

# ANALYZING OF FOREST COVER CHANGE USING MULTI-TEMPORAL SATELLITE IMAGES IN PHNOM TAMAO ZOOLOGICAL PARK, CAMBODIA

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## SUMMARY

The results of forest cover from satellite data provide the various scales from the past periods, in particular, it's have been conducted all over the world including Cambodia for several years. In this study, multi-temporal satellite data were used to quantify forest cover and land cover changes in the park, Ba Ti district, Takeo commune, Cambodia during 1997 - 2017. Landsat 5 data were used for 1997, 2001, 2007 and Landsat 8 images were used for 2013, 2017 with a spatial resolution of 30 m. Normalized Difference Vegetation Index (NDVI) in combination with unsupervised classification was used. After analyzed the results showed that there was the change from years 1997 - 2017 of forest cover change extents. Accuracy assessments of forest cover maps showed highly accurate, over 83.67%. In particular, forest cover extents increased in the period 1997 - 2017 from 1,928.7 ha to 2,162.7 ha (increased by 234 ha), for 2001 - 2007, from 1,758.06 ha to 2,065.68 ha (increased by 307.62 ha), for 2007 - 2013 from 2,065.68 ha to 2,149.2 ha (increased by 83.52 ha), for 2013 - 2017 from 2,149.2 to 2,162.7 ha (increased by 13.5 ha). Forest cover extents decreased by 1,928.49 ha to 1,758.06 ha in the period 1997 - 2001. The main drivers of forest cover extents increased due to good governance in forest conservation of Forest Administration and decreased because of human activities, such as illegal logging, land encroachment, agriculture expansion, and forest fire.

**Keywords:** Forest cover change, GIS and RS, NDVI, Landsat image.

## 1. INTRODUCTION

Cambodia is a country in Asia continent within total cover area 181,035 km<sup>2</sup> (Curtis, 1990). Forest cover is approximately 59% of Cambodia's total land area in 2006, corresponding to approximately 10.7 million hectares (Forestry Administration, 2010). Forest cover has declined to 46.9% in 2014, corresponding to approximately 8,5 million hectares (Ty, Sasaki et al., 2011).

Forest management in Cambodia has been a challenging task for the Cambodian government especially Forest Administration (FA) from the 1950s to the present (Wilkie, 2010). The Forest Administration (FA) plays an important role as government activity in the forestry sector such as conservation, restoration, and enrichment in Cambodia. In addition, Forest Administration was established in 2003 (replacing the former Department of Forestry & Wildlife) (Forestry Administration, 2004).

In Cambodia, there are 20 provinces have been covered by forest. Seven major forest types are recognized in Cambodia, they are evergreen, semi-evergreen, deciduous, Flood-

ed, Bamboo and mangrove forests (Wilkie, 2010). Cambodia has total deciduous forest cover of 4,613,417 ha that corresponding about 25.40% of total area in 2006 (Forestry Administration, 2010). Deciduous forest plays a significant role for providing good and services to human and wildlife, such as firewood, food (mushroom, honey, bamboo shoot, leaf, fish.), carbon sequestration, pollution absorption, wood for construction, landscape amenity, recreation, water supply, climate regulator, habitats for wildlife and biodiversity (Cambodia, 2014.). The deciduous forest in Cambodia has reduced dramatically to 3,480,532 ha, approximately 19.17% of Cambodia's land cover from 2006 to 2014 (Assessment, 2014). The driver of deforestation and forest degradation due to unsustainable management and human activities. Moreover, human activities that cause loss of forest: weak forest law enforcement, overexploitation, forest fire, land encroachment, agriculture expansion and illegal logging (Hosonuma, Herold et al., 2012). Therefore, protecting and reestablishing the forest have become the main

task for Cambodian Forest Administration, local authorities and organizations (Davis, 2005).

Phnom Tamao Zoological Park and Wildlife Rescue Center (PTZPWRC) is protected regenerating forest located in Takeo province, Cambodia. PTZPWRC is one of the deciduous forests in Cambodia within the area of 2,385 ha, there are many kinds of tree species, and it is rich in biodiversity (Forestry Administration, 2018). After 1995, the forest was dramatically sizing down by human activities such as illegal logging for firewood and building material, over exploitation, forest fire (Broadhead and Izquierdo, 2010). Moreover, local villages surrounding the forest caused a threat to the forest. Therefore, the PTZPWRC was established by the government institution of Cambodia Forest Administration in 1995 as protecting regenerating forest (Chesda, 2016).

Remote Sensing is well recognized as an important source of information to quantify forest extents in large areas in previous and present time (Richards and Richards, 1999). Moreover, spectral indices have become very popular in the remotely sensed vegetation features recently. In addition, the reflections of soil and rocks are often much more than the reflection of sparse vegetation that leads to the separation of plant signals difficult (Campbell and Wynne, 2011). This research study to quantify the rate of changing of forest cover based on the Normalized Difference Vegetation Index (NDVI) in Phnom Tamao Zoological

Prak and Wildlife Rescue Centre (PTWRC), Takeo province, Cambodia from the year of 1997 - 2001, 2001 - 2007, 2007 - 2013 and 2013 - 2017. The study later to define drivers of changing in forest cover and propose the practical solution for enhancing forest conservation activities.

## 2. RESEARCH METHODOLOGY

### 2.1. Study site

Phnom Tamao zoological park is situated in Tropang Sap village, Tropang Sap commune, Ba Ti district, Takeo Province that lies in 11°18'2" - 11°18'04" North latitude and 104°48'4" - 104°48'05" East longitude in Cambodia. The center was established in 1995 with an area of over 2,385 hectares of deciduous forest (Chesda, 2016).

### 2.2. Methodology

#### 2.2.1. Data collection method

The literature review is the key method to collect secondary data, including thesis, papers and case studies. The collected data includes Global Positioning System (GPS) in Phnom Tamao zoological park points for analyzing forest cover and check the accuracy. The main forest object in the study is the deciduous forest. The study has downloaded five different Landsat images and calculated forest cover changes during the period of 1997 - 2017 by using multi-temporal remote sensing images, including Landsat 5 (for 1997, 2001 and 2007) and Landsat 8 (for 2013 and 2017) with the spatial resolution of 30 x 30 m (Table 1).

**Table 1. Landsat images used in the study**

ID	Landsat image code	Date	Resolution	Path/Row
1	LC81260522017340LGN00	06/12/2017	30 m	126/52
2	LC81260522013361LGN01	27/12/2013	30 m	126/52
3	LT512605220070225BKT00	25/01/2007	30 m	126/52
4	LT51260522001152BKT00	01/06/2001	30 m	126/52
5	LT51260521997189BKT01	08/07/1997	30 m	126/52

Sources: USGS, 2018

A field survey was conducted by using GPS Garmin 64s to collect information on different land cover types. There are 300 GPS points were collected in this study with an error less than 3m. The survey point data were used to

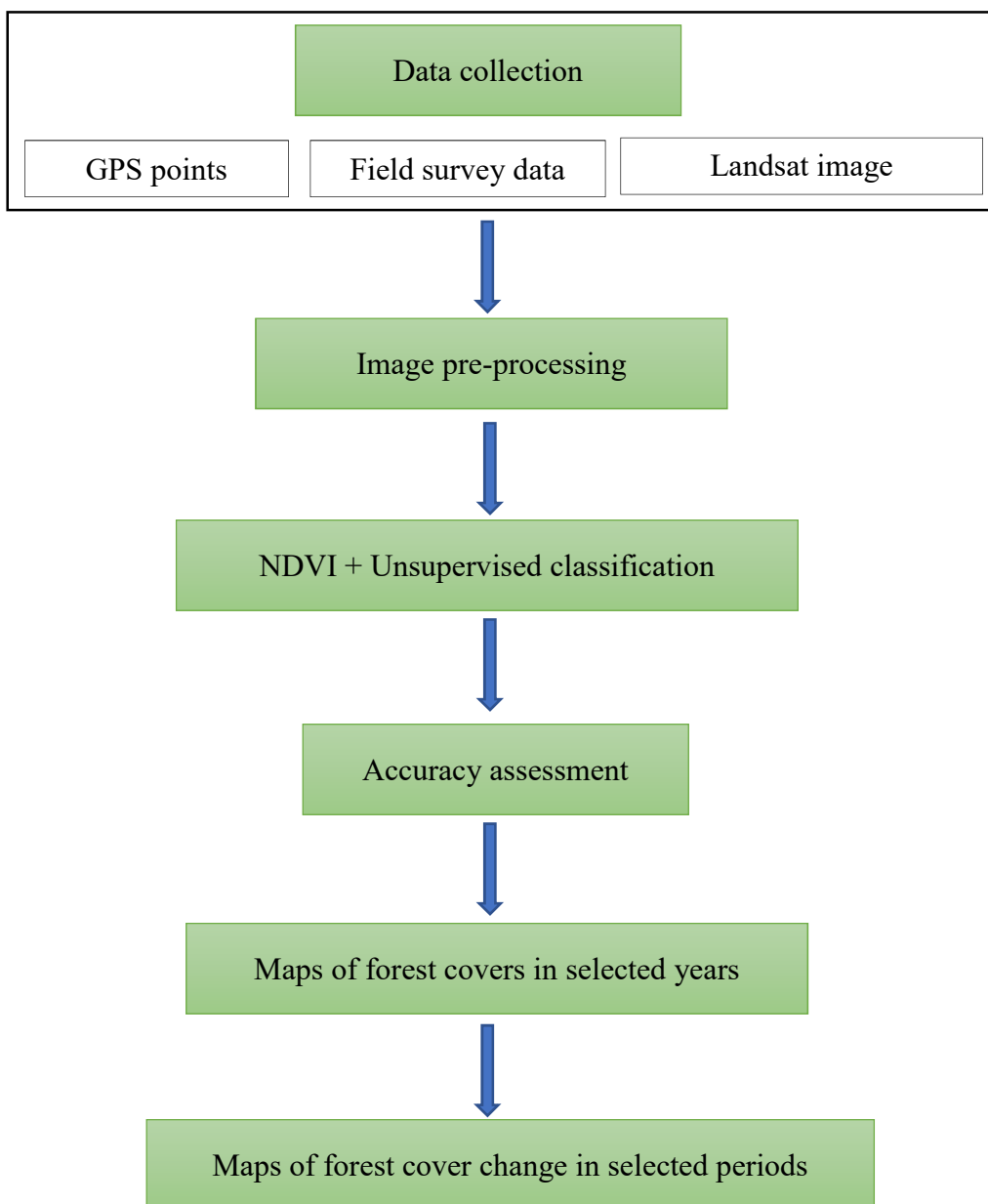
classify land cover types and support image classification processes with the accuracy assessment. Based on field survey information, the study has divided the vegetation into five different land cover types including forest,

built-up and bare land, grassland, water, and others. 300 points have distributed random scattered through all land cover types.

**2.2.2. Data analysis and image processing**

There are five main steps which were used to classify images. They are: (1) Data collection and image pre-processing; (2) Image classification and Normalized Differences Vegetation index (NDVI) calculation; (3) Accuracy

assessment; (4) Building land cover status maps of 1997, 2001, 2007, 2013 and 2017 by using NDVI in combination with unsupervised classification; and (5) Construction of land cover change maps in 5 periods: 1997 - 2001, 2001 - 2007, 2007 - 2013, 2013 - 2017 and 1997 - 2017. ArcGIS 10.3 was used to process and classify the image. The following figure summarizes the research process (Figure 1).



**Figure 1. Flowchart of methods: Green boxes are the main steps to analyze**

**3. RESULTS**

**3.1. Forest cover status assessment**

Forest cover maps in 1997, 2001, 2007, 2013 and 2017 were classified into two land cover types: forest land and non-forest. Normalized Difference Vegetation Index (NDVI)

quantified vegetation by measuring the difference between near-infrared which strongly affects and red light which vegetation absorbs (Burgan and Hartford, 1993). NDVI values range from +1.0 to -1.0. The area of barren rock, sand or snow usually shows very low

NDVI values from 0.1 or less. Sparse vegetation such as shrubs and grasslands or senescing crops may result in moderate NDVI values ap-

proximately 0.2 to 0.5. High NDVI values approximately 0.6 to 0.9 correspond to dense vegetation (Tovar, 2012).

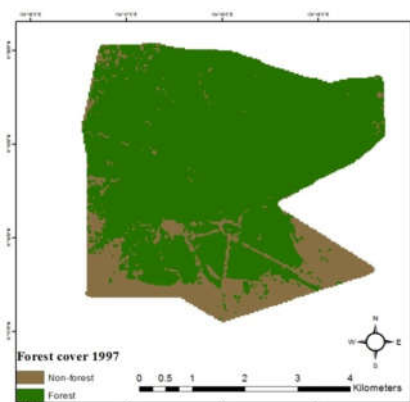
**Table 2. Land cover from 1997 - 2017 (ha)**

Land cover	Year				
	1997	2001	2007	2013	2017
Forest	1,928.7	1,758.06	2,065.68	2,149.2	2,162.7
Non-forest	455.49	626.13	318.51	234.99	221.49
Total	2,384.19	2,384.19	2,384.19	2,384.19	2,384.19

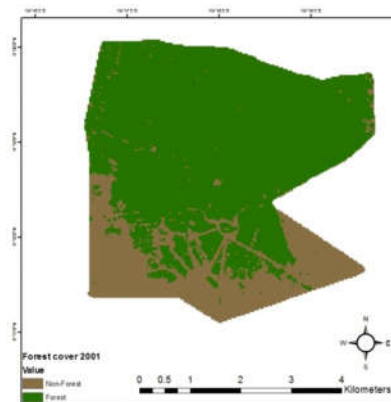
Above table shows that, in general, the forest area increases over years. In 1997, the forest area is 1,928.7 ha (about 80.90% of total area). The forest cover has increased to 2,149 ha in 2013 and 2,162.7 ha in 2017. However, forest covers extents decreased to 1,758.06 ha (about 73.74 %) of forest in 2001. About non-forest area, in 1997, it was about 455.49 ha (approximately 19.10% of total area). However, from 2001 to 2017, the non-forest area was

decreasing significantly, from 626.13 ha in 2001 to 221.49 ha in 2017, meaning the decrease is 64.63% in 16 years. The main reason for forest cover increase is the park. It was established in 1995. And they have worked and protected the forest effectively.

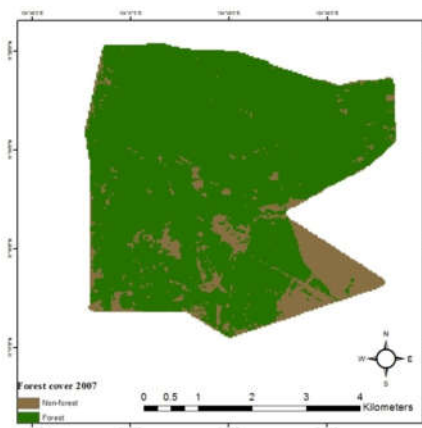
It is more visible in the figure 2a, 2b, 2c, 2d, and 2e below. The forest cover extents were increasing from 1997 to 2017.



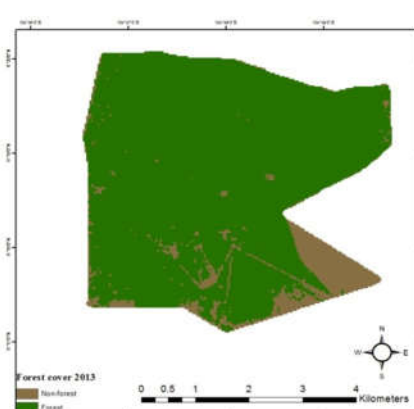
2a. The year 1997



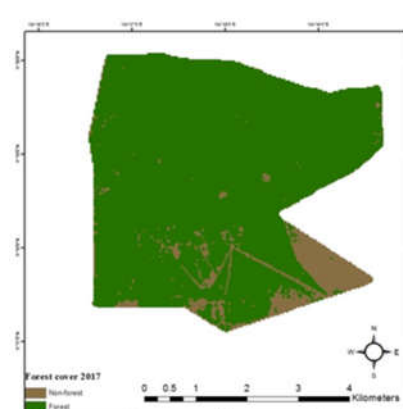
2b. The year 2001



2c. The year 2007



2d. The year 2013



2e. The year 2017

**Figure 2. Forest covers in the park using Landsat 5 & 8 and calculates by NDVI from 1997 to 2017**

3.2. Spatial forest cover change evaluation

3.2.1. Forest cover change from 1997 to 2017

According to the maps of forest covers,

Table 3. Forest cover change detection in selected years periods in Hectare (ha)

Years	Types				Net change detection
	Non-forest	Forest loss	Forest gain	Forest Stable	
1997-2001	423.99	202.14	31.5	1,726.56	-170.64
2001-2007	256.32	62.19	369.81	1,695.87	307.62
2007-2013	206.37	112.14	28.62	2,037.06	-83.52
2013-2017	194.04	27.45	40.95	2,121.75	13.5
1997-2017	189.72	31.77	265.77	1,896.93	234

Forest covers decreased and increased are detected in the net change of all five selected years periods shown in table 3. The result showed about negative and positive change in forest covers in Phnom Tamao Zoological Park.

Forest covers in net change detection during the periods of 1997 - 2001 lost approximately 170.64 ha, 2001 - 2007 forest cover extremely increased to 307.62 ha, 2007 - 2013 forest cover declined to 83.52 ha, forest covers increased to 13.5 ha in 2013 - 2017. The Phnom Tamao Zoological overall increased 234 ha from 1997 - 2017. Base on the results table 3 above, forest cover extents increased because management activities of Phnom Tamao Zoological include:

changing of forest covers in selected periods are as follow in table 3.

participatory development in the land use management structure and regulation with Phnom Tamao Zoological; law enforcement patrols to reduce illegal clearance and logging; monitoring of land use and illegal logging activities and development of payments for environmental service programs for local communities.

The study shows that during the period forest cover in the study area had increased from 1,928.7 ha (80.90%) in 1997 to 2,162.7 ha (90.71%). It is because of the fact that, the management and conservation activities that were cooperated between government and non-organization, which is the result of forest cover increasing.

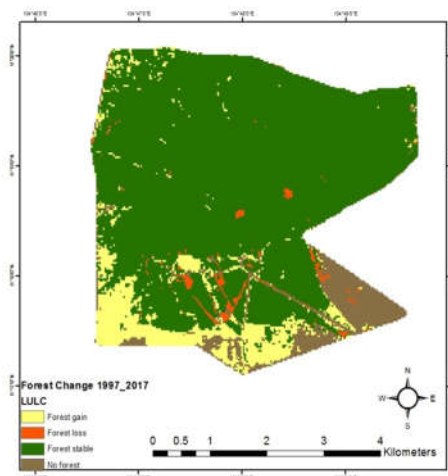


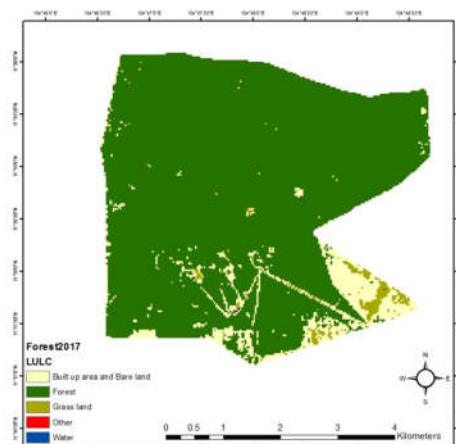
Figure 3. Forest covers the change in years of 1997 – 2017

3.2.2. Land use in the park in 2017

According to Land Use and Land Cover maps in 2017, the forest stable area was approximately the largest area of 2,145.42 ha, built-up and bare land area of around 200.88 ha, grassland area of around 37.26 ha, water approximately of 0.54 ha, and others area of

around 0.09 ha. Land cover has been changing every year because of development and urbanization.

Land use was classified into 5 categories such as forest, built-up & bare land area, water, and grassland and other.



**Figure 4. Land use land cover map 2017**

According to map classifying land use land cover are as follow (Table 4):

**Table 4. Land use land cover for 2017 in Ha**

Year	Type				
	Forest	Built-up & bare land	Grassland	Water	Other
<b>2017</b>	2,145.42	200.88	37.26	0.54	0.09

**3.2.3. Accuracy assessment of the classification**

Classifying of accuracy assessments of image, count truth (GPS points from the field survey in 2017).

Forest cover was classified into 5 categories: Forest, Built-up and Bare land area, Water, Grassland and other (Broadhead and Izquierdo, 2010).

**Table 5. Accuracy assessment for map 2017**

	Forest	Built-up and Bare land	Grassland	Water	Other	Total
Forest	200	18	7	2	0	
Built-up and Bare land	9	23	0	1	0	
Grass land	1	8	23	1	0	
Water	0	2	0	5	0	
Other	0	0	0	0	0	
<b>Total</b>	<b>210</b>	<b>51</b>	<b>30</b>	<b>9</b>	<b>0</b>	<b>300</b>
<b>Accuracy (%)</b>	<b>95.24</b>	<b>45.10</b>	<b>76.67</b>	<b>55.56</b>	<b>0</b>	<b>83.67</b>

**3.3. Drivers of forest cover change from 1997 to 2001**

There appear to be five main features driving deforestation in Phnom Tamao Zoological Park:

**3.3.1. Drivers of deforestation**

Major drivers of Deforestation	
Military	Military bases and roads for legitimate defense purposes, as well as support to illegal logging and encroachment on forests by soldiers
Forest fires	Suppress natural regeneration of degraded forests create carbon emissions from burning
Migrant Encroachment	Migrants seeking forest land to farm or resell
Land Speculation	Forests are felled to establish a claim on land that is later sold, or resold as land prices increase
Agriculture expansion	Population growth drivers additional forest clearing for agricultural land creation
Firewood	90% fuel use from wood with increasing demands from subsistence and commercial users
Illegal logging	High grading of luxury woods causes ongoing forest degradation and loss of biomass

Source: Poffenberger, 2009.

### 3.3.2. Drivers of forest increase

After the Phnom Tamao Zoological Park was established 1995. The management system, conservation, and development strategies have been created by the Forest administration department cooperated with non-profits organization in other to protect wildlife and forest covers. Raising awareness for staff and local people that live surround study area has been done. By the way, local people can earn money from a tour guide, selling food, selling souvenir to the tourist.

## 4. CONCLUSION

This paper aims to investigate forest cover extents changes occurred in Phnom Tamao Zoological Park between 1997 to 2107 by using Remote Sensing Landsat 5&8 and GIS. The land use and land cover (LULC) change were calculated by using the Normalize Different Vegetation Index (NDVI). The main change observed for the time period of 1997 to 2017 was that the area of forest was increased approximately from 1,928.7 in 1997 to 2,162.7 ha in 2017.

In the study area it was found that the deciduous part of forest was degraded after being disturbed by people before 1995. Forest conservation in Phnom Tamao Zoological Park was performed in the study area after run by the government institution of Cambodian Forestry Administration in partnership with an environmental non-profit organization in 2001. Since the forest was fostered by the government in 1995, its cover area has increased rapidly overtime. The forest cover extents has lost 202.14 ha and gained 31.5 ha in the period of 1997 - 2001, forest gained 369.81 ha and lost 62.19 ha in the period of 2001 - 2007, in the period of 2007 - 2013 it has increased 28.62 ha and lost 112.14 ha, and in the final period if time from 2013 - 2017 it has been continuously gaining 40.95 ha and losing 27.45 ha. The forest cover likely increases over time periods. There were five main features for driving deforestation in the park, which are: towns surrounding the forest area, land-grabbing by as-

sociated new villages, roads construction, soil types and forest fire. Findings are reliable database for future conservation of Phnom Tamao Zoological Park and Wildlife Rescue Center.

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## SỬ DỤNG ẢNH VIỄN THĂM ĐA THỜI GIAN ĐỂ XÁC ĐỊNH BIẾN ĐỘNG RỪNG TẠI VƯỜN THÚ PHNOM TAMAO, CAMBODIA

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### TÓM TẮT

Dữ liệu ảnh vệ tinh có thể cung cấp các thông tin về độ che phủ của rừng từ quá khứ đến hiện tại. Công nghệ này đã được ứng dụng trên toàn thế giới, trong đó có Campuchia. Trong nghiên cứu này, dữ liệu viễn thám đa thời gian được sử dụng để xác định độ che phủ rừng và thay đổi độ che phủ rừng trong vườn thú, tại huyện Ba Ti, xã Takeo, Campuchia trong giai đoạn 1997 - 2017. Dữ liệu Landsat 5 được sử dụng cho các năm 1997, 2001, 2007 và ảnh Landsat 8 được sử dụng cho năm 2013, 2017 với độ phân giải không gian là 30 m. Chỉ số thực vật (NDVI) kết hợp với phân loại không giám sát được sử dụng. Kết quả cho thấy có sự thay đổi diện tích rừng rõ rệt từ năm 1997 - 2017. Độ chính xác của bản đồ che phủ rừng là 83,67%. Đặc biệt, độ che phủ rừng tăng trong giai đoạn 1997 - 2017 tăng từ 1.928,7 ha lên 2.162,7 ha (tăng 234 ha), giai đoạn 2001 - 2007, từ 1.758,06 ha lên 2.065,68 ha (tăng 307,62 ha), giai đoạn 2007 - 2013 từ 2.065,68 ha đến 2.149,2 ha (tăng 83,52 ha), giai đoạn 2013 - 2017 từ 2.149,2 lên 2.162,7 ha (tăng 13,5 ha). Độ che phủ rừng giảm 1.928,49 ha xuống còn 1.758,06 ha trong giai đoạn 1997 - 2001. Các nhân tố chính làm tăng độ che phủ rừng là do các chính sách quản lý rừng tốt của ban quản lý vườn và các nguyên nhân chính dẫn đến suy giảm diện tích rừng là do các hoạt động của con người như khai thác trái phép, lấn chiếm đất, mở rộng nông nghiệp và cháy rừng.

**Từ khóa:** Ảnh Landsat, biến động che phủ rừng, GIS và viễn thám, NDVI.

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