

Original article

## Integration of Geo-informatics and Landscape Metrics for Forest Resources Assessment in Thap Lan National Park

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### ABSTRACT

The main objective of the study was to assess the status of and changes in the landscape and landscape types using geo - informatics and landscape metrics. Landsat - TM images from 1987, 2005 and 2007 were used initially to classify 14 land use and land cover classes by digital image processing and visual interpretation. Then, the 14 land use and land cover classes were reclassified into seven landscape types: forest, natural forest succession and forest plantation, urban and built - up, agriculture, grassland, water bodies and miscellaneous landscape to assess their status and changes to the landscape and landscape types using landscape metrics.

The assessment of the status and changes at the landscape level indicated that all three landscape metrics (dominance, contagion and fractal dimension) continued to decrease. The landscape change metric was 0.044 during 1987 - 2005 while it was 0.060 between 2005 and 2007. These results imply that Thap Lan National Park and its surroundings had become more fragmented at the landscape level in the past 20 years. Meanwhile, the landscape types, number of patches and patch density for all landscape types increased and the mean patch area decreased during 1987 - 2005, suggesting that fragmentation had occurred in all landscape types over this period. However, the number of patches and patch density for forest and natural forest succession and forest plantation decreased and their mean patch areas increased during 2005 - 2007, indicating that these landscape types were now compact. In addition, the mean Euclidean nearest-neighbor distance for forest and natural forest succession and forest plantation decreased during 1987 - 2005. However, these metrics were increased during 2005 and 2007. Furthermore, the interspersion and juxtaposition index increased in both periods for almost all landscape types except agricultural land where there was a decrease during 2005 - 2007 and grassland where there was a decrease during 1987 - 2005. These results implied that new patches for almost all landscape types occurred during 1987 - 2007 except for grassland between 1987 and 2005 and agricultural land between 2005 and 2007. In the same manner, during 1987 - 2007, the area - weighted fractal dimensions for the forest, natural forest succession and forest plantation landscape types continuously decreased.

**Keywords:** Geo-informatics, Landscape metrics, Dong Phra Yayen-Khao Yai Forest Complex World Heritage, Thap Lan National Park

## INTRODUCTION

Thap Lan National Park, was inscribed in 2005 as part of the Dong Phrayayen-Khao Yai Forest Complex World Heritage (DPKY-FCWH). The justification for inscription of the DPKY-FCWH contains more than 800 fauna species, including 112 species of mammals, 392 species of birds and 200 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 (UNESCO, 2010). Temporal and spatial landscape changes result from the complex interaction of biological and non-biological factors (Xia *et al.*, 2002). Landscape metrics are used to quantify landscape composition and configuration on a map or remotely sensed image (Frohn and Hao, 2006). Investigating landscape patterns and their changes is a prerequisite to the study of ecosystem function and processes, sustainable resource management and effective land use planning (Matsushita *et al.*, 2006). A large number of metrics and indices have been developed to characterize landscape composition and configuration based on a categorical map pattern (Maile *et al.*, 2004). Landscape change has been largely influenced by human activities, especially in recent times. Population growth and various development activities have caused significant changes in land cover (Lee *et al.*, 2004). Therefore, a study of forest resources assessment integrated with geo-informatics and landscape metrics was undertaken. The main objective was to assess the status of and changes in the landscape and landscape types in Thap Lan National Park and its buffer zone.

## MATERIALS AND METHODS

### Study area

Thap Lan National Park, which contains part of DPKY-FCWH, is situated in Nakhon Ratchasima, Buri Ram and Prachin Buri provinces (Figure 1) located between latitude 14° 05' to 14° 33' North and longitude 101° 50' to 102° 40' East. The study area, including a buffer zone of about 5 km around the park covers 3,824 km<sup>2</sup>.

### Data acquisition

Landsat - TM data in 1987, 2005 and 2007 sourced from the Geo-Informatics and Space Technology Development Agency (GISTDA) were geometrically corrected with image-to-map rectification based on a topographic map of the Royal Thai Survey Department (RTSD). Land use data in 2006 sourced from the Land Development Department (LDD), forest cover data in 2000 and 2004 from the Royal Forest Department (RFD) in the form of vector data and field survey data in 2009 were compiled and used as ancillary data for land use and land cover (LULC) classification.

### Data analysis

#### Land use and land cover classification

Bands 3, 4 and 5 of Landsat - 5 TM data in 1987, 2005 and 2007 were used to classify LULC types with a maximum likelihood classifier. In this study, training areas for the LULC classification were identified based on ground surveys and land use and land cover data from the LDD and the RFD. In addition, visual interpretation for LULC types on the screen was also performed for correction of LULC classes. In this study, 14 LULC categories according to the LDD and RFD classifications were extracted from

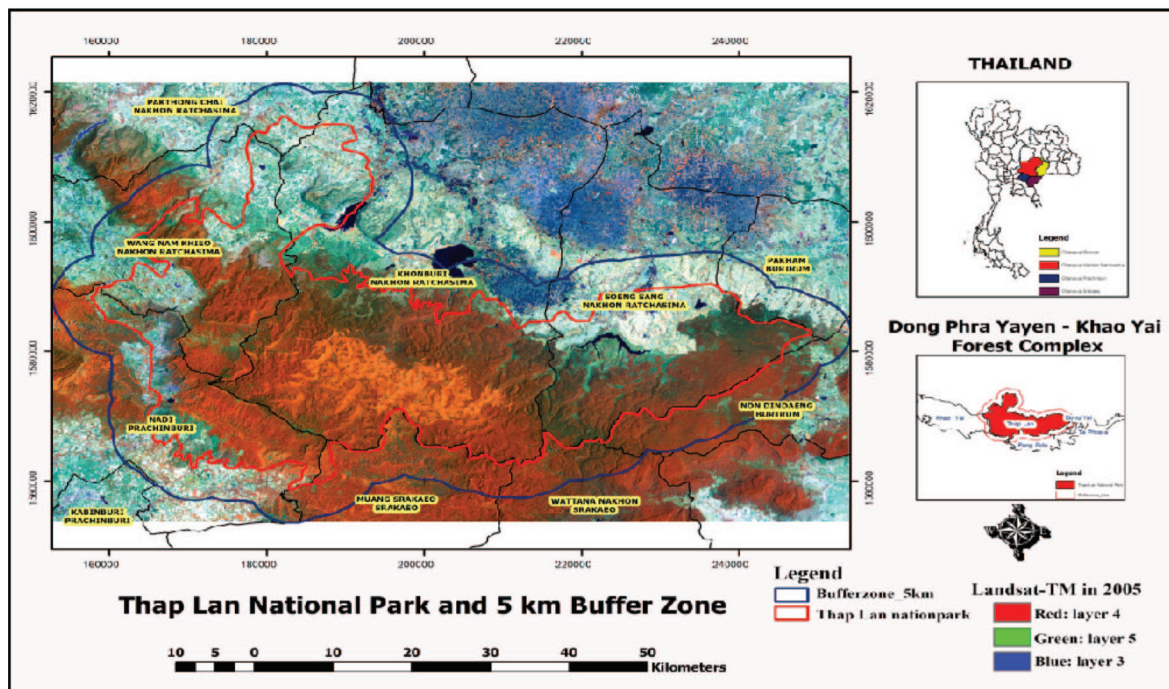


Figure 1 Study area.

remotely sensed data namely, 1) urban and built-up area (U), 2) paddy field (A1), 3) field crop (A2), 4) perennial and orchard (A3A4), 5) dry evergreen forest (DEF), 6) mixed deciduous forest (MDF), 7) dry dipterocarp forest (DDF), 8) bamboo forest (BF), 9) natural forest succession and forest plantation (FSFP), 10) grassland (GL), 11) shrub land (SL), 12) natural water body (W1), 13) reservoir (W2), and 14) miscellaneous land, such as old clearing, uncultivated land, barren land/bare land (M).

#### Assignment of landscape type

The 14 LULC datasets from 1987, 2005 and 2007 in Thap Lan National Park and its buffer were first reclassified into seven landscape types namely, 1) forest landscape (FLT), 2) natural forest succession and forest plantation landscape (NLT), 3) grassland landscape (GLT), 4) agricultural landscape (ALT), 5) urban and built - up landscape (ULT), 6) water body landscape (WLT), and 7) miscellaneous landscape (MLT).

#### Assessment of landscape type and its change

In this step, the area and percentage of each assigned landscape type was first calculated and used to describe the current status of the landscape. Then, post - classification comparison change detection was applied to quantify changes of landscape types between 1987 and 2005, and between 2005 and 2007. This step reported the from - to situation as part of the landscape type information.

#### Assessment of status and change using landscape metrics

For assessment of the current status and changes of the landscape in Thap Lan National Park and its surrounds, various landscape metrics were calculated using FRAGSTATS, a landscape structure analysis program developed by the Forest Science Department, Oregon State University, USA. It has been widely used for quantifying landscape structure in raster format (Mcgarigal

**Table 1** Description of landscape metrics used.

Landscape metric	Description
<b>Landscape level</b>	
<b>Dominance</b>	Dominance is a measure of landscape diversity, or extent to which a few land cover type are dominant in the landscape. The index used here ranges from 0 to 1. High values of D indicated a landscape that is dominated by one or a few landscape types, and low values indicate a landscape where the cover types are represented in approximately equal proportions.
<b>Contagion</b>	Contagion is a measure of the extent that landscape types are aggregated or clumped. High values reflect the clumping of large contiguous patches. Low values reflect a landscape that is dissected into small patches. The contagion index ranges from 0 to 1.
<b>Fractal dimension</b>	Fractal dimension is a measure of the landscape complexity; fractal dimension calculated from perimeter/area has been use widely to describe patch complexity in landscapes. The fractal dimension ranges from 1 to 2; values close to 1 indicate a landscape made up of shapes with simple perimeters, and values close to 2 represent a landscape with very complex perimeters.
<b>Class level</b>	
<b>Class area</b>	Class area equals the sum of the areas of all patches of the corresponding patch type.
<b>Number of patches</b>	Number of patches equals the number of patches in the land cover type or landscape under investigation.
<b>Patch density PD</b>	Patch density equals the number of patches per unit area.
<b>Mean patch area</b>	Mean patch area equals the sum of the areas of all patches of the corresponding patch type (or all patches in the landscape), divided by the number of patches of the same type (or total number of patches).
<b>Area-weighted Fractal Dimension</b>	Area-weighted Fractal Dimension equals the average patch fractal dimension of patches of the corresponding patch type, weight by patch area so that larger patches weight more than smaller patch.
<b>Mean Euclidean Nearest-Neighbor Distance (ENN_MN)</b>	Mean Euclidean nearest-neighbor distance equals the sum of the distances to the nearest-neighboring patches of the same type, based on the shortest edge-to-edge distance, for each patch of the corresponding patch type, divided by the number of patches of the same type.
<b>Interspersion and Juxtaposition Index</b>	Interspersion and juxtaposition index equals minus the sum of each unique edge type divided by the total landscape edge, multiplied by the logarithm of the same quantity, summed over each unique edge type; divided by the logarithm of the number of patch type times the number of patch type minus 1 divided by 2.

and Marks, 1995). Basically, landscape metrics that can provide abundant information about spatial patterns can be divided into three level metrics patch level metrics, class level metrics and landscape level metrics (Xia *et al.*, 2002). In this step, landscape metrics at the landscape and class level were calculated to describe the current status and changes of forest resources and land use (Table 1).

### (1) Status and change of landscape

At the landscape level, landscape three metrics namely, dominance (D), contagion (C) and fractal dimension (F) were computed for the landscape mosaic as a whole. In addition, changes in the landscape were analyzed by calculation of the three-dimensional Euclidean distances that define the distance between landscapes in pattern space as follows:

$$\text{Change } (Z) = [(X_1 - X_2)^2 + (Y_1 - Y_2)^2 + (Z_1 - Z_2)^2]^{1/2}$$

where,  $X$  is dominance,  $Y$  is contagion, and  $Z$  is the fractal dimension and at some magnitude (as yet unknown); this shift would represent a phase change in the landscape (Frohn, 1998). The change metric has a potential range of  $0 < Z < 1.73$  (O'Neill *et al.*, 1996).

### (2) Status and change of landscape type

For the class level, landscape metrics, which were computed for each patch type (class) in the mosaic, were selected based on a review of the previous work of Matsushita *et al.* (2006) namely, 1) class area (CA), 2) number of patches (NP), 3) patch density (PD), 4) mean patch area (AREA\_MN), 5) area-weighted fractal dimension (FRAC\_AM), 6) mean Euclidean nearest-neighbor distance (ENN\_MN) and 7) interspersions and juxtaposition index (IJI).

## RESULTS AND DISCUSSION

### 1. Change of landscape type composition

Post-classification comparison change detection was applied for landscape type change before and after the declaration of DPKY-FCWH in 2005 (Tables 2 and 3 and Figure 2).

#### 1.1 Landscape types change between 1987 and 2005

Before the declaration of DPKY-FCWH in 2005 (1987 - 2005), it was found that urban and built-up, grassland, water body and miscellaneous landscape types had increased by 9.87, 8.17, 30.55 and 42.83 km<sup>2</sup> or with increasing rates of 17.12, 38.33, 92.86 and 97.76% of their areas in 1987, respectively. The average annual increment of urban and built-up, grassland, water body and miscellaneous landscape types gained 0.55, 0.45, 1.70 and 2.38 km<sup>2</sup>, respectively. In contrast, during the same period, forest, natural forest succession and forest plantation and agricultural landscape types lost areas of 45.38, 36.56 and 9.49 km<sup>2</sup>, which represented decreasing rates of their areas in 1987 of 1.73, 9.77 and 1.40%, respectively. The average annual decline in area of forest, natural forest succession and forest plantation and agricultural landscape types was 2.52, 2.03 and 0.53 km<sup>2</sup>, respectively.

#### 1.2 Landscape types change between 2005 and 2007

After the declaration of DPKY-FCWH in 2005, the analysis for the period 2005 - 2007 found that urban and built-up, grassland, water body and miscellaneous landscape types had increased 0.54, 6.41, 20.33 and 168.60 km<sup>2</sup>, respectively, or with increasing rates relative to their areas in 2005 of 0.78, 21.71, 32.04 and 194.60%, respectively. The average annual increment in area for urban and built-up,

grassland, water body and miscellaneous landscape types was 0.27, 3.21, 10.16 and 84.30 km<sup>2</sup>, respectively. In contrast, during the same period, the area of forest, natural forest succession and forest plantation and agricultural landscape types decreased 56.51, 2.95 and 136.42 km<sup>2</sup>, respectively,

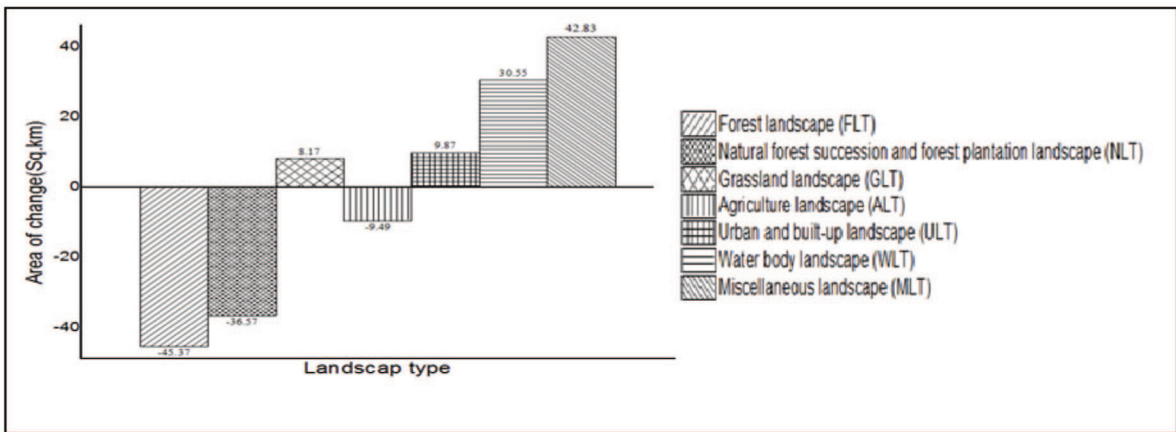
which represented a rate of decrease relative to the area in 2005 of 2.20, 0.87 and 20.40%, respectively. The average annual decline in the area of forest, natural forest succession and forest plantation and agricultural landscape types was 28.25, 1.47 and 68.21 km<sup>2</sup>, respectively.

**Table 2** Change matrix of landscape types between 1987 and 2005.

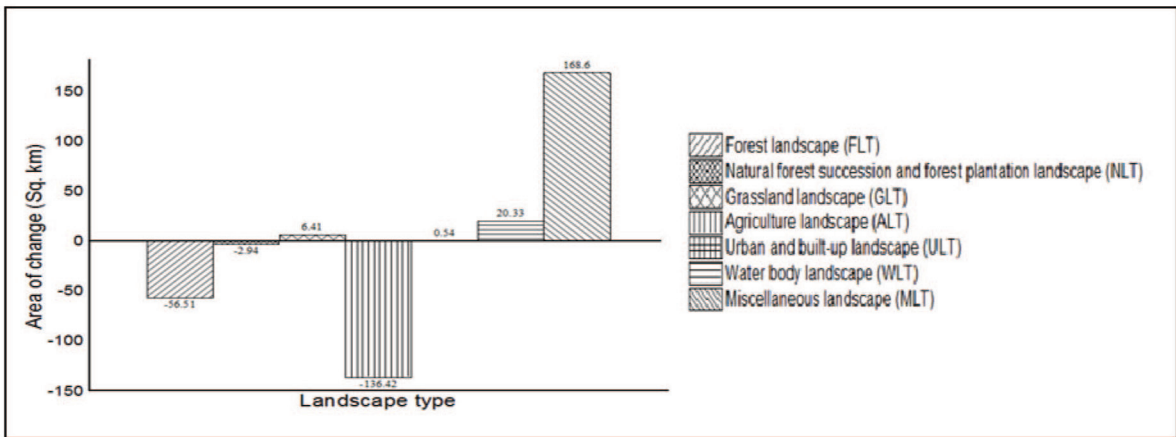
Landscape types in 1987	Landscape types in 2005 (km <sup>2</sup> )							
	FLT	NLT	GLT	ALT	ULT	WLT	MLT	Total
FLT	2 539.79	1.80	0.19	40.99	3.20	15.04	14.96	2 615.96
NLT	29.34	334.81	0.04	0.54	2.07	7.25	0.21	374.25
GLT	0.06	0.72	20.41	0.08	0.01	0.01	0.06	21.34
ALT	1.23	0.29	8.82	625.77	5.31	8.49	28.34	678.24
ULT	0.13	0.04	0.01	0.92	55.86	0.05	0.70	57.71
WLT	0.01	0.01	0.00	0.17	0.22	32.34	0.14	32.90
MLT	0.04	0.02	0.05	0.28	0.91	0.28	42.23	43.81
Total	2 570.59	337.68	29.52	668.75	67.58	63.45	86.64	3 824.21
Area of change (km <sup>2</sup> )	-45.37	-36.57	8.17	-9.49	9.87	30.55	42.83	
Percentage of study area (%)	-1.19	-0.96	0.21	-0.25	0.26	0.80	1.12	
Area per annum (km <sup>2</sup> )	-2.52	-2.03	0.45	-0.53	0.55	1.70	2.38	

**Table 3** Change matrix of landscape types between 2005 and 2007.

Landscape types in 2005	Landscape types in 2007 (km <sup>2</sup> )							
	FLT	NLT	GLT	ALT	ULT	WLT	MLT	Total
FLT	2 511.48	1.04	0.36	7.59	0.39	9.46	40.27	2 570.59
NLT	0.45	332.45	0.03	0.48	0.22	2.22	1.83	337.68
GLT	0.10	0.03	28.37	0.38	0.16	0.01	0.46	29.52
ALT	1.56	0.93	7.07	522.84	1.16	9.18	126.01	668.75
ULT	0.26	0.07	0.01	0.43	65.27	0.07	1.47	67.59
WLT	0.03	0.03	0.01	0.12	0.06	62.45	0.76	63.45
MLT	0.20	0.20	0.07	0.49	0.86	0.39	84.44	86.64
Total	2 514.08	334.74	35.93	532.33	68.12	83.78	255.24	3 824.21
Area of change (km <sup>2</sup> )	- 56.51	-2.94	6.41	-136.42	0.54	20.33	168.60	
Percentage of study area (%)	-1.48	-0.08	0.17	-3.57	0.01	0.53	4.41	
Area per annum (km <sup>2</sup> )	-28.25	-1.47	3.21	-68.21	0.27	10.16	84.30	



(a)



**Figure 2** Distribution of forest and natural forest succession and plantation landscape types changes between (a) 1987 and 2005 and (b) 2005 and 2007.

**2. Status and change of forest resources and land use landscape types**

Under this section, status and change of forest resources and land use landscape types at landscape and class levels are described based on landscape metrics measurement.

**2.1 Status and change at landscape level**

At the landscape level, it was found that all three landscape metrics (dominance, contagion and fractal dimension) of Thap Lan National Park and its 5 km buffer zone continued to decrease from

1987 to 2005 to 2007. In fact, dominance decreased from 0.497 in 1987 to 0.461 in 2005 and to 0.412 in 2007, while contagion decreased from 0.697 in 1987 to 0.673 in 2005 and to 0.645 in 2007. At the same time, the fractal dimension decreased from 1.279 in 1987 to 1.277 in 2005 and to 1.254 in 2007, reflecting that the landscape had become a simple patch. These results imply that Thap Lan National Park and its surrounding buffer had become a more fragmented landscape in the 20-year period (Table 4). In addition, it was found that the landscape change was 0.044 during 1987 - 2005 while it was 0.060 during

2005 - 2007 (Table 5). These results imply that the change in the landscape increased in Thap Lan National Park and its 5 km buffer after the declaration of DPKY-FCWH in 2005. The relative position in the three

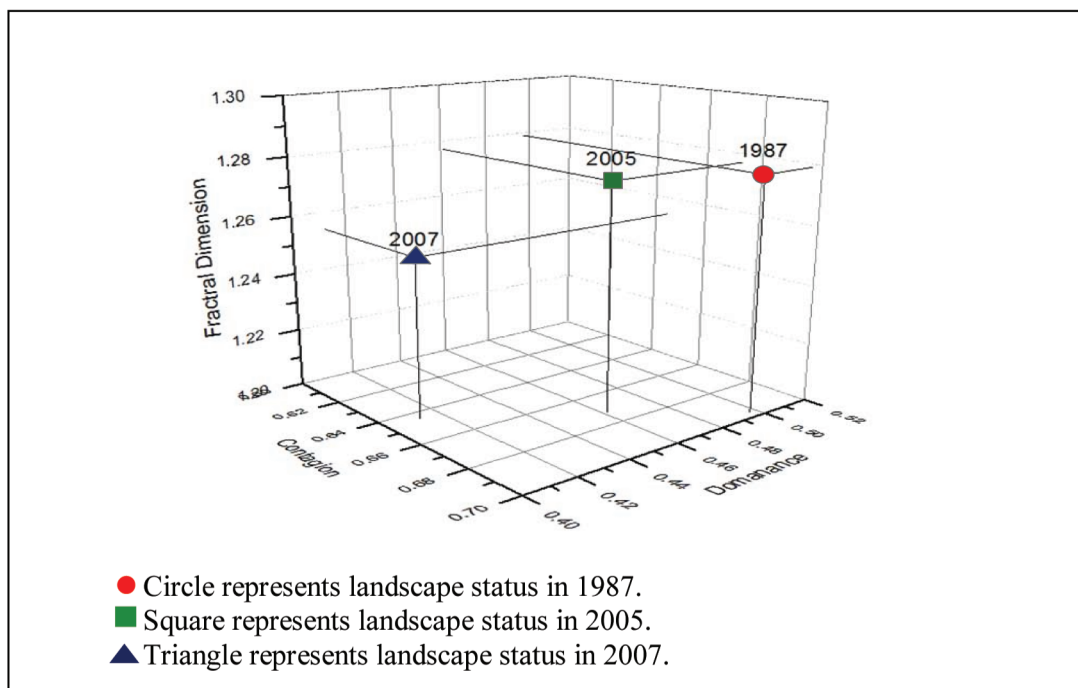
dimensional pattern space of landscape change in the two periods with dominance, contagion and fractal dimension values is presented in Figure 3.

**Table 4** Landscape status in Thap Lan National Park and its 5 km buffer.

Year	Dominance	Contagion	Fractal dimension
1987	0.497	0.697	1.279
2005	0.461	0.673	1.277
2007	0.412	0.645	1.254

**Table 5** Change of landscape in Thap Lan National Park and its 5 km buffer.

Period	Landscape metric			Change
	Dominance	Contagion	Fractal dimension	
1987–2005	0.001316	0.000604	0.000003	0.044
2005–2007	0.002358	0.000749	0.000552	0.060
1987–2007	0.007199	0.002699	0.000635	0.103



**Figure 3** Three dimensional landscape metric feature space and changes in Thap Lan National Park and its 5 km buffer.

**Table 6** Landscape metrics at class level in Thap Lan National Park and its 5 km buffer.

Date	Landscape type	CA	NP	PD	AREA_MN	FRAC_AM	ENN_MN	IJI
1987	FLT	261 596.63	4 097.00	0.59	63.85	1.30	120.34	55.87
	NLT	37 425.25	6 570.00	0.95	5.70	1.21	155.88	35.84
	GLT	2 134.31	875.00	0.13	2.44	1.13	352.55	66.27
	ALT	67 824.00	2 574.00	0.37	26.35	1.29	133.93	83.16
	ULT	5 771.44	156.00	0.02	37.00	1.11	686.69	66.05
	WLT	3 289.69	1 544.00	0.22	2.13	1.12	250.62	63.33
	MLT	4 380.88	4 241.00	0.61	1.03	1.10	163.01	66.61
2005	FLT	257 059.31	5 473.00	0.79	46.97	1.30	106.48	66.07
	NLT	33 768.50	6 571.00	0.95	5.14	1.20	156.41	44.71
	GLT	2 951.50	1 639.00	0.24	1.80	1.12	250.22	65.64
	ALT	66 875.25	3 749.00	0.54	17.84	1.30	109.40	84.79
	ULT	6 758.50	180.00	0.03	37.55	1.11	583.91	74.42
	WLT	6 344.94	1 731.00	0.25	3.67	1.15	243.13	75.40
	MLT	8 664.19	6 593.00	0.95	1.31	1.12	134.13	67.64
2007	FLT	251 408.13	4 313.00	0.54	58.29	1.28	122.09	70.43
	NLT	33 474.25	6 270.00	0.03	5.34	1.20	160.62	51.73
	GLT	3 592.50	2 353.00	0.62	1.53	1.11	220.66	72.99
	ALT	53 232.81	3 721.00	0.91	14.31	1.26	120.92	80.04
	ULT	6 812.19	191.00	0.34	35.67	1.11	594.48	76.61
	WLT	8 378.25	1 558.00	0.23	5.38	1.15	307.82	77.15
	MLT	25 524.06	5 794.00	0.84	4.41	1.14	129.18	77.01

## 2.2 Status and change at class level

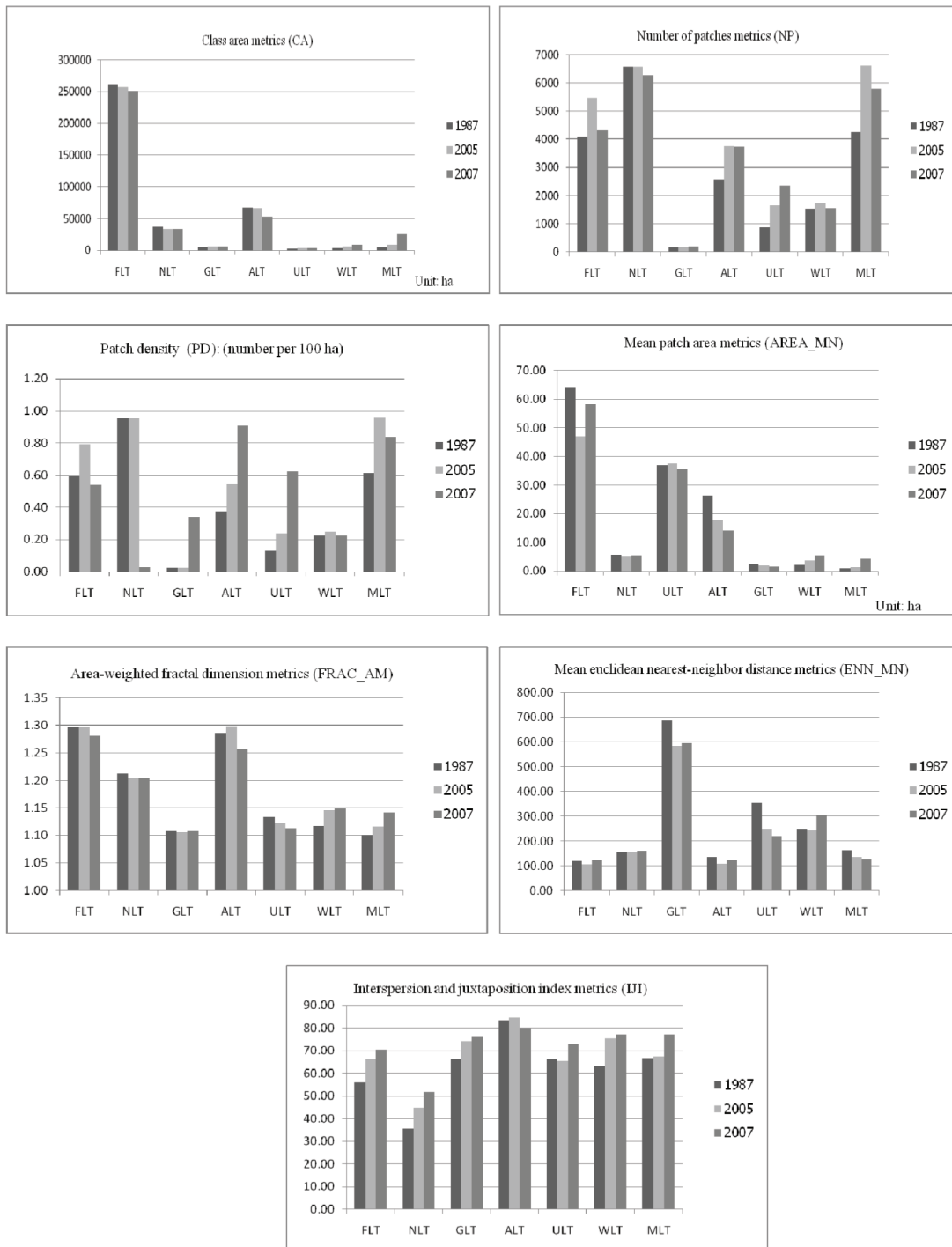
At the class level, the status and change of landscape type was extracted based on selected landscape metrics as shown in Table 6 and Figure 4. The characteristic of each index are described separately.

**Class area.** Forest, natural forest succession and forest plantation and agricultural landscape types continuously decreased over two periods (1987 - 2005 and 2005 - 2007). At the same time, urban and built-up, grassland, water body and miscellaneous landscape types continuously increased. This result implies that interchange had occurred among the landscape types during two periods.

**Number of patches.** During 1987 - 2005, the number of patches for all

landscape types increased suggesting that fragmentation had occurred in all landscape types during this period. In contrast, the number of patches for forest, natural forest succession and forest plantation, agricultural, water body and miscellaneous landscape types decreased during 2005 - 2007, indicating that more aggregation had occurred in these landscape types. At the same time, the number of patches of urban and built-up and grassland landscape types clearly increased showing that fragmentation occurred in these landscape types.

**Patch Density.** The pattern of status change for landscape types based on patch density was the same as for the number of patches. During 1987 - 2005, the patch density for all landscape types increased suggesting that fragmentation



**Figure 3** Comparison of landscape metrics among 1987, 2005, and 2007 in the study at class level.

**Notes:** FLT: Forest landscape; NLT: Natural forest succession and forest plantation landscape; GLT: Grassland landscape; ALT: Agricultural landscape; ULT: Urban and built-up landscape; WLT: Water body landscape; MLT: Miscellaneous landscape.

had occurred in all landscape types during this period. In contrast, the patch density of forest, natural forest succession and forest plantation, water body and miscellaneous landscape types decreased during 2005 - 2007 indicating that more aggregation had occurred in these landscape types. At the same time, the patch density of urban and built-up, agricultural and grassland landscape types clearly increased showing that fragmentation had occurred in these landscape types.

**Mean patch area.** The pattern of status and change for landscape types based on the mean patch area was similar to that observed for the number of patches and patch density. During 1987 - 2005, the mean patch area of forest, natural forest succession and forest plantation, agricultural and grassland landscape types decreased suggesting that fragmentation had occurred in these landscape types during this period. At the same time, the mean patch area of urban and built-up, water body and miscellaneous landscape types increased indicating that less fragmentation had occurred in these landscape types in this period. In contrast, during 2005 - 2007, the mean patch area of forest, natural forest succession and forest plantation, water body and miscellaneous landscape types increased showing that more aggregation had occurred in these landscape types. At the same time, the mean patch area of urban and built-up, agricultural and grassland landscape types clearly decreased which implied that fragmentation had occurred in these landscape types.

**Area - weighted fractal dimension.** During 1987 - 2005, the area-weighted fractal dimension for forest, natural forest succession and forest plantation, urban and built-up and grassland landscape types decreased suggesting that fragmentation had occurred in these landscape types during this period. At the same time, the area-weighted fractal dimension for agricultural, water

body and miscellaneous landscape types increased indicating that less modification had occurred in these landscape types during this period. In contrast, during 2005 - 2007, the area - weighted fractal dimension for forest, natural forest succession and forest plantation, agricultural and grassland landscape types decreased implying that more modification had occurred in these landscape types. At the same time, the area-weighted fractal dimension for urban and built - up, water body and miscellaneous landscape types clearly increased suggesting that less modification had occurred in these landscape types.

**Mean Euclidean nearest-neighbor distance.** During 1987 - 2005, the mean Euclidean nearest-neighbor distance for forest, urban and built-up, agriculture, grassland, water body and miscellaneous landscape types decreased suggesting that more new patches had developed in these landscape types during this period. At the same time, the mean Euclidean nearest-neighbor distance for natural forest succession and forest plantation landscape type increased implying that few patches occurred in this landscape type. In contrast, during 2005 - 2007, the mean Euclidean nearest - neighbor distance for forest, natural forest succession and forest plantation, urban and built - up, agricultural and water body landscape types increased showing that few patches occurred in this landscape type during this period. At the same time, the mean Euclidean nearest - neighbor distance for grassland and miscellaneous landscape types decreased indicating that more new patches had developed in these landscape types. For natural forest succession and forest plantation, the mean Euclidean nearest-neighbor distance in two periods remained about the same.

**Interspersion and juxtaposition index.** In the two periods (1987 - 2005 and 2005 - 2007), the interspersion and juxtaposition index (IJI) for forest, natural forest and forest plantation, urban and built - up,

water body, and miscellaneous landscape types continuously increased implying that new patches of these landscape types continuously occurred during two periods. However, the IJI for the agricultural landscape type increased during 1987 - 2005 while its value decreased during 2005 - 2007. This indicated that new patches of the agricultural landscape type occurred during 1987 - 2005 while no new patches of agricultural landscape type developed during 2005 - 2007. In addition, the IJI for the grassland landscape type decreased during 1987 - 2005 while its value increased during 2005 - 2007 suggesting that no new patches of grassland landscape type developed during 1987 - 2005 while new patches of grassland landscape did develop during 2005 - 2007.

### CONCLUSION

Geo - informatics and landscape metrics can be used to assess and monitor forest resources and land use landscapes that frequently change over time. In fact, landscape patterns are related to all kinds of biological and non-biological factors, whose changes reflect changes in the natural and socioeconomic environment (McGarigal and Marks, 1995). In the current study, it was found that the landscape in Thap Lan National Park changed from 1987 to 2007 due to human activities and socioeconomic changes.

For changes at the landscape level, the fractal dimension, contagion and dominance were all altered. The landscape in the study area has become more fragmented in the past 20 years. In addition to defining the current status of a landscape, the distance metric can also be used to define the direction and magnitude of change through time in a long - term monitoring program such as EMAP, where the distance metrics could be calculated for each remeasurement period.

The metric would indicate how much overall change had occurred in the region and whether the change could be interpreted as degradation or recovery in the landscape pattern (O'Neill *et al.*, 1996).

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### REFERENCES

- Frohn, R.C. 1998. **Remote Sensing for Landscape Ecology: New Metric Indicators for Monitoring, Modeling, and Assessment of Ecosystems.** Lewis Publishers. Boca Raton, Florida.
- \_\_\_\_\_ and Y. Hao. 2006. Landscape metric performance in analyzing two decades of deforestation in the Amazon Basin of Rondonia, Brazil. **Remote Sensing of Environment** 100 : 237 - 251.
- Lee, E., Kyung A Kim, K.Kyungmin and L. Downon. 2004. Forest fragmentation in the lower region of the Han river basin, South Korea from 1983 to 1996. **Ecological Issues in a Changing World - Status, Response and Strategy.** 23:385 - 397.
- Maile C. N., K. McGarigal, and S. A. Cushman. 2004. Behavior of class-level landscape metrics across gradients of class aggregation and area. **Landscape Ecology** 19: 435 - 455.
- Matsushita, B., M. Xu and T. Fukushima. 2006. Characterizing the change in landscape structure in the Lake Kasumigaura Basin, Japan using a high - quality GIS dataset. **Landscape and Urban Planning** 78 : 241 - 250.

- McGarigal, K. and B.J. Marks. 1995. FRAGSTAT: Spatial Pattern Analysis Program for Quantifying Landscape Structure. US Department of Agriculture, Forest Service, **General Technical Report PNW - GT - 351**.
- O'Neill, R.V., C.T. Hunsaker, S.P. Timmins, B.L.Jackson, K.H. Riitters and J.D. Wickham. 1996. Scale problems in reporting landscape pattern at the regional scale. **Landscape Ecology**. 11 (3): 169 - 180.
- United Nations Education, Scientific and Cultural Organization [UNESCO]. 2010. **Dong Phra Yayen - Khao Yai Forest Complex**. Available source: <http://whc.unesco.org/en/list/590>.
- Xia, Z., L. Shengdong. and L. Qifang. 2002. Study on landscape changes in Heshan based on RS and GIS. **IEEE**: 2327–2330.
-