Analyzing Methane (CH_4) Emissions in Rice Fields Using Satellite Data (Case study: Suphan Buri Province, Thailand)

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***Abstract*:** *The purpose of this study is to analyze methane (CH_4) emissions in rice fields areas in Suphan Buri Province, Thailand. By using time series data between 2019 - 2023 and geospatial technology. Suphan Buri Province is an important province in agriculture. Most of the population, more than 80 percent, are employed as farmers, especially rice cultivation. With the area located on the Tha Chin River lowland and a good irrigation system, this makes it possible to grow rice all year round. The use of technology and support from government and private agencies has increased production efficiency, making Suphan Buri a high-quality and important rice producer in the country. This research can study the relationship between water management and methane (CH_4) emissions. In this research process, high-resolution satellite data is used. Using Sentinel-5P to analyze methane (CH_4) emissions and using Senyinel-2 to classify each type of rice field areas with the Random Forest (RF) Algorithm. Moreover, using the Google Earth Engine (GEE) platform to analyze data. According to the results, methane (CH_4) emissions values can be divided into 4 levels, with the highest methane (CH_4) emissions being between 1960 - 1980 parts per billion (ppb, 10^{-9}), and the lowest being between 1900 - 1920 parts per billion (ppb, 10^{-9}). This corresponds to the period for water allocation for rice cultivation. Applying satellite data and geospatial technology for effective monitoring and analysis of methane (CH_4) emissions. This can be used in the formulation of policies and strategies towards climate change management in Thailand. Furthermore, this can be applied to water and rice fields management planning to mitigate environmental impact and promote sustainable agriculture.*

Keywords: Methane (CH_4), Emissions, Rice Fields, Satellite Data

Introduction

Currently, human activities have a significant impact on the environment. One of the most important factors affecting climate change is increasing the amount of greenhouse gas emissions such as methane (CH_4), carbon dioxide (CO_2), and nitrogen oxide (N_2O), which are difficult to prevent. Due to the ongoing human activities, there has been a continuous release of greenhouse gases, such as energy production, commodity production, deforestation, transportation, food production, energy consumption, excessive consumption. These actions have resulted in rapid changes in the Earth, oceans, and atmosphere. It can be seen from the intense heat wave, heavy rainfall, drought, tropical cyclones, and a rapid increase in greenhouse gases that have occurred in recent decades. As greenhouse gases become more concentrated, they result in higher surface temperatures on the planet, with almost every region of the planet experiencing more heat waves, while the period of hot season is increased. This event caused temperatures in the Arctic region to rise at least twice the global average. Studies have shown that in order to reduce the temperature by 1.5 degrees Celsius, it is necessary to reduce greenhouse gas emissions by up to 45 percent but between 2022 and 2023, this decline was only 1 percent. It also found that the increase in methane (CH_4) is very high, and 52 countries out of 198 countries do not report this under the UN Treaty on Climate Change.

Methane (CH_4) is the second largest component of greenhouse gases after carbon dioxide. Methane (CH_4) is the gas that contributes to global warming the most because methane (CH_4) molecules have more heat trapping. 80 times the molecular value of carbon dioxide. However, methane (CH_4) released into the atmosphere lasts for a shorter period of 12 years before atmospheric methane (CH_4) gradually deteriorates, with carbon dioxide remaining in the atmosphere for more than 100 years. This shows that lowering the level of methane (CH_4) emissions in the atmosphere can reduce the Earth's surface temperature faster than reducing the level of carbon dioxide emissions. Methane (CH_4) sources are found in nature, accounting for 30 percent of methane (CH_4) emissions and the other 60 percent from burning fossil fuels, decomposition in livestock, and mountains of garbage or agriculture, especially rice farming in waterlogged fields. This is an incident that occurs due to the release of methane (CH_4) gas under waterlogged conditions that are suitable for rice cultivation. When waterlogging in the field, facultative microorganisms and strict anaerobes decompose organic matter in the soil anaerobically, which is a fermentation process with hydrogen (H) and carbon monoxide. (CO) also occurs. Hydrocarbons (CH) are formed by hydrogen (H) and contain carbon monoxide (CO) as an electron acceptor. This process is called carbon dioxide reduction. This incident causes the release of methane (CH_4) in rice fields areas into the atmosphere.

Therefore, this research uses a geographic information system as a tool to monitor methane (CH_4) gas in rice fields at each period. Data from the Sentinel-5P satellite with the features of the TROPOMI measurement device installed on the satellite are used to effectively measure methane (CH_4) density. Rice fields are classified using the Sentinel-2 satellite with high spatial resolution, making it possible to distinguish the details of rice fields from other areas. This research processed data obtained from satellites using a geographic information system to track methane (CH_4) emissions in rice fields areas, analyzed the relationship between methane (CH_4) and rice farming to obtain a map showing methane (CH_4) emissions in Suphan Buri Province.

Research Methodology

Analysis of Methane (CH_4) Emissions in Rice Fields Using Satellite Data a case study of Suphan Buri Province has collected secondary data from various documents and research results. The methane (CH_4) data from Sentinel-5P and photos from Sentinel-2 were downloaded using the GEE API and stored in Google Drive. The data from Sentinel-2 is then used to classify the area using NDVI and NDWI values and then processed with the process of classifying the paddy area using the Random Forest algorithm. After the classification is completed, data from Sentinel-5P and Sentinel-2 is overlaid to analyze methane (CH_4) emissions in rice fields areas.

Study Area

Suphan Buri is a province located in the central part of Thailand. This is important in terms of history, culture and economy. The area of Suphan Buri Province covers about 5,358 square kilometers. It is located on the Tha Chin River basin which flows through the middle of Suphan Buri Province. This terrain makes Suphan Buri Province an important agricultural source with the process of rice farming by moving seedlings from the plot to planting in the prepared fields. This method helps the rice plant to be healthy and grow better. In addition, machinery is used for cultivation and harvesting, which reduces manual labor and increases the efficiency of rice production. Suphan Buri Province has a good irrigation system from the Tha Chin River and irrigation canals, which allows farmers to grow rice all year round and reduce the risk of drought. The support from government and private agencies is another factor that makes rice cultivation in Suphan Buri successful. Government agencies have supported the development of rice varieties, the use of technology in rice cultivation and pest management. In addition, there is market management and rice export so that farmers can have a stable income and be able to compete in the market. Suphan Buri is an important rice producer in Thailand. With the development of quality rice varieties and the use of technology in cultivation, farmers in this area can produce a lot of high-quality rice.

There are two rice planting periods in Suphan Buri Province, namely Na Prang rice and Na Pi rice. From Picture 1 It shows the planting of Na Prang rice begins from November to April. Rice begins to be planted most in November, and the harvest begins to be harvested most in February. Na Prang rice, it is a rice cultivation outside the rainy season by relying on water sources from the irrigation system, so the cultivation of paddy rice is waterlogged throughout the cultivation by the most popular rice varieties as follows: Breed Kg6 Pathum Thani 1. Na Pi rice, Planting begins from May to October. The most planting begins in May and the most harvested in September, which is the planting of rice during the rainy season. Popular rice varieties such as white jasmine 105, Phitsanulok 2, etc.

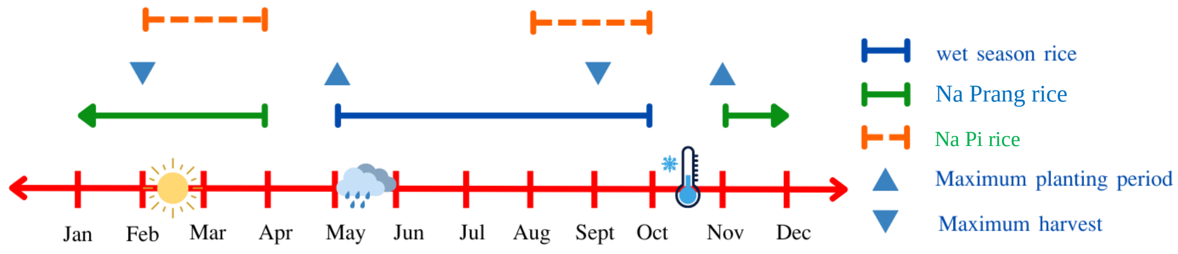


Figure 1: Rice Planting Seasons in Suphan Buri Province, Thailand.

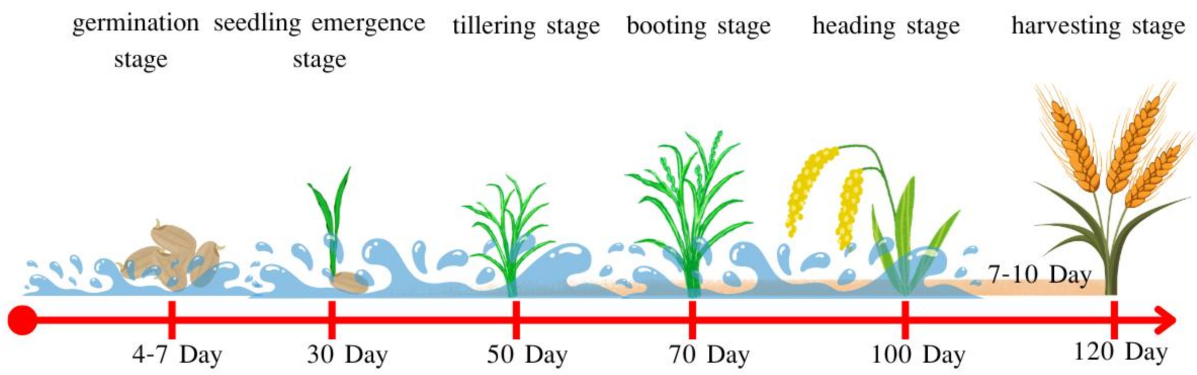


Figure 2: Growth Stages of Rice.

Tools in this research

This research used Google Earth Engine to classify rice field data with the Sentinel-2 satellite in Suphan Buri Province. The data was used from January 2019 to December 2023 due to Google Earth Engine's ability to provide access to data and advanced analytics techniques for big data. To map the area of the field using Google Earth Engine, it is easy to access satellite data of medium and high resolution such as Images from the sensor including Multispectral Instrument (MSI) Thematic Mapper (TM) Enhanced Thematic Mapper (ETM) and Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) The Google Earth Engine (GEE) platform performance focuses on complex line operations for satellite data processing required in large-scale applications such as crop mapping

This research uses Python to retrieve Sentinal-2 and Sentinal-5P satellite imagery because Python is a high-level computer programming language. It is designed as an easy-to-read scripting language, cutting out structural complexity. Python works as an interpreter, which translates a set of instructions line by line to feed them into the processor so that the computer runs according to the program. In addition, the Python programming language can be used in a variety of programming applications without being limited to a specific task. (General-purpose language). Therefore, it has become widely used in many large global organizations such as Google, YouTube, Instagram, Dropbox. And NASA develops a program for downloading data from satellites using the Python language.

This research uses an API to retrieve image data from Google Earth Engine and store it in Google Dive using Python scripts. API stands for Application Programming Interface, which is a method of calling services or data from a system that is installed on another server or on the same network. This approach allows developers to run those services conveniently and quickly and simplifies the installation of add-ons to link data to other systems. The research then used an API to retrieve methane (CH_4) data from the Sentinel-5P satellite and export it as a GeoTIFF file to Google Drive.

After that, the Sentinel-2 satellite images were analyzed by machine learning (ML) using the Random Forest algorithm. Machine Learning is a subfield of artificial intelligence that focuses on the development of algorithms and models that allow computers to learn and make predictions or decisions without being explicitly programmed. It involves the study of statistical models and algorithms that enable computers to analyze and interpret data, identify patterns, and make data-driven predictions or decisions. Machine Learning algorithms can be classified into two main categories: supervised learning and unsupervised learning. In supervised learning, the algorithm is trained on a labeled dataset, where the input data is paired with the corresponding correct output. The goal is to learn a mapping function that can predict the output for new input data. On the other hand, in unsupervised learning, the algorithm is trained on an unlabeled dataset, and the goal is to discover hidden patterns or structures in the data without any prior knowledge or labels. Machine Learning has a wide range of applications, including image and speech recognition, natural language processing, recommendation systems, fraud detection, and autonomous vehicles. Random Forest is a machine learning algorithm that is based on the concept of ensemble learning. It is a collection of decision trees that work together to make predictions. Each decision tree in the random forest is trained on a random subset of the data and a random subset of the features. This randomness helps to reduce overfitting and improves the generalization of the model. During the training process, the random forest (RF) algorithm combines the predictions of all the decision trees to make a final prediction. The algorithm is versatile and can be used for both classification and regression tasks. It is known for its high accuracy and ability to handle large datasets with high dimensionality. Additionally, random forests can provide information about feature importance, making them useful for feature selection and interpretation. Overall, Random Forest is a powerful and widely used algorithm in the field of machine learning.

Data Analysis

The analysis of data from Sentinel-2 using NDVI, NDWI and Random Forest area classification began with downloading satellite images from Sentinel-2 to analyze the integrity of rice fields. The Plant Integrity Index (NDVI) was calculated using Near Infrared (NIR) and Red band data of satellite imagery, which was calculated using the formula (NIR - Red) / (NIR + Red). The NDVI value allows us to monitor the density of plants in that area. The image processing process includes creating a new GeoTIFF file and saving the calculation results to the file, which makes it possible to use the results for further analysis of the density of the rice crop. In terms of water storage analysis in rice fields, NDWI or water index value is used, which is calculated from the Green band and Shortwave Infrared (SWIR) of satellite images. NDWI is used to monitor waterlogged areas that are important for water retention in rice fields and affect methane (CH_4) emissions. The processing is similar to NDVI using the formula (Green - SWIR) / (Green + SWIR). The results help to analyze the water level in the rice fields area and accurately isolate the waterlogged area from other areas. Then, machine learning algorithms such as Random Forest were used to classify rice fields. The process begins by filtering the clouds from the image by processing and creating an image composite from the index value. NDVI and NDWI to improve classification accuracy. This area classification uses SNIC image segmentation to obtain a data group that can be used to train the Random Forest algorithm. The results are then recorded in GeoTIFF format for further analysis. Once the analysis is successful, the data obtained from the analysis of Sentinel-2 and Sentinel-5P satellite images is overlaid to obtain the results of the area analysis. Before overlaying, the Sentinel-5P image must be resampled to the same resolution as Sentinel-2. The result of this overlay allows for a clearer analysis of factors, such as methane (CH_4) generation in waterlogged rice fields areas. Finally, data from Sentinel-2 and Sentinel-5P are used as time series data. This research analyzed data for a period of 5 years to study the relationship between water level in rice fields and methane (CH_4) emissions. This analysis allows us to understand the factors that affect emissions in rice fields areas and can be used to control and reduce greenhouse gas emissions in the future.

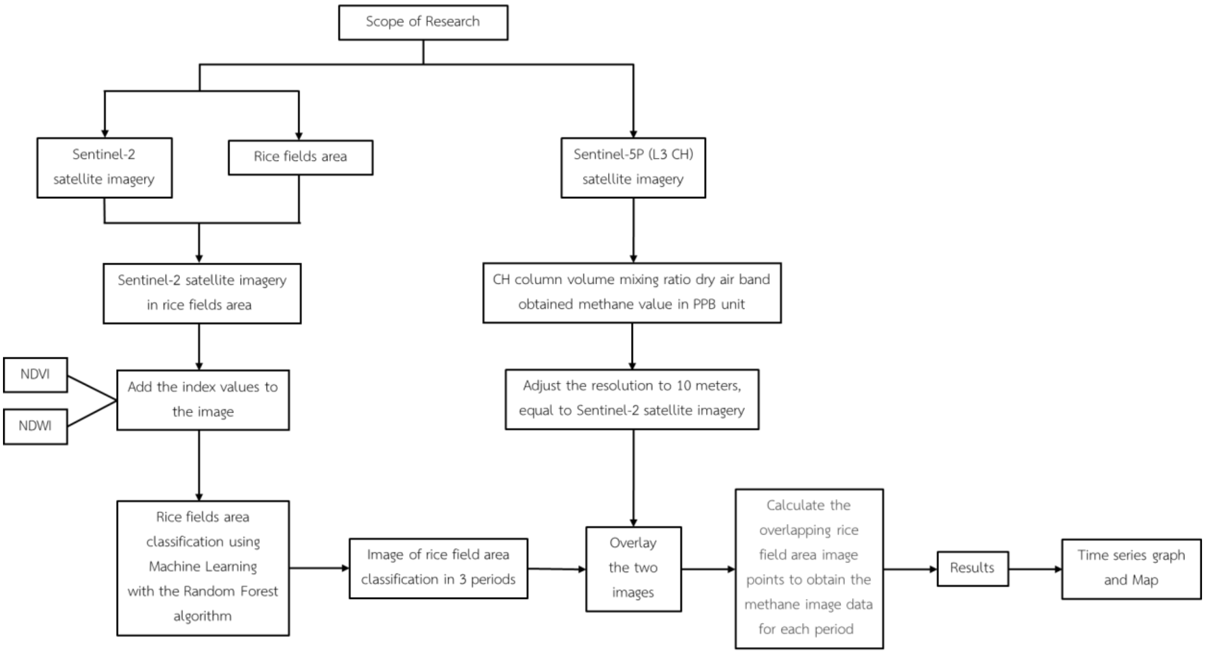
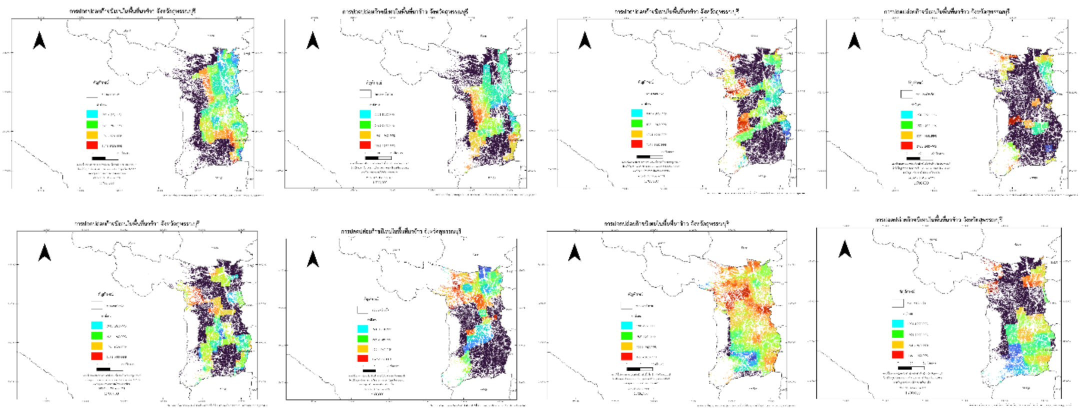


Figure 3: Conceptual Framework.

Results and Discussion

The result, Sentinel-5P can divide methane (CH_4) emissions into 4 color levels: red represents the highest methane (CH_4) emissions between 1960 and 1980 parts per billion (ppb, 10^{-9}). The subsequent category is orange, characterized by methane (CH_4) emissions falling within the range of 1940 to 1960 parts per billion (ppb, 10^{-9}). The color green indicates methane (CH_4) emissions ranging from 1920 to 1940 parts per billion (ppb, 10^{-9}). Furthermore, the color blue represents methane (CH_4) emissions ranging from 1900 to 1920 parts per billion (ppb, 10^{-9}).



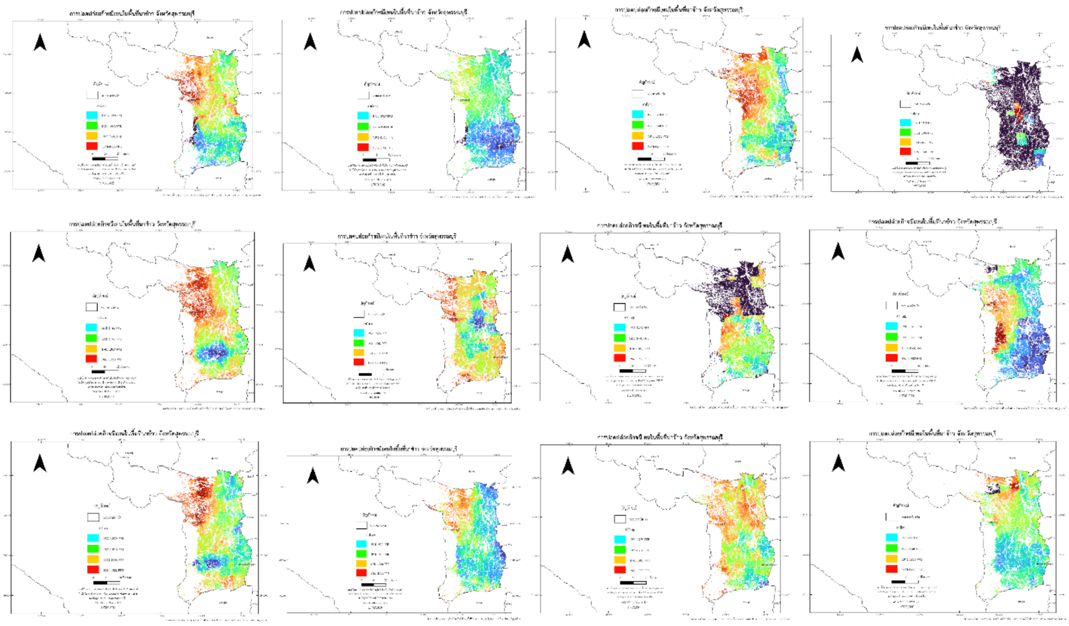
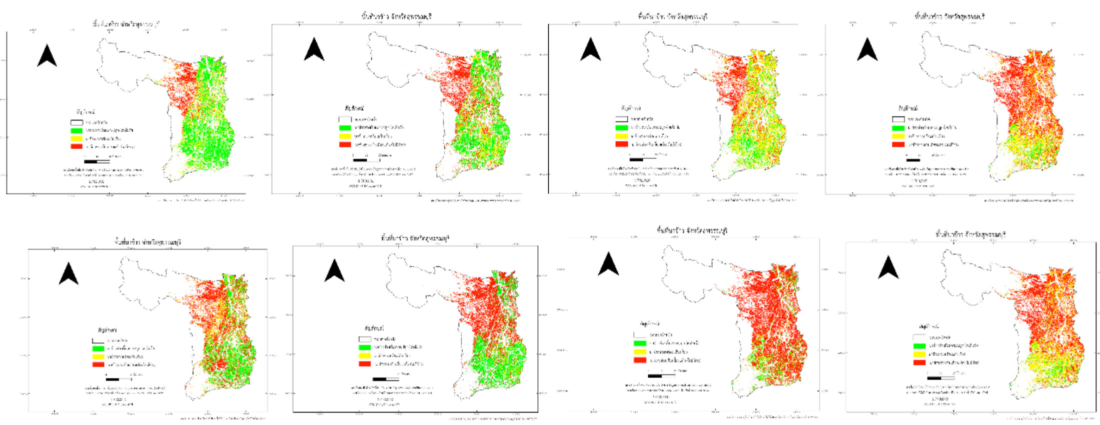


Figure 4: Map of Methane (CH4) Emissions in Rice Fields in Suphan Buri Province, Thailand from January to April from 2019 to 2023.

In addition, the results obtained from the analysis of Sentinel-2 high-resolution satellite imagery analyzing with the Random Forest (RF) algorithm makes it possible to classify rice fields into three types according to the growth stage of rice: green, which represents the rice field area from cultivation to Grain filling and ripening. Yellow represents the ready-to-harvest rice paddy area, and red represents the post-harvest paddy area (no rice). The data obtained from this analysis was used to create a map showing methane (CH_4) emissions in rice fields areas, which can help researchers and interested parties to see a clear overview of methane (CH_4) emissions in rice fields areas and the relationship with rice fields management in each period. The implementation of these steps allows for an effective analysis and visualization of methane (CH_4) emissions in rice fields areas. The results can be used in rice field management planning to reduce methane (CH_4) emissions.



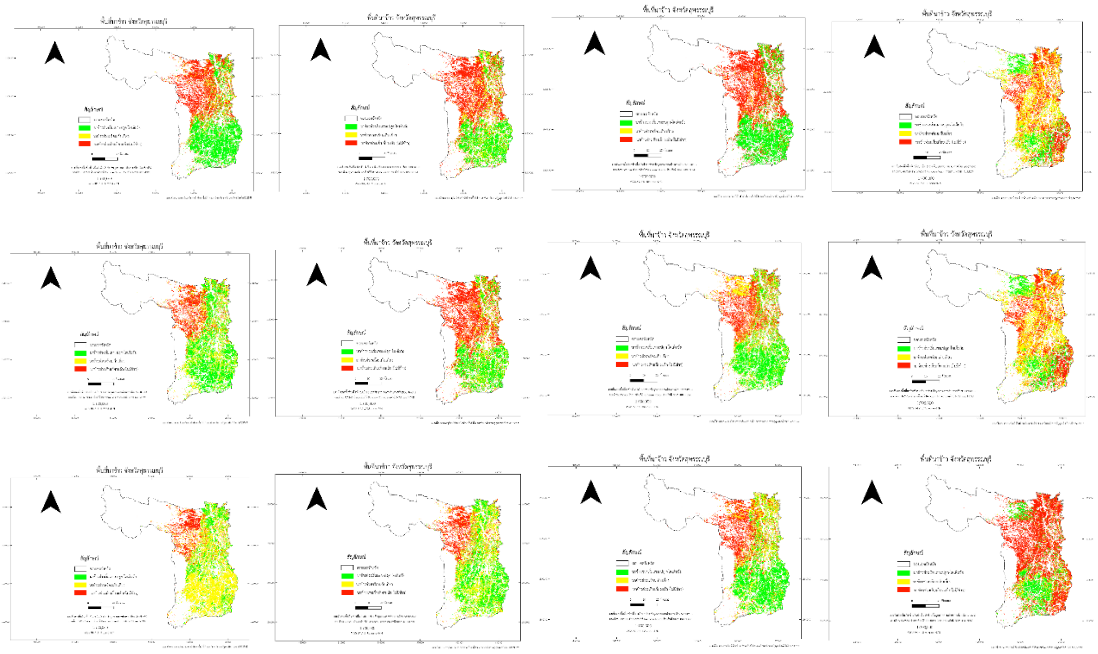


Figure 5: Map of Rice Fields Classification in Suphan Buri Province, Thailand
from January to April from 2019 to 2023.

According to the classification of areas with NDVI values in December 2023, the NDVI values ranged from -1 to 1, with areas with vegetation integrity being close to 1. While in arid areas, the value will be around -1. The results show that the NDVI value is the highest at 0.80 and the lowest at -0.41. The classification of areas using NDWI values showed that the highest NDWI values were 0.67 and the lowest values were -0.52, indicating that areas with high water volumes would have higher NDWI values.

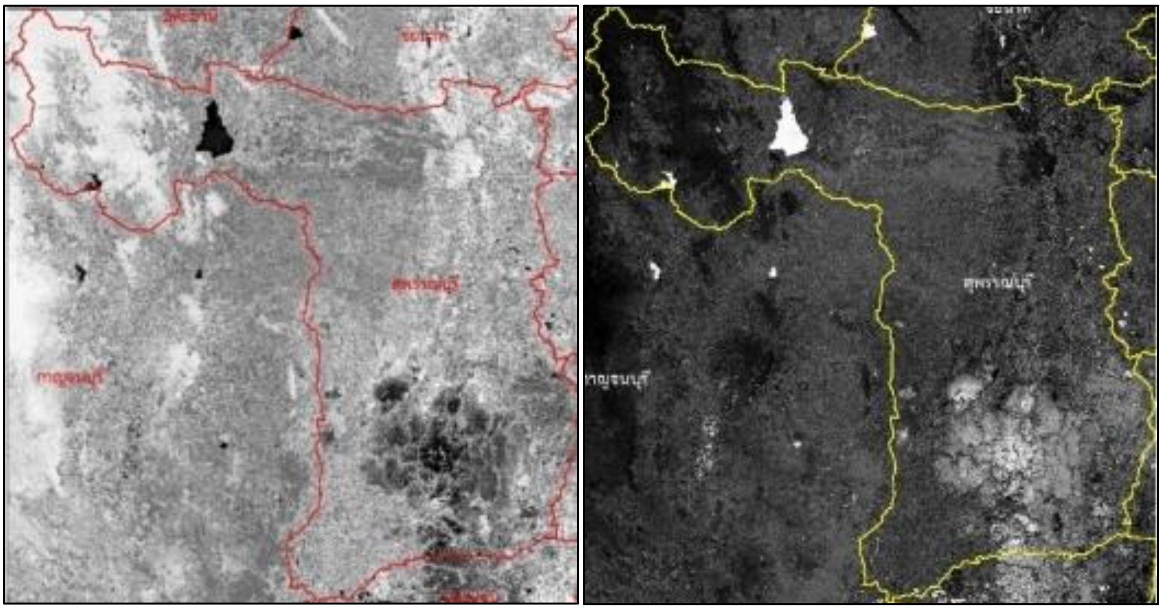


Figure 6: Classification of Areas with NDVI and NDWI.

In order to measure the accuracy of the classification results and to provide a comprehensive evaluation of the algorithm's performance, this study calculates two common statistical indicators that provide accuracy metrics for classification. This metrics are Kappa coefficient and Overall Accuracy. From Table 1 and Table 2, which are data tests for December 2023 using the Random (RF) Forest method, it was found that there was a total accuracy of 97.27 percent for the use of land for rice cultivation in each age group. The results show that in the evaluation of the accuracy of the model and what actually happened to the rice in Ripening or Grain Filling Stage from the accuracy assessment using 1,297 pixels of data, there was a 100 percent accuracy This is because no data is distributed to other classes. Based on the evaluation of the accuracy of ready-to-harvest rice using 635 pixels of data. It has a 99.46 percent accuracy value because the data is distributed to the 84-pixel post-harvest class. and the evaluation of the accuracy of post-harvest rice using 1,255-pixel data. It has a 93.71 percent accuracy value because the data is distributed to the 3-pixel harvest class.

Table 1: Confusion Matrix.

		Grain Filling Stage	**Ready to harvest**	**After harvest**	**Summary**
Reference Map	**Grain Filling Stage**	1,297	0	0	1,297
	Ready to harvest	0	551	84	635
	After harvest	0	3	1,252	1,255
	Summary	1,297	554	1,336	3,187

Table 2: Overall Accuracy.

	Omission Error	**Commission**	**Overall Accuracy**
Grain Filling Stage	0	0	100
Ready to harvest	13.23	0.54	99.46
After harvest	0.24	6.29	93.71
Overall Accuracy	2.73	2.73	97.27

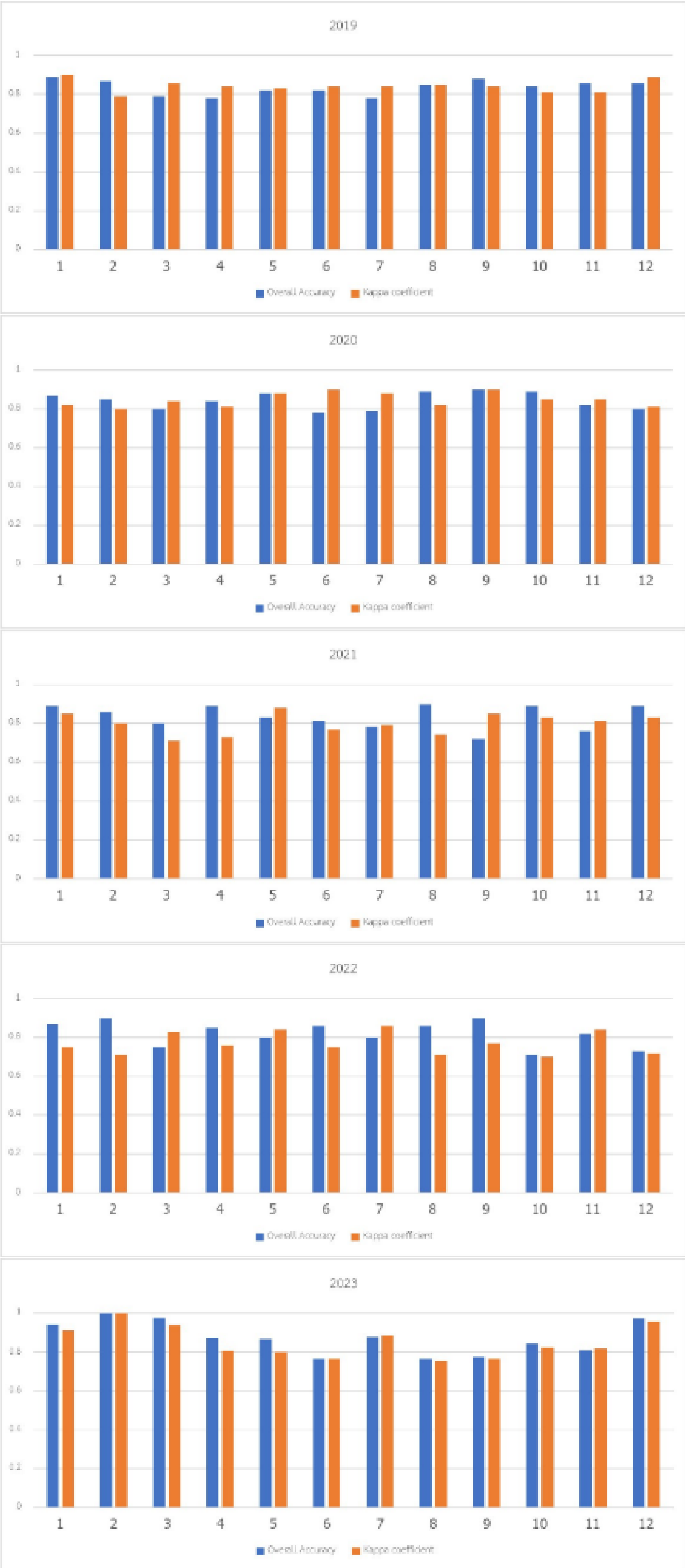


Figure 7: Graph of Comparison of Overall Accuracy and Kappa Coefficient.

The results of this analysis led to the creation of a map showing methane (CH_4) emissions in rice fields in Suphan Buri Province, which shows the relationship between methane (CH_4) emissions and rice growth periods. The maps and graphs obtained from this analysis clearly show an overview of methane (CH_4) emissions in rice fields areas. It also allows researchers to use the results in planning the management of rice fields to reduce methane (CH_4) emissions in the future.

Conclusion and Recommendation

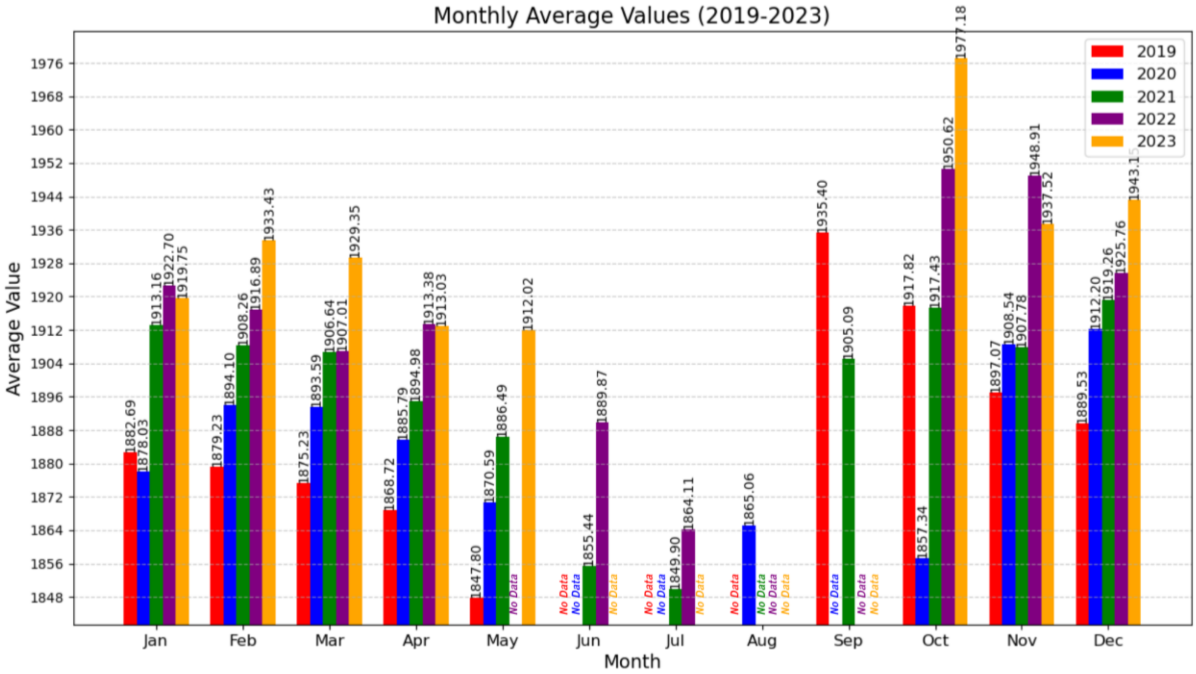


Figure 8: Graph of Comparison of Methane (CH_4) Emissions Over a Period of 5 Years.

From Picture 8 It shows the development of a methane (CH_4) emission tracking tool in the rice fields area of Suphan Buri Province with time series data over a period of 5 years. The evidence shows that in 2019. Methane (CH_4) emissions spike highest in September, and methane (CH_4) emissions are lowest in May. In 2020, methane (CH_4) emissions peak between November and December and are lowest in October. In 2021 methane (CH_4) emissions have been high since the beginning of the year, from January before gradually decreasing and increasing again from September to December, with methane (CH_4) emissions lowest in July. In 2022 Methane (CH_4) emissions spike from October to December, and methane (CH_4) emissions are lowest in July. In 2023 methane (CH_4) emissions are highest from October to December, and in 2023, methane (CH_4) emissions are much higher than in other years. Therefore, from the 8th picture. Therefore, it can be concluded that the methane (CH_4) emission value since 2019 By 2023, methane (CH_4)

emissions will increase every year. The highest emissions of the year are from October to December, but in 2020, methane (CH_4) emissions were very low in October, which may result in Thailand experiencing a drought crisis in 2020.

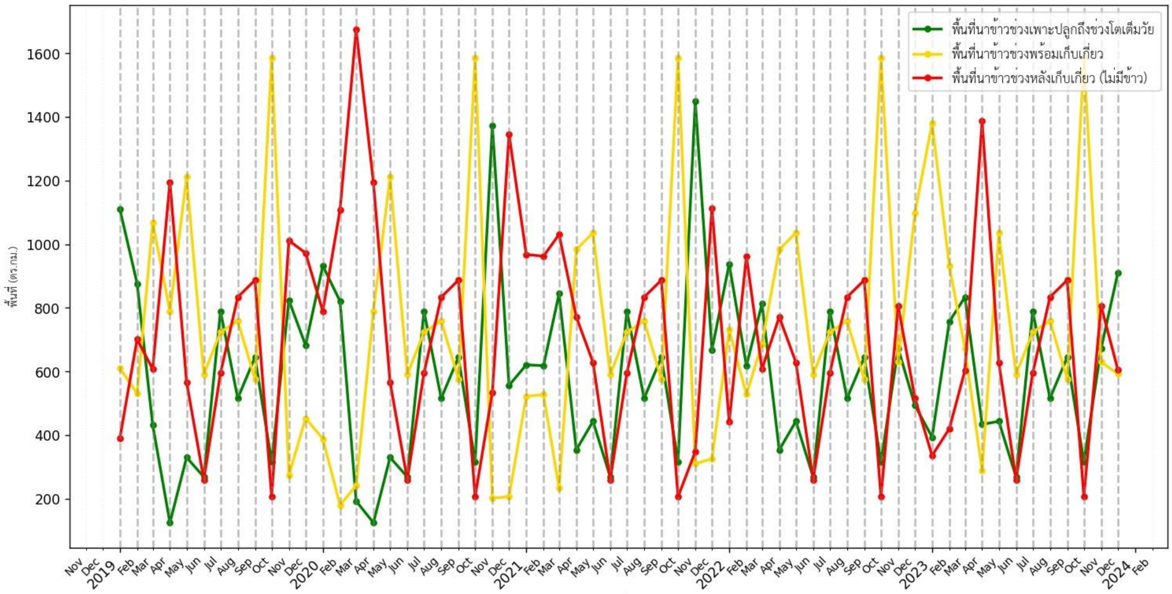


Figure 9: Graph of Classification of Rice Fields Areas.

From Picture 9 when the visual data of the classification of each type of rice fields is displayed as a graph, it can be concluded that Suphan Buri Province is growing rice throughout the year. The relationship between the growth period of rice and methane (CH_4) emission shows that the cultivation to adult rice fields has a high value during the period when the methane (CH_4) emission value gradually increases. This is because, in the early stages of rice cultivation, there is not much organic matter accumulated in the soil of the rice field. When decomposition by microorganisms occurs, there is a release of less methane (CH_4) gas. However, as the rice plants grow, the organic matter that has been decomposed in the rice field area increases. Ready-to-harvest rice fields are high during the period when methane (CH_4) emissions begin to increase, as a result of which the rice plants begin to grow fully. It has a strong root system and creates the right environment for methane-producing bacteria and fully decomposes organic matter in the soil. Post-harvest rice paddies are usually high during the period when methane (CH_4) emissions gradually subside. Rice fields may be drained or allowed to dry out, which reduces the anaerobic conditions required to produce methane (CH_4). Methane (CH_4) emissions are likely to rise at the end of the year. This corresponds to the period when the rice fields are in the Grain Filling stage and are ready to be harvested. This period is usually a period of high temperature and extreme humidity, which is conducive to the production of methane (CH_4) by bacteria in the soil.

The differences in methane (CH_4) emission patterns from year to year reflect changes in the way farmland is managed, such as adjustments to farming periods. Fertilizer use or water management in rice fields. All of this affects methane (CH_4) production and emissions. Understanding this relationship can lead to the development of rice field management practices to reduce methane (CH_4) emissions, such as modifying the farming period. Or the selection of rice varieties with low methane (CH_4) emissions. Ongoing study of this relationship will help in the development of more sustainable and environmentally friendly farming practices in the future.

In this study, the methane (CH_4) emissions data of the Sentinel-5P satellite were missing each month. In the next stage of research, it should be considered using data from other satellites with similar properties and have monthly methane (CH_4) data. Furthermore, it needs to collect ground data or other measurement data that should be used to fill in the missing range and wind and barometric pressure factors should also be used in the research work.

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