AN ANALYSIS OF ECONOMIC CROP PLANTING CALENDAR USING DATA FROM THE MODERATE RESOLUTION IMAGING SPECTRORADIOMETER ON THE TERRA SATELLITE

Jumpol ITSARAWISUT[1,2], Tanutdech ROTJANAKUSOL[1,2], Chaiphat PLYBOUR[1,2], Mehsa SINGHARATH[3], Teerawong LAOSUWAN[1,2*]

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ABSTRACT

Agriculture is a highly significant activity for humanity, serving as a primary food source and a cornerstone of many countries' economies. This research focuses on studying crop planting calendars using data from the Moderate Resolution Imaging Spectroradiometer on the Terra satellite. The study analyzes the Normalized Difference Vegetation Index (NDVI) from May 2022 to December 2023 across various districts in Nong Bua Lam Phu Province. It specifically examines four types of economic crops: rice, fruit trees, perennial trees, and field crops. The study involves random sampling of the largest area within each district and compares these findings to crop planting calendars in the Si Bun Rueang and Suwannakuha districts, with a focus on rice field areas within these two districts. Results indicate distinct differences in NDVI values across times and locations, attributed to varying crop planting cycles in each district. Satellite data clearly illustrate plant growth and changes in NDVI values. This research provides a framework for relevant agencies to manage agricultural water resources more efficiently.

***Keywords**: Crop Planting Calendar, Economic Crops, Remote Sensing, Terra MODIS, NDVI*

1. INTRODUCTION

Agriculture is one of humanity's most critical activities, serving not only as a primary food source sustaining people worldwide but also as a cornerstone of many countries' economies. Effective and sustainable agricultural development is essential to addressing various challenges such as climate change and population growth (Pawlak & Kołodziejczak, 2020). Agriculture contributes not only to food production but also to broader economic and social development (Sibhatu & Qaim, 2017). Countries with robust agricultural systems often experience higher rates of economic growth (Devaux et al., 2020). In addition, agriculture plays a significant role in job creation, particularly in developing countries (Wageningen University, 2015).

A notable study by Viana et al. (2022) emphasized the importance of agriculture for global food security, explaining that it provides stability for billions of people and helps reduce poverty in many regions. In Africa, the World Bank (2022) highlighted agriculture's crucial role in combating hunger and enhancing food security, stressing the need to adopt new technologies to increase productivity and help farmers adapt to climate change. In Asia, IFAD (2019) conducted research on agriculture's role in economic development in developing countries, finding that it contributes to raising rural household incomes and promoting access to better nutrition. These studies illustrate agriculture's vital role in both global and regional development, underscoring the need to support and advance agriculture to create a sustainable and secure future for all.

[1]*Department of Physics, Faculty of Science, Mahasarakham University, Maha Sarakham, Thailand., (JI) drjumpol.i@gmail.com, (TR) tanutdech.r@msu.ac.th, (CP) chaiphat.p@msu.ac.th, (TL)teerawong@msu.ac.th*
[2]*Space Technology and Geo-Informatics Research Unit, Faculty of Science, Mahasarakham University, Maha Sarakham, Thailand*
[3]*Nampapa Nakhoneluang, Vientiane Capital Water Supply State Enterprise, Kaisone Road, Xaysettha District, Vientiane City, Lao P.D.R., (MS) mesha_coltd@yahoo.com*
**Corresponding author: teerawong@msu.ac.th*

Thailand covers a total area of approximately 513,000 km², with around 22.08 million hectares (43% of the country's area) dedicated to agriculture (Sciyouthvolunteer, n.d.). In 2022, Thailand's gross domestic product (GDP) was valued at 17,370,240 million baht. The agricultural sector contributed 1,531,120-million-baht, accounting for 8.81% of the total GDP. Meanwhile, 149.75 million rai of land was used for agricultural purposes, with 34.88 million rai being irrigated land, 23.29% of the total agricultural area. Agricultural land constituted a significant 46.69% of the country's total area. There were 11.63 million agricultural workers, representing 29.31% of the total labor force (Ministry of Commerce, 2024).

Several Thai economic crops have gained global recognition for their quality, particularly rice. In 2023, Thailand exported 3.47 million tons of rice, making it the world's fifth-largest rice exporter (Bangkokbiznews, 2023). Another key economic crop is sugarcane, with Thailand ranked as the world's second-largest sugar exporter. Annual sugar exports exceed 6 million tons, generating $2.961 billion from 47 sugar mills that require over 100 million tons of sugarcane annually (ThaiPBS, 2023). Cassava is also an essential economic crop, with a significant market in China, where it is processed into products such as animal feed, food flavorings, and ethanol (DITP, 2020).

Currently, Thai farmers face challenges in agricultural water use, making water a critical factor in agricultural activities. Understanding the crop growth cycle throughout the year is beneficial for efficient agricultural water management (Jitae, 2019). Remote sensing technology has become a vital tool for studying and monitoring environmental changes, vegetation, and agricultural yields (Laosuwan et al., 2011; Uttaruk & Laosuwan, 2018; Sangpradid et al., 2021; Itsarawisut et al., 2024; Laosuwan et al., 2024). These data are collected from Earth's surface through interactions between electromagnetic radiation and terrestrial materials (Auntarin et al., 2021; Laosuwan et al., 2022; Uttaruk et al., 2022). Remote sensing data form part of high-quality digital geospatial technology that can be analyzed over time (Itsarawisut & Laosuwan, 2022; Ounrit et al., 2022; Turton et al., 2022; Laosuwan et al., 2023; Plybour & Laosuwan, 2023a). Recently, remote sensing technology has advanced significantly, particularly with data obtained from satellites and unmanned aerial vehicles or drones, offering improvements in spatial resolution (Phoophiwfa et al., 2023; Plybour & Laosuwan, 2023b; Zhang & Zhu, 2023). Moreover, data can now be collected across multiple spectral bands, allowing researchers to select specific wavelengths suited for efficient study in various fields (Cottrell et al., 2024). Studies show that remote sensing technology is an effective tool for managing and improving economic crop yields. It enables accurate monitoring of environmental conditions and crop growth (Hatfield et al., 2011; Najafi et al., 2018; Yadav & Geli, 2021; Laosuwan et al., 2024). Remote sensing offers several benefits for managing economic crops: it reduces production risks by continuously monitoring weather and soil conditions, and it optimizes the use of resources such as water and fertilizers by assessing the actual needs of crops at each growth stage. Given these important factors, this study aims to analyze crop planting calendars using data from the Moderate Resolution Imaging Spectroradiometer (MODIS) on the Terra satellite.

2. MATERIALS AND METHODS

2.1. Study Area

Nong Bua Lam Phu Province (**Fig. 1**) is located in the northeastern region of Thailand, between latitudes 16°45′ to 17°40′N and longitudes 101°57′ to 102°30′E, with an elevation of approximately 200 meters above sea level. The terrain primarily consists of highlands and plains. The climate is divided into three seasons, similar to other provinces in the northeastern region: summer, rainy season, and winter. It is influenced by the annual monsoon and classified as a tropical savanna climate, meaning rainfall occurs mainly during the rainy season, alternating with dry periods in winter and summer. (1) Summer occurs from March to April, with average maximum temperatures ranging from 34°C to 36°C. (2) Rainy Season lasts from May to October, with the heaviest rainfall in August and September due to tropical depressions. (3) Winter spans from November to February, with the coldest months being December and January, when average temperatures range from 15°C to 16°C. The average annual rainfall in Nong Bua Lam Phu Province ranges from 978.3 mm to 1,348.9 mm (Royal Irrigation Department, n.d.).

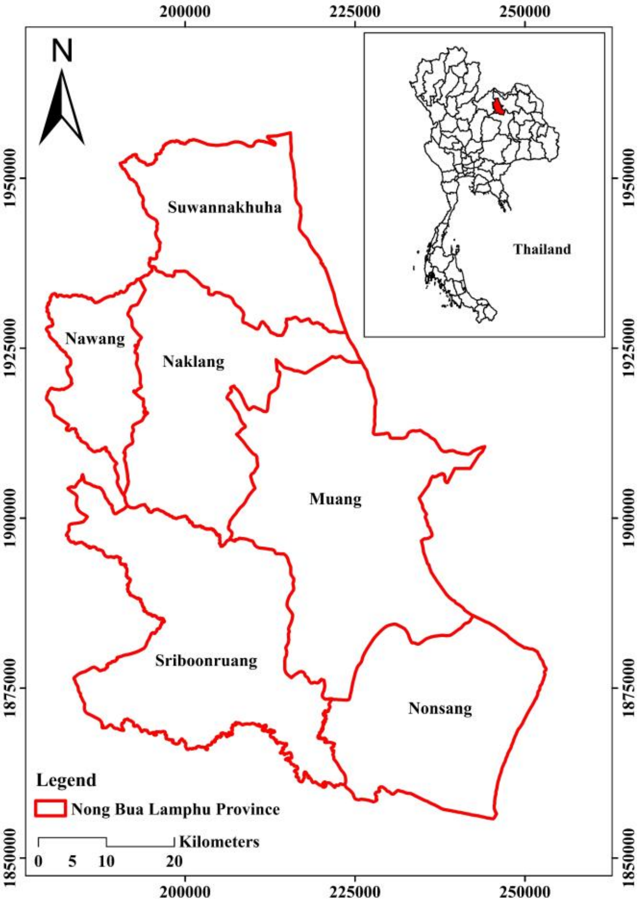

Fig. 1. Study Area.

2.2. Data Collection

The MOD13Q1 dataset provides vegetation index data from the MODIS on NASA's Terra satellite. It includes 16-day composites of vegetation indices at a spatial resolution of 250 meters. The dataset contains the Normalized Difference Vegetation Index (NDVI) and the Enhanced Vegetation Index, along with quality assessment layers and reflectance bands (Earth Engine Data Catalog, n.d.). . This study focuses on the NDVI product from the MOD13Q1 dataset, derived from the MODIS sensor on the Terra satellite, which records reflectance data. NDVI is widely valued for its spatial and temporal resolution, offering 250-meter spatial resolution with data available every 16 days. For this research, NDVI data from May 2022 to December 2023 covering the study area were selected.

2.3. Land Use Data

Land use data for Nong Bua Lam Phu Province were obtained from the Land Development Department in the form of shapefiles, which include layers detailing land use, land utilization, and administrative boundaries (district, sub-district, and provincial levels). The 2021 dataset, the most recent available for the province, was used in this study.

2.4. Crop Planting Calendar Data

Data on the economic crop planting calendar were collected from the Provincial Agricultural Office of Nong Bua Lam Phu.

2.5. Methodology

This study focuses on analyzing NDVI values. Normally, NDVI is calculated using Equation 1 (Tucker, 1979). For this research, the MOD13Q1 dataset – a Terra/MODIS satellite product that provides NDVI values – was used. The data were adjusted to accurate values using Equation 2 (Geographic Information Systems, n.d.). After calculating NDVI values, the coordinate system was converted to WGS 1984 UTM Zone 47N to ensure accurate geospatial mapping. The next step involved randomly selecting the largest cultivation areas of four major economic crops: rice fields, fruit trees, perennial plants, and field crops. This selection focused on identifying large, representative plots to facilitate data analysis and effectively monitor changes in cultivated areas. The process of randomly selecting cultivation areas was conducted in each district of Nong Bua Lam Phu Province. Graphs were then created to present the NDVI values obtained from this analysis.

$$NDVI = (NIR - RED) / (NIR + RED) \tag{1}$$

The well-known NDVI is a simple yet effective index for assessing green vegetation. It evaluates the reflectance of green leaves in the near-infrared spectrum relative to the absorption of chlorophyll in the red spectrum. NDVI values range from −1 to 1. Negative NDVI values (approaching −1) indicate the presence of water bodies. Values near zero (−0.1 to 0.1) generally represent barren areas such as rock, sand, or snow. Low positive values suggest the presence of shrubs and grasslands (approximately 0.2 to 0.4), whereas high values denote temperate and tropical rainforests (values approaching 1).

$$NDVI = [(QC == 0) * (NDVI > 2000) * NDVI] * 0.0001 \tag{2}$$

The formula provided, ndvi = [(qc==0)*(ndvi>2000)*ndvi]*0.0001, is used to modify MOD13Q1 NDVI data. It incorporates a quality control (QC) filter along with a thresholding procedure before scaling the NDVI values. Let us analyze it step by step:

1. QC Filter:

qc==0: This component evaluates the QC band of the MOD13Q1 dataset. It identifies pixels where the QC value equals 0, indicating potentially high-quality data.

2. Thresholding:

ndvi>2000: This phase filters the NDVI values, retaining only those exceeding 2000. This is because the raw NDVI values in the MOD13Q1 product are scaled by a factor of 10,000. Thus, a value of 2000 corresponds to an actual NDVI of 0.2. The threshold effectively isolates vegetation by removing non-vegetative pixels.

3. Scaling:

* 0.0001: Finally, the selected NDVI values are multiplied by 0.0001. This operation converts them to the conventional NDVI range of −1 to 1. Typically, MODIS NDVI data, before scaling, ranges from −2000 to 10,000.

3. RESULTS AND DISCUSSION

3.1. NDVI Analysis

The analysis of NDVI data, collected every 16 days, was limited to high-quality values, resulting in a dataset of 36 entries. This allowed for an effective assessment of vegetation density and richness. In Nong Bua Lam Phu Province, the NDVI analysis revealed a minimum value of 0.3, indicating low-density vegetation typically found in agricultural areas, and a maximum value of 0.8, representing high-density vegetation commonly seen in forested regions. Furthermore, the NDVI values for economic crops in each district of Nong Bua Lam Phu Province (**Fig. 2**) provide insights into vegetation health and growth at different times. The analysis, covering October 2022 to March 2023, is detailed by crop type as follows:

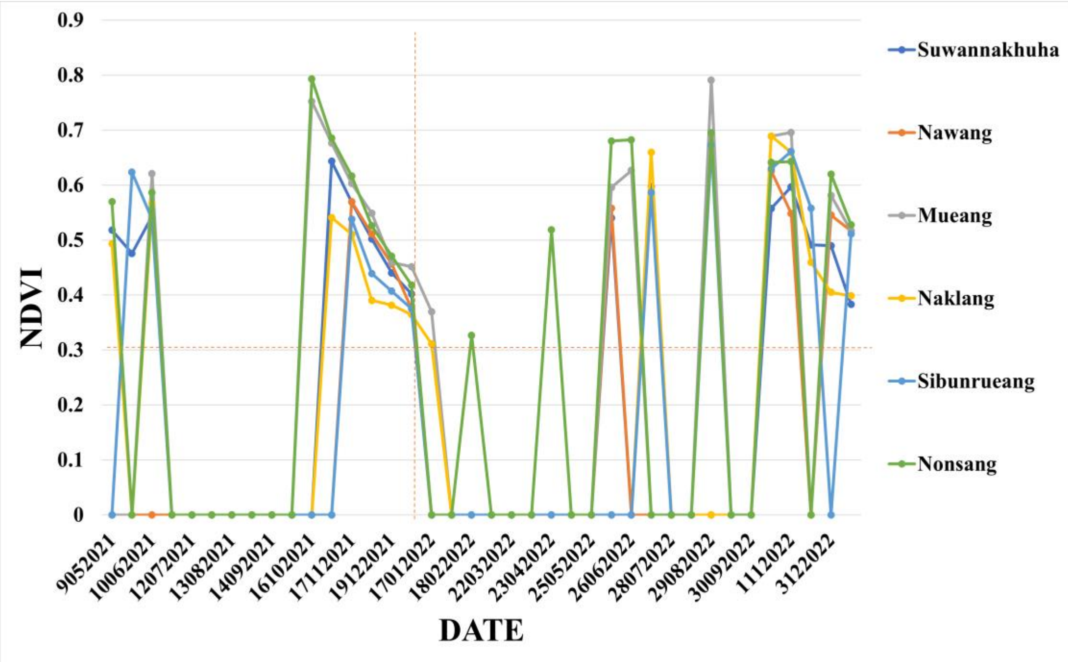

Fig. 2. NDVI Analysis from 2022–2023.

- Rice fields: Nong Singh District recorded the highest NDVI from August 13 to September 14, 2023. In general, rice NDVI values in each district were high from November 2022 to February 2023.
- Field crops: Nong Singh District recorded the highest NDVI from September 30, 2022, to January 17, 2023. Typically, field crop NDVI values were high across districts from September 2022 to November 2023.
- Perennial trees: Si Bun Rueang District had the highest NDVI from November 1, 2022, to January 17, 2023. Overall, perennial tree NDVI values in each district were elevated from November 2022 to January 2023.
- Fruit trees: Nong Singh District showed the highest NDVI from September 30, 2022, to January 17, 2023. Generally, fruit tree NDVI values across districts were high from November 2022 to January 2023. This analysis demonstrates that NDVI data can be effectively utilized for crop planning and maintenance, contributing to improved yields and promoting agricultural sustainability in the region.

3.2. Economic Crop Sampling Results

Studying areas cultivated with economic crops is essential for monitoring changes in crop coverage, which has implications for both economic and environmental outcomes. For the four sampled economic crops – rice, field crops, perennial trees, and fruit trees – **Fig. 3** illustrates their spatial distribution. This study focused on six districts: Suwannakuha, Na Wang, Mueang Nong Bua Lam Phu, Na Klang, Nong Singh, and Si Bun Rueang. The largest cultivation areas in each district were selected for NDVI analysis based on land use data from the Land Development Department. NDVI analysis enables the monitoring of crop health and growth by assessing changes in selected cultivated areas to better understand environmental factors affecting economic crops. According to the sampling results (**Table 1**), Si Bun Rueang District had the largest rice field area at 0.0999 km². Na Klang had the largest area for field crops at 0.0998 km². Na Klang and Nong Singh shared the largest areas for perennial trees at 0.0999 km², while Mueang District had the largest area for fruit trees at 0.0934 km².

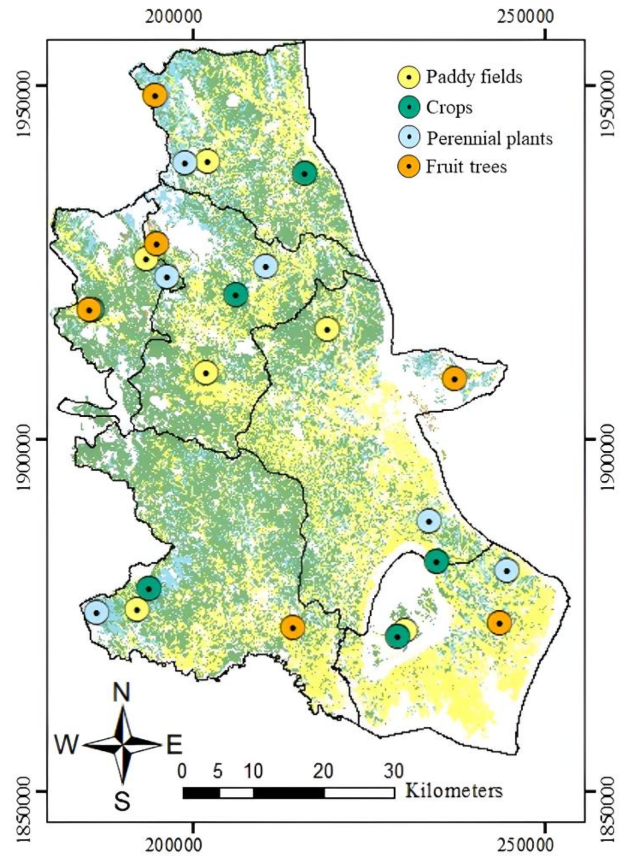

Fig. 3. Economic Crop Sampling.

Table 1.

Largest Area of Economic Crops in Each District.

		Area (km^2)			
Rank	**District**	**Rice Fields**	**Crops**	**Perennial Plants**	**Fruit Trees**
1	Suwannakuha	0.0998	0.0996	0.0997	0.0903
2	Nawang	0.0990	0.0995	0.0972	0.0879
3	Mueang	0.0993	0.0990	0.0996	0.0934
4	Naklang	0.0992	0.0998	0.0999	0.0894
5	Non Sing	0.0997	0.0983	0.0999	0.0706
6	Si Bun Rueang	0.0999	0.0996	0.0985	0.0930

3.3. NDVI Analysis Results Compared to Economic Crop Planting Calendar

To illustrate the comparison between NDVI analysis results and the economic crop planting calendar, this study presents an example from the Suwannakuha District. NDVI values for the district were compared with the economic crop planting calendar from May 2023 to December 2023, as shown in **Fig. 4**. Based on **Fig. 4**, the NDVI values can be analyzed in relation to the crop calendar as follows:

NDVI analysis showed that values for rice fields were recorded from October 16, 2022, to January 17, 2023. When compared with the crop planting calendar (**Fig. 5**), this period corresponds to the planting of dry-season rice from October 2022 to February 2023, with harvesting occurring from March to April 2023. Wet-season rice was planted earlier, from April to September 2022, and harvested from October to December 2022.

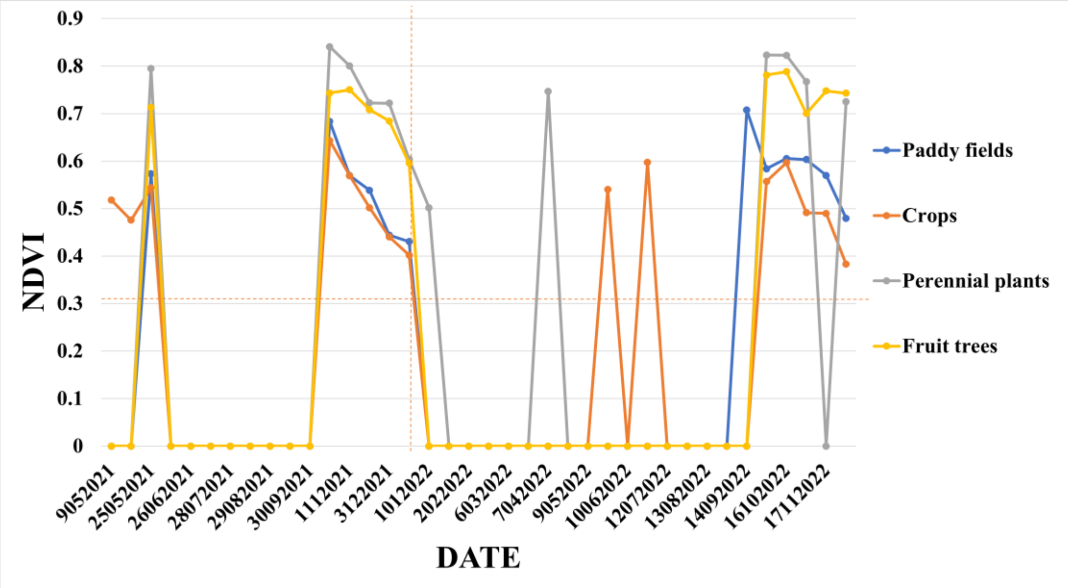

Fig. 4. Economic Crop Sampling NDVI Analysis Results.

No.	Plant Name	Calendar Year												Next Calendar Year											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Wet season rice				Sowing/transplanting			Growing			Harvesting														
2	Dry season rice										Sowing			Growing		Harvesting									
3	Animal feed corn					*Plant		Growing		Harvesting		**Plant		Growing		Harvesting									
4	Sweet corn										**Plant			Growing		Harvesting									
5	Fresh cob corn										**Plant			Growing		Harvesting									
6	Cassava			**Plant		Growing							Harvesting												
											Plant		Growing								Harvesting				
7	Sugarcane	Harvesting									Plant			Growing										Harvesting	
8	Longan		Flower	Growing				Harvesting																	
9	Mango										Flower			Growing			Harvesting								
10	Oil palm	Growing /Harvesting				Plant		Growing /Harvesting											Plant		Growing /Harvesting				
11	Rubber	Cut	Shed leaves			Plant					Cut				Shed leaves			Plant			Cut				
12	Eucalyptus	Growing /Harvesting				Plant			Growing /Harvesting										Plant		Growing /Harvesting				

Fig. 5. Crop Planting Calendar.

- Field crops: NDVI values were recorded from October 16, 2022, to January 17, 2023, aligning with the corn planting season from October 2022 to February 2023, with harvesting from March to April 2023.

- Perennial trees: NDVI values were recorded from October 16, 2022, to February 2, 2023, corresponding to the rubber tapping season from October 2022 to January 2023, followed by leaf shedding from February to April 2023.
- Fruit trees: NDVI values were recorded from October 16, 2022, to January 17, 2023, aligning with the flowering and growth period of mango trees from October 2022 to February 2023.

4. CONCLUSION

The NDVI data analysis and study of economic crops in Nong Bua Lam Phu Province demonstrate the capability to monitor and track vegetation growth in the area. The NDVI analysis using 16-day interval data enables a detailed and accurate assessment of vegetation density and richness, with the lowest NDVI value of 0.3 found in agricultural areas and the highest value of 0.8 in forested areas. Additionally, the NDVI analysis for economic crops in each district from October 2022 to March 2023 provides further insights into crop growth.

The sampling of four types of economic crop cultivation areas across six districts – Suwannakuha, Na Wang, Mueang Nong Bua Lam Phu, Na Klang, Nong Singh, and Si Bun Rueang – shows that Si Bun Rueang District had the largest rice field area at 0.0999 km², while Na Klang had the largest field crop and perennial tree areas at 0.0998 km² and 0.0999 km², respectively. Mueang District had the largest fruit tree area at 0.0934 km². The comparison of NDVI values with the planting calendar in Suwannakuha District reveals consistency with the planting and harvesting periods for economic crops, such as dry-season rice planted from October to February and harvested from March to April.

This research highlights the role of NDVI data in effective crop planning, supporting yield enhancement and agricultural sustainability in the area. Additionally, this data can be used to efficiently assess environmental changes that impact economic crop cultivation.

When comparing the results of this study with similar research, the findings are consistent. For example, the study ‘Beyond Fixed Dates and Coarse Resolution: Developing a Dynamic Dry Season Crop Calendar for Paddy in Indonesia from 2001 to 2021’ (Irawan & Komori, 2024) examined the development of a dry-season paddy crop calendar using NDVI data to improve calendar accuracy. This research demonstrated significant potential for enhancing agricultural management in Indonesia by using NDVI to determine optimal planting and harvesting times.

The authors emphasized the importance of technology in supporting sustainable and efficient agriculture. Similarly, the study ‘Mapping Crop Calendar Events and Phenology-Related Metrics at the Parcel Level by object-based image analysis (OBIA) of MODIS-NDVI Time-Series: A Case Study in Central California’ (De Castro et al., 2018) explored the use of NDVI in satellite image analysis to map crop calendar events and phenology-related metrics at the parcel level.

Using OBIA with MODIS-NDVI time-series data, the study found that NDVI assists in assessing crop status at different times of the year and in analyzing long-term vegetation change trends. In another study, ‘Crop Mapping Using PROBA-V Time Series Data at the Yucheng and Hongxing Farm in China’ (Zhang et al., 2016), researchers investigated crop mapping using PROBA-V satellite time series data. The study found that NDVI plays a crucial role in crop mapping and supports efficient and sustainable agricultural practices.

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