USING MULTI-TEMPORAL REMOTE SENSING DATA TO QUANTIFY FOREST COVER CHANGE IN DIEN BIEN DONG DISTRICT, DIEN BIEN PROVINCE DURING 1991 - 2017

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SUMMARY

Quantifying temporal changes of land use and land cover (LULC), in particular forest covers from satellite images at the various scales has been conducted in Vietnam for several years. However, a few studies have carried out to investigate LULC in Dien Bien Dong district. Hence, using multi-temporal remote sensing data to quantify LULC changes was conducted in Dien Bien Dong district, Dien Bien province during 1991 - 2017. In this study, Landsat data, including Landsat 5 (TM) in 1991, 1999 and 2009, and Landsat 8 (OLI) for 2017 with spatial resolution of 30 m was used to quantify the spatial changes of forest cover exents and then defined the drivers of changes. NDVI (Normalized Difference Vegetation Index) in combination with unsupervised classification was used. As a result showed that there was a change in forest cover extents from 1991 to 2017. Accuracy assessments of classified forest cover maps indicated that there was relatively high accurate with over 85.0%. In particular, forest cover extents declined in the period of 1991 - 2017 from 49,351.7 ha to 37,414.6 ha (decreased by 11,937.1 ha). Forest cover extents decreased by 1,683.7 ha, 9,268.7 ha and 984.6 ha in the period of 1991 - 1999, 1999 - 2009 and 2009 - 2017, respectively. Main drivers of forest cover extents were due to human forces, such as slash and burning, shifting cultivation.

Keywords: Dien Bien Dong, GIS, land use, land cover change, remote-sensing.

I. INTRODUCTION

Nowadays, with the development of advanced technologies, especially in GIS and remote sensing becomes a strategic option that helps to effectively manage natural resources and the environment (Al-Hassideh and Bill, 2008). Determining the area and purposes to enhance the effectiveness of land management, including land use and land cover (LULC) mapping and analysis is very important (Hathout, 2002; Homer et al., 2007; Zhu and Woodcock, 2014). Mapping and monitoring of land covers have been widely recognized as an important scientific goal since created information could be used to support environmental and atmospheric models. Remote sensing and GIS techniques offer highly sophisticated methods and tools for decision makers, and a particularly important application of remote sensing data is the generation of LULC maps (Kauth and Thomas, 1976; Lent and Thorley, 1969; Kass et al., 1994). Remote Sensing and GIS techniques replace some traditional, primitive methods that require a lot of time and efforts. In addition, the development of land cover map requires fast and up-to-date information to gather (Sun et al., 2009). Therefore, applying remote sensing images in combination with geographic information system offers a more accurate land cover maps in the study site (Tran Thu Ha et al., 2016; Wulder et al., 2008).

Dien Bien Dong district is a mountainous upland district where it has been separated from 10 highland communes of Dien Bien district in Dien Bien province. It is located in South East Dien Bien province with a total natural area of 120,000 ha, where is important in terms of defense and security strategy known as an important traffic hub connecting

Dien Bien province with Son La province. Therefore, Dien Bien Dong has many conditions facilitating the exchange of socio-economic development. However, forest cover extents have decreased rapdily over the last decades due to both natural and human-driven forces (Tran Thu Ha et al., 2016). The questions of how much forest cover extents have lost recently and what main drivers leading to forest cover changes remain unanswered and need to be clearly defined. Therefore, using multi-temporal remote sensing data to quantify LULC in Dien Bien Dong district was selected. This study has quantified the LULC changes, including forest covers in Dien Bien Dong district, Dien Bien province during 1991 - 2017. The study intended to provide an overview of the land cover change over the last 26 years, determine drivers of forest cover changes and then propose some applicable solutions to sustainable land use management in study site.

II. RESEARCH METHODOLOGY

In this study, land covers and land use, including forest cover in Dien Bien Dong district were targeted. This study is featured by a mountainous area and very low forest cover. This paper has quantified forest cover extents during the period of 1991 - 2017 by using a series of multi-temporal remote sensing images, including Landsat 5 (1991, 1999, 2009) and Landsat 8 (2017) with Spatial resolution of 30 m x 30 m (Table 1), then determined drivers of LULC change in Dien Bien Dong district.

Table 1. Remote sensing data used in this study

No	Image codes	Date	Spatial resolution (m)	Path x Row
1	LT05_L1TP_128045_19910212_20170127_01_T1	12/02/1991	30	128 x 45
2	LT05_L1TP_128045_19990306_20161220_01_T1	06/03/1999	30	128 x 45
3	LT05_L1TP_128045_20090112_20161028_01_T1	12/01/2009	30	128 x 45
4	LC08_L1TP_128045_20170323_20170329_01_T1	23/03/2017	30	128 x 45

Source: https://earthexplorer.usgs.gov

Survey method

Interview data was collected from interviews, which are considered as a good way to obtain additional information from local people who are living there. Due to their past understandings about LULC change and its drivers, so collecting information from them would be useful for historical LUCL change analysis. To have a good result from the interview, survey questions were designed with targeted interviewees, including local community and staffs of management broad of Dien Bien Dong district. In addition, using reference materials is another way to get information. The study used supplemental information of LULC from peer-interview papers, scientific reports and official documents in relation to Dien Bien Dong.

From these data, study would provide an overview status of LULC as well as driving factors of LULC change.

Field survey was conducted to collect information of various land use/land cover types by using GPS Garmin 78s. There were 900 ground control points collected in this study. The collecting data with an error was less than 5 m. The survey aimed to classify land cover types and support image classification and for accuracy assessments. Based on characteristics or bio-physical attributes of the area through field survey, this study divided land use types into five different types of land cover classes, including water, built-up, forest, field and others. With a total of 900 points divided for each land cover class (Table 2).

**Table 2. Number of ground control points (GCPs) collected by GPS for land covers**

No	Land cover class	Number of GCPs
1	Forest	300
2	Non forest[1]	600
Total		900

(*[1]Non forest includes water with 100 points, built-up area with 100 points, field with 300 points and others with 100 points*).

Images processing and classification

To classify image, there are three main steps used (Figure 1), including (1) Data collection and image pre-processing; analysis and and image interpretation, (2) Construction of land cover map status of 1991, 1999, 2009 and 2017 using Normalised Differences Vegetation Index (NDVI) in combination with unsupervised classification, and (3) Construction of land cover change maps in three periods of 1991 - 1999, 1999 - 2009 and 2009 - 2017. In order to process and classify images, ArcGIS 10.1 software was used.
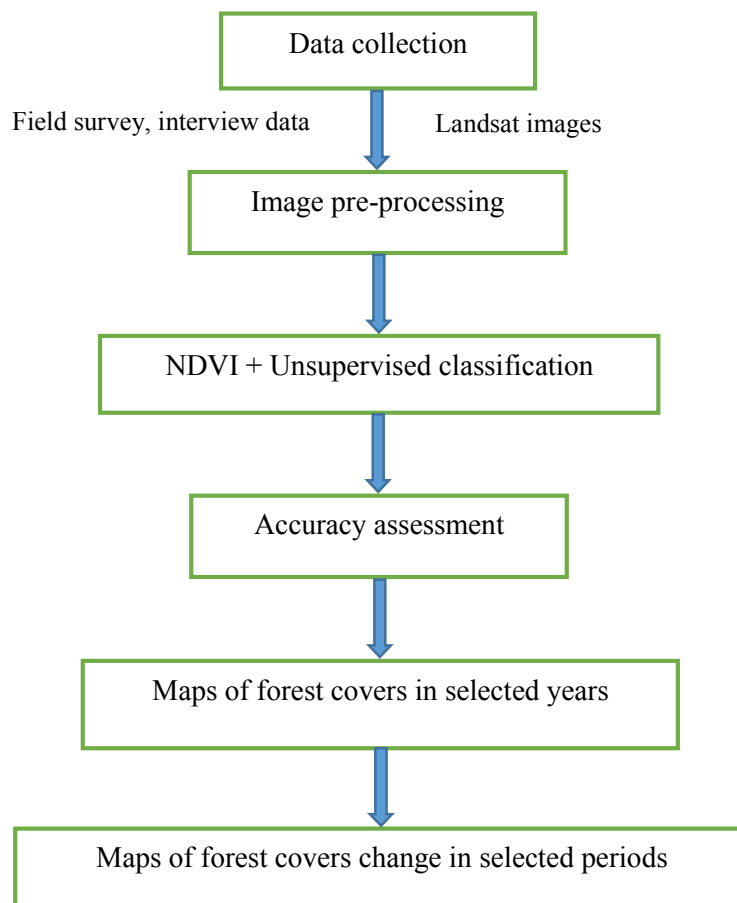
Figure 1. Overview flowchart of methods used for forest cover mapping

III. RESULTS

3.1. Assessing the status of forest covers in selected years

Maps of forest covers status in 1991, 1999, 2009 and 2017 were classified into two types land cover classes, including forest land and non-forest.

Table 3. Summary of land cover extents from 1991 - 2017 (ha)

Land covers	Year			
	1991	**1999**	**2009**	**2017**
Forest	49,351.7	47,668.0	38,399.2	37,414.6
Non-forest	70,760.3	72,444.0	81,712.7	82,697.3
Total	120,111.9	120,112.0	120,111.9	120,111.9

As shown in table 3, figure 2 and figure 3, the forest cover extents intends to decrease over time, from 1991 to 2017. In particular, there were 49,351.7 ha of forest cover (accounting for 40.89% of total area), about 70,760.3 ha of non-forest (occupied 59.11%) in 1991. However, extents of forest covers decreased to 47,668.0 ha, 38,399.2 ha and 37,414.6 ha in 1999, 2009 and 2017, respectively. In contrast, extents of non-forest increased from 1991 to 2017.
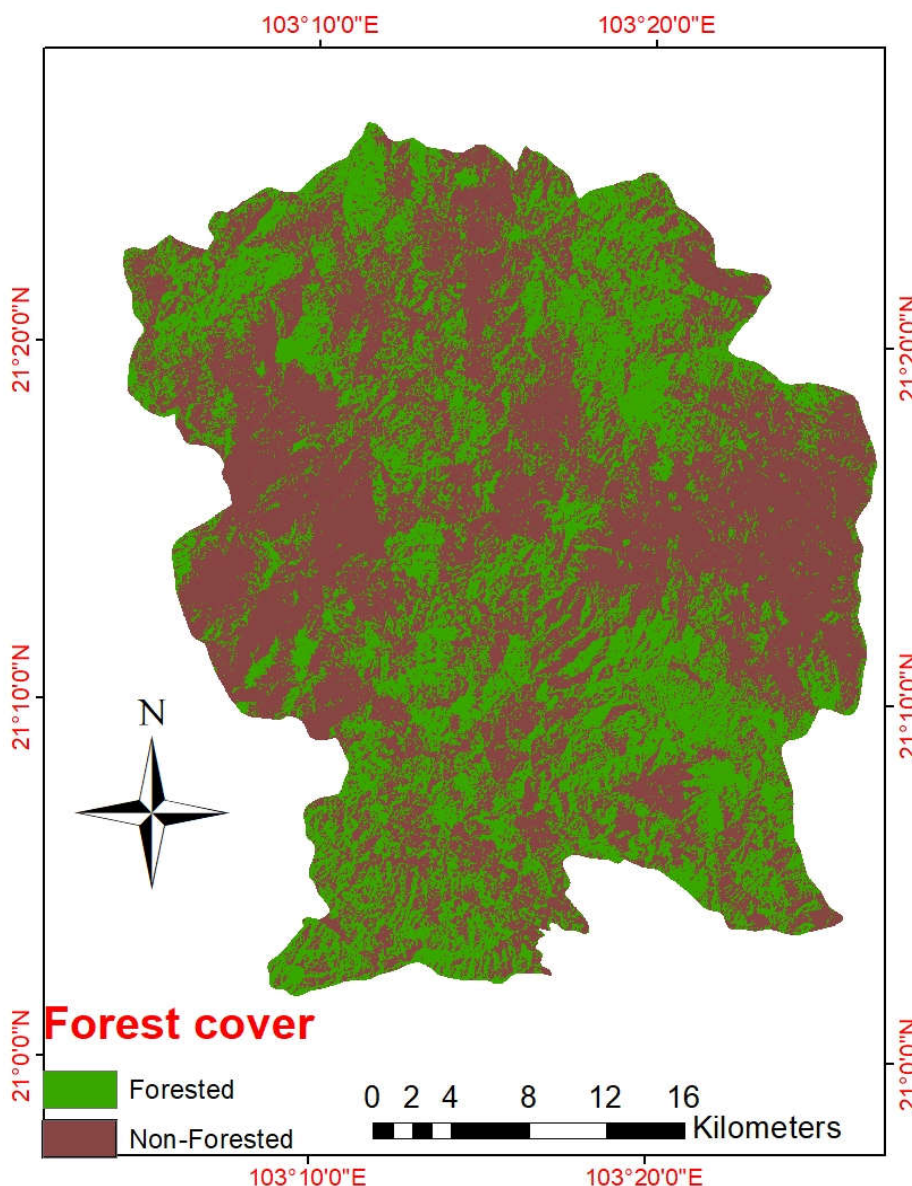

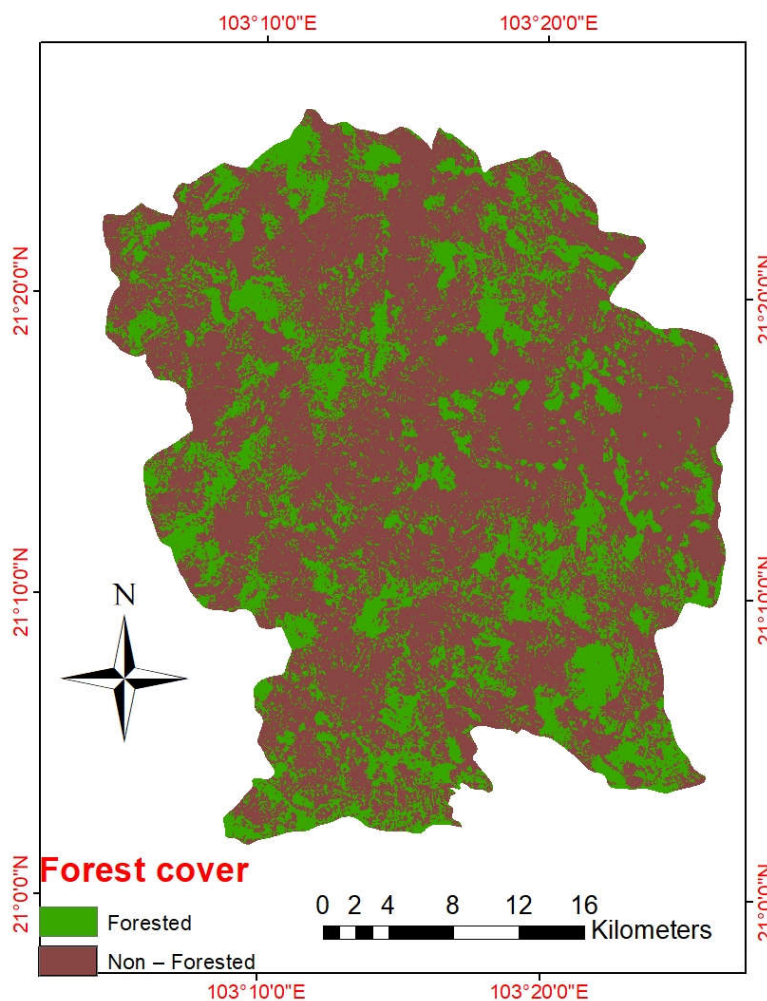**Figure 2. Forest covers in Dien Bien Dong by Landsat 5 in 1991**

Figure 3. Forest covers in Dien Bien Dong by Landsat 8 in 2017

Accuracy assessments of LULC classification

For accuracy assessments of image classification, ground control points from field survey in 2017 and additional information from Google Earth in 1991, 1999 and 2009 were used. As a result showed in table 4.

Table 4. Summary of accuracy assessments of forest cover maps in selected years

Year	Classes	Forest	Non-forest	Total	Accuracy (%)
	Forest	78	5	90	86.7
1991	Non-forest	3	74	80	92.5
	Total	40	43	170	89.4
	Forest	80	10	90	88.9
1999	Non-forest	5	72	80	90.0
	Total	42	51	170	89.4
	Forest	76	14	90	84.4
2009	Non-forest	11	69	80	86.3
	Total	38	66	170	85.3
	Forest	112	8	120	93.3
2017	Non-forest	6	94	100	94.0
	Total	118	102	220	93.6

As shown in table 4, by using NDVI classification in combination with unsupervised classification, maps of forest covers in four selected years are at high accuracy. In particular, the accuracies of forest covers mapping are at 89.4%, 89.4%, 85.3% and 93.7% in 1991, 1999, 2009 and 2017, respectively. With these results, using the NDVI in combination with the unsupervised classification is reasonable for forest covers mapping in Dien Bien Dong due to the relatively high accuracy. Besides, there are still confusions between forest covers and non-forest covers during assessments conducted. The errors may be due to the spectral disturbance of the image, the effect of the angle of the image, the shade of the terrain cannot be eliminated in the process of image processing.

### 3.2. Spatial forest cover change and drivers of change

Based on the maps of forest covers, study spatially quantified changes in forest covers in selected periods as shown in table 5.

Table 5. Forest cover change detection in selected periods

Years	Types				
	No forest	Forest loss	Forest gain	Forest stable	Net change detection
1991 - 1999	57207.3	15236.6	13552.9	34115.0	-1683.7
1999 - 2009	62450.2	19262.5	9993.8	28405.4	-9268.7
2009 - 2017	63026.3	19671.0	18686.4	18728.2	-984.6

As shown in table 5, forest covers lost are detected in net change of all three selected periods. These findings indicate that there have been a negative change in forest covers in Dien Bien Dong district. In particular, there were a loss of 1683.7 ha, 9298.7 ha and 984.6 ha of forest covers in net change detection during the period of 1991 - 1999, 1999 - 2009 and 2009 - 2017, respectively. It is also notable that period of 1999 - 2009 with largest forest cover extents was lost compared with other periods.
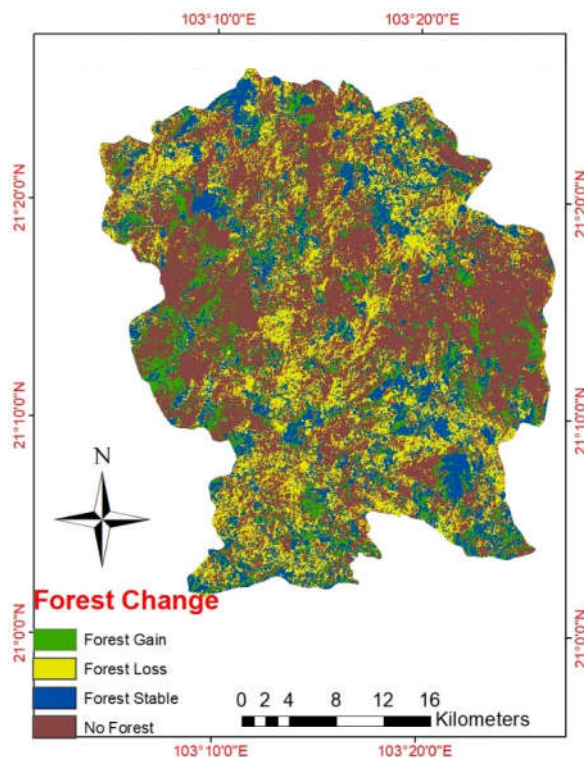
Figure 4. Forest covers change in the period of 1991 - 2017

Drivers of Forest cover change in selected periods

Period of 1991 - 1999: In this period, Dien Bien Dong district was just newly established and management broad was under the arrangement with a lack of professional and skilled staff management. In addition, more than 90% of the population were ethnic minorities with nearly 50% of poor households, limited intellectual level and low rate of socio-economic growth additionaly contributed to make situation much worse. The main economic activities of the local people included shifting cultivation, which was dependent on upland fields. In addition, there were netheir programs nor projects applied to encourange local people to participate in forest protection. Therefore, some areas of the forests were cleared simply for cultivating crops and improving local livelihoods.

Period of 1999 - 2009: This period was featured with extremely difficult economic conditions together with poor infrastructure system. There was a tendency of ethnic people's migration for shifting cultivation after only 2 to 3 years of cultivation when the upland rice was degraded, eroded and washed away by water, land was unable to be cultivated. Consequently, leaving behind the wilderness, the villagers continued to cut down the forest to make slash and burning. Local people did not realized the importance of forest resources and when slash and burning activities led to occurrence of forest fires more often. This could explains why the largest forest cover extents were lost in this period.

Period of 2009 - 2017: In this period, the area of forest continuously decreased because of increasing growth rate of population, leading to increasing demand for forest resources. Along with that, the illegal forest exploitation, deforestation and forest fires have

kept the forest covers extents of Dien Bien Dong reducing. According to Mr. Nguyen Trong Muoi, Deputy Director of Dien Bien Dong District Forest Protection Department (Personal communication, 2017), in recent years, the number of violations of the Law on Forest Protection and Development has increased. In 2015, forest rangers discovered, prosecuted and fired with over 70 million VND. Of which, 6 cases of deforestation with the area of forest cleared over 20 ha were caught, mainly protection forests and productive forests. Forest fires is also a continuous occurrence. In the first six months of 2016, there were 17 cases of forest fires and 182 ha of forests were destroyed by fires. However, this period, the loss of forest cover extents was less than 2009, because in this period the management broad have applied some big projects, such as forest and land allocation, forest plantation and financial support from Payments for ecosystem services program.

3.3. Solutions for sustainable forest management

Based on the findings identified in Dien Bien Dong, including poor infrastructure, many poor ethnic minorities with low awareness, lack of staff management, ineffective management plans. The study purposes some key solutions for sustainable forest management in Dien Bien Dong district, these include:

Lack of human resources: A number and quality of forest managers should be increased and improved by providing more training courses and workshops to enrich the required knowledge for natural resources management in the area.

Effective forest management plans: Enhancing measures in the forest management, protection and development should be prioritised with focusing on the prevention and control of

forest fires in dry season. Promoting dissemination of measures in the management, protection and development of forests to agencies, departments, unions, communes, towns in the district also should be paid into attention.

Improvement of local livelihoods: Intensive development in agroforestry and agricultural cultivation techniques should be carried out to contribute to increasing products and incomes of local people.

Public media enhancement: Raising local awareness of the important roles and benefits of forest should be carried out. Encouraging local people to plant and protect forests, use natural resources in a sustainable way should be taken into account as designing land use planning.

Enhancement of scientific research: Promoting scientific research in the area, including on monitoring and management forest resources should be prioritised. The scientific researches would help policy makers to drive reasonal decisions on sustainable forest development and planning.

Enhancement of forest policies: Land and forest allocation to individual households and communities under 30a/2008/NQ-CP of Government should be reviewed and revised. In addition, Land and forest land allocation under the Plan No. 388/KH-UBND dated 20/02/2013 was issued by Dien Bien Provincial People's Committee should be revised to complete procedures for allocation of land, forest, granting forestry land use right certificates to individuals and organizations, in particular strictly dealling with violations of the Law on Forest Protection and Development.

IV. CONCLUSION

This study has successfully constructed the status of land cover maps in 1991, 1999, 2009 and 2017 and maps of forest covers change in three periods of 1991 - 1999, 1999 - 2009 and 2009 - 2017. As result shown that there are a high accuracy in all selected years, over 85.0% of map accuracy. The results show forest cover extents declined from 37,414.6 ha in the period of 1991 -1999 and 9,268.7 ha in the period of 1999 - 2009 and 984.6 ha in the period of 2009 - 2017.

The study has also conducted the interview and information obtained from document materials indicated that human is the main driving forces of forest cover change rather than natural factors. The main human drivers of forest cover change included shifting cultivation, depending on upland fields and illegal logging, main contribution of natural induced (forest five some time by human), landslide and erosion. The study also found that Dien Bien Dong is a poor district, with low economic conditions, poor infrastructure and have many ethnic groups with low education. Therefore, management plans should be combined between sustainable use of resources and local livelihood improvements in combination with certain local conditions.

ACKNOWLEDGEMENT

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SỬ DỤNG DỮ LIỆU VIỄN THÁM ĐA THỜI GIAN ĐỊNH LƯỢNG THAY ĐỔI ĐỘ CHE PHỦ RỪNG TẠI HUYỆN ĐIỆN BIÊN ĐÔNG, TỈNH ĐIỆN BIÊN GIAI ĐOẠN 1991 - 2017

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TÓM TẮT

Nghiên cứu về sự thay đổi độ che phủ của rừng và sử dụng đất theo thời gian thông qua việc sử dụng các tư liệu viễn thám trên nhiều quy mô khác nhau đã được tiến hành ở Việt Nam trong những năm trở lại đây. Tuy nhiên, có rất ít nghiên cứu được áp dụng để điều tra việc sử dụng đất và thay đổi độ che phủ đất hay sự thay đổi độ che phủ của rừng tại huyện Điện Biên Đông. Do vậy, nghiên cứu sử dụng dữ liệu viễn thám đa thời gian để định lượng việc thay đổi độ che phủ của rừng và xác định các nguyên nhân tác động đến sự thay đổi độ che phủ tại huyện Điện Biên Đông, tỉnh Điện Biên trong giai đoạn 1991 - 2017 được thực hiện. Trong nghiên cứu này, chúng tôi sử dụng dữ liệu hình ảnh vệ tinh, Landsat 5 (TM) cho các năm 1991, 1999, 2009 và Landsat 8 (OLI) năm 2017 với độ phân giải không gian 30 m. Chỉ số NDVI (chỉ số khác biệt thực vật được chuẩn hóa) kết hợp với phương pháp phân loại không kiểm định được sử dụng. Kết quả nghiên cứu cho thấy độ chính xác của các bản độ che phủ rừng sau phân loại đạt trên 85,0%. Với kết quả này có thể nói phương pháp kết hợp NDVI và phân loại không kiểm định là phù hợp và có thể sử dụng cho khu vực nghiên cứu. Kết quả cho thấy độ che phủ rừng giảm trong giai đoạn 1991 - 2017 từ 49.351,68 ha xuống còn 37.414,62 ha (giảm 11.937,06 ha), giai đoạn 1991 - 1999 giảm 1.683,72 ha, giảm 9.268,74 ha giai đoạn 1999 - 2009 và giảm 984,6 ha giai đoạn 2009 - 2017.

Từ khóa: Điện Biên Đông, GIS, sử dụng đất, thay đổi che phủ đất, viễn thám.