Available online at https://li02.tci-thaijo.org/index.php/ssstj

Suan Sunandha Science and Technology Journal

Analysis of Land Use Changes with the Google Earth Engine (GEE) Platform: A Case Study in Saraburi Province

Tanachart Inpuron[1], Rattanawat Chaiyarat[1], Poonperm Vardhanabindu[1], Pattana Suwansumrit[2], Monthira Yuttitham[1*]

[1]Faculty of Environment and Resource Studies, Mahidol University, Phutthamonthon Sai 4 Road, Nakhon Pathom 73170, Thailand
[2]Faculty of Architecture, Rajamangala University of Technology Thanyaburi, Pathum Thani 12110, Thailand
***Corresponding author e-mail: monthira.yut@mahidol.ac.th**

Received: *9 April 2024* / **Revised:** *24 June 2024* / **Accepted:** *30 July 2024*

Abstract

The increasing trend of industrial development has led to rapid changes in land use over the past few years. The changes in land use in Saraburi Province were studied during three periods: the years 2000, 2010, and 2021, using Landsat satellite imagery processed with the Google Earth Engine (GEE) platform. The Random Forest (RF) machine learning algorithm was employed to classify land use activities into five categories based on the criteria set by the Department of Land Development. The overall accuracy values for land use were 83.59%, 82.42%, and 80.78%, respectively. The changes in land use have clearly affected the urban and built-up area. In 2000, there were only 7,561.15 ha, but by 2021, the area had increased to 34,221.11 ha. Forest areas also saw an increase. In 2000, there were only 79,626.26 ha, which increased to 163,542.05 ha in 2021, reflecting that Saraburi Province places importance on green areas. In contrast, agricultural areas decreased, which was attributed to the increasing number of households, according to the statistical report from the Department of Provincial Administration. In 2000, there were 168,979 households, and by 2021, they had increased to 288,275 households, resulting in a change in land use from agricultural areas to urban and built-up areas, totaling 22,114.95 ha. This information can be used as a guideline for planning development and land use to promote Saraburi Province, aiming towards becoming an eco-industrial city that is livable and has sustainable environmental quality in the future.

Keywords: Land-use changes, Landsat satellite, Google Earth Engine, Sustainability, Saraburi

1. Introduction

At present, Thailand has continuously increased land use as a result of economic expansion in many regions. The main activities are in the industrial sector, which is a factor that causes changes in land use. In addition, the trend of industrial development also stimulates the economy. As a result, the population has increased, leading to the expansion of community areas and buildings. All these changes are considered important factors that greatly influence land use. Saraburi Province is one of the provinces with the most continuous economic development.

The province's location has geographic characteristics that are conducive to the expansion of the investment sector and convenient transportation, which can connect the transportation sector to many regions. This supports the expansion of the industrial sector and the size of the city, which have grown together, causing continuous changes in land use. In developing the province, the 20-year national strategy, 23 master plans under the national strategy, and government administration plans have been adopted. These include the National Economic and Social Development Plan No. 12 (Office of the National Economic and Social Development Board, 2017), the Upper Central Region Development Plan, and the Strategy of the Ministry of Interior 2018-2022, as well as an analysis of the potential of the provinces and the needs of the people to be used in connection with the determination of the provincial vision.

The current development goals of Saraburi Province are focused on developing it into an eco-industrial city. The objective is to develop Saraburi Province into a livable, eco-industrial city with balanced and continuous growth. Therefore, geo-informatics technology has been introduced for remote sensing that is suitable for analyzing large spatial data. Using Landsat satellite image data, which is considered a natural resource survey satellite (Geo-Informatics and Space Technology Development Agency (Public Organization) [GISTDA], 2009), it is appropriate to classify land uses. When analyzing data on the Google Earth Engine platform, which is a

platform used to analyze geospatial data provided in an open-source manner, it can be used to analyze spatial data free of charge (Supatra & Puttanawarat, 2021). In this study, the objective was to examine land use changes in Saraburi Province. Geo-informatics technology was applied to analyze the context and factors affecting land use change. The aim is to provide guidelines for promoting Saraburi Province towards becoming a livable eco-industrial city with sustainable environmental quality in the future.

2. Materials and Methods

2.1 Data acquisition

2.1.1 Satellite datasets

This research uses satellite image data from Landsat-5 TM and Landsat-8 OLI, covering Saraburi Province for three periods: 2000, 2010, and 2021. These images were selected based on their availability on the Google Earth Engine platform, which covers the study period. Details are shown in Table 1.

Table 1. Satellite datasets used in the analysis.

Satellites	Data characteristics		
	Resolution (m)	Band	Acquisition
Landsat-5 TM	30	Visible (band 1 - 3) NIR (band 4) SWIR (band 5)	2000, 2010,
Landsat-8 OLI	30	Visible (band 2 - 4) NIR (band 5) SWIR (band 6)	2021

Source: GISTDA (2009)

2.1.2 Digital data files on the administrative boundaries of Saraburi Province are from the Geo-Informatics and Space Technology Development Agency (Public organization).

2.1.3 Geographic Information System data analysis program.

2.2 Methods for analyzing land use and land use change

Land use analysis involves selecting satellite image data from the study area, which is the boundary of Saraburi Province. Landsat 5 and Landsat 8 satellite images that are free of clouds or other obstructions affecting the analysis were selected. Using the Google Earth Engine (GEE) platform and interpreting satellite images with supervised classification, the efficiency of the Random Forest (RF) machine learning algorithm in land use classification is demonstrated by an overall accuracy of 92.00% (Intarat, 2022). It was used for three time periods: 2000, 2010, and 2021. Land use activity data were classified into five categories based on the criteria of the Land Development Department: urban and built-up area, agricultural area, forest area, water body, and miscellaneous area.

Land use changes were studied using the land use data interpreted from satellite images, classified into three periods: the first period between 2000 and 2010, the second period between 2010 and 2021, and the third period between 2000 and 2021.

2.3 Methods of verifying the correctness of land use

Validation of land use classification involves comparing the results of the classification of land use in each category obtained from interpreting satellite images with land use data from the closest year provided by the Land Development Department. This comparison is conducted using the Confusion Matrix method by selecting checkpoints to compare the interpretations with reference data from the Land Development Department. The desired overall accuracy percentage (P) is set to be equal to 80%, the acceptable error value is set to 5%, and the confidence level is set to 95% (Z = 1.96). For this study, a total of 256 points (according to binomial probability theory and stratified distribution) were examined using the equalized stratified random sampling format in the GIS program (Fitzpatrick-Lins, 1981). The error matrix is a statistical tool used to measure the accuracy of data classification. By comparing the data obtained from classification with reference data, it helps to explain the overall accuracy, which can be easily calculated. It also provides useful information for evaluating accuracy. To calculate overall accuracy (OA), the ratio of the sum of the number of correctly classified points (the diagonal elements of the matrix) to the total number of points examined is used. This ratio is then expressed as a percentage. The overall accuracy value, in percentage form, indicates how accurately the entire classification system classifies the data compared to the reference data. An OA value closer to 100% indicates a more accurate classification of the data.

The Kappa coefficient is calculated using statistical methods to test the consistency between two sets of data. It does not rely on assumptions about whether the data is normally distributed. This differs from the calculation of overall accuracy (OA), which measures the accuracy of all classifications. According to McHugh (2012), the Kappa coefficient is divided as follows:

A confidence value of 0.81 and above	means very high confidence.
Confidence values from 0.61 to 0.80	indicate high confidence.
Confidence values ranging from 0.41 to 0.60	indicate moderate confidence.
Confidence values ranging from 0.21 to 0.40	indicate low confidence.
A confidence value less than 0.20	means no confidence.

3. Results and Discussion

The study of land use for the years 2000, 2010, and 2021, using Landsat satellite images and analyzing land use on the Google Earth Engine (GEE) platform with the Random Forest (RF) machine learning algorithm, categorized land use activity data into five categories based on the criteria of the Land Development Department, as shown in Table 2. These categories are as follows:

As shown in Figure 1, land use in 2000 revealed that the agricultural area was the largest, covering 224,021.20 ha (64.34%), followed by forest area with 79,626.26 ha (22.87%), miscellaneous area with 31,668.67 ha (9.10%), urban and built-up area with 7,561.77 ha (2.17%), and water body with 5,263.19 ha (1.51%). In 2010, it was found that the agricultural area had the largest extent, covering 181,850.80 ha (52.23%), followed by the forest area with 119,630.29 ha (34.36%), the miscellaneous area with 24,917.79 ha (7.16%), the urban and built-up area with 15,139.94 ha (4.35%), and the water body with 6,621.64 ha (1.90%).In 2021, it was found that the forest area had the largest extent, covering 163,542.05 ha (46.97%), followed by the agricultural area with 115,576.70 ha (33.20%), the miscellaneous area with 23,705.06 ha (6.81%), the urban and built-up area with 34,221.11 ha (9.83%), and the water body with 11,115.54 ha (3.19%).

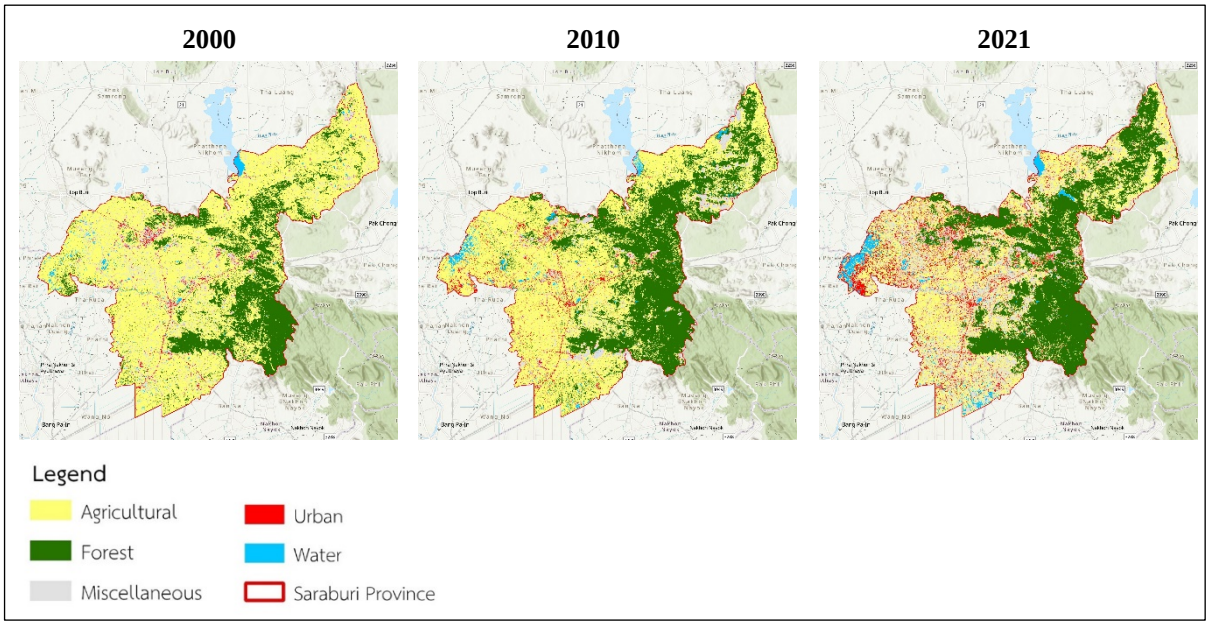

Figure 1. Land use map of Saraburi Province in 2000, 2010, and 2021.

Table 2. Land use in 2000, 2010, and 2021.

Land use	Land use area (ha)		
	2000	2010	2021
Agricultural area	224,021.20	181,850.80	115,576.70
Forest area	79,626.26	119,630.29	163,542.05
Miscellaneous area	31,688.67	24,917.79	23,705.06
Urban and built-up area	7,561.15	15,139.94	34,221.11
Water body	5,263.19	6,621.64	11,115.54
Total	**348,160.46**	**348,160.46**	**348,160.46**

When comparing the accuracy of land use in this study with that of the Land Development Department, the overall accuracy in this study is close to that of the Land Development Department. The overall accuracy was 83.59%, 82.42%, and 80.78% for the years 2000, 2010, and 2021, respectively (Table 3).

Table 3. Accuracy values of land use data classification.

Validation	Land use		
	2000	2010	2021
Kappa Coefficient	0.74	0.72	0.72
Overall Accuracy	83.59	82.42	80.78

The land use changes over the three time periods using data from satellite images are as follows:

In the first period, between 2000 and 2010, it was observed that the agricultural and miscellaneous areas decreased, while the forest area, water body, and urban and built-up areas increased. The proportion of land use areas was higher when interpreting satellite images, as shown in Figure 2. The urban and built-up area increased to 7,578.79 ha, which is consistent with the Department of Provincial Administration statistics indicating that the number of households in 2010 increased by 55,089 from 2000, leading to a change in the agricultural area. Concurrently, the forest area increased during this period, which aligns with the objectives of the 8th National Economic and Social Development Plan. This plan focused on natural resource and environmental management, aiming to conserve and restore natural resources to maintain ecosystem balance and enhance the quality of life for communities, thus serving as a crucial foundation for the country's long-term development process (Table 4).

Table 4. Land-use in 2000 and 2010.

Land use	Land use area (ha)		
	2000	2010	Land use change
Agricultural area	224,021.20	181,850.80	(-) 42,170.40
Forest area	79,626.26	119,630.29	(+) 40,004.03
Miscellaneous area	31,688.67	24,917.79	(-) 6,770.88
Urban and built-up area	7,561.15	15,139.94	(+) 7,578.79
Water body	5,263.19	6,621.64	(+) 1,358.45
Total	**348,160.46**	**348,160.46**	

Note: (+) means the area has increased. (-) means the area has decreased.

Table 5. Land-use change matrix as observed between in 2000 and 2010.

	Land use class	2010 (ha)					
		A	F	M	U	W	Total 2000
2000 (ha)	**A**	145,223.10	52,144.43	15,735.28	7,209.89	3,708.49	**224,021.20**
	F	10,927.40	63,614.79	3,653.97	890.85	539.25	**79,626.26**
	M	20,431.44	2,888.89	4,133.51	3,869.91	364.92	**31,688.67**
	U	2,810.79	456.91	1,211.11	3,009.83	72.50	**7,561.15**
	W	2,458.06	525.27	183.92	159.46	1,936.48	**5,263.19**
	Total 2010	**181,850.80**	**119,630.29**	**24,917.79**	**15,139.94**	**6,621.64**	**348,160.46**

Note: A = Agricultural area, F = Forest area, M = Miscellaneous area, U = Urban and built-up area, W = Water body

In the second period, between 2010 and 2021, it was observed that the agricultural area decreased. Conversely, the forest area, miscellaneous area, water body, and urban and built-up areas are likely to have increased. During this period, the population in Saraburi Province increased significantly by 30,818 people. The proportion of land use areas was determined by interpreting satellite images. The urban and built-up area increased to 19,081.17 ha, which is consistent with Department of Provincial Administration statistics showing that the number of households in 2021 increased by 64,207 from 2010, leading to changes in the agricultural area. Simultaneously, the forest area increased due to the objectives of the 11th National Economic and Social Development Plan, which aimed to manage natural resources and the environment adequately to maintain ecological balance and provide a solid foundation for national development (Table 6).

Table 6. Land-use change in 2010 and 2021.

Land use	Land use area (ha)		
	2010	2021	Land use change
Agricultural area	181,850.80	115,576.70	(-) 66,274.10
Forest area	119,630.29	163,542.05	(+) 43,911.75
Miscellaneous area	24,917.79	23,705.06	(-) 1,212.73
Urban and built-up area	15,139.94	34,221.11	(+) 19,081.17
Water body	6,621.64	11,115.54	(+) 4,493.90
Total	**348,160.46**	**348,160.46**	

Note: (+) means the area has increased. (-) means the area has decreased.

Table 7. Land-use change matrix as observed between in 2010 and 2021.

	Land use class	2021 (ha)					
		A	F	M	U	W	Total 2010
2010 (ha)	**A**	86,872.74	51,832.04	15,571.06	21,969.86	5,605.09	**181,850.80**
	F	13,811.98	100,039.87	2,669.65	2,097.35	1,011.45	**119,630.29**
	M	9,395.28	8,658.91	3,368.83	3,186.13	308.64	**24,917.79**
	U	4,150.94	2,196.74	1,933.66	6,502.61	356.00	**15,139.94**
	W	1,345.76	814.49	161.87	465.16	3,834.37	**6,621.64**
	Total 2021	**115,576.70**	**163,542.05**	**23,705.06**	**34,221.11**	**11,115.54**	**348,160.46**

Note: A = Agricultural area, F = Forest area, M = Miscellaneous area, U = Urban and built-up area, W = Water body

In the third period, between 2000 and 2021, it was observed that agricultural areas and miscellaneous areas had noticeably decreased. Meanwhile, forest areas, water bodies, and urban and built-up areas exhibited an increasing trend. This economic growth was a result of continuous industrial development initiatives within Saraburi Province. Since the Industrial Estate Authority of Thailand established the Nong Khae Industrial Estate in 1990 and the WHA Saraburi Industrial Estate in 1988, a significant amount of employment and land use has been created. Consequently, statistics from the Registration Office, Department of Provincial Administration, report that the number of households increased from 168,979 in 2000 to 288,275 in 2021, an increase of 41.3%. During this period, Saraburi Province focused on developing the area into a city of international trade and investment in green industry while creating a happy society. This aligns with the objectives of the provincial development plan, which emphasizes promoting industrial economic development while considering environmentally friendly industrial practices and increasing green areas within the province (Table 8).

Table 8. Land-use change from 2000 to 2021.

Land use	Land use area (ha)		
	2000	2021	Land use change
Agricultural area	224,021.20	115,576.70	(-) 108,444.50
Forest area	79,626.26	163,542.05	(+) 83,915.78
Miscellaneous area	31,688.67	23,705.06	(-) 7,983.60
Urban and built-up area	7,561.15	34,221.11	(+) 26,659.97
Water body	5,263.19	11,115.54	(+) 5,852.35
Total	**348,160.46**	**348,160.46**	

Note: (+) means the area has increased. (-) means the area has decreased.

Table 9. Land-use change matrix as observed between in 2000 and 2021.

Land use class		2021 (ha)					
		A	F	M	U	W	Total 2000
2000 (ha)	A	94,183.81	83,565.27	16,934.61	22,114.95	7,222.56	**224,021.20**
	F	6,035.76	70,296.73	1,236.52	1,381.87	675.38	**79,626.26**
	M	12,546.24	7,647.62	4,287.61	6,766.43	440.76	**31,688.67**
	U	1,668.79	1,292.76	1,095.03	3,427.96	76.60	**7,561.15**
	W	1,142.10	739.66	151.30	529.89	2,700.24	**5,263.19**
	Total 2021	**115,576.70**	**163,542.05**	**23,705.06**	**34,221.11**	**11,115.54**	**348,160.46**

Note: A = Agricultural area, F = Forest area, M = Miscellaneous area, U = Urban and built-up area, W = Water body

Table 10. Land-use change over 3 periods.

Land use	Year			Land use area (ha)		
	2000	2010	2021	2000-2010	2010-2021	2000-2021
Agricultural area	224,021.20	181,850.80	115,576.70	(-) 42,170.40	(-) 66,274.10	(-) 108,444.50
Forest area	79,626.26	119,630.29	163,542.05	(+) 40,004.03	(+) 43,911.75	(+) 83,915.78
Miscellaneous area	31,688.67	24,917.79	23,705.06	(-) 6,770.88	(-) 1,212.73	(-) 7,983.60
Urban and built-up area	7,561.15	15,139.94	34,221.11	(+) 7,578.79	(+) 19,081.17	(+) 26,659.97
Water body	5,263.19	6,621.64	11,115.54	(+) 1,358.45	(+) 4,493.90	(+) 5,852.35
Total	**348,160.46**	**348,160.46**	**348,160.46**			

Note: (+) means the area has increased. (-) means the area has decreased.

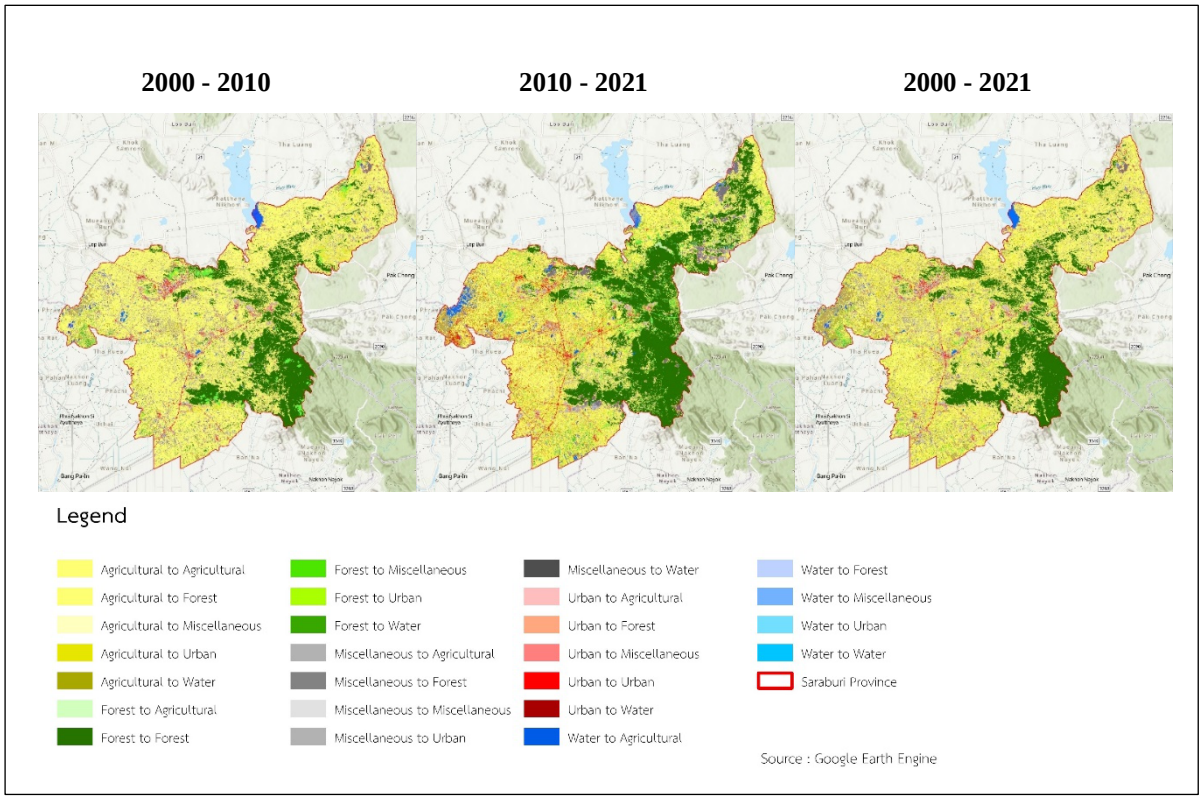

Figure 2. Map of Land-use change, Saraburi Province, 3 periods.

4. Conclusions

The results of the study of land use in Saraburi Province for the years 2000, 2010, and 2021 showed overall accuracies of 83.59%, 82.42%, and 80.78%, respectively. The analysis of land-use changes over these three periods clearly indicated changes in area, particularly in the urban and built-up areas, which have been continuously increasing. The area of urban and built-up land was only 7,561.15 ha in 2000 but increased to 34,221.11 ha by 2021, representing a growth of 26,659.96 ha (Table 10). This increase is attributed to the continuous economic growth in Saraburi Province, which has developed into an industrial city. Conversely, agricultural land use decreased significantly, from 224,021.20 ha in 2000 to 115,576.70 ha in 2021, a reduction of 108,444.50 ha over 20 years. This trend is consistent with Pannon's (2018) study on the Bang Pakong River Basin, which reported significant decreases in agricultural land due to urbanization driven by population growth. Similarly, in Saraburi Province, agricultural areas have been repurposed for other uses.

The forest area, however, showed a tendency to increase due to Saraburi Province's focus on developing itself into an international trade and investment hub for green industries. The provincial development plan emphasizes industrial and economic growth while increasing green spaces, leading to an expansion in forest areas. This indicates that Saraburi Province prioritizes its development plans and forest conservation.

The data obtained from this research can be used for spatial development and land use planning in the province. It can also serve as a policy guideline to promote Saraburi Province towards becoming a livable eco-industrial city with sustainable environmental quality in the future.

Acknowledgements

The author expresses gratitude to the Geo-Informatics and Space Technology Development Agency (Public Organization) and the Department of Land Development for providing data support for this study.

Conflict of Interest

There is no conflict of interest.

ORCID

Author: Tanachart Inpuron
https://orcid.org/0009-0009-6568-6975

References

Fitzpatrick-Lins, K. (1981). Comparison of sampling procedures and data analysis for a land-use and land-cover map. *Photogrammetric Engineering and Remote Sensing*, *47*(3), 343-351.

Geo-Informatics and Space Technology Development Agency (Public Organization). (2009). *Space technology and geo-informatics*. Bangkok, Thailand: Amarin Printing and Publishing Public Company.

Intarat, K. (2022). Land use classification in Nakhon Nayok Province using machine learning algorithms and Sentinel-2 image. *Burapha Science Journal*, *27*(2), 1153-1171.

McHugh, M. L. (2012). Interrater reliability: the kappa statistic. *Biochemia Medica*, *22*(3), 276-282.

Office of the National Economic and Social Development Board. (2017). *The Twelfth National Economic and Social Development Plan (2017-2021).* Bangkok, Thailand: Office of the Prime Minister.

Pannon, S. (2018). *Land use change and its impacts on water pumping in Bang Pakong River basin, Thailand* (Master's thesis). Asian Institute of Technology, Thailand.

Supatra, P., & Puttanawarat, N. (2021). *Development of geographic information systems and spatial data analysis.* Faculty of Science and Technology, Prince of Songkhla University, Surat Thani Campus.