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Assessment of forest change in a rural district using satellite imagery: A case study in Loc Ninh, Binh Phuoc Province, Vietnam

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ABSTRACT

Forests play a crucial role in preserving the living environment for humans, but their area is increasingly shrinking under the influence of socio-economic development. This study presents the results of applying remote sensing and GIS to assess forest resource changes in a rural district - Loc Ninh, Binh Phuoc Province, Vietnam. The study used Landsat 5 TM and Landsat 8 OLI images and processed them using ENVI 4.7 and ArcGIS Desktop 10.7 software to create forest distribution maps for the periods 2000, 2010, and 2020. The research results show that the forest area in Loc Ninh rural district experienced significant changes during the 2000-2020 period. The total forest area lost was over 13.4% (8824 ha) compared to 2000. The reasons are explained by the pressure of rapid population growth, remnants of shifting cultivation practices, as well as the consequences of land use conversion and expansion for production purposes. The research results provide valuable reference materials for forest management and protection in Loc Ninh rural district, Vietnam.

Keywords: Landsat image, Remote sensing, deforestation, Vietnam.
Article type: Short Communication.

INTRODUCTION

Forests play a crucial role in protecting the living environment for plants and animals and providing food for humans. Additionally, forests also regulate the air, store a large amount of greenhouse gases, and are an important factor in combating global climate change (UN Environment Programme World Conservation Monitoring Centre, 2023). Vietnam has a forest area of over 14,790,075 ha (Ministry of Agriculture and Rural Development 2023). However, due to the rapid economic development process as well as the rapid urbanization along with the population increase, forests in Vietnam are exploited for various purposes. As a result, the natural forest area is increasingly shrinking, the quality of the forests is deteriorating, and the composition of flora and fauna is decreasing (UN Environment Programme World Conservation Monitoring Centre 2023). Binh Phuoc province, located in the border area adjacent to Cambodia, is one of the provinces with a large forest area in Vietnam. According to statistical records, the forest area in this province is about 156,000 ha. However, due to the rapid socio-economic development, the forest area is increasingly being converted for various land use purposes. Therefore, forest management and protection here are receiving increasing attention from the government and the people. Nevertheless, the forest management database system still has many limitations, mainly based on land use current status maps on paper and actual observations, with little stored data. Additionally, the application of modern techniques, such as remote sensing, to monitor forest resource changes here has not been adequately addressed. Together with the development of science and technology, remote sensing and Geographic Information System (GIS) are considered powerful tools, providing invaluable support for researching and addressing environmental and natural resource-related issues (Khorram *et al.* 2016). The use of multi-temporal remote sensing data in monitoring forest changes has been applied in many studies worldwide as well as in Vietnam (Venkatappa *et al*. 2020; Hasan *et al*. n.d.; Hoang *et al*. 2020; Ghafoor *et al.* 2022; Loi 2023). To contribute to the

scientific basis for proposing more effective forest management solutions in Binh Phuoc Province, the study of applying remote sensing combined with GIS to build forest change maps is essential. The purpose of this study is to use remote sensing and GIS to monitor forest cover changes in a rural district - Loc Ninh, Binh Phuoc Province from 2000 to 2020. Based on this, to establish the current status and changes in forest cover maps from 2000 to 2020, contributing to the scientific basis for proposing more effective forest management and utilization solutions in Loc Ninh district in particular and Binh Phuoc Province in general.

MATERIAL AND METHODS

Study area

Loc Ninh district is a mountainous border district in the West - Northwest of Binh Phuoc Province, with a border length of over 100 km adjacent to Sanuol district, Kratie Province, and Mimot district, Congpongcham Province of Cambodia. The geographical location is determined by the following coordinates: - North Latitude: $11^0$29'33" - $12^0$05'00". East Longitude: $106^0$24'57". Regarding the border: The West and the North border Cambodia. A small part of the West - South border adjoins Tay Ninh province. The East borders Bu Dop district and Phuoc Long district, Binh Phuoc province. The south borders Binh Long district, Binh Phuoc Province. The natural area is 86,297.52 hectares, accounting for 12.6% of the natural area of the entire Binh Phuoc Province. The population in 2006 was 113,312 people. The boundary of Loc Ninh district is formed by 15 communes and 1 town, including: Loc Ninh town and the communes of Loc Quang, Loc Phu, Loc Hiep, Loc An, Loc Hoa, Loc Thanh, Loc Tan, Loc Thien, Loc Thanh, Loc Thai, Loc Dien, Loc Thuan, Loc Khanh, Loc Hung and Loc Thinh. National Highway 13 passes through the center of the district, connecting with Cambodia through the Hoa Lu border gate, and there will be a trans-Asia railway passing through in the future. This is an advantage in the future socio-economic development with neighboring countries. Loc Ninh has a high terrain from the North, gradually decreasing to the South, located in a tropical climate region with distinct monsoons, rainy season from May to October, and dry season from November to April of the following year. Forest land accounts for over 60% of the district's area, while the rest is agricultural land, mostly high-weathered basaltic red soil, suitable for high-income crops such as coffee, cashew, pepper, and rubber.

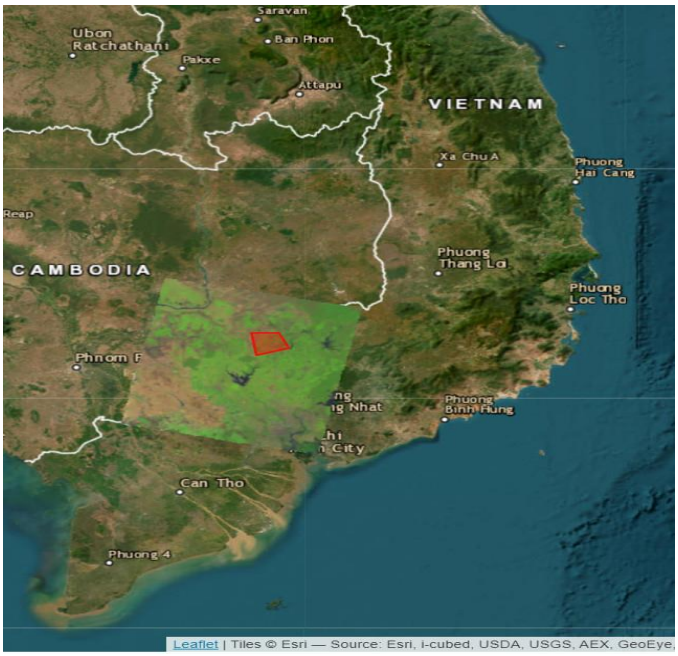

Fig. 1. Study area and Landsat scene.

Satellite imagery data

The remote sensing method uses magnetic electromagnetic radiation to investigate and measure the characteristics of the land surface. Each land surface object will have its own characteristics of radiation, reflection, or absorption of electromagnetic waves. These characteristics will be recorded and expressed in the form of images. From this image data source, experts can classify and identify different objects based on the aforementioned features combined with the spatial relationships between the objects. In this study, multi-temporal Landsat satellite data

were used (Table 1). This data has been corrected and provided by USGS. In addition to Landsat image data, to capture the attribute characteristics of land surface objects as well as forest cover, this study also conducted field surveys and collected data from local reports and local statistical surveys.

Table 1. Landsat imageries data.

Time	Landsat Scene ID	Date acquired	Spatial resolution
2000	LT05_L2SP_125052_20000319_20200907_02_T1	19/03/2000	30m
2010	LT05_L2SP_125052_20100211_20200825_02_T1	11/02/2010	30m
2020	LC08_L2SP_125052_20200223_20200822_02_T1	23/02/2020	30m

Land use/land cover classification and forest cover change

After the data is loaded, it will be processed using ENVI software. The preprocessing process includes: image channel merging, color composition, image cutting, and image quality enhancement. In the next step, the classification process with Supervised Classification validation was selected to divide the current cover status in the research area. This method is used by researchers in studies of land cover, where each pixel is calculated to probably belong to a certain type and it is assigned a name with the highest probability of belonging to that type. The Maximum Likelihood Classifier classification method is built based on the assumption of the probability density function according to the normal distribution law, so the distribution function of the image data must follow the Gaussian distribution law. Accordingly, the surface cover layer in the Loc Ninh district is divided into 5 classes: 1) residential areas, 2) agricultural land, 3) forests, 4) water surfaces, and 5) bare land.

Accuracy evaluation and classification process

The cover map established from remote sensing images always contains some types of errors due to factors from the classification technology to the method of image acquisition. Therefore, it is necessary to conduct an accuracy assessment after the classification of the resulting maps (Congalton & Green 2009). The accuracy results may or may not be achieved depending on the purpose of the user and the subsequent application of the map. The level of accuracy may also be acceptable for a specific purpose but not for another. The most common method for accuracy assessment is to use the error matrix or the confusion matrix (Congalton & Green 2009). The error matrix is a square one in which the number of rows and columns corresponds to the number of land cover types that we have given. The rows in the matrix represent the information obtained from remote sensing on the current map, while the columns represent the reference data obtained in the field survey. From this table, it provides us with accuracy measurement indices such as average classification accuracy, percentage of omission and commission errors, and the Kappa coefficient - an index evaluating the influence of randomness. Omission error is the percentage of pixels that should be in the given classes but are not present in reality. The error due to commission indicates the pixels that belong to the given classes in the map, but in reality, they belong to other classes. These values are based on samples while checking the error of pixels of undefined land cover classes compared to the classification in the map. Errors due to commission and omission can also be represented in terms of user's accuracy and producer's accuracy. The user's accuracy represents the probability of appearance, meaning that a pixel is classified as belonging to a certain class and actually appears both in its own layer and outside the actual area, while the producer's accuracy represents the percentage of the class provided that is correctly identified on the map. One of the simplest indices commonly used is the Kappa coefficient (K) to count and evaluate the compatibility between different data sources or when applying different algorithms. The method of determining the Kappa coefficient is calculated as follow:

$$K = \frac{(T - E)}{(1 - E)}$$

where: T is the overall accuracy given by the error matrix. E is the quantity that expresses the desired (expected) accurate classification. After classification, the image undergoes post-classification processing to generate layers capable of producing a map by generalizing information. The Majority Analysis method is used to combine individual pixels, either misclassified within their containing layers or taking the result of the minority pixel in the filtering window as a replacement for the center pixel.

RESULTS AND DISCUSSION

Classification results and post-classification processing

The most accurate classification method (MLC) and the majority analysis method were used to smooth the classification results. The classified image results (after classification processing) are shown in Figs. 3a, 3b, and

3c. The overall accuracies were 86%, 92%, and 93% for the years 2000, 2010, and 2020, respectively. The corresponding Kappa indices for the classification results in 2000, 2010, and 2020 were 0.77, 0.82, and 0.85, respectively. Thus, overall accuracy all exceeded 0.85 and were at a good level (Jensen 2005). The lower overall accuracy in 2000 was due to the lower quality of Landsat 5 TM image data, leading to confusion in classifying residential areas and bare land.

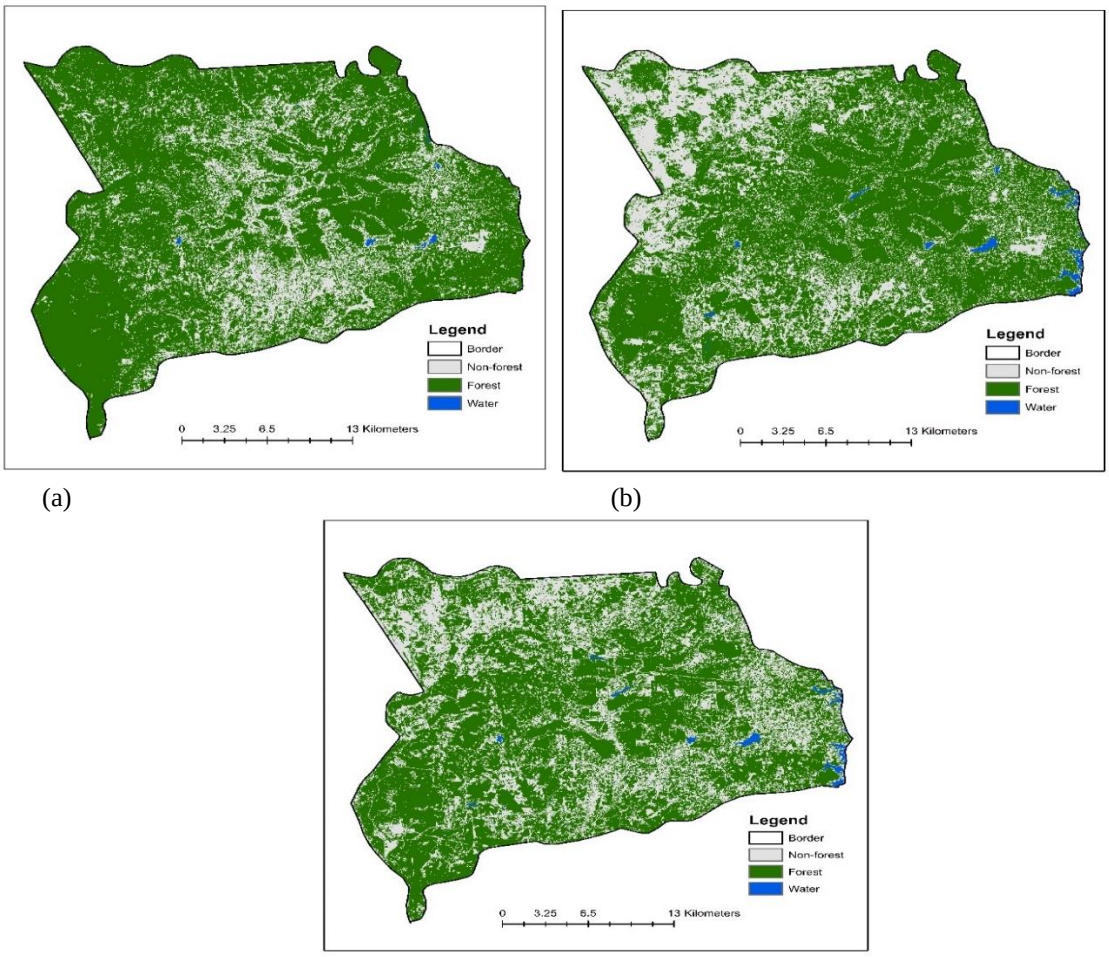

Fig. 3. Loc Ninh Forest Status (a) in 2000, (b) in 2010, (c) in 2020.

Loc Ninh Forest Status in the 2000-2020 Period

Fig. 3 illustrates the current forest distribution in Loc Ninh district, Binh Phuoc Province, Vietnam. The research results show distinct differences in the forest status over the years 2000, 2010, and 2020. The calculated forest area from the 2000 map was 65,601 ha (accounting for 76% of the district's natural land area), but by 2020, this area had reduced to only 56,777 ha (66% of the district's natural land area). Forested areas were concentrated along the border with Cambodia and in the eastern and southeastern parts of the district (Fig. 3).

Forest cover change over the study periods

From the forest distribution maps for the years 2000 to 2020, it was possible to create a forest change map in Loc Ninh district during this period. As a result, the study calculated the changing forest areas in Loc Ninh district over the years, as shown in Fig. 4 and Table 2.

Table 2. Forest area changes during each period.

Classification	2000-2010	2010-2020	2000-2020
Non-Forest	6127	2287	8414
Forest	-6573	-2251	-8824
Water	446	-36	410

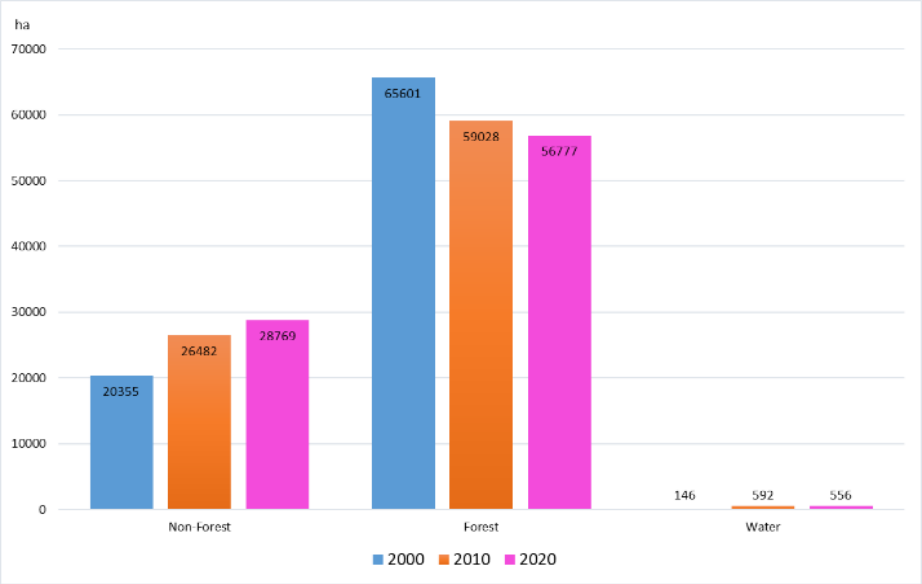

Fig. 4. Forest area changes in Loc Ninh District over the years 2000-2020.

Period 2000 - 2010

During the 2000-2010 period, the forest area in the rural district tended to decrease significantly. The total forest area of Loc Ninh district declined significantly from 65,601 ha (2000) to 59,028 ha (2010; Fig. 4). Forest area decreased sharply in the northwestern and western areas (Fig. 3b). According to the calculations, the forest area decreased by more than 6,573 ha, accounting for over 10% of the 2000 forest area lost by 2010. Meanwhile, non-forest areas increased by 6,127 ha from 2000 to 2010. The fundamental reason for the forest decline during this period was the process of land use conversion in economic development, where a significant portion of the forest area was converted to agricultural land (Pham Thu Thuy *et al.* 2012; Bảo *et al.* 2022). The entire district converted 6,100 ha of forest to other types of land, mostly for agriculture and residential areas. Many forest areas in Loc Ninh were severely destroyed to make way for rubber and cashew plantations. Although this brought high economic value to the coastal residents, it had a negative impact on the local ecosystem. Meanwhile, only a small portion of the bare land was converted to forest.

Period 2010 - 2020

During the 2010-2020 period, the forest area decreased from 59,028 ha (2010) to 56,777 ha (2020; Fig. 4). Specifically, the lost forest area was concentrated in the eastern, northeast, and central parts of the district (Fig. 3c). Although the decline in forest area in the study area had slowed down, it still could not return to the level of 2000. The results showed that the forest restoration efforts in the research area were effective. The restructuring of the economy led to changes in land use, which not only brought economic efficiency but also contributed to the efficient exploitation of the area's resources. Policies to strengthen forest management and utilization had been effectively implemented and had yielded results.

Period 2000 - 2020

The research results showed a significant fluctuation in the forests of rural Loc Ninh district during the 2000-2020 period. From 2000 to 2010, the forest area showed a clear downward trend, and although it continued to decline, the forest area gradually recovered during the 2010-2020 period. The fundamental reason for this change was the transformation of land use in economic development, in which forests were mainly converted to agricultural land and residential areas (Pham Thu Thuy *et al.* 2012). Over the past 20 years, the entire district had destroyed 8,824 ha of forest to convert to other types of land, mainly for agriculture and residential purposes (Table 2). In addition to land use conversion based on economic development planning, a considerable part of the forest was illegally destroyed due to the poor awareness of the local people and the lack of strict management (Pham Thu Thuy *et al.* 2012; Bảo *et al.* 2022). Therefore, although the forest area had not fully recovered to its original state, the efforts of the local government in implementing reforestation projects, enhancing forest monitoring and protection

activities in rural Loc Ninh district, Binh Phuoc Province had achieved certain successes, gradually contributing to the sustainable recovery and development of the forest.

CONCLUSION

The research results show that using satellite imagery to assess forest area changes in a rural area is an effective and scientifically rigorous method. Especially when field surveys cannot be conducted, this is one of the optimal methods for assessing forest area changes. The research results also indicate that the forest area in rural Loc Ninh district underwent significant fluctuations during the 2000-2020 period. The total forest area lost was more than 13.4% compared to the year 2000. Therefore, it is necessary to further strengthen reforestation, restoration, and forest protection efforts. The main reason for this decline is the conversion of forest area to agriculture and residential areas. Conservation and development of the forest system in Binh Phuoc Province are considered strategic tasks in the direction of the province's socio-economic development. Although the government has made many efforts in protecting and developing forests in general in recent years, the implementation has not been truly effective due to difficulties in human resources and funding. Below are some proposals for effectively exploiting and using forests in the area to ensure sustainable development:

There should be close coordination between the government and the people, the research contributions of domestic and international scientists in the general restoration and development of forests.

Actively promote, mobilize, and raise awareness about the significant role of the forest ecosystem, especially among students and young people.

Find effective forest exploitation methods that achieve high economic value while also protecting natural forests, such as developing ecotourism models.

Enhance the participation of local community organizations in the management, protection, and development of natural forests. Support funding for the construction of some agricultural development and livestock models to improve the livelihoods of farmers, thereby reducing pressure on the forest.

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