CHEMICAL ENGINEERING TRANSACTIONS

VOL. 106, 2023

A publication of AIDIC

The Italian Association of Chemical Engineering
Online at www.cetjournal.it

Guest Editors: Jeng Shiun Lim, Nor Alafiza Yunus, Peck Loo Kiew, Hon Huin Chin

ISBN 979-12-81206-05-2; **ISSN** 2283-9216

DOI: 10.3303/CET23106110

Land Use Change Monitoring Systems for Spatial GHG Emissions and Removals Assessment in Chiang-Mai, Thailand

Wasinee Wannasiri[a,*], Angsana Chaksan[b]

[a]Geography Field of Study, Faculty of Liberal Art, Thammasat University. 99 Moo 18, KlongLuang, Rangsit, Prathumthani, Thailand.
[b]Asian Institute of Technology, 95 Moo 8, Khlong Nueng, Khlong Luang, PathumThani, Thailand
wasinee.w@arts.tu.ac.th

Using of Geo-Informatics and Google Earth Engine (GEE) technology provide the smart system to access the land information that is very important to achieve the country's goals on Climate change. The purpose of this research were to develop the land use change monitoring system by integration of Geo-Informatics and the GEE technology and to create the spatial GHG emissions and removals datasets in Chiang-Mai. Four periods (2019-2021) of Landsat-8 and Sentinel satellite imagery were used to interpret land use and land use changes. Main types of land use change based on amount of biomass were analyzed: forest land, cropland, grassland, wetland, settlement and others land. Cropland are divided into 4 sub-groups base on amount of biomass: rice fields, rubber, oil palm and other agriculture. Then the datasets of land use change were used to assess the amount of greenhouse gas emissions and reduction using the calculation method referring to the IPCC Good Practice Guidance for LULUCF (GPC) and 2006 IPCC Guidelines for National Greenhouse Gas Inventory. The results of the study are summarized as follows: Chiang Mai Province abundant with forest areas accounted for 69.9 % of the total area. There is a national forest national park and many wildlife sanctuaries. According to the interpretation of satellite images, it was found that Chiang Mai has continued to expand urban areas and agricultural areas. Most of the land has been transformed from abandoned grasslands. It wasn't modified from the forest area as in the past. This is due to the measures of forest preservation and reforestation. As a result, GHG emissions are reduced. The analysis results show that when deducting the emission value from the amount of greenhouse gas storage, Chiang Mai Province has GHG storage of -967,349.16 tCO_2 -1,308,790.00 tCO_2 -1,277,804.35 tCO_2 in 2019, 2020 and 2021 respectively. The results of this study are used as supporting information for the project to develop an approach to reduce GHG at the area base. This is another step forward in using geospatial technology to assess and manage carbon. This makes it possible to show the amount of GHG in the form of a map. Including the ability to identify emissions or reservoirs of GHG as well. The developed GHG monitoring system will benefit government agencies or the private sector to formulate more efficiently targets for reduction implementing projects.

1. Introduction

Leaders from around the world have made climate action a priority and have committed to achieving net zero emission by 2050. Thailand is a UNFCCC member country in the Non-Annex I Parties group, which joined the Paris Agreement by ratifying it in 2016. Thailand has submitted a proposal for the country's contribution to greenhouse gas reduction and climate change action (Nationally Determined Contribution: NDC) to the United Nations Framework Convention on Climate Change: UNFCC Secretariat. Thailand setting a minimum greenhouse gas emissions reduction target at 20 % and set an advanced target of 25 percent by 2030 (NDC,2021). According to the results of Thailand's Long-term Strategy study, in the case of controlling the global average temperature increase of no more than 2 degrees, Thailand expects to be able to control greenhouse gas emissions to net zero by 2090. Agriculture and Land use and Land use change (LULUC) sector of Thailand emit the second largest amount of GHG after the energy sector (TBUR, 2016). The data used for assessment

Paper Received: 27 September 2023; Revised: 14 October 2023; Accepted: 3 November 2023
Please cite this article as: Wannasiri W., Chaksan A., 2023, Land Use Change Monitoring Systems for Spatial GHG Emissions and Removals Assessment in Chiang-Mai, Thailand, Chemical Engineering Transactions, 106, 655-660 DOI:10.3303/CET23106110

in this sector involves geospatial data. Traditional methods of national GHG inventory extract the data from relevant department, which have been table data format. Data census usually uses survey methods which to be time consuming and labor intensive. Land use interpretation from satellite images also takes time and requires specialized expertise. GGE facilitates rapid and convenient land use analysis, resulting in a continuous dataset of land use changes from year to year and able to analyze long-term GHG map trends. Using GGE for monitoring land use changes results in smart access to land information with remains free for academic and research. It is very valuable to drive climate change operations according to reach the country's goals. The objective of this research is to develop the land use change monitoring system to assess the change of biomass. It uses remote sensing technology to interpret land use from satellite images and analyze land use changes by geographic information technique through the GGE system. Then the spatial GHG emissions and removals were calculated by using standard methods according to the GPC for LULUCF and the 2006 IPCC Guidelines for National GHG Inventory. GHG assessment using the geographically data approach allows the spatial display of greenhouse gases to identify the sources of emissions and storage of GHG. That is different from the national GHG inventory report which only derives the total amount of emissions in each sector. This developed system helps government agencies set a plan to reduce GHG and increase carbon storage efficiently, consistent with the characteristics of each area.

2. Study area

The area of study in this research is Chiang Mai Province. Chiang Mai Province is an economic center province in northern Thailand where the main income of the population comes from agriculture and tourism. The province has a variety of land use activity patterns. There is a plan to develop the province into a city center for international tourism and services as well as a center for trade, investment and transportation, affecting the trend of expansion of community areas and urban areas. Chiang Mai Province is located on the northern border of Thailand. It has a total area of approximately 2,204,110 ha. The area of approximately 83 % of the province is mountainous and the foothill plains are rich in forest areas (Figure 1a). Forests include natural forests, forest plantations, and other forests, which account for 69.9 % of the total area. The most common type of forest in Chiang Mai is mixed deciduous forest, followed by montane evergreen forest and other forest plantations. (Figure 1b). Chiang Mai has a total emission of 6,307,706 t CO_{2eq}. Sector of road transport accounted for 22.65 %, followed by land use change accounting for 18.7 %. Therefore, the LULUC monitoring system should be emphasized in order to track GHG emissions and reduction.

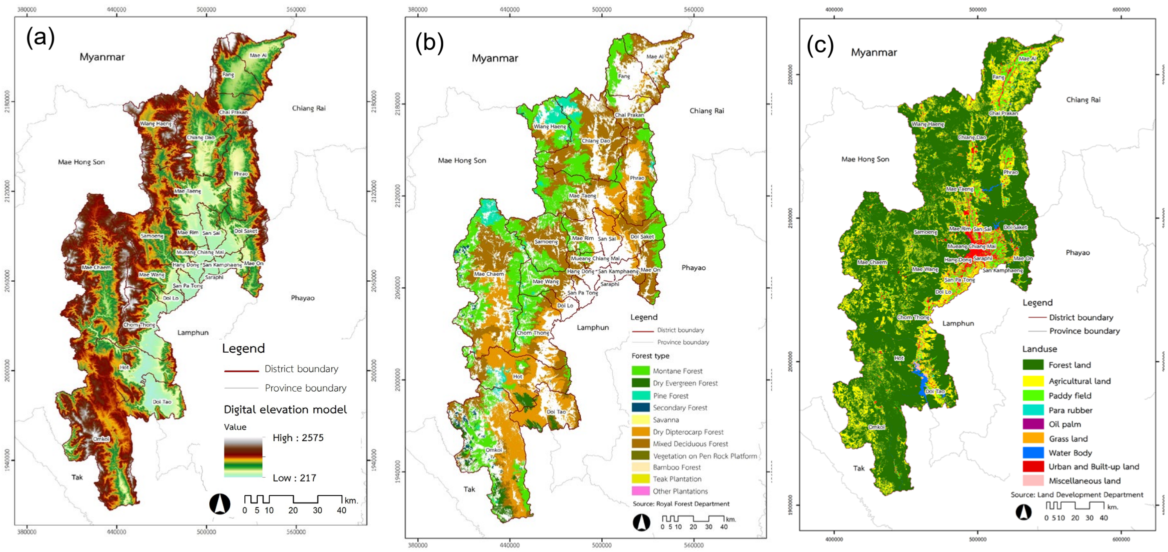

Figure 1: (a) Topography, (b) Forest type, (c) Land use

3. Research Methodology

The data analysis process follows the project framework as shown in Figure 2, which consists of main operational, including the steps for acquiring satellite image data (data acquisition), preparing satellite image data (data preparation), image management before interpretation (pre-processing), land use classification and field survey (processing), accuracy assessment (post-processing), GHG calculation and map display. Each step has details as follows.

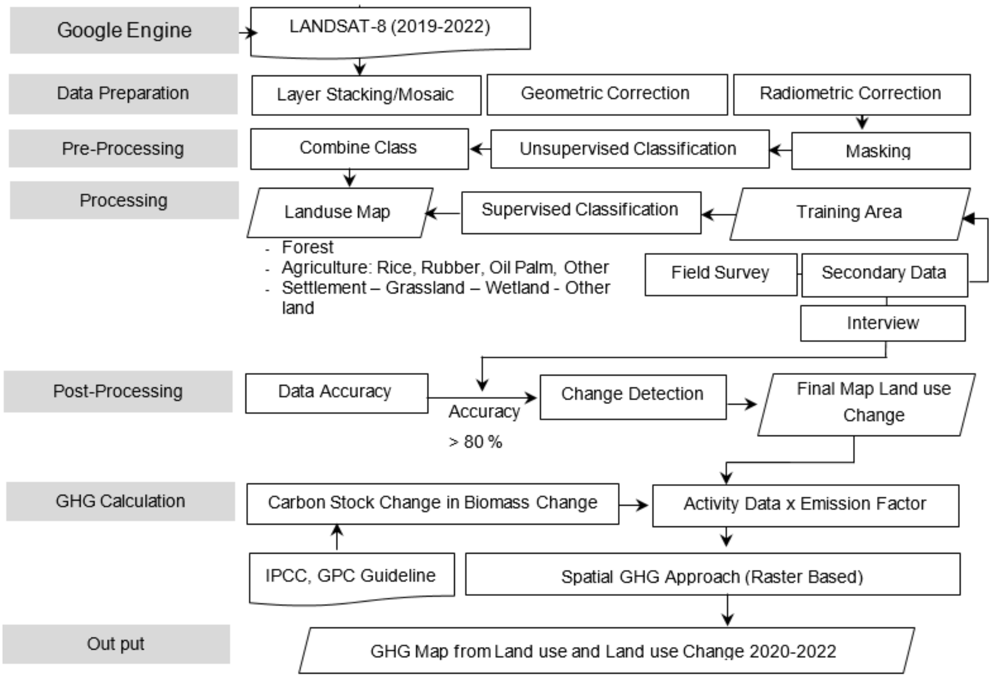

Figure 2: Methodology framework

3.1 Satellite data acquisition

This study estimates the amount of GHG from changes in carbon stock changes from LULUC using satellite imagery data in the Google Earth Engine system. Landsat 8 (30 x 30 m) satellite imagery is used for land use classification and uses Sentinel-2 (15 x 15 m) satellite imagery for clearly area which mix of reflectance. To achieve consistent results, satellite images from the same period are used every year in 2019-2022.

3.2 Image Processing

This step involves input of satellite image, image manipulation before interpretation and interpretation of land use using the functions of Google Earth Engine. The land use interpretation will classify the main land uses into 6 categories: (3B1) Forest land, (3B2) Cropland with agricultural land divided into 4 subtypes: rice fields, rubber, oil palm, and other agriculture, (3B3) Grassland, (3B4) Wetlands, (3B5) Settlements and (3B6) Other land. The result of this step is a land use map of Chiang Mai Province for 4 periods in 2019 to 2022. Field data were surveyed for use in checking the accuracy of the image interpretation, with random survey locations distributed across all types of use at a total of 50 points. Land Development Department officials were interviewed to gain in-depth information about drivers of land use change.

3.3 Land use change detection

The analysis of land use changes is based on the 2006 IPCC guideline, using 2 year land use maps to compare changes between the base year and the calculation year. Each type of land use activity in the two periods is considered separately into two parts: remaining land and land use changing, such as forest land converts to cropland, etc. The base year and calculation year data will be used to determine the code and when the changes are analyzed using GIS techniques, there will be 12 main land use groups and 36 sub-land use groups.

3.4 GHG accounting

The amount of carbon in plants and soil varies according to activities in each area and time period, caused by both natural processes and human activities. Land use change analysis are essential processes for reporting emissions and removals. Carbon stock is calculated using the gain-loss method, in which the amount of change in carbon stock per year is equal to the difference between the increases of carbon stock (ΔC_{Gain}) and the decreases of carbon stock per year (ΔC_{Loss}). The annual increase in carbon stock (ΔC_{Gain}) is the growth of above-ground and below-ground biomass in each type of land use. Annual increase in biomass carbon stocks due to biomass increment (ΔC_{Gain}) and annual decrease in carbon stocks due to biomass losses (ΔC_{Loss}) can be calculated by Equation 3.2.4 and 3.2.6 respectively. The equation referring in chapter 3 of IPCC Good Practice Guidance (GPC) for LULUCF.

3.5 Spatial GHG emission and removal

The process of calculating greenhouse gases uses Raster spatial data with a pixel size of 30 x 30 m to be consistent with the Minimum mapping unit of Landsat- 8 satellite images. Converting the land use change data set from vector to raster format, then multiplying it with the coefficient of GHG emission factors. (tCO_2 /year/pixel). The emission factors used for this study was verified from several sources., including the 2006 IPCC Guidelines, the Third National Communication (TNC) and Biennial Update Report to the UNFCCC. When the calculation is complete, the data sets are summarized using the Combine Raster method along with the land use boundaries and administrative boundaries. Then create a map of GHG emissions and removals. The map shows the distribution of carbon values in units of t CO_2/y/pixel. The pixel with the same emissions or storage values will be shown with the same color symbol. If any pixel is absorbed, it will have a negative value. If it is part of emissions, it will have a positive value.

4. Results and discussion

4.1 Land use and Land use Change

In 2022, Overview of Chiang Mai Province has approximately 69 % forest area, 23 % agricultural area, and 4.1 % urban and built-up area as shown in Figure 3. Due to population increase and economic expansion, the agricultural areas, residential areas and buildings are therefore likely to increase. Areas that tend to decrease include: forest area, water source area and other areas.

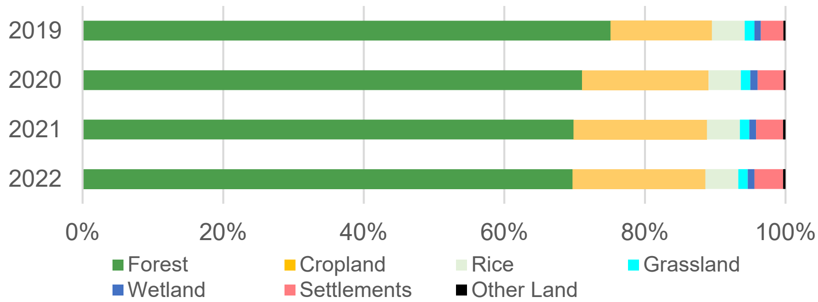

Figure 3: Time Series of Land use in 2019-2022

The forest area of Chiang Mai province decreased by 2.62 % from 2019 - 2022. Land transition was a change from forest to degraded forest first. Then it became a deserted area and abandoned. However, the study found that some of forest area has increased, which reflects to the efforts of conserve, restore degraded forests, and forest plantation causing the forest area to increase by 0.58 % from 2019 – 2022.
Chiang Mai Province has about 23 % of agricultural land, with 4.7 % of rice fields. The remaining area for cultivation is rotating crops, fruit trees, and perennial trees. In addition to rubber being an important source of carbon stock, fruit trees such as oranges and longans are also good sources of carbon storage for Chiang Mai province.

Table 1: Land use change of Chiang Mai Province in 2019-2022

Land Categories (ha)	FL (3B1a)	L – FL (3B1b)	CL (3B2a)	L > CL (3B2b)	GL (3B3a)	L > GL (3B3b)	WL (3B4a)	L> WL (3B4b)	SL (3B5b)	L > SL (3B5b)	OL (3B6a)	L > OL (3B6b)
2019-2020	1,560,828	6,002	405,020	92,413	19,388	9,909	20,235	2,708	70,596	10,980	4,501	1,530
2020-2021	1,531,046	8,671	477,764	43,374	20,546	9,025	20,112	1,322	79,500	5,085	4,215	3,450
2021-2022	1,508,863	26,740	480,966	39,270	21,348	8,499	19,114	2,000	80,818	8,926	4,611	2,954

FL: Forest land Remaining Forest Land, L > FL: Land Converted to Forest Land, CL: Cropland Remaining Cropland, L> CL: Land Converted to Cropland, GL: Grassland Remaining Grassland, L> GL, Land Converted to Grassland, WL: Wetlands Remaining Wetlands, L> WL: Land Converted to Wetlands, SL: Settlements Remaining Settlements, L > SL: Land Converted to Settlements, OL: Other Land Remaining Other Land, L > OL: Land Converted to Other Land

From the analysis of land use changes from 2019-2022 shown in Table 1, it was found that there were changes in land use from any area. went to be the most agricultural area, but it was found that there was a decrease from 92,413 ha to 43,374 ha to 39,270 ha respectively, found mostly in Mae Chaem District, and Chiang Dao District, etc. Chiang Mai province has a residential and built-up area of 0.41% , which has a continuous increase from 70,596 ha to 89,74 ha in 2019 - 2022 as show in Figure 4. Because Chiang Mai is a province with many tourists and investment from both the public and private sectors. As a result, it has become difficult to find land for development in the saturated city central because there is no more land to allocate and sell. The city began to expand outwards according to the development of infrastructure and tends to grow towards the east. It's called the new economic area. Much of the expansion of the city area has been adapted from the area. Much of the urban expansion has been converted from agricultural land and abandoned land.

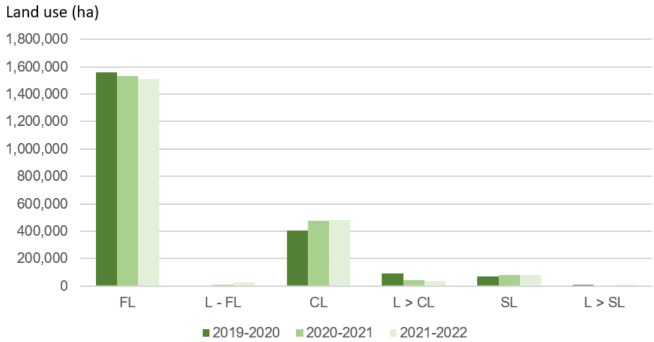

Figure 4: Land use change of Chiang Mai Province in 2019-202

4.2 GHG emission and removals

Chiang Mai Province had net emissions of -967,349. tCO_2, -1,308,790 tCO_2, and -1,277,804 tCO_2, in 2020-2022 respectively (Table 2). The forest area stores the most carbon sink equal to 2,585,698.01 tCO_2/y in 2022. Areas of the province with GHG sequestration are shown with negative (-) numbers showing blue and green symbols on the map (Figure 5b). There is a retention value of -0.12 to -0.86 tCO_2 per image pixel (equal to 900 sqm in actual area). The area with the most greenhouse gas emissions is the area converted to agricultural land (Figure 5a), with total emissions of approximately 768,139 tCO_2, 641,479 tCO_2, and 639,776 tCO_2, in 2020-2022 respectively. In addition, (3B3b) Land Converted to Grassland, (3B5b) Land Converted to Settlements and (3B6b) Land Converted to Other Land are also important contributors to greenhouse gas emissions. On the map, they are shown in shades of orange.

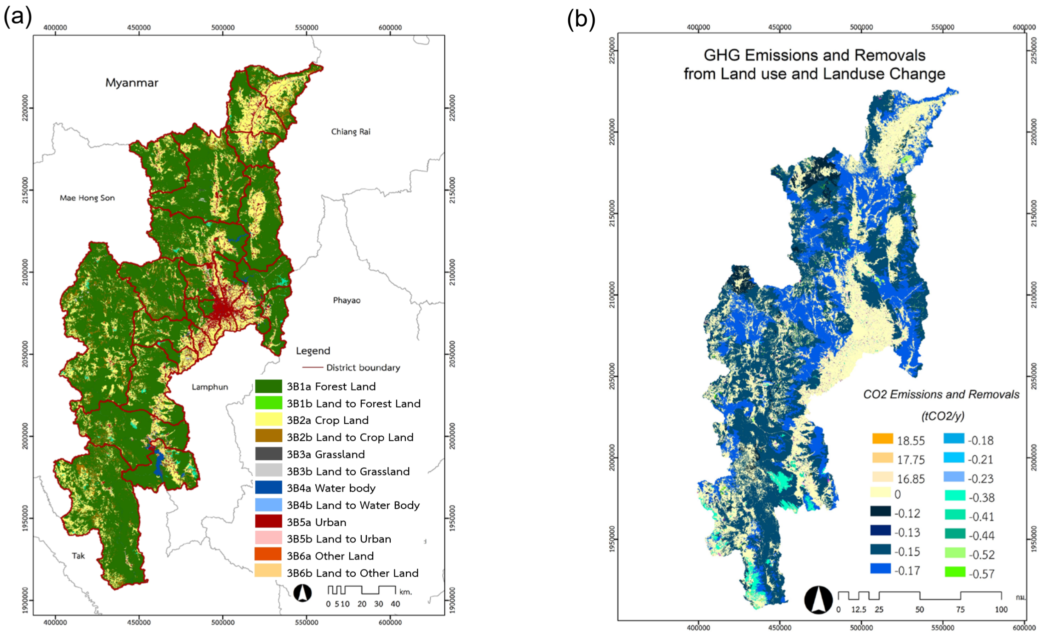

Figure 5: Land use change map (a) GHG emission and (b) removals map

Table 2: GHG emissions and removal from land use and land use changes in Chiang Mai Province

Code	Land Categories	GHG emission and removal (tCO_2)		
		2000	2021	2022
3B1a	Forest land Remaining Forest Land	-2,578,270	-2,587,982	-2,585,698
3B1b	Land Converted to Forest Land	-61,113	-31,275	-78,278
3B2a	Cropland Remaining Cropland	-25,776	-35,810	-28,748
3B2b	Land Converted to Cropland	768,139	641,479	639,776
3B3b	Land Converted to Grassland	677,808	571,792	572,786
3B5b	Land Converted to Settlements	192,136	109,398	159,893
3B6b	Land Converted to Other Land	59,727	23,609	42,465
	Total	-967,349	-1,308,790	-1,277,804

None GHG emissions or removal in Grassland Remaining Grassland, Wetlands Remaining Wetlands, Land Converted to Wetlands, Settlements Remaining Settlements, Other Land Remaining Other Land.

5. Conclusion

Chiang Mai Province is a large province with an area of 2,204,110 ha. It has a variety of land use types and is rich in forest areas, which account for 69.92 % of the total area, consisting of natural forests, forest plantations, and reforestation. However, many areas have deforestation and converted to other land uses. This results in a reduction in forest carbon storage. In addition, it was found that Chiang Mai Province continues to expand its cities and agricultural areas. These are the parts that cause greenhouse gas emissions. The study found that most of the areas that were converted to urban and agricultural areas were converted from abandoned grassland areas, not from forest areas. This may be due to conservation and reforestation measures, which are consistent with the results from interviews with forest officials. This causes the area changed from forest to agricultural land to tend to decrease and thus reduce greenhouse gas emissions. When the emission value is subtracted from the removal value, it makes Chiang Mai Province a province with storage of up to -967,349 tCO_2 -1,308,790 tCO_2 and -1,277,804 tCO_2 in 2000 to 2022 respectively. The developing of land use monitoring system are useful for assessment the amount of GHG emission and removals from land use at the area base. Results from this study will support provincial GHG reduction projects and impact assessment. The developed algorithm is another step forward in using geo-informatics and GGE technology to manage climate change. The most important and useful technology in this study is Google Engine that increases efficiency in acquiring multi-temporal satellite image data and can also interpret land use and analyze land use change conveniently. The spatial GHG assessment system can identify the sources of GHG emissions and removal, which is not only extremely useful in carbon management planning but will also help government agencies set policies and planning. The implementation of GHG reduction projects will be consistent with the characteristics of each area. Let to Thailand achieve the reaching carbon neutrality and respond to Climate action on Sustainable Development Goals.

Acknowledgements

The authors gratefully acknowledge Thailand Greenhouse Gas Management Organization (TGO), which supports research funds

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