Monitoring of Forest Land Use/Cover Change in Cat Tien National Park, Dong Nai Province, Vietnam Using Remote Sensing and GIS techniques

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Abstract. The Cat Tien National Park in the south of Vietnam represents a protected ecological area. It is located in tropical rainforest zone. For monitoring purposes of forest land use/cover change of the park satellite images (Landsat 5, Landsat 7 and Sentinel-2A) taken in 1988, 2003 and 2019 were used. NDVI was used for the estimation of vegetation quality. Forest land use/cover were classified by 5 categories using maximum likelihood classifier algorithm in ENVI 5.3. After classification, differentiation of forest land use/cover was analyzed on every image. Deforestation took place in 1988-2003 periods and broad-leaved forest areas have undergone reduction. Currently, new policies were introduced to reduce deforestation and therefore support free growth of tropical forest areas.

1. Introduction
The object of this investigation commonly known as Nam Cat Tien was founded in 1978 for the purpose of nature landscape reservation. In 1992 national park was reorganized to Cat Tien National Park. Since 2011 it became biosphere reservation as part of the UNESCO program. The area is located between 10°20'50" – 11°32'13" N and 107°11'13" – 107°28'20" E and has an area of about 41052.91 ha (figure 1).
Figure 1. Cat Tien National Park location.

The forest ecosystem of the Cat Tien National Park is virgin tropical rainforest. Satellite image data and forest inventory in 1992 showed that forestlands in the national park are under human impact because of urban population growth in Dong Nai province.

2. Materials and Methods

2.1. Materials

The materials for the research were satellite images and forest inventory maps (table 1). All satellite images were taken in dry season of 1988, 2003 and 2019 with cloud cover less than 10%. Source of images is https://earthexplorer.usgs.gov/ [1, 2].

Table 1. Details of satellite images used.

| Entity ID | Data parameters | Date       | Collected by                  |
|-----------|-----------------|------------|------------------------------|
| LT51240521988007BKT00 | Landsat-5 Spatial resolution 30 m | 07.01.1988 | U.S. Geological Survey       |
| LE71240522003072BKT01 | Landsat-7 Spatial resolution 30 m | 13.03.2003 | U.S. Geological Survey       |
| L2A_T48PYT_A019234_201 90227T031435 | Sentinel-2A Spatial resolution 10 m | 27.02.2019 | European Space Agency       |
| T48PYT_20190227T030651 | Spatial data grouped in different layers Scale 1:20 000 | Year 2015 | Cat Tien National Park administration |

2.2. The research methodology

The research methodology included different stages.

**Image preprocessing** – correction and improving of satellite images. Radiometric calibration of Landsat-5 and Landsat-7 data was made in ArcGis 10.5. SNAP software with Sen2Cor algorithm was used for atmospheric correction of Sentinel-2A data [3].

**Forest lands use/cover classification** was provided by supervised maximum likelihood classifier, which proposes normal distribution of vegetation imaging and calculates probability of single pixel affiliation to certain vegetation class [4, 5]. We used ENVI 5.3 for this classification algorithm.
Classification of forest lands use/cover using elements of satellite image interpretation were proposed in this study. Table 2 shows the elements of satellite image interpretation.

**Table 2. Elements of satellite image interpretation.**

| Forest land use/cover category | Forest land use/cover category |
|-------------------------------|-------------------------------|
| Broad-leaved forest           | Mixed forest                  |
| Land without vegetation cover | Meadows and shrubs            |
| Wetlands                      |                               |

**Classification accuracy assessment** was provided using satellite images. We compared classified images with data from other sources such as Google Earth images and forest inventory maps made in 2015. Confusion matrices are tables containing comparison of created map with control values [6]. Four accuracy assessment results were collected: user accuracy; producer accuracy; overall accuracy and Kappa index.

User accuracy is total amount of correct pixels in category divided by number of pixels classified in this category. Result is commission error. Producer accuracy is index showing quality of defined vegetation area classification. Kappa index measures the agreement between classification (X) and control values (Y).

We used formula below for Kappa index calculation [7]:

$$\text{Kappa} = \frac{P_0 - P_e}{1 - P_e},$$  

where, $P_0$ - relative observed agreement among raters; $P_e$ - hypothetical probability of chance agreement.

Kappa value $= 1$ means complete agreement and kappa $= 0$ means no agreement between classification results and control data values. We used Confusion Matrix tool in ENVI 5.3 for this accuracy assessment.

**Vegetation change detection** – The forest land use/cover cover most of the Cat Tien National Park area and therefore NDVI was used for vegetation change detection with formula below [8]:

$$\text{NDVI} = \frac{\text{NIR} - \text{RED}}{\text{NIR} + \text{RED}},$$  

where, NIR – near infrared band value for a cell; RED – red band value for the cell.

NDVI value ranges from $-1$ to $+1$ [9]. Positive NDVI values are specific for vegetation [10, 11]. They increase with growth of plant biomass [12, 13]. We used next sensor bands for NDVI calculation: B3 (RED), B4 (NIR) [14] for Landsat images and B4 (RED), B8 (NIR) [15] for Sentinel images. We classified vegetation for 1988-2019 period and divided it for 3 categories: low vegetation density ($0<\text{NDVI}<0.2$), middle vegetation density ($0.2<\text{NDVI}<0.5$), high vegetation density ($\text{NDVI}>0.5$) [16, 17].

For the purpose of **forest lands use/cover change detection** we have statistics of its area in 1988-2019 period. Based on the three new maps we created in 1988, 2003 and 2019, Arcgis 10.5 was used to portray the dynamics of forest land use/cover change [18, 19] that have taken place in Cat Tien National Park for 31 years. These maps show dynamics of forest lands use/cover for 31 years by categories.

All remote sensing data analysis process is shown on figure 2.
Based on the results of the survey of Landsat-TM images, maps of forest land use/cover of Cat Tien National Park in 1988, 2003 and 2019 were developed (figure 3).

The accuracy assessment of image classification of different time periods (1988, 2003, 2019) are given in table 3.
Table 3. The results for the accuracy assessment of satellite image classification.

| Forest land use/cover categories | Year 1988 | User’s accuracy | Producer’s accuracy | Year 2003 | User’s accuracy | Producer’s accuracy | Year 2019 | User’s accuracy | Producer’s accuracy |
|----------------------------------|-----------|-----------------|--------------------|-----------|-----------------|--------------------|-----------|-----------------|--------------------|
| Broad-leaved forest              | 94.00     | 90.38           |                    | 96.08     | 94.23           |                    | 96.08     | 98.00           |                    |
| Mixed forest                     | 80.36     | 88.24           |                    | 88.46     | 86.79           |                    | 90.74     | 92.45           |                    |
| Meadows and shrubs               | 79.63     | 86.00           |                    | 85.19     | 90.20           |                    | 90.38     | 90.38           |                    |
| Land without vegetation cover    | 86.00     | 84.31           |                    | 88.68     | 90.38           |                    | 94.64     | 91.38           |                    |
| Wetlands                         | 97.67     | 87.50           |                    | 97.96     | 94.12           |                    | 92.59     | 92.59           |                    |
| Overall accuracy, %              | 86.96     |                 |                    | 91.12     |                 |                    | 92.88     |                 |                    |
| Kappa index                      | 0.84      |                 |                    | 0.89      |                 |                    | 0.91      |                 |                    |

In the table 3 shows that the accuracy of user, producer and overall is quite good, Kappa index indices greater than 0.84 indicate that the classification results have reached a level of significant consistency.

Maps of NDVI index for 1988, 2003 and 2019 show vegetation dynamics over a given period (figure 4). Vegetation inventory on NDVI index maps are shown in figure 5.

![Figure 4. Map of NDVI index in Cat Tien national park in 1988 (A), 2003 (B) and 2019 (C).](image-url)
The analysis showed that over the past 31 years, in Cat Tien has seen a trend towards vegetation restoration in general; between 1988 and 2003, the NDVI index decreased, some forest areas were in a state of degradation. In particular, areas along populated areas were found to have a lower NDVI index, reflecting anthropogenic impacts in these areas. In the period 2003-2019, the NDVI index increased, forest areas are in a state of recovery. On the territory of Cat Tien national park recorded index value NDVI < 0.92, a significant proportion of the area of national park is covered with forest vegetation with high density, indicating that Cat Tien is dominated by tropical moist evergreen broad-leaved forest with a significant supply of wood.

The forest vegetation described in this study is almost similar to that given by other researchers, such as Kuznetsov (2015) [20].

The inventory of forest land use/cover by category in Cat Tien National Park between 1988 and 2019 is shown in table 4.

| Forest land use/cover categories | Year 1988   | Year 2003   | Year 2019   |
|----------------------------------|-------------|-------------|-------------|
|                                  | ha          | %           | ha          | %           |
| Broad-leaved forest              | 24546.61    | 59.79       | 20668.72    | 50.35       |
| Mixed forest                     | 10770.50    | 26.24       | 14136.46    | 34.43       |
| Meadows and shrubs               | 2782.49     | 6.78        | 3052.62     | 7.44        |
| Land without vegetation cover    | 2685.35     | 6.54        | 2871.47     | 6.99        |
| Wetlands                         | 267.95      | 0.65        | 326.34      | 0.79        |
| Total                            | 41052.91    | 100         | 41052.91    | 100         |

As can be seen from figure 3 and table 4, the dominant type of forest and vegetation cover on protected areas is broad-leaved forests, the share of which is about 59.79%, 50.35%, 65.20%, respectively, for 1988, 2003 and 2019. In the period 1988-2003, the area of broad-leaved forests decreased by 3877.89 ha (9.45%). This is due to illegal logging in Cat Tien. In the period 2003-2019, the area of broad-leaved forests decreased by 6096.49 ha (14.85%). After 13 years towards the end of Vietnam war in 1988, the welfare of the people living in the buffer zone in the Cat Tien was still quite difficult. Due to lack of funds, residents illegally cut down the forests of protected areas to sell wood and grow food crops in the cuttings. Thus, the area of broad-leaved forest was reduced. This created favorable conditions for the growth of mixed forest in the cleared area. Also in the east of Cat Tien, where there is a zone of the main distribution of broad-leaved forest, the forest area has been transformed into land without vegetation cover, meadows and shrubs. In the period 2003-2019, the
state forestry policy of Vietnam to attract and create conditions for the development of ecotourism in Cat Tien for the inhabitants of the region, especially indigenous communities, was effective. During this period, the level of well-being of the local population has increased, directly reducing the burden on forest ecosystems, contributing to the development and protection of forest. Along with the good performance of the forest protection work carried out by Cat Tien national park management unit, the situation of deforestation and transformation of forest lands into agricultural fields was quickly prevented, and the number of forest fires decreased. To assess the transfer of forest land use/cover in Cat Tien from one category to another, we have compiled a matrix of their dynamics over the past 31 years (table 5).

**Table 5.** Matrix of forest land use/cover change in Cat Tien National Park by category from 1988 to 2019.

| Forest land use/cover categories | Area (ha), 2019 | Total 1988 |
|----------------------------------|----------------|-------------|
|                                  | Broad-leaved   | Mixed       | Meadows and shrubs | Land without vegetation cover | Wetlands | Total 1988 |
| Area (ha), 1988                   | forest         | forest      | shrubs             | cover                        |          |            |
| Broad-leaved forest              | 21315.01       | 3120.33     | 77.51              | 33.22                        | 0.54      | 24546.61    |
| Mixed forest                    | 4071.39        | 6594.18     | 33.50              | 68.74                        | 2.69      | 10770.50    |
| Meadows and shrubs              | 706.26         | 1145.16     | 898.90             | 30.23                        | 1.94      | 2782.49     |
| Land without vegetation cover    | 645.84         | 295.26      | 495.52             | 1226.82                      | 21.91     | 2685.35     |
| Wetlands                         | 26.70          | 6.52        | 12.67              | 85.32                        | 136.74    | 267.95      |
| Total 2019                      | 26765.20       | 11161.45    | 1518.10            | 1444.33                      | 163.83    | 41052.91    |

In the table 5 shows that, the area of forest vegetation in Cat Tien national park tended to increase during the study period. The area of meadows, shrubs and land without vegetation cover decreased by 1241.03 ha (3.02%) and 104.13 ha (0.25%), respectively, due to the fact that part of these lands for 31 years was planted with forest crops. The area of wetlands decreased by 1264.39 ha (3.08%). In Cat Tien national park, the dry season lasts six months in a row, resulting in a fairly low water level in the area, which has led to the transformation of part of the wetlands into land without vegetation cover.

3. Conclusions
Long-term studies of forest land use/cover in Cat Tien national park have shown that in the period from 1988 to 2019, they are dominated by tropical moist evergreen broad-leaved forest. The magnitude of forest land use/cover change in broad-leaved, mixed forest, meadows and shrubs, land without vegetation cover and wetlands are respectively 5.40%, 0.95%, 3.02%, 0.25% and 3.08%. For 31 years, the area of forest land use/cover under broad-leaved and mixed forest of Cat Tien national park increased by 2609.54 hectares (6.36%), respectively and area of other categories of forest decreased. Government reforms in Vietnam to improve the management system of protected areas have increased the area of land use/cover with forest vegetation and preserve the development of forest ecosystems in protected areas.

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