of 1987, 1997, 2003 and 2006 were used to classify land use and land cover using supervised classification of Maximum Likelihood algorithm. In addition, visual interpretation was also performed for correction of land use and land cover classes (Congalton, & Green, 2009, p. 183). In this study, the land use classification referred to Land Development Department's land use categories at 10 land-used types, including Dry Evergreen Forest (DEF), Mixed Deciduous Forest (MDF), Dry Dipterocarp Forest (DDF), paddy field, field crop, perennial and orchard, grassland, water body, urban and built-up area, and other lands (old clearing, uncultivated land, barren land/bare land).

2.3 Accuracy assessment

The process for accuracy assessment of interpreted land use in 2006 was conducted in these following steps: 1) calculation of sample size 2) sampling design selection.

In practice, number of sample size is firstly calculated based on statistics and sampling design was then selected for locating observing points for accuracy assessment. Then classified land use and land cover was compared with ground information as matrix error for accuracy assessment.

1. Calculate of number sample size

The actual number of ground reference test samples to be used to assess the accuracy of individual categories in a remote sensing classification map is a very important consideration (Jensen, 2005). In practice, number of sample size was firstly identified based on multinomial distribution with desired level of confidence of 90% and a precision of 10% as following Equation:

$$N = \frac{B\Pi_i(1-\Pi_i)}{b_i^2} \qquad \text{Eq. 4.1}$$

Where B is the upper (α/k) x 100^{th} percentile of the chi square (x^2) distribution with one degree of freedom, Π_i (i = 1, 2, ...k) is the proportion of the population in the i^{th} category, b is the absolute precision of the sample and k is the number of classes (Congalton, & Green, 2009, p. 183).

2. Selection of sampling design

In this study, stratified random sampling technique was applied for locating observing points for accuracy assessment.

3. Accuracy Assessment

In practice, classified land use and land cover in 2006 was compared with ground information in 2009 as matrix error for accuracy assessment with overall accuracy and kappa hat coefficient of agreement as following.

Overall accuracy is compute:

$$\textbf{Overall} \cdot \textbf{accuracy} = \frac{\sum_{i=1}^{k} \mathbf{x}_{ii}}{\mathbf{N}} \qquad \text{Eq. 4.2}$$

Where k is the number of rows in the matrix, x_{ii} is the number of observation in row i and column i and is N the total number of observations (Congalton, & Green, 2009, p. 183)

Kappa hat coefficient, $\hat{K}$, is computed:

$$\hat{K} = \frac{N\sum_{i=1}^{k} x_{ii} - \sum_{i=1}^{k}(x_{i+} \times x_{+1})}{N^2 - \sum_{i=1}^{k}(x_{i+} \times x_{+1})} \qquad \text{Eq. 4.3}$$

Where k is the number of rows in the matrix, x_{ii} is the number of observation in row i and column i and x_{i+} and x_{+i} are the marginal totals for row i and column i respectively and N is the total number of observations (Congalton, & Green, 2009, p. 183).

Results

1. Accuracy assessment

Classified land use and land cover in 2006 was compared with ground information in 2009 for accuracy assessment using overall accuracy and kappa hat coefficient of agreement. In practice, error matrix between land use and land cover type in 2006 and the reference land use and land cover types from field survey in 2009 is firstly constructed and accuracy assessment is then evaluated using the above mentioned methods. In this study, 168 randomly stratified sampling points based on multinomial distribution theory with desired level of confident 90 percent and a precision of 10 percent were used for accuracy assessment. The error matrix between the classified land use and land cover in 2006 and the reference land use and land cover from field survey in 2009 was shown in Table 1. It was found that the overall accuracy was 87.50% and Kappa hat coefficient of agreement was 0.87.

Table 1 Error matrix between land use and land cover in 2006 and ground reference data in 2009

Land use and land cover in 2006	Reference Data in 2009										
	U	A1	A2	A3A4	DEF	MDF	DDF	GL	W1	M	Total
Urban and built-up area (U)	12	0	0	0	0	0	0	0	0	0	12
Paddy field (A1)	0	6	0	0	0	0	0	1	1	0	8
Field crop (A2)	0	0	11	0	0	0	0	1	0	0	12
Perennial and orchard (A3A4)	0	0	0	9	0	0	0	0	1	0	10
Dry evergreen forest (DEF)	0	0	0	0	12	0	0	0	0	0	12
Mixed deciduous forest (MDF)	0	2	0	1	0	36	0	2	0	0	41
Dry dipterocarp forest (DDF)	0	0	0	0	0	0	12	0	0	0	12
Grassland (GL)	0	1	0	0	0	0	0	17	0	0	18
Water body (W1)	0	3	0	0	0	0	0	3	21	0	27
Other lands (M)	0	0	1	2	0	0	0	0	1	12	16
Total	12	12	12	12	12	36	12	24	24	12	168

2. Land Use Classification in ThapLan National Park between 1987 and 2006

Land use classification in ThapLan National Park was analyzed by the data obtained from Landsat-5 TM imagery in December of 1987, 1997, 2003, and 2006, which can systematically be classified into 10 categories: Dry Evergreen Forest, Mixed Deciduous Forest, Dry Dipterocarp Forest, paddy field, field crop, perennial and orchard, grassland, water body, urban and built-up area, and other lands (old clearing, uncultivated land, barren/bare land). The images were geometrically corrected using topographic maps with the scale of 1:370,000. The dominant land use of ThapLan National Park during 1987-2006 (Figure 3-7) was the forestland (85.17-87.80%) which are Dry Evergreen Forest (DEF), Mixed Deciduous Forest (MDF), and Dry Dipterocarp Forest (DDF) covering the areas of 1,224.71-1,252.14, 473.11-500.58, and 161.72-197.15 km^2, respectively. The forestland was declining from the total of 1,948.73 km^2 in 1987 to 1,890.20 km^2 in 2006, the rate of decrease of 3.08 km^2/yr was observed which mainly reflects the decline of MDF and DDF. The most decreasing land use was the DDF, followed by MDF which were 35.43 and 24.24 km^2 or 1.60 and 1.09% of total area, respectively. In contrast, the agricultural and other lands (paddy field, field crop, perennial and orchard, grassland, and other lands), accounting for 11.20-12.98%, tended to increase with time from 248.50 km^2 in 1987 to 280.69 km^2 in 2006 and seem to encroach into DDF and MDF. During the study period, field crop, grassland, and other lands increased with the area of 13.52, 12.73, and

17.66 km^2, whereas the paddy field and perennial and orchard decreased with the area of 8.76 and 2.96 km^2, respectively. During 1987-1997, water body, covered for 0.50% of total area in 1987, was sharply increased (20.58 km^2 or 0.95% of total area) attributed by the construction of Lam Plai Mat dam. Urban and building area, covering for 0.50-0.68% of total area, was gradually increasing from 11.11 km^2 in 1987 to 15.00 km^2 in 2006.

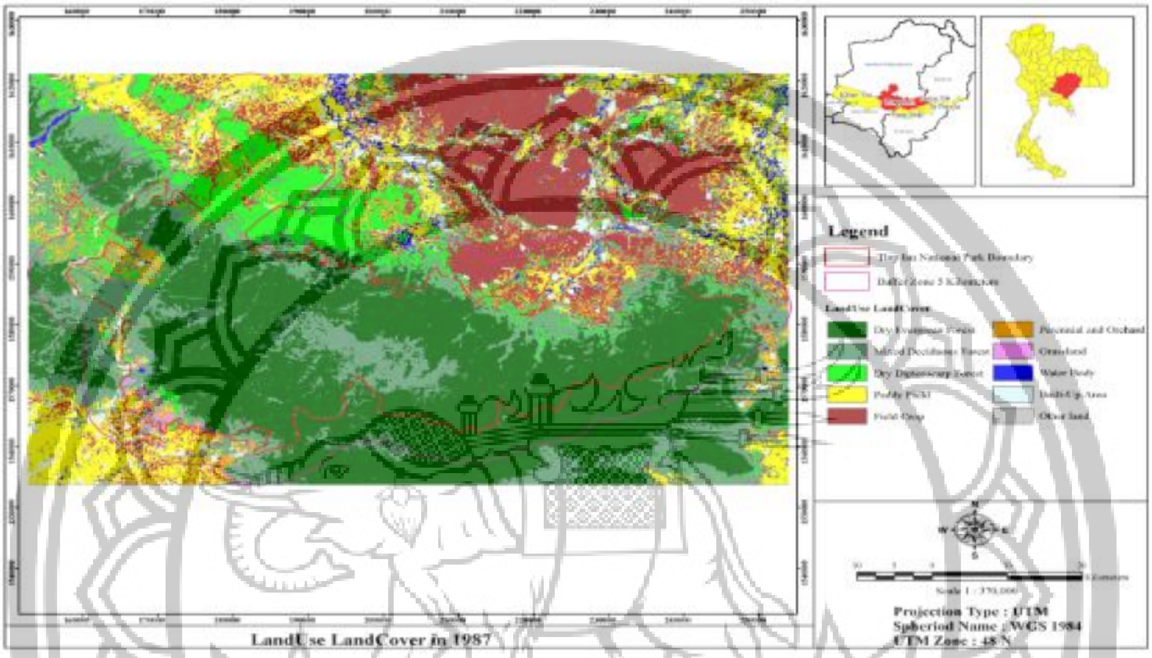

Figure 3 Land use of ThapLan National Park in 1987

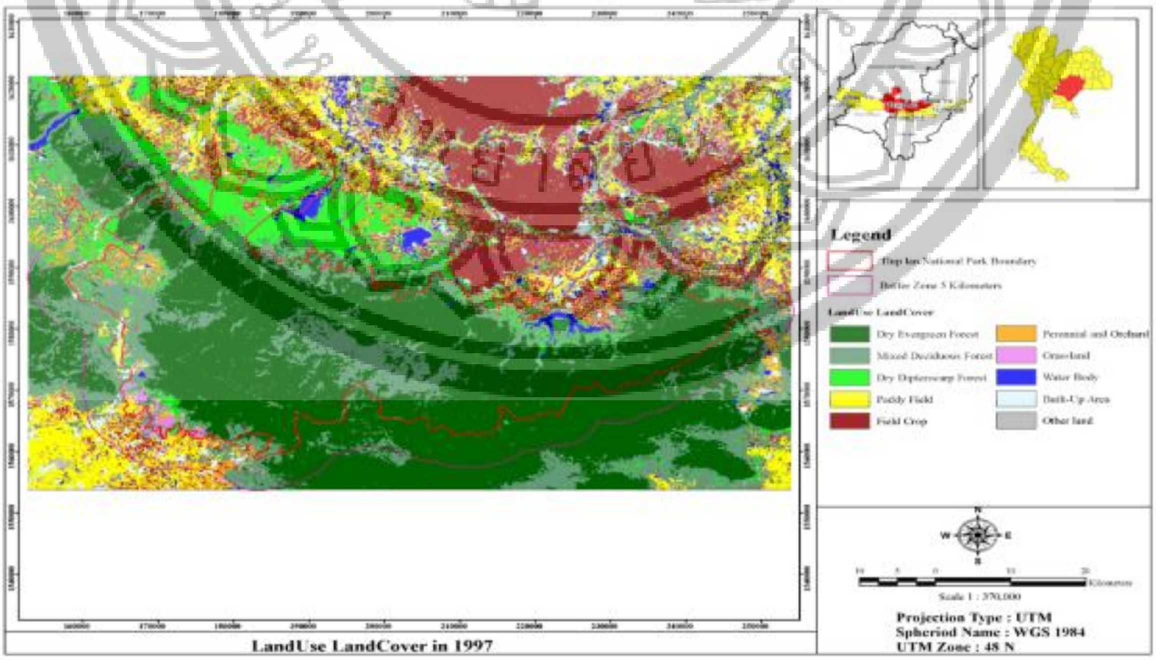

Figure 4 Land use of ThapLan National Park in 1997

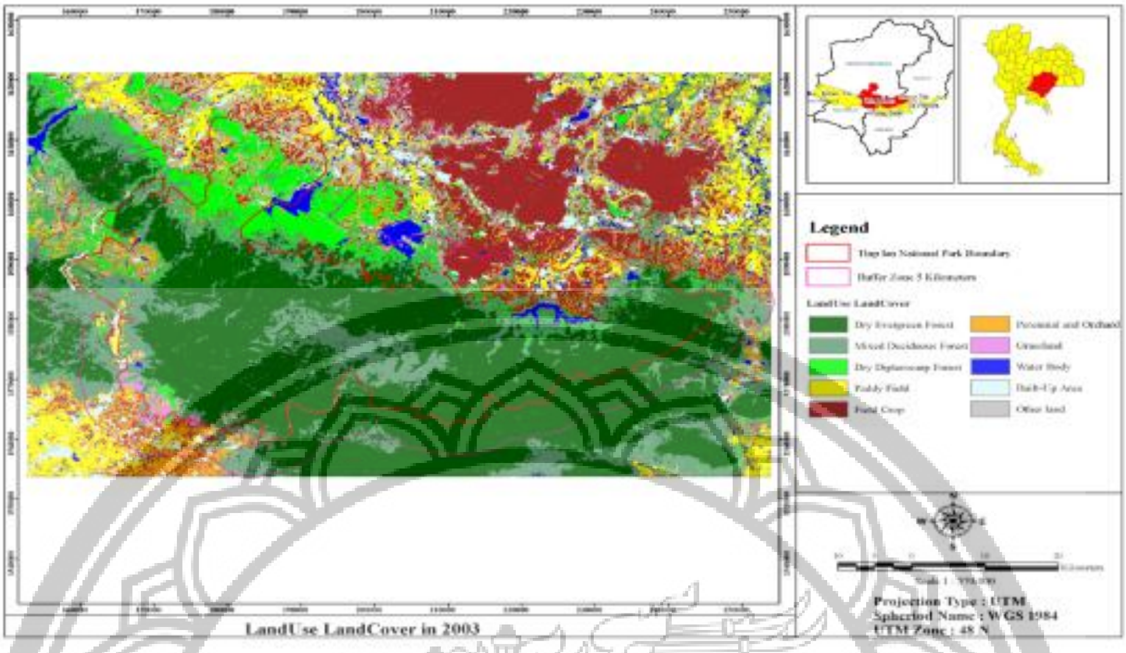

Figure 5 Land use of ThapLan National Park in 2003

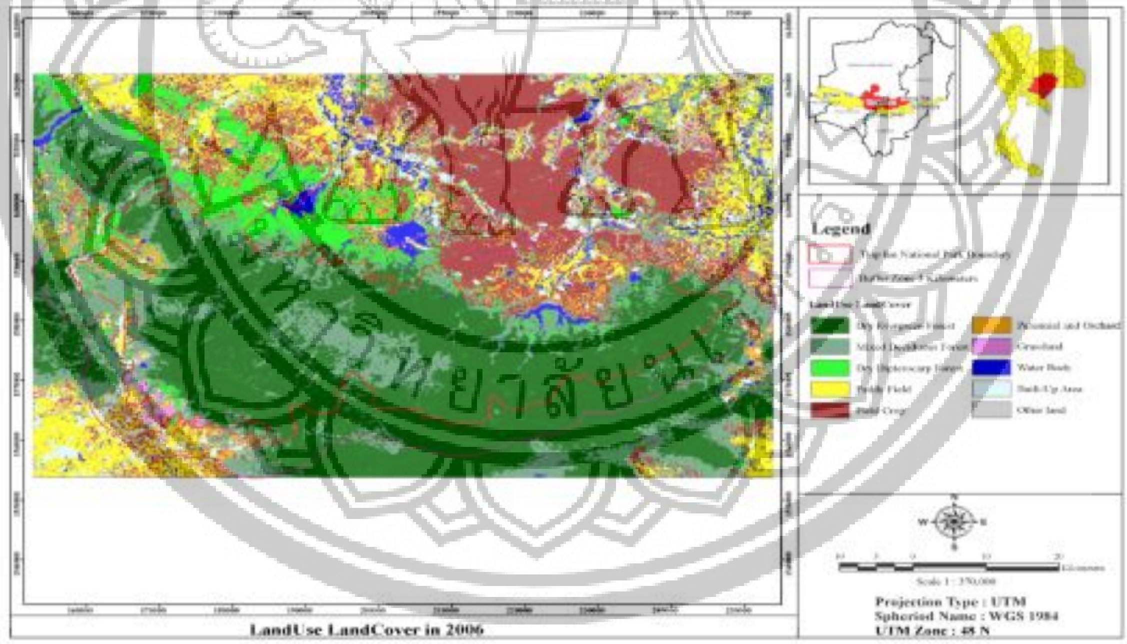

Figure 6 Land use of ThapLan National Park in 2006

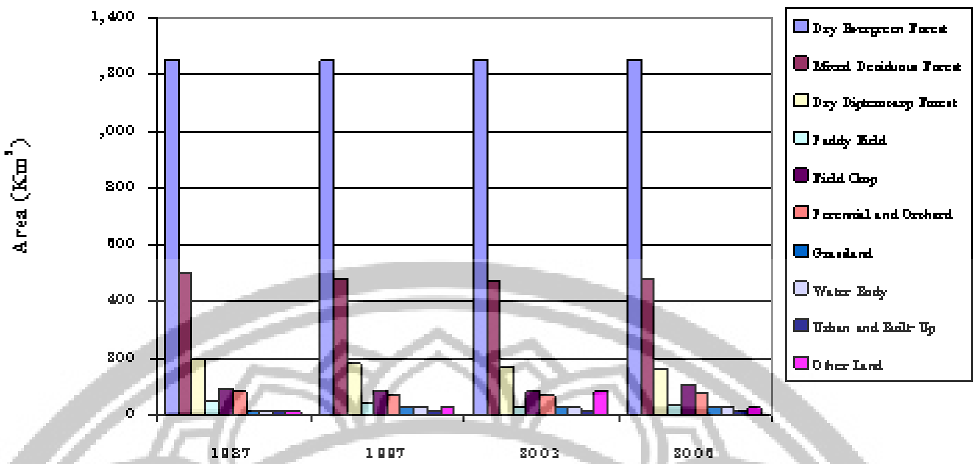

Figure 7 Land use of the ThapLan National Park in 1987, 1997, 2003, and 2006

3. Land Use Classification of the 5 km Buffer Zone around ThapLan National Park between 1987 and 2006

The land use classification of the 5 km buffer zone showed a similar trend as inside the ThapLan National Park, but higher percentages of change were observed in the buffer zone. The forestland in the buffer zone, accounting for 60.65-64.89% of total area, was decreasing from the total of 1,041.35 km^2 in 1987 to 973.28 km^2 in 2006, the rate of decrease of 3.58 km^2/yr was observed (higher than the inside of ThapLan National Park). The most decreasing land use was DDF, followed by MDF which were 39.33 and 28.67 km^2 or 2.45 and 1.79% of total area, respectively. The agricultural and other lands were increased from the total of 479.63 km^2 in 1987 to 513.05 km^2 in 2006, which was due to the deforestation of DDF and MDF. The overall changes of agricultural and other lands revealed that field crop, perennial and orchard, grassland, and other lands increased by the area of 13.23, 1.75, 11.64, and 32.72 km^2, whereas paddy field decreased by the area of 25.92 km^2. Water bodies were also sharply increased during 1987-1997, by the construction of Munbon and Lum Sae dams. The urban and built-up area gradually increased from 46.73 km^2 in 1987 to 59.10 km^2 in 2006. The increment of urban and built-up area was 0.65 km^2/yr.

Discussion

Knowledge about land use/land cover has become important to overcome the problem of biogeochemical cycles, loss of productive ecosystems, biodiversity, deterioration of environmental quality, loss of agricultural lands, destruction of wetlands, and loss of fish and wildlife habitat (Mottet, Ladet, Coque, & Gibon, 2006, pp. 296-310). The land use classification methodology presented here accurately quantified change in multiple land uses that occurred at different spatial and temporal scales. The classification results have shown that ten land use types, including Dry Evergreen Forest (DEF), Mixed Deciduous Forest (MDF), Dry Dipterocarp Forest (DDF), paddy field, field crop, perennial and orchard, grassland, water body, urban and built-up area, and other lands (old clearing, uncultivated land, barren land/bare land) were classified based on the classification of Land Development Department

(LDD) and the Royal Forest Department (RFD) in ThapLan National Park and 5 km buffer zone were performed by using 1987, 1997, 2003, and 2006 Landsat-TM data. Land use of ThapLan National Park showed that between 1987 and 2006 the amount of forestland decreased from 1,948.73 km^2 to 1,890.20 km^2, while those of the 5 km buffer zone decreased from 1,041.35 km^2 to 973.28 km^2. Similarly, some studies found human activity leading to conversion of forested area (Homdee, Pongput, & Kanae, 2011, pp. 1-6). Monitoring of land cover change using remote sensing data is certainly an imprecise task. Although our estimates of land use are based on classification maps, and maps are simply generalization of reality, it is important to acknowledge that these might contain errors (Cayuela, Benayas, & Echeverría, 2006, pp. 208-218). The overall accuracies of the land cover maps for 1987, 1997, 2003, and 2006 were above 80% and, hence, met the target accuracy threshold of 80-85% for thematic mapping in satellite remote sensing (Were, Dick, & Singh, 2013, pp. 208-218).

Conclusions

Land use and land cover change (LUCC) is one of the key impact factors for the climate and ecological system change. The reduction of forestland with the increment of inappropriate agricultural and settlement areas affect the carbon cycle and cause the net carbon dioxide (CO_2) release into the atmosphere. Therefore, the main objectives of this study are to assess land use classification in ThapLan National Park during 1987-2006 by the remote sensing technique. The use of Landsat-TM data to detect land use and land cover classification has been generally a success. The results quantify LUCC patterns in in ThapLan National Park during 1987-2006 and demonstrate the potential of Landsat data to provide an accurate, economical means to map and analyze changes in land cover over time that can be used as inputs to land management and policy decisions.

Recommendations

1. To improve the accuracy of land use classification assessment, more satellite images should be used in the analysis, correlated with more field survey. Also the comparison among different years, pixel by pixel, should be used to reduce anomalies in changes of each image.

2. More forest sampling plots should be placed randomly around the study area especially in Dry Dipterocarp Forest to increase the accuracy of forest structure and carbon storage evaluation.

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