Monitoring of Forest Land Cover Change in Binh Chau - Phuoc Buu Nature Reserve in Vietnam Using Remote Sensing Methods and GIS techniques

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Abstract. Binh Chau - Phuoc Buu Nature Reserve is located in the tropical rainforest zone of southeast Vietnam. For monitoring purposes of forest land cover change in Reserve 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 cover were classified by 5 categories using maximum likelihood classifier algorithm in ENVI 5.3. After classification, differentiation of forest land cover was analysed on every image. The results confirm that the area of meadows and shrubs increased from 16.3% in 1988 to 19.1% in 2019, and conversely, the area of broad-leaved forests decreased from 80.7% to 77.3%. Thus, there is a general degradation of forest vegetation.

1. Introduction
In accordance with Decision No 194/CT of 08.09.1986, Binh Chau - Phuoc Buu Nature Reserve was recognized as a specially protected natural area of Vietnam by the Prime Minister of the Republic of Vietnam. The object of study is located in the province of Ba Ria - Vung Tau, with an area of 11293 ha, between $10^\circ27'57" - 10^\circ37'46"$ north latitude and $107^\circ24'31" - 107^\circ36'07"$ east longitude (figure 1).
Binh Chau - Phuoc Buu Nature Reserve is the only remaining natural forest of *Dipterocarpaceae* family, located on the coast of Vietnam. Rare, valuable and endemic species of flora and fauna, listed in the Red Book of Vietnam and the International Union for Conservation of Nature (IUCN), live in the Binh Chau - Phuoc Buu Nature Reserve. However, in recent years, the structure of forest land cover in Reserve has changed. This led to a change in the habitat of plants and animals, the number of individuals decreased, and many rare and endangered species were threatened. Therefore, the issue of forest land cover monitoring in Reserve plays an important role.

2. Methods and Materials

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 1988, 2003 and 2019 with cloud cover less than 10%. They are downloaded for free from the website of US Department [1, 2].

| Entity ID | Data parameters | Date       | Collected by                  |
|-----------|-----------------|------------|-------------------------------|
| LT51240531988055BKT00 | Landsat-5 Spatial resolution 30 m | 24.02.1988 | U.S. Geological Survey        |
| LE71240532003056BKT00 | Landsat-7 Spatial resolution 30 m | 25.02.2003 | U.S. Geological Survey        |
| S2A_MSIL1C_20191224T03 1131_N0208_R075_T48PYS_20191224T055653 | Sentinel-2A Spatial resolution 10 m | 24.12.2019 | 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 [3].

*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 [4, 5]. 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
Confusion matrixes 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. Overall accuracy - Kappa index measures the agreement between classification (X) and control values (Y). Kappa index calculation [7]:

$$Kappa = \frac{P_o - P_e}{1 - P_e},$$  

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.

Vegetation change detection – The forest land cover cover most of Binh Chau - Phuoc Buu Nature Reserve area and therefore NDVI was used for vegetation change detection with formula below [8]:

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

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 ($0 \leq NDVI < 0.2$), middle vegetation density ($0.2 \leq NDVI < 0.5$), high vegetation density ($NDVI \geq 0.5$) [16].

For the purpose of forest land 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 cover change [17, 18] that have taken place in Binh Chau - Phuoc Buu Nature Reserve for 31 years. These maps show dynamics of forest lands cover for 31 years by categories.

All remote sensing data analysis process is shown on figure 2.
Figure 2. Flow chart of research methodology.

3. Results and Discussion
Based on the results of the survey of Landsat-TM images, maps of forest land cover of Binh Chau - Phuoc Buu Reserve 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 2.
Figure 3. Classified forest land cover maps of Binh Chau - Phuoc Buu Nature Reserve in 1988 (a), 2003 (b) and 2019 (c).

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

| Forest land cover categories               | Year 1988 |          | Year 2003 |          | Year 2019 |          |
|--------------------------------------------|-----------|----------|-----------|----------|-----------|----------|
|                                            | User’s    | Producer’s| User’s    | Producer’s| User’s    | Producer’s|
|                                            | accuracy  | accuracy  | accuracy  | accuracy  | accuracy  | accuracy  |
| Broad-leaved forest                        | 94.00     | 92.16    | 97.92     | 95.92    | 97.92     | 95.92    |
| Meadows and shrubs                         | 86.00     | 86.00    | 89.58     | 91.49    | 90.20     | 95.83    |
| Land without vegetation cover              | 84.31     | 89.58    | 86.00     | 87.76    | 93.75     | 91.84    |
| Wetlands                                   | 95.45     | 91.30    | 93.33     | 91.30    | 95.45     | 93.33    |
| Overall accuracy, %                        | 89.94     | 91.71    | 94.33     |          |          |          |
| Kappa index                                | 0.86      | 0.89     | 0.92      |          |          |          |

In the table 2 shows that the accuracy of user, producer and overall is quite good. Kappa index indices greater than 0.86 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 Binh Chau - Phuoc Buu Reserve in 1988 (a), 2003 (b), 2019 (c).
Figure 5. Diagrammatic illustration of vegetation area by category of density.

In the Reserve, the highest values of NDVI index are 0.73, 0.70, and 0.77, respectively for 1988, 2003, and 2019. These indexes are registered in the center of the southern part of Reserve, where the forest occupies the largest area. Over the past 31 years, there has been a tendency to restore forest vegetation. However, in the northern part of Reserve, there is a lower value of the NDVI index, reflecting the anthropogenic impact on forest lands. The area of high vegetation density tends to decrease from 1988 to 2003, and to increase from 2003 to 2019. However, in general, the area of high vegetation density has not yet been restored by 1988. On the territory of Binh Chau - Phuoc Buu Reserve registered an increase in the NDVI index to 0.77 in the current year and an increase in the area with a high density of vegetation. This indicates that the Reserve is dominated by tropical moist semi-deciduous broad-leaved forest. Dominant species in forest vegetation are represented by such as: Dipterocarpus costatus Gaertn., Dipterocarpus dyeri Pierre., Dipterocarpus intricatus Dyer., Dipterocarpus obtusifolius Teysm., Hopea ferrea Pierre., Hopea recopei Pierrei, Anisoptera costata Korth., Lithocarpus dinhensis (Hickel & A.Camus) A. Camus, Afzelia xylocarpa (Kurz) Craib., Dalbergia oliveri Gamble ex Prain, Sindora siamensis Teysm. ex Miq. var. siamensis.

The inventory of forest land cover by category in Binh Chau - Phuoc Buu Reserve between 1988 and 2019 is shown in table 3.

Table 3. Change in forest land cover by category in Binh Chau - Phuoc Buu Reserve between 1988 and 2019.

| Forest land cover categories            | Year 1988  | Year 2003  | Year 2019  |
|-----------------------------------------|------------|------------|------------|
|                                        | ha   | %     | ha   | %     | ha   | %     |
| Broad-leaved forest                    | 9108.9 | 80.7  | 8464.3 | 74.9  | 8724.6 | 77.2  |
| Meadows and shrubs                     | 1846.0 | 16.3  | 2519.8 | 22.3  | 2157.1 | 19.1  |
| Land without vegetation cover          | 310.4  | 2.7   | 289.6  | 2.6   | 379.5  | 3.4   |
| Wetlands                               | 27.7   | 0.3   | 19.3   | 0.2   | 31.8   | 0.3   |
| Total                                  | 11293  | 100   | 11293 | 100   | 11293 | 100   |

As can be seen from figure 3 and table 3, the dominant type of forest and vegetation cover on protected areas is broad-leaved forests, the share of which is about 80.7%, 70.5%, 77.3%, respectively, for 1988, 2003 and 2019. However, the area of broad-leaved forests of Reserve has decreased over the past 31 years. This is due to the social conditions of the inhabitants of Vietnam. After the end of the war in the southeast Vietnam in 1975, Vietnam's economy was in crisis. From 1988 to 2003, indigenous agricultural communes arbitrarily cut down the forests of protected areas in order to grow crops on clearings due to the lack of funds for their purchase. In addition, some residents living on the border of Reserve illegally harvested wood for lumber production and heating. Along with general economic difficulties, the policy on managing and conserving the forests of Binh Chau - Phuoc Buu Reserve was ineffective during this period. Some residents received documents certifying the rights to a land plot located in the Reserve. This led to the fact that residents cut down the forests of protected areas and developed these lands. From 1988 to 2003, the area of broad-leaved forests decreased by 644.6 ha (5.7%), the area of meadows and shrubs increased by 673.8 ha (6.0%). The forest ecosystem...
of Binh Chau - Phuoc Buu Reserve has changed. However, Ba Ria - Vung Tau province has the greatest potential for oil, gas and seaports, and therefore, from 2003 to 2019, the region's economy began to develop rapidly. Faced with difficulties in managing the forest lands of protected areas, from 2003 to 2019, Ba Ria - Vung Tau People's Committee developed many forest restoration programs in Binh Chau - Phuoc Buu Reserve. As a result of one of the programs, some residents were relocated from the reserve to other territories, which helped significantly reduce deforestation, helped preserve natural coastal forests and protect the environment. At the same time, they carried out the restoration of natural forests in the Reserve. Forest area during this period increased by 260.3 ha (2.3%), while meadows and shrubs decreased by 362.7 ha (3.2%). To assess the transfer of forest land to other categories, we compiled a matrix of their dynamics (table 4) for a 31-year observation period.

**Table 4.** Matrix of forest land cover change in Binh Chau - Phuoc Buu Reserve by category from 1988 to 2019.

| Area (ha), 1988 | Broad-leaved forest | Meadows and shrubs | Land without vegetation cover | Wetlands | Total 1988 |
|----------------|---------------------|--------------------|-------------------------------|----------|------------|
| Area (ha), 2019 | 7927.4              | 1116.2             | 62.1                          | 3.2      | 9108.9     |
| Broad-leaved forest | 773.2              | 948.7              | 120.4                         | 3.7      | 1846.0     |
| Meadows and shrubs | 22.1               | 80.8               | 190.9                         | 16.6     | 310.4      |
| Land without vegetation cover | 1.9           | 11.4               | 6.1                           | 8.3      | 27.7       |
| Wetlands              |                     |                    |                               |          |            |
| Total 2019            | 8724.6              | 2157.1             | 379.5                         | 31.8     | 11293      |

In the table 4 shows that, over the past 31 years the area of broad-leaved forests in the Binh Chau - Phuoc Buu Reserve has a tendency to decrease. The area of forest converted to 1181.5 ha (10.5%) and 797.2 ha (7%) converted to other categories of forest land. In particular, meadows and shrubs, land without vegetation cover predominate. The areas of meadows and shrubs, land without vegetation cover increased by 69.1 ha and 4.1 ha, respectively, due to deforestation. The area of wetlands in Reserve is small and has changed little over the past 31 years. However, these lands play an important role in maintaining the water balance of Reserve and are a source of water for animals.

To estimate the volumes of deforestation and reforestation for the forest land cover of Binh Chau - Phuoc Buu Reserve, the data on the areas for 31 years of research were compared (figure 6). Figure 6 shows that, the areas of logged and restored forests between the parts of Reserve are different. In the northern part of Reserve, there is a tendency to degradation of vegetation, and in the southern part, on the contrary, to restoration. This is due to state policy in connection with the division of Reserve’s land in accordance with management objectives.

The northern part of Reserve can be classified as a reforestation zone. Forests are protected and restored naturally. However, important roads pass through this section. The daily volume of traffic in the northern part of Reserve is huge, which leads to difficulties in maintaining the forests of protected areas. In addition, residential areas are distributed along the northern border. Residents here have an income mainly from agriculture. However, urban development has reduced the area of agricultural land. Conversely, an increase in population density has led to the need to expand the farmland of farmers. Therefore, deforestation in the northern part of Reserve continues. These are the main reasons leading to the degradation of forest vegetation.
The southern part of Reserve can be classified as a strictly protected area. Here, forest land has been preserved in its original form. Forests are monitored and protected to ensure the natural development of ecosystems. In addition, half of the eastern border of the southern part of Reserve borders on the sea, where few inhabitants live, which directly reduces the anthropogenic pressure on forest ecosystems.

4. Conclusions
Long-term studies of forest land cover in Binh Chau - Phuoc Buu Reserve have shown that broad-leaved forest prevails in the period from 1988 to 2019. The change in land areas of broad-leaved forests, meadows and shrubs, land without vegetation cover and wetlands is 3.4%, 2.8%, 0.6% and 0.04%, respectively. For 31 years of observations, the area of broad-leaved forests in Reserve decreased by 384.3 ha (3.4%), and the areas of other categories of forest lands increased accordingly. The monitoring of forest land cover was opened and other causes of vegetation degradation in Reserve. These are the socio-economic conditions of Vietnamese citizens. On the lands of Reserve and near its borders, there are residential buildings, near which residents illegally cut down woody vegetation, and on the cuttings they grow food, and use wood as a building material. Thanks to the measures taken by the government of Vietnam in recent decades, the situation with vegetation cover in protected areas is normalizing. The area of woody vegetation is being restored, and the proportion of meadows and shrubs, land without vegetation cover is being reduced. Policies for the conservation and restoration of woody vegetation in Vietnam's specially protected natural areas should continue.

References
[1] Kovyazin V F, Do Quang Huy, Tran Hoang Hieu and Do Hong Hanh 2018 Definition of categories of forest lands in Kim Hy Nature Reserve of Vietnam using GIS technologies [in Russian - Opredelenie kategorij lesnyh ugodij v prirodnom zapovednike Kimhi respubliki Vietnam s primeneniem GIS–Tekhnologij] Forest journal 6/366 pp 39-47 DOI: 10.172.38/issn0536-1036.2018.6/39
[2] Kovyazin V F, Romanchikov A and Kitcenko A 2019 Classification of lands infrastructure forest fund// IOP Conference Series: Earth and Environmental Science. Volume 316. 012622
[3] Marina-Ramona Rujoiu-Mare et al 2017 Land cover classification in Romanian Carpathians and Subcarpathians using multi-date Sentinel-2 remote sensing imagery European Journal of Remote Sensing. 50:1, pp 496-508
[4] Kovyazin V F, Usoltsev V, Osmirko A, Tsepordey I and Chasovskikh V 2019 Additive model of Larix sp. forest stand biomass sensitive to temperature and precipitation variables in Eurasia// IOP Conference Series: Earth and Environmental Science. vol 316 012074
[5] Ryazanov S S, Sahabiev I A and Galimov D Z 2015 Classification of the land cover of the Kuibyshev reservoir Islands using remote sensing data [in Russian - Klassifikaciya zemnogo pokrova ostrovov kuibyshevsogo vodohranilishcha s ispol'zovaniem dannyh distancionnogo zondirovaniya] Russian journal of applied ecology pp 50-55

[6] Kovyazin V F, Lebedev Yu, Lebedeva T and Romanchikov A 2019 Value of Forest Ecosys-tem Natural Potential in the Areal Regional Richness Structure IOP Conference Series: Earth and Environmental Science vol 316 012027

[7] Congalton R G, Oderwald R G and Mead R A 1983 Assessing landsat classification accuracy using descrete multivariate analysis statistical techniques. Photogrammetry Engineering and Remote Sensing vol 49 12 pp 1671-78

[8] Rouse J W, Haas R H, Schell J A and Deering D W 1974 Monitoring vegetation systems in the Great Plains with ERTS, eds S C Freden, E P Mercanti, and M Becker Third Earth Resources Technology Satellite –I Symposium. Volume I: Technical Presentations, NASA SP-351, NASA, Washington, D C pp 309-317

[9] Viktorovich B V and Vagitovich A Z 2017 Vegetation indices and their use for mapping mountain landscapes of The Russian Caucasus [in Russian - Vegetacionnye indekсы i ih ispol'zovanie dlya kartografirovaniya gornyx landshtafov Rossijskogo Kavkaza] The electronic scientific journal "Argo". Series: natural and technical Sciences pp 3-21

[10] Kovyazin V F and Dang Thi Lan Anh 2019 Monitoring of forest lands of Kim Hy Reserve in Vietnam with using GIS technologies [in Russian - Monitoring lesnyh zemel' zapovednika «Kim Hy» Vietnama s ispol'zovaniem GIS–Tekhnologij] Astrakhan Bulletin of Ecological Education, Astrakhan, 3 pp 95-102

[11] Manylov I V 2011 Assessment of the accuracy of class recognition in automated processing of aerial photographs [in Russian - Ocenenk tochnosti raspoznavaniya klassov pri avtomatizirovannoj obrabotke aerofotosnimkov] Journal of Instrument Engineering. vol 54 5 pp 35-39

[12] Labutina I A and Baldina E A 2011 Use of remote sensing data for monitoring of protected areas ecosystems. Methodical manual [in Russian - Ispol'zovanie dannyh distancionnogo zondirovaniya dlya monitoringa ekosistem OOPT. Metodicheskoe posobie] World Wildlife Fund (WWF Russia). UNDP/GEF/ICI project "Biodiversity Conservation in the Russian part of the Altai-Sayan Ecoregion" Moscow p 88

[13] Zholobov D A and Baev A V 2015 Specification of values of normalized vegetative index (NDVI) by transpiration mask overlay method [in Russian - Utochnenie znachenij normalizovannogo vegetativnogo indeksa (NDVI), metodom nalozheniya transpiracijonnogo maski] Innovations in science: sat. XLV international. science-pract. Conf. 5 (42). (Novosibirsk: Sibak) pp 164-185

[14] Haque M I and Basak R. 2017 Land cover change detection using gis and remote sensing techniques: a spatio-temporal study on Tanguar Haor, Sunamganj, Bangladesh. The Egyptian Journal of Remote Sensing and Space Sciences 20 pp 251–263

[15] Hankui K Z et al 2018 Characterization of Sentinel-2A and Landsat-8 top of atmosphere, surface, and nadir BRDF adjusted reflectance and NDVI differences Remote Sensing of Environment pp. 482-494 doi:10.1016/j.rse.2018.04.031

[16] Dang Viet Hung, Dang Thi Lan Anh and Potokin A F 2019 Monitoring vegetation of Dong Nai Reserve with using GIS technologies (Vietnam) [in Russian - Utochnenie znachenij normalizovannogo vegetativnogo indeksa (NDVI), metodom nalozheniya transpiracijonnogo maski] Innovations in science: sat. XLV international. science-pract. Conf. 5 (42). (Novosibirsk: Sibak) pp 164-185

[17] Kovyazin V F and Nguyen T X 2019 Izvestiya News of the Development of predictive models of transformation of the land of Vietnam [in Russian - Izvestiya Razrabotka prognoznogo modeli transformacii zemel'nyh ugodij Vietnam] Tomsk Polytechnic University. Engineering of geo-resources. Tomsk. vol 330 9 p 221-229

[18] Kovyazin V F and Romanenko M 2019 Problem of temporary logging roads’ inventory as real estate items IOP Conference Series: Earth and Environmental Science. vol 316 012024