Predicting Forest Land Cover Changes in Ba Be National Park of Vietnam

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Abstract. The study is conducted in Ba Be National Park which is the specially protected natural area (SPNA) of Vietnam. The paper analyzes changes and makes prediction of forest land cover in National Park. For these purposes satellite images (Landsat-5 and Landsat-8) acquired for the year of 1992, 2003 and 2019 were used. The Normalized Difference Vegetation Index (NDVI) was used to identify vegetation quality. Forest land cover was classified by 5 categories using maximum likelihood classifier algorithm. In order to detect and evaluate forest land cover change, supervised classification and image differencing method are applied. Then, Cellular Automata and Markov Chain model is employed predict of forest land cover in this area. The results of the study indicate that forest land cover change is being transformed in Ba Be National Park. According to our estimate, from 1992 to 2019, the area covered by woody vegetation increased by 1.1%. By 2035, the area of broad-leaved forests will increase by 9.7%, due to a decrease in areas of meadows and shrubs. The increase in forest cover protected areas is explained by the measures taken by the Vietnamese government to expand the forest area in the country.

1. Introduction

In accordance with Decision №83/1992/TTg of 10/11/1992, Ba Be National Park was recognized as a specially protected natural area of Vietnam by the Prime Minister of the Republic of Vietnam and since recognized by the ASEAN Heritage Parks Organization. The object of study is located in Bac Can province, with an area of 10048 ha, between 22°06’12” – 22°08’14” north latitude and 105°09’07” – 105°12’22” east longitude (figure 1).
In recent years, the structure of forest land cover in Ba Be National Park is changing, which leads to change in the habitat of plants and animals that live in it. Therefore, predicting of forest land cover change in Ba Be National Park is an urgent task for preserving the biodiversity of forest ecosystem.

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 1992, 2003 and 2019 with cloud cover less than 10%. They are downloaded free of charge from U. S. Department of State website.

Table 1. Details of Landsat images used.

| Entity ID          | Data parameters            | Date         | Collected by                        |
|--------------------|----------------------------|--------------|-------------------------------------|
| LT51270451992295BJC02 | Landsat-5 Spatial resolution 30 m | 21.10.1992 | U.S. Geological Survey              |
| LT51270442003357BJC00 | Landsat-5 Spatial resolution 30 m | 23.12.2003 | U.S. Geological Survey              |
| LC81270442019273LGN00 | Landsat-8 Spatial resolution 30 m | 30.09.2019 | U.S. Geological Survey              |

2.2. There search methodology

The research methodology included different stages.

Image preprocessing – correction and improving of satellite images. Radiometric calibration of Landsat-5 and Landsat-8 data was made in ArcGis 10.5 [2,3].

Vegetation change detection – The vegetation in Ba Be National Park is mostly evergreen forest and therefore NDVI was used for vegetation change detection with formula below [4]:

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

where NIR – near infrared band value for a cell; RED – red band value for the cell. NDVI value ranges from -1 to +1. Positive NDVI values are specific for vegetation [5]. They increase with growth of plant biomass. We classified vegetation for 1992–2019 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).
Forestlands 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 2010 and 2015. Confusion matrixes are tables containing comparison of created map with control values. Four accuracy assessment results were collected: user’s accuracy, producer’s accuracy, overall accuracy and Kappa index.

User’s accuracy is total amount of correct pixels in category divided by number of pixels classified in this category [6]. Result is commission error. Producer’s 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]:

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

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.

For the purpose of forestland cover change detection we have statistics of its area in 1992–2019 period. Based on the three new maps we created in 1992, 2003 and 2019, Arcgis 10.5 [8] was used to portray the dynamics of forest land cover change that have taken place in Ba Be National Park for 27 years.

The predictive of forest lands SPNA was carried out using models of Cellular Automata and Markov chains. Cellular Automata (CA) is a bottom-up dynamic model with a spatiotemporal calculation. It is discrete in space-time and state and can carry out complex time-space simulations [9,10]. CA is a discrete dynamic system, which is a collection of cells equally connected to each other. All cells form the so-called lattice of a cellular automaton [11]. In this study, the cell is the image grid cell, the unit size is 30*30 m, and the whole land use spatial pattern is the cell space [12].

The model of cellular automata can be expressed as follows [13]:

$$S_{(t, t+1)} = f(S_{(t)}, N)$$

where, $S$ is the set of states of the finite cells; the t and t+1 are different moments; N is the neighborhood of cells; f is the transformation rule of local space.

The Markov chain is a statistical tool that describes the probability of land cover change from one period to another by developing a transition probability matrix between the two periods, based on neighbourhood effects [14]. Here, the Markov chain model could be described as a set of states, $S = \{S1, S2, S3, S4\}$, where: 1 – broad-leaved forests, 2 – meadows and shrubs, 3 – land without vegetation land cover and 4 – wetlands. Thus, state $S_{t+1}$ in the system could be determined by former state $S_t$ in the Markov chain using the following formula:

$$S_{t+1} = P_{ij} * S_t$$

where, $S_t$, $S_{t+1}$ – state of forest land at time t and t + 1; $P_{ij}$ is the state transition probability matrix.

$$P_{ij} = \begin{bmatrix} P_{11} & \cdots & P_{14} \\ \vdots & \ddots & \vdots \\ P_{41} & \cdots & P_{44} \end{bmatrix} \quad (0 \leq P_{ij} < 1 \text{ and } \sum_{i,j=1}^{4} P_{ij} = 1, \ (i,j = 1, 2, 3, 4))$$

The CA-Markov model effectively combines the advantages of two models: a) the ability to model spatial changes in complex systems of the CA model and b) long-term predictive of the Markov chain model [14]. In this work, the CA-Markov model is used for two purposes: firstly, to verify the accuracy of the CA-Markov model by modeling the state of forest lands in 2019, and secondly, to
predict the state of forest cover for 2035. All results were obtained using «CA_MARKOV» module in IDRISI program.

The accuracy of the predicted model was assessed by measurement agreement between two categorical images, a "comparison" map and a "reference" map on the objectives: 1 – agreement in terms of the quantity of cells in each category and 2 – agreement in terms of the location of cells in each category [16]. The measurement agreement results are statistical indicators: disagreement due to quantity (Quantity disagreement), disagreement due to location at the grid cell level (Allocation disagreement), Kappa for no information or overall accuracy of the predicted model (Kno) and traditional Kappa index (Kstandard). When the values of disagreement are 1, the simulation is considered imperfect, and if it is 0, then the simulation is considered perfect. Kappa values of 0.61–0.80 means substantial, while 0.81–1 means almost perfect [17]. All indexes are calculated using «VALIDATE» module in IDRISI.

3. Results and Discussion

The NDVI indices obtained for 1992, 2003, and 2019 show the dynamics of vegetation cover areas over the entire study period (figure 2).

The analysis of the data in figure 2 indicates that over the past 27 years there has been a tendency to restore vegetation as a whole throughout National Park. From 1992 to 2003, forest areas near settlements are subject to degradation. Significant changes in land cover National Park have also been noted.

![Figure 2. Dynamics of forest land cover by vegetation density categories.](image)

These areas are characterized by a low NDVI index, which is associated with anthropogenic impact on these natural ecosystems. From 2003 to 2019, an increase in the area of land with a high density of vegetation was noted. On the territory of Ba Be National Park registered an increase in the NDVI index to 0.76 in the current year and an increase in the area with a high density of vegetation. This indicates that the National Park is dominated by tropical broad-leaved evergreen forest on limestone and on lowland. Dominant species in forest vegetation are represented by such as: Burretiodendron hsiennu, Garcinia fragraeoides, Chukrasia tabularis, Duabanga sonneratioides, Fernandoa brilletii, Castanopsis ferox, Pterospermum heterophyllum, Taxotrophis ilicifolia[18].

Based on the satellite imagery classification results, maps of forest landcover National Park were developed in 1992, 2003 and 2019 (figure 3).
Figure 3. Forest land cover map of Ba Be National Park in 1992 (a), 2003 (b) and 2019 (c).

The assessment of the accuracy of satellite image classification in the period from 1992 to 2019 is given in table 2.

Table 2. Accuracy assessment of satellite image classification.

| Forest land cover classes     | Accuracy, % | Year 1992 | 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          | 93.8        | 91.8      | 96.3      | 94.6      | 94.3      | 96.2      |
| Meadows and shrubs           | 81.1        | 81.8      | 86.0      | 89.6      | 90.2      | 93.9      |
| Land without vegetation      | 81.1        | 83.3      | 90.3      | 84.9      | 92.1      | 87.5      |
| Wetlands                     | 87.5        | 89.7      | 93.8      | 95.7      | 96.2      | 94.4      |
| Overall accuracy, %          | 86.4        | 91.6      | 93.2      |
| Kappa index                  | 0.85        | 0.89      | 0.91      |

From the data of table 2 it can be seen that user’s accuracy and producer’s accuracy of the research is quite high. The overall accuracy of land cover maps for 1992, 2003, and 2019 is more than 86%, and Kappa index is 0.85, which indicates that we have achieved significant consistency in the classification results and reference data. Thus, the results were initially considered acceptable for comparison after classification.

The inventory data of land cover classes in Ba Be National Park for the period from 1992 to 2019 are shown in table 3.

Table 3. Change in forest land cover classes in Ba Be National Park.

| Forest land cover classes     | Year 1992 | Year 2003 | Year 2019 |
|------------------------------|-----------|-----------|-----------|
|                              | ha | %    | ha | %    | ha | %    |
| Broad-leaved forest          | 7730.6 | 76.9 | 6870.7 | 68.4 | 7836.2 | 78.0 |
| Meadows and shrubs           | 1660.1 | 16.5 | 2668.3 | 26.6 | 1747.9 | 17.4 |
| Land without vegetation      | 285.8 | 2.8 | 160.5 | 1.6 | 75.6 | 0.8 |
| Wetlands                     | 371.5 | 3.7 | 3485 | 3.5 | 388.4 | 3.9 |
| Total                        | 10048.0 | 100.0 | 10048.0 | 100.0 | 10048.0 | 100.0 |
As can be seen from the data in table 3, the dominant type of vegetation in National Park is broad-leaved forest, which accounts for more than 2/3 of the area. However, the area of broad-leaved forest has changed over the past 27 years. The livelihoods of the indigenous peoples living in National Park depend mainly on agricultural production. The main cultivation culture is rice, which is cultivated only in mountainous areas, so local farmers have low incomes. In addition, due to the lack of high-quality agricultural land, as well as the lack of irrigation systems in the communes, the economic difficulties of the indigenous people in the region are causing. Between 1992 and 2003, residents of indigenous agricultural communes arbitrarily cut down the forests of National Park in order to sell harvested wood, and grow crops that could not be bought due to lack of funds. Over 11 years, due to deforestation of broad-leaved forest, their area decreased by 859.9 ha (8.6%), and the area of meadows and shrubs increased by 1008.2 ha (10.0%). Residents living in and around protected areas have anthropogenic impact on the forest ecosystem of National Park. To solve this problem, Ba Be National Park has developed an investment program for the conservation of forest land cover. Accordingly, for the resettlement of residents from the territory of National Park, Don Den resettlement zone was allocated, which is located outside the borders of the protected areas, but near the commune. In this residential buffer zone, the commune develops the infrastructure of the territory to improve the quality of life of farmers. In addition, the indigenous population is actively involved in the restoration and protection of forests, as well as in the development of ecotourism in National Park. Additional, work in the forest increases the incomes of residents, and landscaping of National Park reduces the load on the natural ecosystem. As a result of the measures taken, the forest area from 2003 to 2019 increased by 965.5 ha (9.6%), and land without vegetation cover, meadows and shrubs decreased by 1005.4 ha (10%).

Validation of the land use/cover prediction model was conducted through simulating a past time period [19, 20]. The predicted results of forest land cover in Ba Be National Park in 2019 are shown in figure 4, and accuracy assessment of predicting model is presented in table 4.

![Figure 4. Forest land cover in 2019: projected map (a), predicted with true value (b).](image)

**Table 4.** Comparison of actual and projected forest land cover map of 2019.

| Designation          | Value   |
|----------------------|---------|
| Quantity disagreement| 0.0099  |
| Allocation disagreement| 0.0729 |
| Kno                  | 0.8965  |
| Kstandard            | 0.8566  |
From the data of table 4 it is seen that the value of “Quantity disagreement” is 0.0099, and “Allocation disagreement” is 0.0729. The overall accuracy index of the predicted model is 0.8965 and the Kappa index is 0.8566. The latest indices show good agreement between the actual and simulated land cover maps; therefore, the predicted model for the state of forest land cover National Park is reliable and significant predicting accuracy has been achieved.

The predictive results of vegetation cover were created by running the CA – Markov model in IDRISI (figure 5).

**Figure 5.** Predicted results of forest land cover status by category in Ba Be National Park in 2035: predictive map(a), statistics (b).

The trend in forest land cover status by category in the Ba Be National Park from 2003 to 2035 is shown in figure 6.

**Figure 6.** Dynamics of forest landcover class in Ba Be National Park and predicted for 2035.

The predicted results show that the trend of increasing the forest area of National Park will continue. By 2035, the area of broad-leaved forests will increase by 969.9 ha (9.7%), and wetlands by 6.5 ha (0.1%). The total area of meadows and shrubs uncovered by vegetation will decrease by 976.4 ha (9.7%). Forest land areas at the end of the predict period will be as follows: broad-leaved forests will reach 8806.1 ha (87.6%), meadows and shrubs – 782.9 ha (7.8%), uncovered by vegetation – 64.1
ha (0.6%) and wetlands – 394.9 ha (3.9%). Broad-leaved, high-growing stands will occupy the largest areas of forest protected.

4. Conclusions
Long-term studies from 1992 to 2019 of forest land cover Ba Be National Park showed that, they are dominated by natural broad-leaved forest class, but there is a tendency to change the state of all categories of vegetation cover. Over 27 years of observation, the area of broad-leaved forests of National Park increased by 105.6 ha (1.1%) and wetlands 16.9 ha (0.2%), respectively, the areas of other classes of forest land cover decreased. According to predict model developed, if the Government's Vietnam policy regarding the protected areas of the country, and in particular National Park, will continue to protect the environment and improve land use management, then the area of forest ecosystems will increase by 2035. This will help preserve and even increase the biodiversity of the forest ecosystems of Ba Be National Park, in particular, and preserve the environment in the northeastern region of Vietnam as a whole.

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