Analysis of changes in the agricultural and forest areas and the impact of socio-economic activities in the Ba River Basin, Vietnam

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Abstract. In the Ba river basin, the natural forest area has been decreasing and agriculture area has been increasing at an uneven rate for the last 30 years. Objective of this research is analysing the change in the agricultural and forest areas under the impact of socioeconomic activities in this basin. Landsat satellite images with a resolution of 30 m acquired from 1989 to 2019 were used to assess the changes. To enhance the classification speed of data, this research applied the online Google Earth Engine platform and GIS tools to process and edit results. The results showed that the largest decrease in forest area was from 1989-2000 (~159,000 ha) while the agricultural area increased the most in the period 2010-2017 with more than 176,000 ha. The main reasons of conversion forest land into agricultural land such as fruit trees and perennial industrial crops were the increasing of population and agricultural prices. Besides, the demand of electricity caused the deforestation for hydropower plantations.

1. Introduction

The progress of science and technology has played an important role in the socio-economic development of each country, especially in the current period. It is a driving force of economic development, a lever to increase the speed of resource exploitation but also the cause of habitat pollution. Assessment the changes of agriculture and forest areas plays an important role in natural resources and land use management. In recent decade, remote sensing method has been widely applied to observe the surface of the earth. Therefore, objective of this research is analyzing the change in the agricultural and forest areas under the impact of socioeconomic activities in the Ba River Basin by remote sensing and GIS method.
The Ba river is the largest river in the central coastal region, with a main stream length of 374 km. It originates from the 1,549 m high Ngoc Ro mountaintop of the Truong Son Range and flows through the four provinces of Kon Tum, Gia Lai, Dak Lak and Phu Yen into the East Sea. The Ba river basin has about 13,900 km$^2$ area [1] and is located from 12°35’ to 14°38’ North latitude and 108°00’ to 109°55’ East longitude and surrounded in north, east and southeast by high mountains and forest cover. The part of the valley located between the mountains with the Ba River, large reservoirs, major traffic routes such as National Road 19, National Road 25, and National Road 29, which have created favorable conditions for agricultural development.

2. Data and methodology

2.1. Data

Landsat 5 and 8 satellite images collected in six times 1989, 2000, 2005, 2010, 2017, and 2019 in dry season were used in this research (Table 1). The total number of Landsat scenes used in the research is 149 images including 3 scenes (Path/Row: 124/50, 124/51 and 123/51) and used bands: SWIR, NIR, Red, Green, Blue.
Table 1. Detailed information on Landsat images.

| No. | Satellite | Spatial resolution (m) | Sensor_ID                  | Day of acquisition | Scenes |
|-----|-----------|------------------------|----------------------------|--------------------|--------|
| 1   | Landsat 5 | 30                     | LANDSAT/LT5_L1T_TOA       | Jan-May 1989       | 20     |
| 2   | Landsat 5 | 30                     | LANDSAT/LT5_L1T_TOA       | Jan-July 2000      | 25     |
| 3   | Landsat 5 | 30                     | LANDSAT/LT5_L1T_TOA       | Jan-May 2005       | 20     |
| 4   | Landsat 5 | 30                     | LANDSAT/LT5_L1T_TOA       | Jan-July 2010      | 19     |
| 5   | Landsat 8 | 30                     | LANDSAT/LC8_L1T_TOA       | Jan-May 2017       | 27     |
| 6   | Landsat 8 | 30                     | LANDSAT/LC8_L1T_TOA       | Jan-May 2019       | 38     |

Besides, socio-economic data in this research included population, production price of perennial industrial crop, monthly average income per capita, deforestation area, etc. collected from statistical yearbooks and other sources (Official electronic newspaper).

2.2. Methodology

2.2.1. Google Earth Engine
The Google Earth Engine (GEE) provides a cloud platform to access and seamlessly process large amount of freely available satellite imagery, including those acquired by the Landsat 8 remote sensing satellite. Google Earth Engine works through the online interface of the JavaScript Application (API) called Code Editor. On this interface, users can write and run scripts to share and repeat the processes of analyzing and processing geographic data. Code Editor helps users perform all functions available in Earth Engine [2].

Earth Engine stores satellite imagery data in a public data repository that includes historical images for more than 40 years. The images are added daily, then made available for data mining at a global scale [2].

2.2.2. Methods of processing, analyzing and interpreting images
Atmospheric correction and cloud removing method were conducted on the GEE platform for Landsat image data. Then they were processed and classified on the GEE platform into forest (tropical forests, dipterocarp forests), agriculture (rice, coffee, pepper, tea…), others (urban, bare land). Afterward the classification results were exported to the GIS formats to edit, evaluate the classification accuracy and map land use/land cover.

Assessment of the classification accuracy was based on field survey samples in 2017 and 2019 into three categories including forest, agriculture, others. Error matrix, overall accuracy and kappa coefficient were calculated for these categories.
2.2.3. Methods of analyzing the impact of socio-economic activities
The socio-economic data collected was compared with the changes in land use/land cover area to analysis of socio-economic activities impact on the change of agricultural and forest areas. Research methodology diagram is shown in Figure 2.

![Research methodology diagram](Diagram)

3. Result and discussion

3.1. Classification accuracy assessment

| Classified Data | Reference Data |
|-----------------|----------------|
|                 | 2017           | 2019           |
|                 | Forest | Agriculture | Others | Total | Forest | Agriculture | Others | Total |
| Forest          | 34     | 13          | 0       | 47    | 70     | 30          | 0       | 100    |
| Agriculture     | 3      | 106         | 1       | 110   | 31     | 466         | 2       | 499    |
| Others          | 0      | 2           | 13      | 15    | 0      | 9           | 45      | 54     |
| Total           | 37     | 121         | 14      | 172   | 101    | 505         | 47      | 653    |

Overall Accuracy 89%  Overall Accuracy 89%
Kappa Coefficient 0.77  Kappa Coefficient 0.71
There were 653 sample points used in image accuracy assessment (Table 2). The classification results for 2017 and 2019 are both demanding with kappa coefficient above 0.7 and overall accuracy of 89%.

3.2. The results of classification and the changes of agricultural and forest areas
Agricultural and forest areas in the Ba river basin in 1989, 2000, 2005, 2010, 2015, 2016, 2017 and 2019 was showed in Figure 3. In the period of 1989 - 2019, the areas with the most change of land use/land cover (LULC) concentrated in four main regions: The West, the South West, the East and the Southeast of the Ba River basin (Figure 3 and Table 3).

Table 3. Land use/land cover area in the Ba river basin from 1989 to 2019.

| Class name | Area in 1989 | Area in 2000 | Area in 2005 |
|------------|--------------|--------------|--------------|
|            | ha           | %            | ha           | %            | ha           | %            |
| Forest     | 1,055,049    | 79.2         | 906,138      | 68.0         | 667,612      | 50.1         |
| Agriculture| 176,969      | 13.3         | 290,630      | 21.8         | 329,713      | 24.7         |
| Others     | 100,592      | 7.5          | 135,842      | 10.2         | 335,285      | 25.2         |
| Total      | 1,332,610    | 100.0        | 1,332,610    | 100.0        | 1,332,610    | 100.0        |

Figure 3. Agricultural and forest areas in the Ba river basin in 1989, 2000, 2005, 2010, 2015, 2016, 2017 and 2019.
Table 3 and Figure 4 showed that the forest area tended to decline to an alarming level, with lost area of 553,321 hectares with the rate 1.4%/year in the period 1989 - 2019. In 1989, nearly 80% of the basin was covered by forest. However in 2019, it reduced to 37.7% and distributed mainly in the North and the East of Gia Lai province (K'Bang, Mang Yang, Dak Po, Kong Chro, Ia Pa, Krong Pa districts, etc.), partly distributed in the southwest and south of Dak Lak province (Ea Kar, M'Drak districts, etc.) and Phu Yen province (Song Hinh district, Son Hoa district, Tuy Hoa city, etc.).

In the detail, the year 2000, 68% remained, reducing 11.2% of forest area comparing with 1989 with the rate 1%/year. Most notably, in 2005, the area was 50.1%, and the reduce rate of the period 2000-2005 was 3.6%/year. Contrastly, in the period 2005-2010, due to the decision of the government on reforestation, the forest area was increased to about 1.5%. However, it continued to decline rapidly to 2017 and 2019. In 2019, the forest cover was only 37.7% that means it reduced half of area comparing in 1989 (Figure 4).

There is almost no forest in western of the basin and the mouth of the Da Rang River. The areas where the forest area gradually decreased and disappeared such as Mang Yang, Chu Se, Kron Chro, Phu Thien, Dak Po districts of Gia Lai province; Ea H’Leo, Krong Nang, M’Drak districts of Dak Lak province; Song Hinh, Phu Hoa, Son Hoa districts of Phu Yen province. The decrease in forest area was due to the demand for population and production, and lands for construction such as hydropower (Song Ba Ha, Krong H’Nang, An Khe-Kanak hydroelectric reservoirs, lakes), irrigation works, exploitation, and conversion of forests to other uses as prescribed by the government [3] [4].

|                | 1989 | 2000 | 2005 | 2010 | 2017 | 2019 |
|----------------|------|------|------|------|------|------|
| Forest         | 687,526 | 51.6 | 602,353 | 45.2 | 501,728 | 37.7 |
| Agriculture    | 472,084 | 35.4 | 648,305 | 48.6 | 686,526 | 51.5 |
| Others         | 173,000 | 13.0 | 81,952  | 6.2  | 144,356 | 10.8 |
| Total          | 1,332,610 | 100.0 | 1,332,610 | 100.0 | 1,332,610 | 100.0 |

Table 3

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Figure 4. Percentage of land use/land cover area in the Ba river basin (%) in the period of 1989-2019.

While forest land decreased sharply, the agricultural areas increased by 509,557 ha (38.2%) with the rate of 1.3%/year in the period 1989 - 2019, and accounted for 51.5% of the entire basin area in 2019. The area of agricultural land varies the most in the western and southwest regions such as Mang Yang, Kong Chro, Zhuge, Phu Thien, Ayun Pa districts, etc. of Gia Lai province; Ea H’Leo District, Krong Nang, M’Dak districts, etc. of Dak Lak province; Song Hinh, Son Hoa, Phu Hoa districts, etc. of Phu Yen province. Most of the places were converted from forest land into agricultural land.
In the period of 1989-2005, agricultural land increased by 11.4% (0.7%/year). In the period of 2005-2019, it increased faster than, with 26.8% (1.9%/year). The fastest increase rate was in the period 2010-2017 with 14.2% (2%/year), the lowest was the period 2000-2005 with 2.9% (0.6%/year). The increase in agricultural land area leads to a decrease in the area of other land types in the basin, mainly forest land.

All three provinces in the Ba river basin tended to reduce forest area and increase agricultural area at an uneven rate in the period from 1989 to 2019. The main converting areas were located in crowded residential areas as well as have convenient transportation systems with national highways and inter-provincial roads connecting the areas such as National highways 25, 29, 19, etc. Consequently, it was convenient for the transportation of goods and development of agricultural activities. In addition, these areas are located near major irrigation works such as Ayun Ha lake, Ka Nak hydropower lake in Gia Lai province, Ba Ha river hydropower lake, Song Hinh hydropower lake in Phu Yen province as well as along big rivers such as Hinh river, Ea Ayan river, etc.

3.3. Socio-Economic activities impact on the change of agricultural and forest areas

3.3.1. To agricultural area

In the Ba river basin industrial crops such as pepper, cashew nuts, coffee, rubber, … have strongly developed [5], [6]. The period of 2000-2013, the production price of perennial industrial crop such as coffee, rubber, pepper, cashew nuts rose with a value of 254%, 86%, 56% and 63%, respectively (According to OECD) [6]. These were the main crops that contributed to improving people's income and significantly increasing local budget revenues in recent decades.

![Production price of perennial industrial crop from 2000 to 2013](image)

**Figure 5.** Production price of perennial industrial crops from 2000 to 2013 [6].

Therefore, it can be seen that one of the main reasons for the increasing agricultural area is market demand, which is a slash-and-burn economy based shifting cultivation. These activities are increasingly out of control, this is also the cause of the degraded forest area. Due to difficult living conditions and high prices of agricultural products, people have gradually encroached on forest land and shifted to agricultural production [7] [8].
Table 4. Monthly average income per capita at current prices in Dak Lak province (thousand VND) [9].

|          | 2010     | 2012     | 2014     | 2016     | 2018     |
|----------|----------|----------|----------|----------|----------|
| Gia Lai  | 1027,0   | 1590,7   | 1804,3   | 1946,5   | 2350,0   |

Table 5. Monthly average income per capita at current prices in Gia Lai province (thousand VND) [10].

|          | 2010     | 2015     | 2016     | 2017     | 2018     |
|----------|----------|----------|----------|----------|----------|
| Dak Laki | 1538,39  | 2176,04  | 2320,00  | 2504,00  | 2740,45  |

Table 6. Monthly average income per capita at current prices by income source in Phu Yen province (thousand VND) [11].

|                  | 2008 | 2010 | 2012 | 2014 | 2016 |
|------------------|------|------|------|------|------|
| Salary & wage    | 265,0| 397,7| 653,1| 839,2| 926,2|
| Agricultural, forestry & fishing | 233,7| 301,5| 403,6| 654,9| 610,0|
| Non-agricultural, forestry & fishing | 183,8| 228,2| 310,3| 373,6| 510,1|
| Others           | 84,9 | 86,0 | 78,8 | 146,1 | 175,2 |

Table 4, 5, 6 showed monthly average income per capita in Dak Lak, Gia Lai and Phu Yen provinces. High production prices of agricultural products make the agricultural economy in the Ba River basin are strongly developing, helping people's quality of life to be more improved.

As above analyzing, it can be seen that the increase of agricultural land was impressive due to the conversion of forest land. In recent years, with the rapid population growth and the demand of the market, people has cut forest to convert to food production and planted crops area with high profitability such as fruit trees, perennial industrial crops, etc which made the quality of life of people in this basin increase [12].

3.3.2. To forest area

The decrease forest area is due to the demand for population and production, and lands for construction such as hydropower (Ba Ha river, Krong H’Nang, An Khe-Kanak hydroelectric reservoirs lake, etc.), irrigation works, exploitation, forest fires and conversion of forests to other uses as prescribed by the government [13] [14].
Figure 6. Average population in Gia Lai, Dak Lak and Phu Yen [15] [16].

Figure 6 showed that the population of 3 provinces in the Ba/Da Rang river basin grew rapidly both naturally and mechanically. Dak Lak’s population in 2018 was 1,919 thousand people, an increase of 15.08% compared to that in 2003. Phu Yen’s population in 2018 was 909.5 thousand people, a 8.70% increase from 2003. Gia Lai’s population increased by 35.06%, from 1,079.9 thousand people in 2003 to 1,458.5 people in 2018. The rapidly growing population also contributes to the negative impact on the forest. Free migrants have become the main deforestation subjects, shifting cultivation of wandering hilltribes custom. These caused the converting forest land to commercial crops or industrial crops such as rubber and coffee in the Central Highlands and accounted for 40-50% of the lost forest area in the basin [15].

The population grew rapidly as a result of the massive in-migration of lowlanders after the reforms began to take effect in 1990. Between the census of 1999 and 2009 the Highland provinces experienced the highest demographic growth rates in the country [17]. During this Renovation period, many lowland people from poor northern and central provinces moved to the region to set up coffee gardens, which became highly profitable in the new market conditions. Correspondingly, northern minority people are moving to the Central Highlands because of poverty, population pressure, and depleted natural resources in the Northern Highlands, and the relative abundance of farm and forest land in the Central Highlands [18].

The Central Highland is home to vast areas of land and forests, so many migrants moved into natural and protected forests, clearing cut forest for production or putting up tents illegally and causing increasing damage to forest land. The impact of both planned and spontaneous migration of ethnic Vietnamese, who traditionally have lived in the lowlands and the Red River Delta in the north has been dramatic [19]. Inevitably, the massive influx of new settlers resulted in land disputes. These included conflicts between migrants and indigenous residents, between managers of state-owned farms or forests and residents or migrants who have begun using land zoned for state use, and between earlier migrants who have staked out a plot of land and spontaneous migrants who arrived later [20]. Problems were also caused by unauthorized land sales to new migrants, as well as clearing of forest land by migrants for new farm plots. In fact, the result of the migration was often massive deforestation and conflict over lands traditionally inhabited by the ethnic minorities [18].

The deforestation for hydropower in the Central Highlands in recent years has caused serious ecological consequences for this area. It is undeniable that hydropower projects in the Central Highlands have recently brought electricity to the region and the country, contributing to regulate water resources
between the rainy season and the dry season, limit floods, serve irrigation for the project area and downstream area, develop infrastructure, etc. Hydropower development also contributes to increased income from agricultural productions due to the regulation of water from other places.

However, the massive development of hydroelectricity on the major rivers of the Central Highlands has caused many consequences to the environment and natural ecosystems. Thousands of hectares of watershed forest, protective forest, and forest land have been cleared cut for hydroelectric projects. The forest was taken away too much is the cause of increasing floods. According to the plan, when the project is completed, the forest will be replanting but in fact this number is too small compared to the area of forest to be destroyed. In Phu Yen, there are three large hydropower plants in operation: Ba Ha river hydropower, Vinh Son Song Hinh hydropower and Krong H’Nang hydropower. The total area of forest land lost by these three hydroelectric power plants was more than 10,000 ha.

Thousands of hectares of watershed forests, protective forests, and forest land in Phu Yen province were allocated for hydropower projects, but the reforestation of lost forests was very few. The more hydroelectric power, the more people lose productive land and they have destroyed more forest area for production. When allowing the implementation of hydropower projects, due to the limited area for reforestation after hydroelectricity, this region has no longer had land funds for reforestation. Besides, there are still many shortcomings in compensating land when building reservoirs and hydropower plants. The area of land being compensated less than the area of the household before resettlement; paddy land is compensated by dry and worse land so people can not carry out production. Therefore, they became unemployment, poverty and had to find other cultivating land. This caused illegal deforestation and cultivation, causing further deforestation.

![Forest area were cut down in Phu Yen, Gia Lai, Dak Lak provinces in the period 1995-2016 (hectares)](image_url)

**Figure 7.** Forest area were cut down in Phu Yen, Gia Lai, Dak Lak provinces in the period 1995-2016 (hectares) [16].

Figure 7 showed the area of deforestation in Phu Yen, Gia Lai and Dak Lak provinces in the period 1995 - 2016. It can be seen that forests in Dak Lak were the most destroyed in the period from 1995 to 2002, especially in 1995, 1997, 1998, 1999 and 2000 with the rate 1,000-3,000 ha/year. In Gia Lai and Phu Yen, destroyed forest area was the highest in the period 1995-1999.
The decrease of forest area has led to the decline of forest biodiversity, rare species of animals and plants are at risk of extinction are the main cause of the climate change, environmental incidents are increasingly fierce.

4. Conclusions
The processing of satellite imagery data on the Google Earth Engine platform shows the effectiveness of the tool. Classification results showed that the natural forest area has been decreasing and agriculture area has been increasing at an uneven rate in the period of 1989-2019.

In general, the decrease in forest area and the increase in agricultural area. The reason for this transformation was mainly due to economic development and industrial and expansion of agricultural land. There is a decrease in forest land area because of the conversion of forest land to agricultural land as well as illegal forest clearance and forest fires. The increasing agricultural area is caused of the socio-economic development and market demand, which is a slash-and-burn economy based shifting cultivation.

The results of this research have generally assessed the changing situation of forest cover and agriculture area, which can serve as a basis for further development of other studies such as the effects of climate change on human and the environment, detailed analysis of key areas for management purposes.

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