# Using Multi–Temporal Landsat Remote Sensing to Evaluate Changes in Mangrove Forest Extent within the Red River Delta Biosphere Reserve

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**Abstract:** The Red River Delta Biosphere Reserve (established in 2004) is a UNESCO biosphere reserve in the coastal region of northern Vietnam, including 3 provinces of Thai Binh, Nam Dinh, and Ninh Binh, with a total area of 105,000 hectares, which is a major economic region of the Red River Delta and the Northern Region.The mangrove forest here is like a "green wall" to protect the seawall, protect against windstorms, high tides, and sea level rise.This study uses multi – temporal remote sensing technology combined with GIS, a set of data to monitor mangrove developments of the Ministry of Agriculture and Rural Development from 1990 to 2020.The results of satellite image analysis show that in the period from 1990 to 2022, the area of mangrove forests in the study area increased by 4,169.72 hectares (an increase of 2.3 times compared to the period before 1990), an average of 115.83 hectares/year.

However, according to forest data, the area of mangrove forests has a huge difference of thousands of hectares in the years before 2005. The reason is that the statistical method of afforestation results only adds years of afforestation, there is no assessment of forest development results. In the past years of 2016, the area of mangrove forests according to the statistical method of comparison reports with the results of Landsat remote sensing image interpretation is not much different, specifically in 2020 the difference is 236.25 hectares; in 2022, the difference is 191.74 hectares. Data on mangrove areas will be an important scientific basis for assessing changes in mangrove areas and developing plans for mangrove restoration and development. On the other hand, providing data, data, and maps on mangrove forest fluctuations serves as a basis for important policies and solutions in the mangrove restoration strategy in Vietnam in general as well as in the Red River Biosphere Reserve in particular.

**Keywords***:* Changes in mangrove forest area, Lands at satellite imagery , The Red River Delta Biosphere Reserve, Mangroves.

## I.      Introduction

Mangrove forests are a typical ecosystem of tropical and subtropical coastal areas, which is a transitional ecosystem between the freshwater environment and the marine environment. Mangrove forests have many environmental, social, and economic effects, especially in terms of protecting seawalls, preventing erosion, fixing coastal and riverside land, limiting storms, sea waves and rising tides, and contributing to climate regulation [1]. Therefore, the study of this ecosystem is very necessary in science as well as practice.

The Red River Delta Biosphere Reserve was recognized by UNESCO in 2004 and received the title in 2008. The Red River Biosphere Reserve includes 3 provinces Thai Binh, Nam Dinh, and Ninh Binh with 05 districts of Thai Thuy, Tien Hai (Thai Binh province), Giao Thuy, Nghia Hung (Nam Dinh province), and Kim Son (Ninh Binh province) with an area of more than 105,000 hectares, central area: 14,000 hectares, buffer zone: 37,000 hectares, the transition area is over 54,000 hectares. Including 01 Xuan Thuy National Park, 01 Wetland Nature Reserve of Thai Binh province, and many large alluvial areas of thousands of hectares [2]. This is an important area for biodiversity conservation in Southeast Asia, especially the conservation of wetland habitats and mangrove forests, which are home to many rare species of wild birds that migrate and reside in Vietnam. The mangrove forest here is considered as a green wall to protect the seawalls and villages from being destroyed by storms, sea level rise, and even tsunami disasters. This is a specific biosphere reserve of national and world importance.

In fact, in recent decades, agencies and organizations such as the Danish Red Cross Society, the Republic of Korea and Japan, Program 327 to green bare land, bare hills, and coastal areas, Program 661 with the project to plant 5 million hectares of new forests and other projects of the Government have supported to invest in the development of projects and plant many areas of mangrove forests in the Red River Delta Biosphere Reserve.

However, in the past (from 2015 onwards), this area has not been fully statistical, reflecting the current situation as the basis for coming up with solutions for mangrove management, protection, and development. In addition, if there is sufficient data, the status of mangrove forests will be a practical database for the Agriculture and Rural Development sector to have plans for dike protection, flood, and storm prevention in areas with weak soils, maintenance planning, and renovating the sea dike every year[3]. The results of the assessment of regional mangrove fluctuations will provide an important, timely, and accurate database for the Agriculture and Rural Development sector plan to develop policies, strategies, and industry development plans in the field of coastal protection erosion reduction, landslides harm people's lives and socio-economic areas along the Red River[4]. On the other hand, the results of fluctuations in mangrove forest development will provide more detailed data information than the national statistical data system, scientific research topics, or planning projects, the investment project does not have information and data on the current status of the mangrove forest development area of the Red River Delta Biosphere Reserve, as a basis for proposing management solutions, serving the management and operation, directing and administering the response to natural disasters such as storms, saltwater intrusion, and rising tides.

Therefore, it is necessary to monitor and supervise the fluctuations of mangrove forests in the Red River Delta Biosphere Reserveand should be implemented immediately to have a set of data and information on the current status of mangrove forest areas for the management, operation, direction, and administration of response to natural disasters such as storms, etc.high tides, large waves, saltwater intrusion as well as a basis for developing plans for dike protection, maintenance and maintenance of seawalls in the North in particular and Vietnam in general.

## II. Research objects and methods

### 2.1. Research objects

Object of study: Mangrove forest.

Study location: In communes and districts with mangrove forests in Thai Binh, Nam Dinh and Ninh Binh provinces.

Scope of the study: Coastal mangrove forests in the 3 provinces mentioned above.

Research goals: focusing on the status of mangrove forest areas changing in some periods in the 1990s; 2005; 2020 and 2022, the study period in 2023.

### 2.2. Research materials and methods

### 2.2.1. Materials

The study uses Landsat 5 and Landsat 8 remote sensing images referenced from the https://earthexplorer.usgs.gov/ website to interpret and establish maps of the status and fluctuations of mangroves from 1990 to 2022.

*Table 1. Usage Data*

| Year | Data type | Date | Rosoluiton |
|------|-----------|------|------------|
| 1990 | Landsat 5 | 07/09/1990 | 30m |
| 2005 | Landsat 5 | 11/05/2005 | 30m |
| 2020 | Landsat 8 | 20/05/2020 | 30m |
| 2022 | Landsat 8 | 17/10/2022 | 30m |

Data sources on annual forest developments of the Ministry of Agriculture and Rural Development, Forest Protection Departments of Thai Binh, Nam Dinh, and Ninh Binh provinces annual statistics on forest developments (in 2022), field survey data on the status of forests in the study area in 2023.Data sources on annual forest developments of the Ministry of Agriculture and Rural Development, Forest Protection Departments of Thai Binh, Nam Dinh, and Ninh Binh provinces annual statistics on forest developments (in 2022), field survey data on the status of forests in the study area in 2023.
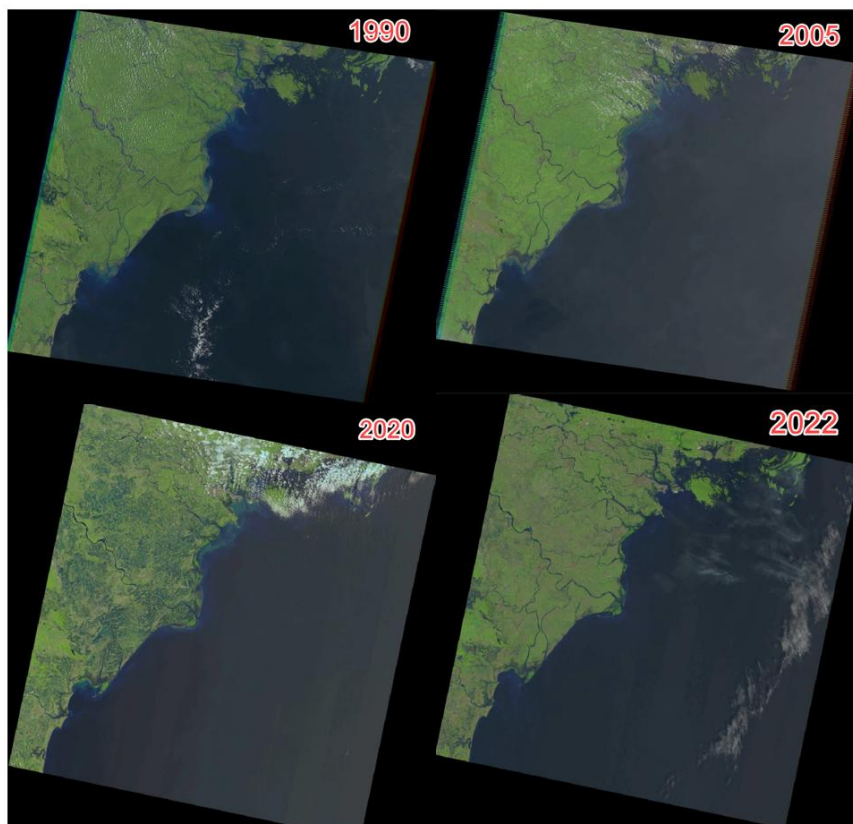


*Figure 1. Satellite images used in research*

**2.2.2. Research methods**

Research using remote sensing, mapping, and geographic information system (GIS) methods with a 4-step processing process including 1) Collecting; 2) Classification and interpretation of photos; 3) Establishing a map of the current state of forests by year and 4) Establish a map of forest fluctuations.

In this study, the most approximate classification method is used: Maximum Likelihood Classifier - MCL. This method is based on the hypothesis that "Spectral bands with a standard distribution will be classified into the class in which it has the highest probability. The calculation is not only based on distance but also the trend of grayness variation in each layer"[5]. This is an accurate classification method but takes a long time to calculate and depends on the standard distribution of the data.

The method of synthesis and evaluation to compare and evaluate with photo interpretation data used in the study on the current state of mangroves in the past and present periods of 1990, 2005, 2020, and 2022 (These are the 15-year statistical timelines of the current status of mangrove forest area, is also the time when mangrove trees can achieve the most stable growth and development in the biological cycle. Combined with the results of investigation and field surveys on the distribution, species composition, and area of mangrove forests of the project in 2023.

### III. Research and discussion results

The results of the classification of satellite images show that the total area of mangrove forests in 3 provinces in 1990 was 3,877.12 hectares, of which the mangrove forest area of Thai Binh province with 2,143.21 hectares accounted for 55.28%, Nam Dinh province with 1,454.52 hectares accounted for 37.51% and Ninh Binh province with 279.38 hectares accounted for 7.2%. In 2022, the total mangrove forest area of 3 provinces is 7,219.66 hectares, mainly distributed in Thai Binh province with an area of 3,969.49 hectares, accounting for 54.98%, the mangrove forest area of Nam Dinh province with 2,609 hectares, accounting for 36.14%, Ninh Binh province with a forest area of at least 640.37 hectares, accounting for 8.87% (Table 2,3, Figure 2). Compared with the annual forest statistics of the Ministry of Agriculture and Rural Development, specifically in 1990, 2005, 2020, and 2022, respectively: The area of mangrove forests in 3 provinces is 12,364.6 hectares; 12,252.7 ha; 7,484.1 hectares and 7,411.4 hectares. In particular, the fluctuation is very strong in 1990 and 2005 with a huge difference. This can be explained because the statistical method of afforestation in 2016 and earlier is statistics on the planting area according to the cumulative method of years. Therefore, the level of forest maturity of the actual forest area has not been assessed, so it leads to a huge fluctuation in mangrove data at that time.

*Table 2. Mangrove forest area in the study area*

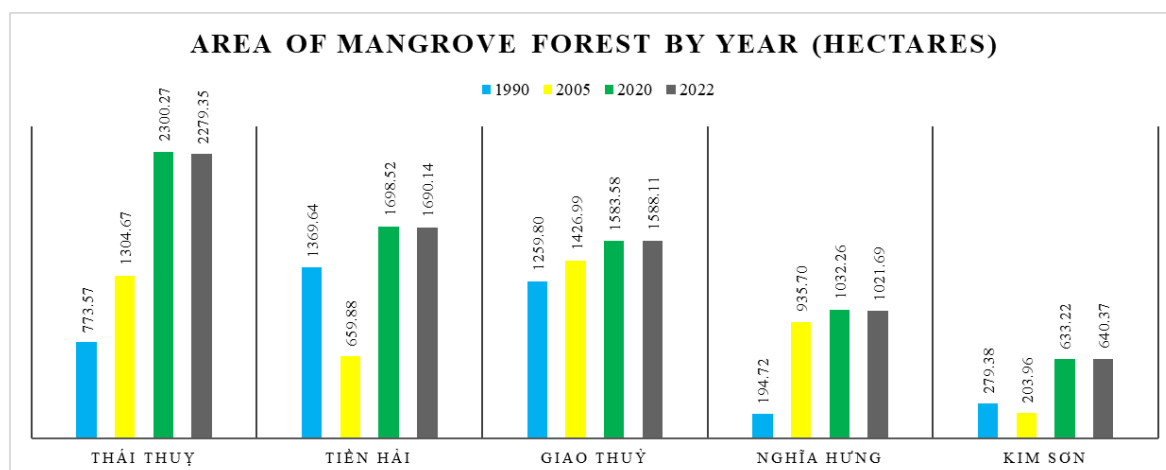| No | Province | District | Mangrove area (ha) | | | |
|----|----------|----------|------|------|------|------|
| | | | **1990** | **2005** | **2020** | **2022** |
| | | Thai Thuy | 773.57 | 1,304.67 | 2.300,27 | 2.279,35 |
| 1 | Thai Binh | Tien Hai | 1,369.64 | 659.88 | 1698,52 | 1.690,14 |
| | | **Total** | **2,143.21** | **1,964.55** | **3998,79** | **3.969,49** |
| | | Giao Thuy | 1,259.80 | 1,426.99 | 1.583,58 | 1.588,11 |
| 2 | Nam Dinh | Nghia Hung | 194.72 | 935.70 | 1.032,26 | 1.021,69 |
| | | **Total** | **1,454.52** | **2362.69** | **2.615,84** | **2.609,80** |
| 3 | Ninh Binh | Kim Son | 279.38 | 203.96 | 633,22 | 640,37 |
| **Total 3 provinces** | | | **3.877,12** | **4.531,20** | **7,247.85** | **7,219.66** |

*Figure 2. Chart of mangrove forest area by number of years and districts*

*Table 3. Statistics on mangrove forest area in some typical years*

| No | Province | 1990 | | 2005 | | 2020 | | 2022 | |
|---|---|---|---|---|---|---|---|---|---|
| | | A_MARD (ha) | A_this study (ha) | A_MARD (ha) | A_this study (ha) | A_MARD (ha) | A_this study (ha) | A_MARD (ha) | A_this study (ha) |
| 1 | Thai Binh | 7.500,0 | 2.143,21 | 7.304,0 | 1.964.55 | 4,170.6 | 3.998,79 | 4.099,7 | 3.969,49 |
| 2 | Nam Dinh | 4.456,7 | 1.454,52 | 4.343,6 | 2.362.69 | 2,699.1 | 2.615,84 | 2.681,1 | 2.609,80 |
| 3 | Ninh Binh | 407,9 | 279,38 | 605,1 | 203.96 | 614,3 | 633,22 | 630,7 | 640,37 |
| | Total | **12.364,6** | 3.877,11 | **12.252,7** | 4.531,20 | **1.964,55** | 7.247,85 | **7,411.4** | **7.219,66** |

*A_MARD: Mangrove forest area according to statistics of the Ministry of Agriculture and Rural Development, A_this study: Mangrove area according to satellite image interpretation (ha)*

### 3.1. Changes in mangrove forest area in the period 1990-2005

In the period from 1990 to 2005, the area of mangrove forests in all provinces increased, of which Nam Dinh province increased the most with 1,032.48 hectares (an increase of more than 70%), an average annual increase of 68.83 hectares, mainly concentrated around the mouth of the Day River of Nghia Hung district. This result is because during this period, the alluvial land at the mouth of the river is thriving and most of the land area is planted with mangrove forests. In the area of Xuan Thuy National Park, Giao Thuy district, Nam Dinh province, the forest area increased by 1,124.93 hectares. During this period, the area of mangrove forests in Thai Binh province increased by 90.16 hectares, mainly concentrated in the Thai Thuy district, Tien Hai district with a significant decrease of 549.24 hectares. In Ninh Binh province, the area of mangrove forests decreased by 7.26 hectares, the forest area lost by 264.91 hectares, while the restored forest area was only 257.65 hectares (Table 4). The basic reason for the decline of mangrove forests is the conversion of land use in economic development, in which most of the mangrove forest area is converted to aquaculture at this stage.

*Table 4. Mangrove fluctuations in the period 1990-2005*

| No | Province | District | Constant forest area (ha) | Lost forest area (ha) | Restored forest area (ha) | Variable forest area (ha) |
|---|---|---|---|---|---|---|
| | | Thai Thuy | 163,16 | 610,42 | 1.249,82 | 639,41 |
| 1 | Thai Binh | Tien Hai | 191,83 | 1.177,82 | 628,57 | -549,24 |
| | | **Total** | **354,98** | **1.788,23** | **1.878.39** | **90,16** |
| | | Giao Thuy | 414,71 | 845,09 | 1.124,93 | 279,84 |
| 2 | Nam Dinh | Nghia Hung | 71,86 | 111,20 | 863,84 | 752,64 |
| | | **Total** | **486,57** | **956,29** | **1.988,77** | **1.032,48** |
| 3 | Ninh Binh | Kim Son | 11,51 | 264,91 | 257,65 | -7.26 |
| | **Total 3 provinces** | | **853,07** | **3.009,43** | **4.124,81** | **1.115,39** |

### 3.2. Changes in mangrove forest area in the period 2005-2020

During this period, the area of mangrove forests in the provinces has increased sharply. The total area of mangrove forests in Thai Binh province increased by 1,398.04 hectares, about 93.2 hectares/year, the forest area lost in both districts was less than the restored forest area from 672.88 hectares to 725.16 hectares (Table 4). The total area of mangrove forests in Nam Dinh province increased by 1199.44 hectares, an average of nearly 80 hectares per year. In Ninh Binh province, the area of mangrove forests increased by 306.66 hectares by about 20.44 hectares/year, the area of restored forests was more than the lost forest area of 306.6 hectares. (Table 5). The results show that the restoration of mangrove forests in the study area during this period was very effective. The transformation of the economic structure leads to a change in the structure of land use that not only brings economic efficiency but also contributes to the effective exploitation of the strengths of resources in the research area. Policies to strengthen the management and exploitation of mangrove forests have been effectively implemented and have been effective in this area [3].

*Table 5. Changes in mangrove forests in the period 2005-2020*

| No | Province | District | Stable forest area (ha) | Lost forest area (ha) | Restored forest area (ha) | Variable forest area (ha) |
|---|---|---|---|---|---|---|
| | | Thai Thuy | 1.266,93 | 151,11 | 876,27 | 725,16 |
| 1 | Thái Bình | Tien Hai | 669,36 | 159,51 | 832,39 | 672,88 |
| | | **Total** | **1.936,29** | **310,62** | **1.708,66** | **1.398,04** |
| | | Giao Thuy | 1.300,42 | 245,63 | 921,39 | 675,76 |
| 2 | Nam Định | Nghia Hung | 777,42 | 160,83 | 684,51 | 523,68 |
| | | **Total** | **2.077,84** | **406,46** | **1.605,90** | **1.199,44** |
| 3 | Ninh Bình | Kim Son | 165,88 | 105,76 | 412,42 | 306,66 |
| | **Total 3 provinces** | | **4.180,01** | **822,84** | **3.726,98** | **2.904,14** |

### 3.3. Changes in mangrove forest area in the period 2020-2022

This is a period with a short period of review, so the volatility is not large. During this period, the forest area of Thai Binh province increased by 306.63 hectares (up 8.4%), mainly on the coast of Thai Thuy district. In contrast, on the coast of Nam Dinh, the area of mangrove forests decreased by 59.72 hectares, mainly in the Nghia Hung district. The area of restored or newly planted forests in Nghia Hung district was only 125.78 hectares while the area of lost forests was 198.54 hectares (Table 5). During this period, the area of mangrove

forests in Kim Son district fluctuated slightly by about 11.78 hectares, of which the area of recovered forests was 75.17 hectares, and the area of lost forests was 63.39 hectares (Table 6).

*Table 6. Changes in mangrove forests in the period of 2020-2022*

| No | Province | District | Forest area in 2020 (ha) | Lost forest area (ha) | Restored forest area (ha) | Variable forest area (ha) |
|---|---|---|---|---|---|---|
| 1 | Thái Bình | Thai Thuy | 2.071,35 | 69,10 | 315,53 | 246,43 |
| | | Tien Hai | 1.311,81 | 186,41 | 246,61 | 60,20 |
| | | **Total** | **3.383,16** | **255,51** | **562,14** | **306,63** |
| 2 | Nam Định | Giao Thuy | 1.978,04 | 242,13 | 255,17 | 13,04 |
| | | Nghia Hung | 1.263,01 | 198,54 | 125,78 | -72,76 |
| | | **Total** | **3.241,05** | **440,67** | **380,95** | **-59,72** |
| 3 | Ninh Bình | Kim Son | 512,82 | 63,39 | 75,17 | 11,78 |
| | | **Total 3 provinces** | **7.137,03** | **759,57** | **1.018,26** | **258,69** |
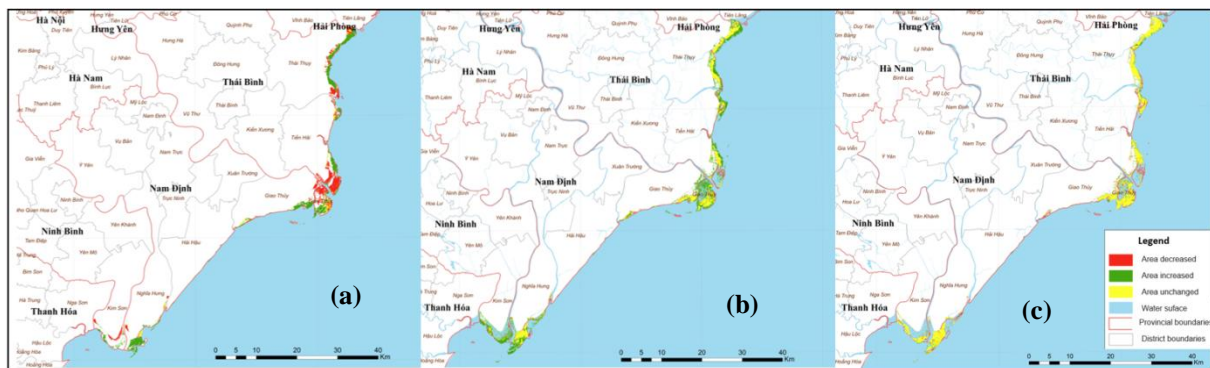


*Figure 3. Map of forest fluctuations in periods*
*(a1990-2005, (b)2005-2020, (c) 2020-2022 period*

## IV. Conclusions

The results of remote sensing image analysis and establishment of mangrove change maps from 1990 to 2022 show that the mangrove forest area of The Red River Delta Biosphere Reserve tends to increase. Each stage has different fluctuations in each region, there is no uniformity or regularity. In the period of 1990-2005, the area of mangrove forests in Tien Hai district, Thai Binh province decreased by about 549.24 hectares, while other areas all increased, the strongest was the coastal area of Nghia Hung district, Nam Dinh province with an increase of 752.64 hectares. In the period of 2020-2022, the trend changed when the coastal forest area of Nghia Hung district, Nam Dinh province decreased while other areas increased slightly. The mangrove forest area of Kim Son district, Ninh Binh province is relatively stable every year, the proportion of forests in basic years is less fluctuating, decreasing every year due to the decline in the process of planting new forests and adding forests. The interpretation of the results is very intuitive and detailed about the fluctuations of mangrove forests in the Red River Biosphere Reserve. The process of fluctuations continues to take place and may be more complicated by the impacts of climate change and sea level rise. Therefore, it is necessary to update more frequently to identify major fluctuations in a timely manner to develop plans for forest restoration and mangrove development in accordance with mangrove settlement conditions

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