Monitoring of Forest Land Cover Change in Nui Ba Ra Protected Landscape in Vietnam Using Remote Sensing Methods and GIS techniques

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Abstract. Nui Ba Ra Protected Landscape is a specially protected natural area of Vietnam. Protected Landscape is located in Ba Ra Mountain, one of the three highest peaks in the southeast of the country. For monitoring purposes of forest land cover change, Landsat-5 and Sentinel-2A images taken in 1995, 2007 and 2019 were used. To assess the vegetation cover in the Protected Landscape, the Normalized Plant Index Method (NDVI) was used. Allocated forest land is categorized by maximum likelihood in ENVI 5.3. For each satellite image, a statistical analysis of forest land cover change was performed after classification. The results confirm that the area of meadows and shrubs increased from 2.6% in 1995 to 8.1% in 2019, and the area of mixed forests decreased from 96.0% to 89.2%. Thus, there is a general degradation of woody vegetation.

1. Introduction

Nui Ba Ra Protected Landscape, with an area of 854.3 ha, is located in Binh Phuoc province of Vietnam. Geographical coordinates are within 11°48'10” – 11°50'10” north latitude and 106°59'10” – 107°01'05” east longitude (figure 1).

Figure 1. Nui Ba Ra Protected Landscape location in Vietnam.
Nui Ba Ra Protected Landscape plays an important role in the conservation of catchment forest and the natural environment in the region. In order to protect the landscape of Protected, the research object was created in accordance with the Resolution of the Prime Minister of Vietnam No. 194/CT of 08/09/1986. The center of Protected Landscape is Ba Ra Mountain 723 m above sea level [1]. Its height rises from the lowlands in the area of Truong Son Ridge of Vietnam. Protected Landscape also contains traces of bases and temples built during the US military operations in Vietnam. Due to these historical and cultural values, in accordance with the Decision of the Minister of culture of Vietnam No. 1556/BT of 20.04.1995, Nui Ba Ra Protected Landscape is also recognized as a cultural and historical monument of national significance. However, several disturbing factors decrease the influence of protected areas: small budgets, restricted enforcement rights, insufficient personnel and equipment infrastructure, lack of awareness and mismanagement [2]. The study of the vegetation cover of the earth is crucial for assessing the ecological state of the environment [3]. In order to design the meaningful conservation strategies, comprehensive information and current status of forest cover/forest types on the basis species composition as well as information of changes in forest cover with time, is required. It is difficult task, to acquire such information on the basis of field assessment and monitoring [4]. Especially in the complex landscape of Nui Ba Ra Protected Landscape, field monitoring is extremely difficult.

Remote sensing provide a systematic, synoptic view of earth cover at regular time intervals and useful for changes in land cover and to reveals aspect of biological diversity directly [5]. Their contribution to the effective assessment, monitoring and management of forest in developed countries is invaluable [6]. Therefore, the use of remote sensing methods and GIS technologies for the management of forest lands of protected areas in Vietnam is highly recommended. In addition, since the creation of Protected Landscape, no studies have been conducted to monitor the vegetation cover of forest lands in the region using remote sensing methods and GIS technologies. In this study, we used Sentinel-2A and Landsat-5 satellite images with a spatial resolution of 10 and 30 m, respectively, to classify the state of forest cover in Protected Landscape from 1995 to 2019. Monitoring allowed us to establish the dynamics of the areas and the reasons for the change in various categories of forest cover in Nui Ba Ra Protected Landscape.

2. Materials and methods

2.1. Materials

The materials for the research was satellite images and forest inventory maps (table 1). All satellite images were taken in dry season of 1995, 2007 and 2019 with cloud cover less than 10%. They are downloaded for free from the website of US Department [7].

| Entity ID | Data parameters | Date       | Collected by          |
|-----------|-----------------|------------|-----------------------|
| LT51250521995033CLT00 | Landsat-5 Spatial resolution 30 m | 02.02.1995 | U.S. Geological Survey |
| LT51250522007034BKT00 | Landsat-7 Spatial resolution 30 m | 03.02.2007 | U.S. Geological Survey |
| S2A_MSIL1C_LIC_T48PYU_A019234_20190227T031435 | Sentinel-2A Spatial resolution 10 m | 27.02.2019 | European Space Agency |

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 [8].
**Vegetation change detection** – The forest land cover covers most of Protected Landscape area and therefore NDVI was used for vegetation change detection [9] with formula below (1):

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

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

NDVI value ranges from –1 to +1. Positive NDVI values are specific for vegetation. They increase with growth of plant biomass [10]. We classified vegetation for 1995-2019 period and divided it for 3 categories: low vegetation density (0≤NDVI<0.2), middle vegetation density (0.2≤NDVI<0.5), high vegetation density (NDVI≥0.5).

**Forest lands 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. We used ENVI 5.3 for this classification algorithm.

**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 1995. Confusion matrices are tables containing comparison of created map with control values. 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. Overall accuracy - Kappa index measures the agreement between classification (X) and control values (Y) [11]. Kappa index calculation (2):

\[
\text{Kappa} = \frac{P_o - P_e}{1 - P_e}
\]

where, \(P_o\) - 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.

For the purpose of forest land cover change detection we have statistics of its area in 1995-2019 period. Based on the three new maps we created from 1995 to 2019, Arcgis 10.5 [12], was used to portray the dynamics of forest land cover change that have taken place in Nui Ba Ra Protected Landscape for 24 years. These maps show dynamics of forest lands cover by categories.

All remote sensing data analysis process is shown on figure 2.

![Figure 2. Flow chart of research methodology.](image-url)
3. Results

Based on the results of the survey of Landsat-TM images, forest land cover maps of Nui Ba Ra Protected Landscape in 1995, 2007 and 2019 were developed (figure 3).

As can be seen from figure 3, the high NDVI indices for Protected Landscape cover are mainly recorded in the center of the study area, where the height of the mountains exceeds 400 m above sea level. This is the most strictly protected area in Protected Landscape, all anthropogenic impacts are prohibited. Therefore, in this zone of Protected Landscape, vegetation has a high density (NDVI ≥ 0.5). However, in areas with mountain heights of less than 400 m, a lower NDVI value was revealed, and low and medium density of vegetation prevail along the border of Protected Landscape. In the current year, an increase in the NDVI index to 0.74 and the largest area with a high density of vegetation was recorded on the area of Protected Landscape. This indicates that humid tropical mixed forest is being restored in Protected Landscape. Dominant species in forest vegetation are represented by such as *Lagerstroemia calyculata* Kurz, *Afzelia xylocarpa* (Kurz) Craib., *Sindora siamensis* Teysm. ex Miq., *Hopea odorata* Roxb., *Dipterocarpus alatus* Roxb., *Dipterocarpus dyeri* Pierre. found together with bamboo species, such as *Bambusa procera* A. Chev. & A. Camus [13].

Based on the satellite imagery classification results, maps of forest land were developed for the vegetation cover of Protected Landscape in 1995, 2007 and 2019 (figure 4).

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**Figure 3.** Classified forest land cover maps of Protected Landscape in 1995 (a), 2007 (b) and 2019 (c).

**Figure 4.** Map of forest lands of Nui Ba Ra Protected Landscape in 1995 (a), 2007 (b) and 2019 (c).
The accuracy assessment of image classification of different time periods from 1995 to 2019 are given in Table 2.

**Table 2.** The results for the accuracy assessment of satellite image classification.

| Forest land cover categories | Year 1995 | Year 2007 | Year 2019 |
|-----------------------------|-----------|-----------|-----------|
|                             | User’s accuracy | Producer’s accuracy | User’s accuracy | Producer’s accuracy | User’s accuracy | Producer’s accuracy |
| Mixed forest                | 89.8       | 88.0      | 95.8      | 90.2      | 97.9       | 95.9       |
| Meadows and shrubs          | 89.8       | 81.6      | 83.3      | 90.0      | 91.8       | 91.8       |
| Land without vegetation     | 79.5       | 85.4      | 85.1      | 87.0      | 88.9       | 93.0       |
| Roads and land of historical monuments | 92.1 | 87.5 | 95.2 | 90.9 | 95.7 | 93.8 |
| Overall accuracy, %         | 85.8       | 89.9      | 93.6      |
| Kappa index                 | 0.84       | 0.86      | 0.92      |

In the Table 2 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.

The inventory of forest land cover by category in Protected Landscape between 1995 and 2019 is shown in Table 3.

**Table 3.** Change in forest land cover by category in Nui Ba Ra Protected Landscape.

| Forest land cover categories | Year 1995 | Year 2007 | Year 2019 |
|-----------------------------|-----------|-----------|-----------|
|                             | ha        | %         | ha        | %         | ha        | %         |
| Mixed forest                | 819.9     | 96.0      | 742.2     | 86.9      | 762.4     | 89.2      |
| Meadows and shrubs          | 22.6      | 2.6       | 85.4      | 10.0      | 69.3      | 8.1       |
| Land without vegetation     | 10.0      | 1.2       | 17.1      | 2.0       | 7.7       | 0.9       |
| Roads and land of historical monuments | 1.8 | 0.2 | 9.5 | 1.1 | 14.9 | 1.7 |
| Total                       | 854.3     | 100       | 854.3     | 100       | 854.3     | 100       |

The classification of land in 1995 and 2007 in Protected Landscape showed that mixed forests were the main land use, respectively covering 819.9 ha (96.0%) and 742.2 ha (86.9%), followed by meadows and shrubs - 22.6 ha (2.6%) and 85.4 ha (10.0%), land without vegetation cover - 10.0 ha (1.2%) and 17.1 ha (2.0%), roads and land of historical monuments - 1.8 ha (0.2%) and 9.5 ha (1.1%). Similarly, Sentinel-2A satellite imagery in 2019 showed that mixed forests were the main land uses: 762.4 ha (89.2%), followed by meadows and shrubs respectively - 69.3 ha (8.1%), roads and land of historical monuments - 14.9 ha (1.7%) and land without vegetation cover - 7.7 ha (0.9%). From 1995 to 2007, mixed forests, meadows and shrubs, respectively, had the largest decrease and increase in area compared to other land categories - 77.6 ha (9.1%) and 62.8 ha (7.4%). In contrast, from 2007 to 2019, mixed forests, meadows and shrubs, respectively, had the largest increase and decrease in area compared to other land categories, respectively - 20.2 ha (2.4%) and 16.1 ha (1.9%). For 24 years, in Nui Ba Ra Protected Landscape, the amount of land change in mixed forests, meadows and shrubs, land without vegetation cover, roads and lands of historical monuments are 6.7%, 5.5%, 0.3% and 1.5%, respectively. This result concludes that the main change in land use cover in the study area was a change in mixed forests, followed by meadows and shrubs.

To assess the transfer of forest land to other categories, we compiled a matrix of their dynamics for 24 years observation period (Table 4).
Table 4. Matrix of forest land cover change in Protected Landscape by category from 1995 to 2019.

| Forest land cover categories | Area (ha), 2019 |
|-----------------------------|----------------|
|                            | Mixed forest   | Meadows and shrubs | Land without vegetation cover | Roads and land | Total 1995 |
| Area (ha), 1988             |----------------|-------------------|-------------------------------|---------------|------------|
| Mixed forest                | 739.9          | 61.8              | 5.7                          | 12.4          | 819.9      |
| Meadows and shrubs          | 15.4           | 57                | 1.0                          | 0.5           | 22.6       |
| Land without vegetation cover| 7.1           | 1.8               | 1.0                          | 0.1           | 10.0       |
| Roads and land of historical monuments | 0.0 | 0.0               | 0.0                          | 1.8           | 1.8        |
| Total 2019                  | 762.4          | 69.3              | 7.7                          | 14.9          | 854.3      |

From the data in table 4 it is seen that from 1995 to 2019, 739.9 ha, 5.7 ha, 1.0 ha and 1.8 ha, respectively, of land under deciduous forests, meadows and shrubs, land without vegetation cover, roads and lands of historical monuments in 1995 remained in the same forest land categories in 2019. The area of the forest land category has decreased the most over the past 24 years in Protected Landscape - mixed forests from 57.5 ha (6.7%). The reduced forest area is mainly converted to meadows and shrubs, which is 61.8 ha (7.2%). Their main reason is associated with anthropogenic factors. According to a 2003 land statistics report in Nui Ba Ra Protected Landscape [14], the conversion of illegal land use goals from forest to agricultural land, illegal exploitation of forest products, and deforestation have changed the structure of vegetation cover. In addition, during the dry season, many large fires occurred in Protected Landscape [15]. With extremely rough terrain, all the cliffs are steep with hot weather and strong winds, so the fight against forest fires faces many difficulties. These fires often come from the negligence of residents in the process of illegal exploitation of forest resources and from tourists. As a result of fires, many natural forests were lost. These are also the main reasons that led to an increase in the area of meadows and shrubs over the past 24 years by 46.8 ha. However, forest area tended to decrease mainly between 1995 and 2007 and is increasing over the last period of the study. This is due to the issuance of a number of decrees of the Government of Vietnam on improving the management of natural resources and the conservation of forest ecosystems in Nui Ba Ra Protected Landscape, such as afforestation, restoration of degraded forests and expansion of infrastructure. Thus, from 1995 to 2019, the area uncovered by vegetation decreased by 2.3 ha (0.3%), and the area of roads and lands of historical monuments increased by 13.1 ha (1.5%).

4. Conclusions

Studies of vegetation on the forest lands of Nui Ba Ra Protected Landscape showed that from 1995 to 2019, mixed forests prevail on them. Over 24 years of observation, the size of the reduction in the area of mixed forest lands and land without vegetation cover are 3.4% and 0.4%, but the areas of other categories of forest land have increased accordingly due to deforestation and forest fires. The Government policy of Vietnam on the conservation of woody vegetation in Nui Ba Ra Protected Landscape for the period from 2007 to 2019 gave a positive effect. There is a natural restoration of mixed forests with high density of woody vegetation. Consequently, it is necessary to continue government measures to restore natural tropical forests and conservation of woody plant species on the forest lands of protected areas in Vietnam.

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