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Original Paper

Building Land Cover Objects Following the IPCC Guidelines for Carbon Emission Estimation. Case Study in the Central Highlands of Vietnam

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Abstract

We estimated the carbon emissions in the field of Land Use, Land Use Change, and Forestry (LULUCF) by using advanced technology to build the input data. Remote sensing, including satellite remote sensing and Unmanned Aerial Vehicles (UAV) with transparency, multi-time, and wide coverage characteristics, is useful in this area. The article focuses on the proposed regulations and building process of subjects in the land cover of the Vietnamese mainland following the guidance of the Intergovernmental Panel on Climate Change as applied to carbon emission estimation. We propose a process to estimate carbon emissions using the Agriculture and Land Use Greenhouse Gas Inventory software with input data extracted from the remote sensing images. An experiment on land cover change was carried out over ten years between 2006 and 2016 in the Central Highlands of Vietnam. The results obtained with remote sensing data classification for land cover categories achieved a reliability of 69% for the year 2006 and 66% for the year 2016. The carbon emission estimation data were checked and used in Vietnam's biennial update report to the United Nations Framework Convention on Climate Change, including content and updated information on the greenhouse gas inventory.

Keywords

carbon, remote sensing, landsat, land cover, ALU software

1. Introduction

In the past, Greenhouse Gas (GHG) emission estimation in Vietnam often used local statistics, calculated with Excel software. Currently, the United Nations Framework Convention on Climate Change (UNFCCC, 2012) recommended that countries should apply advanced technology to the built land use, land use change, and forestry dataset for carbon emission estimation; specifically, remote sensing technology was encouraged for use with data transparency continuity to make a basis for comparison between calculation years (IPCC, 2003; IPCC, 2006). In addition, the Agriculture and Land Use Greenhouse Gas Inventory Software (ALU), which was provided by Intergovernmental Panel on Climate Change (IPCC) is the software that has been applied in Vietnam. The ALU software is a dedicated software with the function of Quality Control (QC) and Quality Assurance (QA) (ALU, 2014) in regulation with the IPCC guidelines. IPCC (2003, 2006) provided the guidance for the method's use with three "Tiers", which could provide the tally results from the minimum to maximum degree of the uncertainty. The specific contents were as follows:

TIER 1: Calculated data and emission coefficients are taken from globally announced data sources, such as the Food and Agriculture Organization of the United Nations (FAO) reports and websites.

TIER 2: This tier uses the same methods and formulas as TIER 1, but the calculation data and emission coefficients are taken from a national data source.

TIER 3: The higher grade method used in TIER 3 includes improved inventory models and systems to focus on specific cases in each country repeated over time and is supported by high-resolution spatial data that is detailed at a provincial grade or ecological region. This tier gives an estimated result with higher certainty compared to TIER 1 and TIER 2.

Recently, Vietnam has been carrying out monitoring of the GHG emissions and absorption in the process of land use, land use change, and forestry planning using remote sensing materials. In the process of applying remote sensing technology, it is necessary to refer to the IPCC technical regulations for the input dataset in the field of LULUCF to the GHG emission estimations under Vietnamese natural conditions.

The implementation of national GHG inventory must comply with the IPCC guidelines based on the Guidelines for National Greenhouse Gas Inventories, 1996 Revised (IPCC, 1996) and Good Practice Guidance for Managing Uncertainty in GHG inventories (GPG, 2000). Depending on the availability of the input data, each country can choose a different approach, closely related to the level of increased complexity in the data accuracy requirements.

The emission coefficients used during the inventory process were the coefficients proposed by the IPCC and could be applied to many territories with the same climate zones. Countries often use national data sources for spatial data, default emission coefficients, and GHG emissions following the IPCC guidelines or FAO database (IPCC, 2003).

Table 1. Basic Land Use Data

Times T1	**Times T2**	**Land cover/land use change (T1-T2)**
F=18	F=19	F = +1
G=84	G=82	G = -2
C=31	C=29	C = -2
W=0	W=0	W = 0
R=5	R=8	R = +3
O=2	O=2	O = 0
Total =140	Total =140	Total =0

F = Forestland; G = Grassland; C = Cropland;

W = Wetland; R = Residential land; O = Other land.

The coefficients of stock change and GHG emissions were applied to specific regional data. We chose to use spatial and time data corresponding to the national coefficients with higher resolutions and greater detail. These data were identified for each specific region and spatial land cover system.

According to the IPCC guidelines, the total area data of land use should be equal to the country area. Depending on the availability of the input data, each country determines the subjects in the land cover based on their natural conditions.

Besides, remote sensing technology used to calculate vegetation biomass is typically used for Above-Ground Biomass (AGB), whereas Below-Ground Biomass (BGB) is calculated based on the inventory results of AGB via the correlation between the AGB and BGB. For the subject of forestland, Cairns et al. (1997) synthesized more than 160 biomass studies in tropical and temperate forests. The results showed that the ratio of AGB and BGB was 0.26, with fluctuations in the range of 0.18-0.30; this ratio did not change greatly between species, soil types, or latitudes. The research results also suggest that, in the case of lacking specific correlation equations for each location, the species and forest types could be used in recognized general equations; e.g., the root biomass (Y) of a tropical forest (tons RB/ha) can be calculated using the following equation:

$$Y = \text{Exp}\ \{- 1{,}0587 + 0{,}8836 * \text{LN(AGB)}\}$$

In which,

LN: Natural logarithm

AGB: Aboveground biomass.

In Vietnam, the dataset in the field of LULUCF is a data system collected though land statistical progress, such as forestry, agriculture, total land inventory, published research results, national statistical data, or extracted from remote sensing data. These data were combined into the LULUFC dataset by area classification, including forest land, cropland, grassland, wetlands, residential land (residential and infrastructure), and other land. A classification system of land cover objects was applied to the whole country as a land use status map classification system. Land cover was established to serve specific purposes for the forest layer, the vegetation soil layer, etc. Currently, Vietnam uses the classification regulations following the land use purposes defined in the Circular No. 27/2018/TT-BTNMT, dated December 14, 2018, of the Ministry of Natural Resources and Environment, which focuses on the statistics, land inventory, and mapping of the land use status (MONRE, 2018).

To build the input dataset in the field of LULUCF for GHG emission estimations based on the classification system of land use objects in MONRE (2018), the combination of classes necessary to determine the six types (categories) of land cover objects (forestland, grassland, cropland, wetland, residential land, and other land) needed for the IPCC guidelines is proposed in Table 3. For example, for investigation, collecting, and classification, forestland includes evergreen broad-leaved forests, deciduous forests, planted forests, mangroves, and other forests. Cropland includes annual cropland, perennial cropland, and wet rice.

In the process of building a land cover object dataset, the technical requirements for those objects must comply with the current legal documents on the technical regulations for the production of optical sensing images with high and super high resolution, using the reference system and national coordinate system of Vietnam (VNPM, 2000), as well as the converted parameter system between the international coordinate system WGS-84 and the national coordinate system VN-2000 (MONRE, 2007).

The article proposes regulations regarding the process for subjects in land cover for the Vietnamese mainland following IPCC guidelines; experimented carbon emission estimation in the Central Highlands region by using the ALU software with the input data extracted from the remote sensing images.

2. Method

2.1 The Subjects in Land Cover in the Field of LULUCF in Vietnam Natural Condition

Based on IPCC guidelines (IPCC, 2003; IPCC, 2006) and MONRE (2018), the land cover in the field of LULUCF in Vietnam natural condition as follows:

Table 2. Vietnam Land Cover Classification System

Code_IPCC	Subject_IPCC	Code_IPCC_Vietnam	Classification system in Vietnam natural condition
1	**Forestland**	1.1	Evergreen broad-leaved forest land
		1.2	Deciduous forest land
		1.3	Planted forest land
		1.4	Mangrove land
		1.5	Other forest land
2	**Cropland**	2.1	Annual cropland

		2.2	Perennial cropland
		2.3	Rice land
3	**Grassland**	3	Shrubland, grassland
4	**Residential land**	4	Residential land, industrial land, mineral exploitation land, transportation, etc.
5	**Wetland**	5	Rivers, streams, aquaculture, swamps, etc.
6	**Other land**	6	Unused flat land, unused hilly land, rocky mountain land without trees, sand, etc.

Input remote sensing image data must be preliminary assessed for cloud cover. Cloud cover assessment is divided into levels and denoted by letters:

- Level A: Remote sensing image with cloud coverage under 10%;
- Level B: Remote sensing image with cloud coverage from 10-25%;
- Level C: Remote sensing image with cloud coverage of 25% or more.

In this study, only remote sensing images with level A or B were used.

The map must be established following the Vietnam regulation of MONRE (2000), on the use of Vietnam’s national reference system and coordinate system (MONRE, 2007); Decision No. 05/2007/QD-BTNMT dated February 27, 2007 on using the parameter system to convert between the WGS-84 international coordinate system and Vietnam national coordinate system (VN2000); the scale of the map is chosen based on the size, area, and shape of the administrative unit; the characteristics and size of the overlay status content elements must be indicated on the overlay status map. The error of reciprocity of the drawing map content elements does not exceed ± 0.3 mm calculated according to the scale of the base map; the error of displacement of the drawing map content elements must not exceed ± 0.2 mm calculated according to the scale of the map (MONRE, 2018).

The content of the land cover status or change map is divided into seven layers, including the math base layer, terrain layer, traffic layer, hydro system layer, and administrative boundary; each class is divided into subjects. Each layer can consist of one or several objects with the same properties, each object is marked with a unique and uniform code on the map.

2.2 The Process to Estimate Carbon Emissions Based on Land Cover Information Using Remote Sensing Data

Based on the the above basises, the process to estimate carbon emission based on land cover information using remote sensing data is expressed in Figure 1

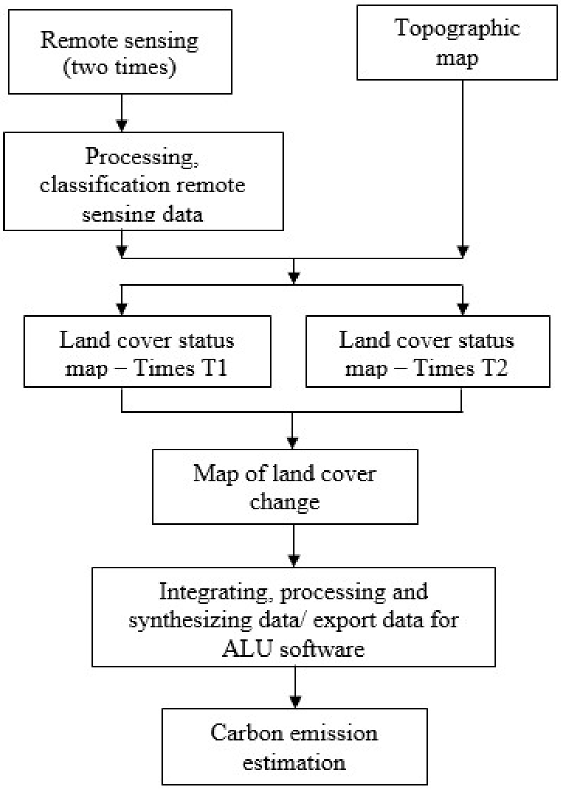

Figure 1. The Proposed Process of Carbon Emission Estimation Based on Land Cover Information in the Field of LULUCF Using Remote Sensing Data

In which:

a) Remote sensing image data: Remote sensing image data must be collected at two time intervals of 10 years and ensure unified and homogeneous data.

b) Imagery processing and classification: First, we processed the remote sensing image data to create a homogeneous image, eliminating the clouded effect on data quality and creating color composite images for the study area, while using a random classification method to classify the images (Li et al., 2014) with a classification key that offers a suitable classification sample set. Then, we evaluated the accuracy and reliability of the classification results. The data layers were classified by type, with the categories following IPCC guidelines and natural object classification regulations for Vietnam (MONRE, 2018).

We assessed the accuracy of the object classification using the Kappa Khat error matrix method (Congalton, 1991). The first step in the accreditation process was to identify high-resolution image areas on Google Earth twice. Checkpoints were randomly generated in the ArcGIS software and then loaded into buffering areas with a size of 2 ha. These areas were converted into the KML file format and loaded into Google Earth. Through visual image analysis, the land cover properties were assigned to random checkpoints. The number of these checkpoints was then verified to again attribute them to topographic mapping data at the same time. The checking process was conducted for the whole study area out with the number of sampling points for each result.

d) Land cover status/change: After inputting the classification results, an overlay dataset was built for two points at the same place to assess the area accuracy and consolidation according to the required ratio. In the process of building a land cover objects' dataset, the technical requirements for those objects must comply with the current legal documents on the technical regulations for the production of optical sensing images with high and super high resolution, using the reference system and national coordinate system of Vietnam (MONRE, 2015), as well as the converted parameter system between the international coordinate system WGS-84 (VNPM, 2000) and the national coordinate system VN-2000 (MONRE, 2007). The next step was to import and overlay data for the two periods and calculate and determine the specific changes.

g) Integrating, processing and synthesizing data/ export data for the ALU software. Land cover data serving for carbon emission estimation using the ALU software, combining the soil and climate/ecological zoning data. The work included converting data to the same data format and correlating the spatial relationships between geographic subjects.

h) Carbon emission estimation using the ALU software.

We performed emission estimation in the ALU software to check the data accuracy in the input data table related to the data entry. The next step was to run the software and export the emission results.

3. Case Study in the Central Highlands of Vietnam

3.1 Study Area and Input Data

a) Study area

The Central Highlands of Vietnam is not a single plateau but a series of adjacent and stratified plateaus. The Central Highlands is located in the range from 11°17' to 15°26' North latitude, from 107°19' to 108°54' East longitude. The Central Highlands has a special geographical position with an altitude from 250 to 2,500 m. It is upstream of four large river systems. This plateau is located near the middle of Vietnam with a radius of equal distance from Southeast Asian countries not exceeding 2,000 km.

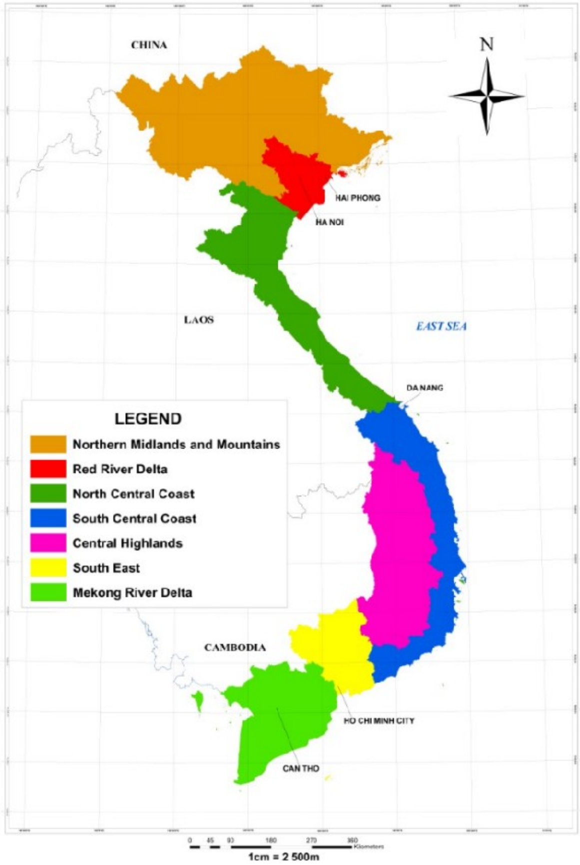

Figure 2. Location Map of Seven Sreas in Vietnam

b) Input data

Landsat remote sensing data for 2006 and 2016 of USGS Landsat mission (USGS) in the Central Highlands of Vietnam were collected. The estimated Landsat remote sensing data for one year is the composite data of all Landsat images acquired for the study area, with cloud cover under 20%. The Landsat images included reflected spectral images at the top atmosphere (TOA) of six multispectral channels: Blue, Green, Red, Nir, SWIR1 and SWIR2, with applied preprocessing (image conversion calculation from gray values (DN)) to reflect the value in front of the sensor.

The map material was a topographic map at the scale of 1: 100,000 or 1: 50,000 in the VN-2000 coordinate system. This was used as the base map serving for establishing the land cover status map from the remote sensing images.

3.2 Results

a) Image processing and land cover results in the Central Highlands.

From the imagery processing result at the time of 2006, the obtained land cover status with six criteria is presented in Figure 3.

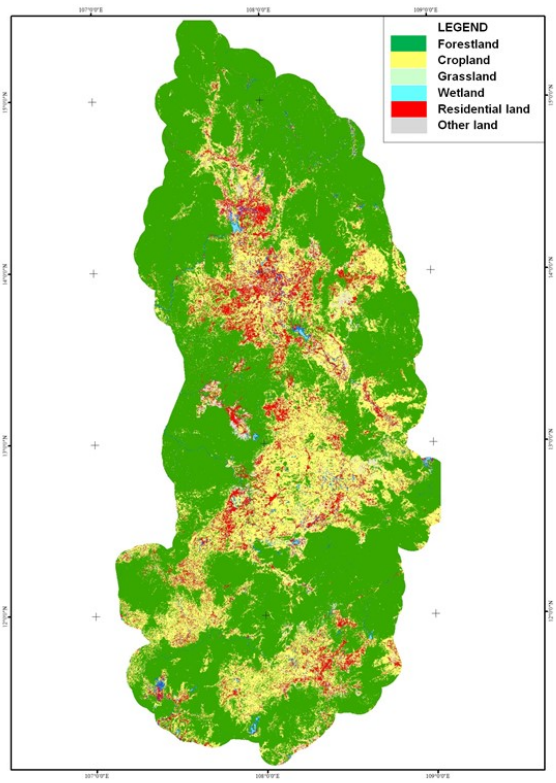

Figure 3. Illustration of the Land Cover Data from the Lands at Image in the Year of 2006

From the imagery processing result at the time of 2016, the obtained land cover status with six criteria is presented in Figure 4.

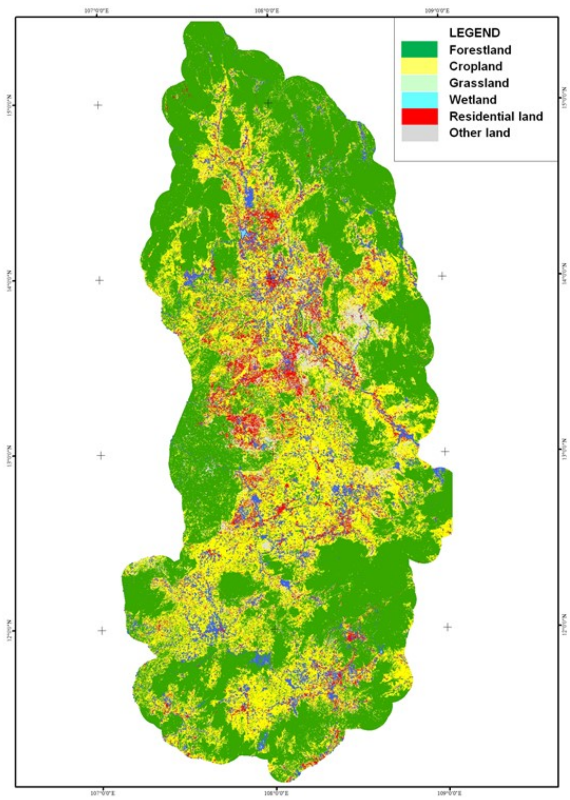

Figure 4. Illustration of the Land Cover Data from the Lands at Image in the Year of 2016

Overlapped data were extracted to establish the land cover change map for the period of 2006-2016, with the results shown in Figure 5.

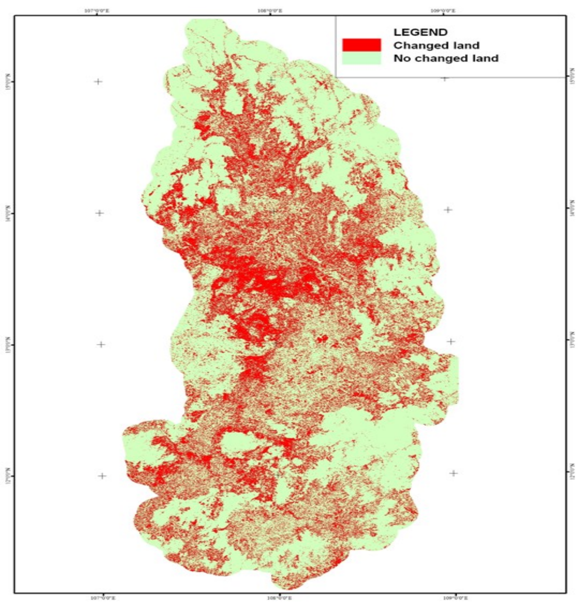

Figure 5. Illustration of the Land Cover Change in the Period of 2006-2016

Table 3. The Land Cover's Subject Change in the Years of 2006 and 2016

The source of emission/absorption		Area (Unit: ha) 2006 (Before conversion)	2016 (After conversion)
Land cover change			
A. Forestland	**Total**	**3,276,146**	**2,480,274**
	1. Primary forestland	2,308,673	2,308,673
	2. Land converted to forestland	967,473	171,601
B. Cropland	**Total**	**1,495,423**	**2,174,963**
	1. Primary cropland	32,726	32,726
	2. Land converted to cropland	1,462,697	1,058,749
C. Grassland	**Total**	**22**	**7,063**
	1. Primary grassland	0	0
	2. Land converted to grassland	22	7,063
D. Wetland	**Total**	**92,880**	**120,720**
	1. Primary wetland	32,726	32,726
	2. Land converted to wetland	60,154	66,988
E. Residential land	**Total**	**456,484**	**430,839**
	1. Primary residential land	32,726	32,726
	2. Land converted to residential land	423,758	261,628
F. Other land	**Total**	**143,410**	**250,505**
	1. Primary other land	32,726	32,726
	2. Land converted to other land	110,684	217,779

Following the method of accuracy evaluation as mentioned above, the first step in the accreditation process was to identify the high-resolution image areas on Google Earth for 2006 and 2016. The checking process was conducted for the whole study area with a total of 191 sampling points for 2006 and 196 sampling points for 2016. The results of LULUFC land cover dataset establishment followed the IPCC guidelines and showed all the main land cover objects that were easily acquired from remote sensing images. Statistical analysis showed that the results achieved a reliability of 69% for the year 2006 and 66% for the year 2016, which shows that this method obtained a relatively high accuracy. The matrix used for evaluating the classification accuracy shows the percentage of errors in the classification process that were distributed over most layers.

b) Carbon emission estimation results.

Carbon emissions and absorption in this field included the carbon stock change in the five carbon tanks (aboveground biomass, belowground biomass, dead tree, falling object and soil, and soil), the above and below ground biomass were generally called "fresh biomass", and dead wood and falling subjects were generally called "litter".

The GHG inventory results in the field of LULUCF (2006-2016) in the Central Highlands were estimated based on the ALU software. The main sources of emission and absorption from the forestland and cropland are shown in Table 4. In the period of 2006-2016 in the Central Highlands, the total amount of negative greenhouse gas emissions (absorption) in the field of LULUCF was 19.13 million tons CO_2. In particular, forestland, cropland, and grassland absorbed greenhouse gases with an uptake volume of 17.36 million tons of CO_2, 2.31 million tons of CO_2, and 0.77 thousand tons of CO_2, respectively, whereas the greenhouse gas emissions for others were as follows: wetland, with 65.79 thousand tons of CO_2; residential land, with 273.09 thousand tons of CO_2; and other land, with 201.25 thousand tons of CO_2.

Table 4. Carbon Emission/Absorption Estimation in the Central Highlands of Vietnam for the Period of 2006-2016

Unit: Thousand tons CO_2

Source of emission/absorption		Total CO_2	CO_2 by fresh biomass	CO_2 by litter	CH_4	N_2O
Land cover subject		**-19,133.64**	**-19,237.04**	**91.24**	**7.99**	**4.18**
A. Forestland	**Total**	**-17,362.45**	**-17,362.53**	**-**	**0.05**	**0.03**
	1. Primary forestland	-16,112.39	-16,112.47	NA	0.05	0.03
	2. Land converted to forestland	-1,250.06	-1,250.06	NE	IE	IE
B. Cropland	**Total**	**-2,310.55**	**-2,389.34**	**69.48**	**6.11**	**3.20**
	1. Primary cropland	-1,069.36	-1,069.36	NA	NA	NA
	2. Land converted to cropland	-1,241.19	-1,319.98	69.48	6.11	3.20
C. Grassland	**Total**	**-0.77**	**-1.34**	**0.51**	**0.04**	**0.02**
	1. Primary grassland	0.00	0.00	NA	NA	NA
	2. Land converted to grassland	-0.77	-1.34	0.51	0.04	0.02
D. Wetland	**Total**	**65.79**	**63.48**	**2.03**	**0.18**	**0.10**
	1. Primary wetland	NE	NE	NE	NA	NA

	2. Land converted to wetland	65.79	63.48	2.03	0.18	0.10
E. Residential land	**Total**	**273.09**	**262.61**	**9.31**	**0.77**	**0.40**
	1. Primary residential land	-	NE	NA	NA	NA
	2. Land converted to residential land	273.09	262.61	9.31	0.77	0.40
F. Other land	**Total**	**201.25**	**190.07**	**9.91**	**0.83**	**0.44**
	1. Primary other land	NE	NA	NA	NA	NA
	2. Land converted to other land	201.25	190.07	9.91	0.83	0.44

4. Discussion

Different ground objects, including forestland, grassland, cropland, wetland, residential land, and other land, have different spectral characteristics (Yu, 2017). The total carbon emissions always followed the overall world trend (Olivier, 2017). In this study, we focused on the proposed categories of land cover based on the IPCC guidelines applied in the Vietnam natural condition to illustrate the results of Vietnam's land cover and carbon emission calculations in the Central Highlands of Vietnam, which was estimated with the ALU software using remote sensing data. As described in the Results Section, with the ground objects' characteristics of an afforestation effort in Vietnam, the land cover classification was conducted using remote sensing imagery and the carbon emissions/absorption following each specific period.

Using remote sensing data for estimating carbon emissions is useful (Lu et al. 2013), and satellite-based measurements of greenhouse gases have been facilitating an effective method of monitoring atmospheric constituents with the development of highly accurate sensors. This is also becoming the major data source to detect changes in the atmospheric CO_2 concentration at regional and global scales (Yoshida et al., 2011; Crisp et al., 2015; Lei et al., 2014; Buchwitz et al., 2015).

Statistical analysis showed that the results achieved a reliability of 69% for the year 2006 and 66% for the year 2016, which shows that this method obtained a relatively high accuracy. The classification accuracy of 2016 shows that the classification result achieved a lower accuracy compared to the year 2006. The evaluated results for the classification accuracy showed the percentage of errors in the classification process that were distributed over most layers; however, the largest error percentages fell into the groups of forestland and grassland. The cause of this confusion comes from the fact that these two objects have large spectral homogeneity for their subcategories, which created two categories; whereas residential land and vacant land belong to other land types (Yifan et al., 2018).

The accuracy assessment result showed the fact that grassland is interspersed with forestland was also a cause of confusion during classification by spectral similarity. The mixed population with vegetation is also a cause of the confusion when classifying, as the source of this error is difficult to avoid even with the traditional method (interpretation by eye). The homogeneity in the spectrum was the main cause of this percentage error. The skills of the technicians who extracted the samples also had a significant influence on these errors. In some cases, the results of this error would be acceptable even with traditional methods. The grassland class was easily confused with the forestland layer during classification.

The value of carbon emissions in Vietnam reached 19.38 million tons of CO_2 in 1994 and 15,11 million tons of CO_2 in 2000 (MONRE, 2003), as well, the absorption reached 20.72 million tons of CO_2 in 2010 (MONRE, 2010) and increased up to 34.2 million tons of CO_2 in 2013. This means that the trend in the field of LULUCF applied for the Vietnam mainland changed from carbon emissions to carbon absorption in 2010 and continued to increase its absorption due to afforestation and forest protection activities. This shows a difference compared to other countries.

Many countries showed a decrease in CO_2 emissions in recent years, most notably the United States (–2.0%), the Russian Federation (–2.1%), Brazil (–6.1%), China (–0.3%), and within the European Union (–6.4%). In contrast, the largest absolute increases were seen in India (+4.7%) and Indonesia (+6.4%) with smaller increases in Malaysia, the Philippines, Turkey, and Ukraine. For many of the largest emitting countries, this is a continuation of a common trend. With an estimated 0.2% increase in CO_2 emissions, emissions in the European Union remained more or less the same in 2016 (Olivier and Peters, 2018). In contrast to most of the main emitters, the collective emissions from the rest of the world show a rising trend.

5. Conclusions

Remote sensing technology has become a useful tool in greenhouse gas emission estimation due to its transparency, accuracy, multi-time qualities, and wide coverage. To create an inventory of greenhouse gas and carbon stock changes over time, the results cannot be directly calculated from the remote sensing data but must be used in combination with software, such as the ALU software, to estimate the carbon emissions.

The results showed that the total amount of negative greenhouse gas emissions (absorption) in the field of LULUCF was 19.13 million tons of CO_2. In particular, forestland, cropland, and grassland absorbed greenhouse gases with an uptake volume of 17,36 million tons of CO_2, 2,31 million tons of CO_2, and 0.77 thousand tons of CO_2, respectively, whereas the greenhouse gas emissions for the remaining land types were as follows: wetland, with 65,79 thousand tons of CO_2; residential land, with 273,09 thousand tons of CO_2; and other land, with 201,25 thousand tons of CO_2.

The development of technical regulation will help the State management units gradually improve the legal document system, implementing the state management function to be easier and more convenient. The proposal and experimentation of the carbon emission calculation process in the field of LULUCF showed that land cover information extracted from remote sensing images reached high accuracy and effectively determined the object variation.

Remote sensing technology application is also of use for Vietnam to monitor the GHG emissions and absorption in the field of LULUCF. In the long term, highly accurate GHG inventory data and information sources help to determine the amount of carbon emissions and absorption in the field of LULUCF to help manage the quantitative emissions participating in the carbon market in the future.

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