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MONITORING OF LAND-USE CHANGE IN 2 PERIODS BY USING REMOTE SENSING TECHNOLOGY AND SPECTRAL INDICES

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ABSTRACT

This research aims to monitor land-use change in 2 periods, i.e., 2019 and 2023, by using Remote Sensing Technology and band indices. Research methodology consisted of: 1) classifying land-use based on data obtained from Sentinel-2 satellite into 4 types including: agriculture, forest, urban, and water; 2) analyzing Normalized Difference Vegetation Index (NDVI), Normalized Difference Built - up Index (NDBI), and Normalized Difference Water Index (NDWI) as well as analyzing relationship between land-use and NDVI, NDBI, and NDWI; and 3) comparing land-use change of 2019 and 2023. The results revealed that land-use change in Mueang Maha Sarakham District, Maha Sarakham Province, in 2 periods of time was as follows: reduced areas were agriculture and forest, and increased areas were urban and water.

Keywords: remote sensing, digital image processing, land-use change, NDVI, NDBI, NDWI.

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INTRODUCTION

Land-use in each area is dynamic and varied based on economic and social conditions whereas it can be adjusted by local people at any time [1], especially, when there is any change in the population situation, i.e., when the number of people is increased, demand on land-use is also increased. Consequently, the format of land-use in such areas has changed, especially with, the increase of urban buildings. [2] However, with limitations on area sizes or lands, land-use format is in the manner of substitution, for example, adjustment of agricultural areas as commercial and residential areas, etc. [3]. Urban expansion is the key factor highly affecting to land-use change of Thailand in the past 10 years. Agricultural areas have been changed as community and commercial areas rapidly respond to the expansion of large provinces like Bangkok, Chiang Mai, Khon Kaen, etc. [4, 5]. Simultaneously, since Maha Sarakham Province is located next to Khon Kaen Province, urban expansion reaches Maha Sarakham Province unavoidably. If land-use change is rapid without planning, there may be some social and environmental problems or impacts, for example, traffic jams, pollution, waste, and sewage.

Currently, Remote Sensing Technology plays a role in the analysis of natural resources and the environment [6-15], especially, land-use planning [16-20], because it is a kind of technology that can record data on the condition of land cover or types of land-use, types of land-use and local resources in different periods [21-23]. Application of data obtained from Remote Sensing Technology like satellite will help to analyze land-use formats and compare land-use change in various periods [24, 25]. This research aims to monitor land-use change in 2 periods, i.e., 2019 and 2023, by using Remote Sensing Technology and band indices. The research hypothesizes that the proportion of agriculture would be reduced whereas the proportion of urban would be increased to respond to economic and social expansion in land-use change in 2 periods, i.e., 2019 and 2023.

STUDY AREA

Maha Sarakham Province (Figure-1) is located in the central area of the northeastern part of Thailand at the longitude of 102° 50´E and latitude of 16 ° 40´N with an approximate area of 5,300 square kilometers and 130 - 230 meters above sea level. For seasons of Maha Sarakham Province, are classified based on the characteristics of the weather of Thailand into 3 seasons: winter – starts from the mid of October to the mid of February; summer - starts from the mid of February to the mid of May; and rainy season - starts from the mid of May to the mid of October. Administrative sub-districts of Mueang Maha Sarakham District, Maha Sarakham Province, are divided into 14 sub-districts and 185 villages.

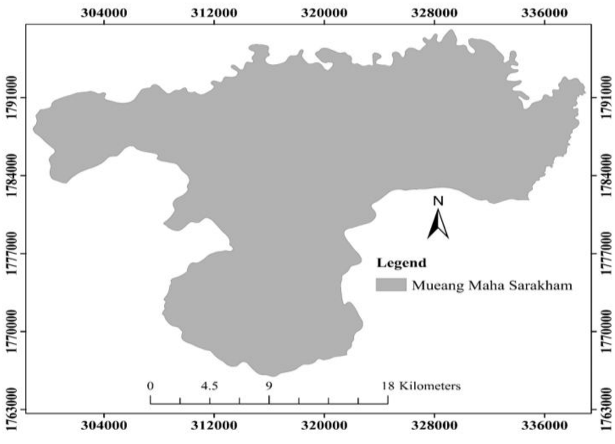

Figure-1. Mueang Maha Sarakham, Maha Sarakham Province.

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MATERIALS AND METHODS

Satellite Data

Data obtained from the Sentinel-2 satellite with a Multi-Spectral Imager (MSI) system consisted of 13 bands (Table-1) covering from visible band to the shortwave infrared band with spatial resolution at 10, 20, and 60 meters based on wavelengths. The data recording cycle was repeated at the same position every 5 days. In this research, data were collected from the Sentinel-2 satellite on December 20th, 2019, and December 14th, 2023. Selected data were those with cloudy conditions not over 20%.

Table-1. Sentinel-2 Band.

Bands	Central wavelength (nm)	Bandwidth (nm)	Spatial resolution (m)
Band 1 - Coastal Aerosol	443	20	60
Band 2 - Blue	490	65	10
Band 3 - Green	560	35	10
Band 4 - Red	665	30	10
Band 5 - Vegetation Red Edge	705	15	20
Band 6 - Vegetation Red Edge	740	15	20
Band 7 - Vegetation Red Edge	783	20	20
Band 8 - NIR	842	115	10
Band 8A - Vegetation Red Edge	865	20	20
Band 9 - Water Vapor	945	20	60
Band 10 - SWIR - Cirrus	1380	30	60
Band 11 - SWIR	1610	90	20
Band 12 - SWIR	2190	180	20

Classification of Land-Use

The researchers used data obtained from the Sentinel-2 satellite to classify land-use. For this research, land-use is classified into 4 types including agriculture, forest, urban, and water. Supervised Classification in the form of Maximum Likelihood Classification was used by mainly considering on mean vector and covariance matrix of each data type. Moreover, the hypothesis was also set that each data type had *a* normal distribution. The probability of each pixel was calculated to find the data type.

Analysis of NDVI, NDBI, and NDWI

Normalized Difference Vegetation Index (NDVI)

NDVI is a proportionating difference of surface reflection between Near Infrared wavelength and RED wavelength with the sum of both wavelengths for adjusting as normal distribution as shown in Equation 1. Subsequently, NDVI was adjusted to range from -1 to 1 which would facilitate interpretation, i.e., 0 means there were no green plants whereas 0.8 or 0.9 means there is a high density of green plants. If the land surface was covered by plants, there would be a higher reflection value in Near Infrared wavelength than that of RED wavelength. Consequently, NDVI had a positive value whereas land surface would have a similar reflection value of both wavelengths making NDVI close to zero. For the water surface, the reflection value of Near Infrared wave length was lower than that of RED wavelength making NDVI negative.

$$NDVI = \frac{NIR - RED}{NIR + RED} \tag{1}$$

Where;
NIR = Reflection in the Near Infrared Band
RED = Reflection in the RED Band

Normalized Difference Built-Up Index (NDBI)

NDBI (Equation 2) is an analysis of the normalized difference index of buildings for finding the relationship between urban surface temperature and types of land cover. It was conducted by analyzing data obtained from satellite based on consideration of wave reflection of the density of construction materials during daytime and nighttime and the temperature of each period.

$$NDBI = \frac{SWIR - NIR}{SWIR + NIR} \tag{2}$$

Where;
SWIR = Reflection in the Short Wave Infrared Band
NIR = Reflection in the Near Infrared Band

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Normalize Difference Water Index (NDWI)

NDWI (Equation 3) is an analysis of the normalized difference index of moisture level in soil or plants that can be found from solar radiation dose reflected from soil or plants in NIR wavelength and SWIR wavelength. If there was high water content in soil or plants, radiation in SWIR wavelength would be highly absorbed with a low reflection level. Consequently, NDWI would be higher.

$$NDWI = \frac{GREEN - NIR}{GREEN + NIR} \quad (3)$$

Where;
Green = Reflection in the Green Band
NIR = Reflection in the Near Infrared Band

Comparison of Land-Use Change

In this research, a comparison of land-use change was conducted to compare land-use change between 2019 and 2023.

RESULTS AND DISCUSSIONS

Results of Land-Use Classification

Results of land-use classification of 2 periods, i.e., 2019 and 2023, were shown in Figure 2 and Table-2. In 2019 and 2023, agriculture was calculated to be 68.04% and 62.78% whereas forest was calculated to be 12.3% and 5.32%. Urban was calculated to be 17.24% and 26.81% whereas water was calculated to be 2.43% and 3.09%. It could be noticed that urban was increased explicitly due to the larger number of housing developments in Mueang Mahasarakham District caused by a larger population and higher demands of residential areas.

Results of Analysis on NDVI, NDBI, and NDWI

Results of NDVI analysis based on data obtained from the Sentinel-2 satellite are shown in Figure-3. From Figure-3, it shows a comparison between NDVI in 2019 (Figure-3a) and 2023 (Figure-3b). From the results of NDVI analysis, it could be noticed that NDVI in 2023 had a higher number of land cover in the form of plants than those of 2019 explicitly.

Results of NDBI analysis based on data obtained from the Sentinel-2 satellite are shown in Figure-4. From Figure-4, it showed it showed a comparison between NDBI in 2019 (Figure-4a) and 2023 (Figure-4b). From the results of NDBI analysis, it could be noticed that NDBI in 2023 had a higher number of land cover in the form of buildings than those of 2019 explicitly. These results also represented that land-use was changed from agriculture to urban.

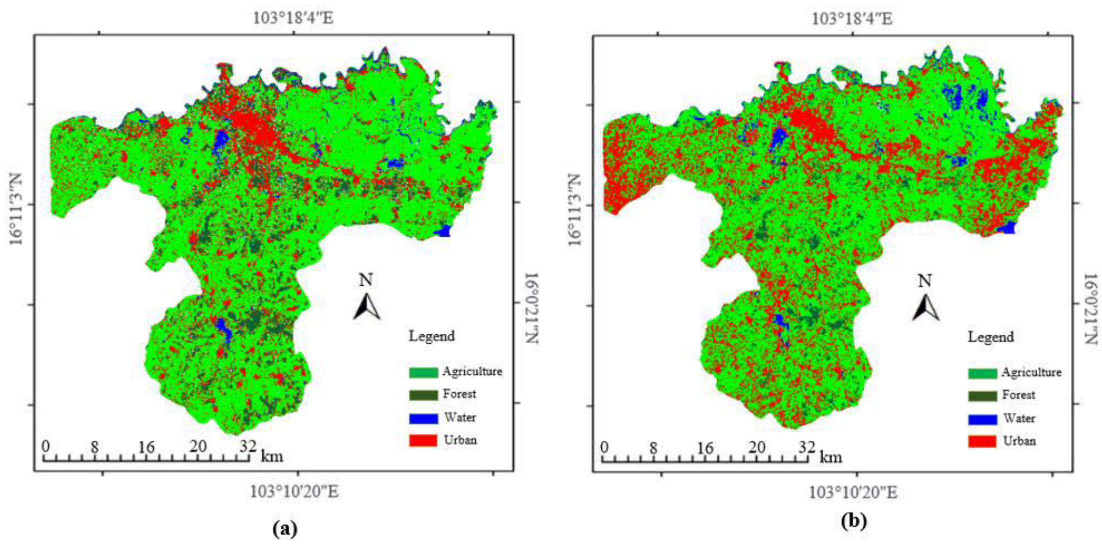

Figure-2. Land-use classification (a) 2019 and (b) 2023.

Table-2. % of Land-use classification.

Land-use Type	2019 (rai)	2023 (rai)	%	
			2019	2023
Agriculture	236,729.72	236,719.28	68.04	62.78
Forest	42,771.96	18,506.8	12.3	5.32
Urban	59,994.86	93,271.61	17.24	26.81
Water	8,454.88	10,758.23	2.43	3.09
Total	347,951.41	347,951.41	100.00	100.00

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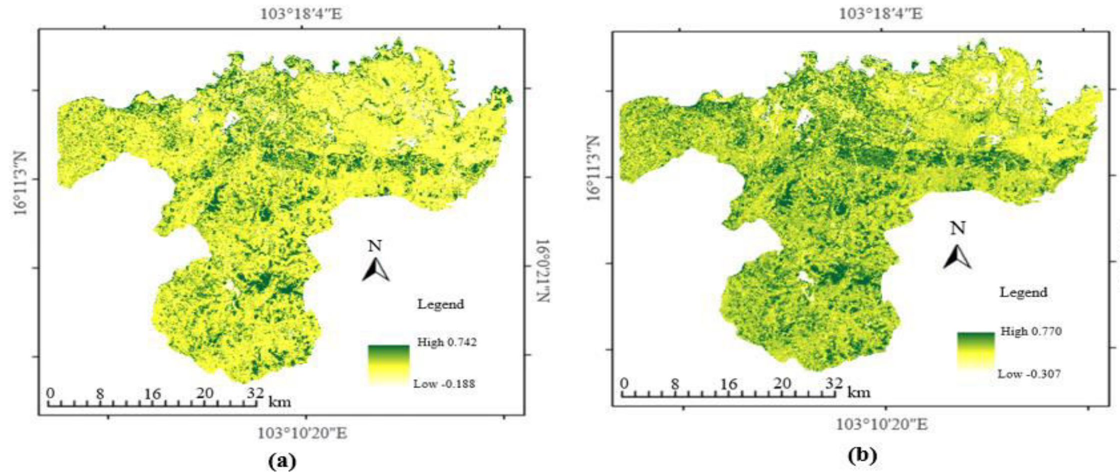

Figure-3. NDVI (a) 2019 and (b) 2023.

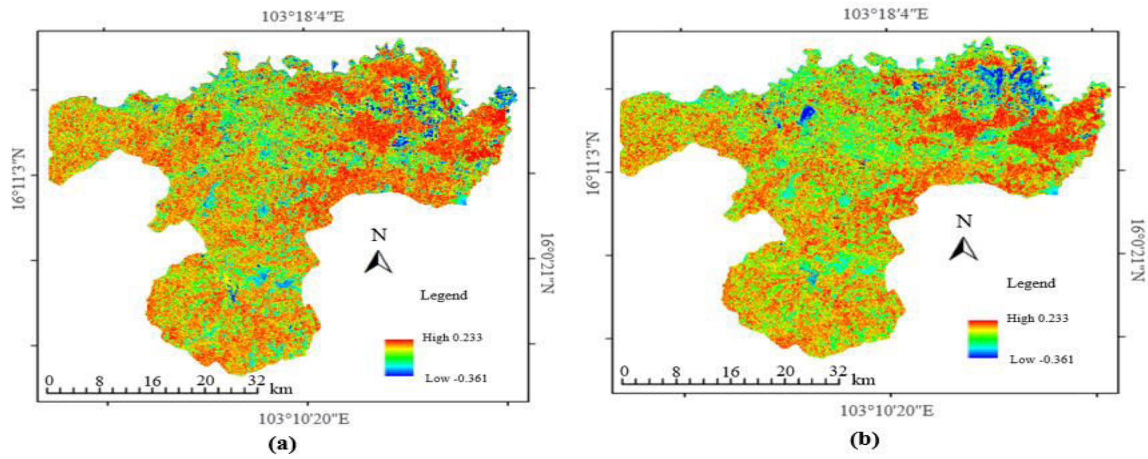

Figure-4. NDBI (a) 2019 and (b) 2023.

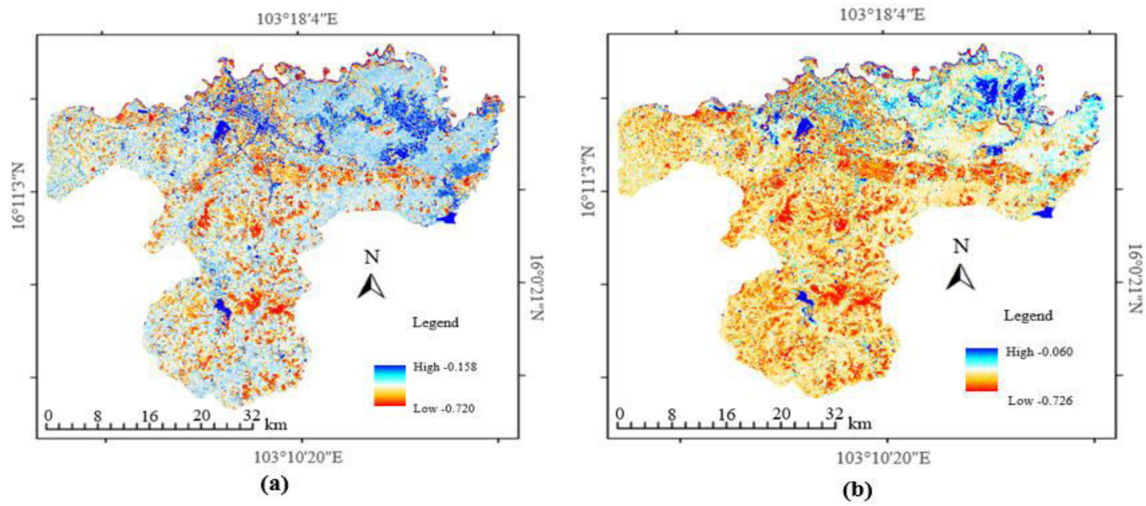

Figure-5. NDWI (a) 2019 and (b) 2023.

Results of NDWI analysis based on data obtained from the Sentinel-2 satellite are shown in Figure-5. From Figure-5, it shows a comparison between NDWI in 2019 (Figure-5a) and 2023 (Figure-5b). From the results of NDWI analysis, it could be noticed that NDWI in 2023 had a higher number of land cover in the form of water than those of 2019 explicitly.

Results of Comparison on Land-Use Change

In this research, a comparison of land-use change was conducted to compare land-use change between 2019 and 2023. The obtained results shown in Figure 6 could be explained as follows:

- Land-use change of lands with plants was changed in 2019 and 2023. During 5 years, most land-use was agriculture, for example, rice fields, sugar cranes, home grown vegetables, and a few areas of forest. Land-use in the form of plant use in 2019 was calculated to be 68.04% of total research areas whereas that of 2023 was calculated to be 64.78% of total research areas. The analysis results revealed that land-use in the form of plant use was reduced by 0.003% of total areas.

- Land-use change of lands with buildings was changed in 2019 and 2023. During the 5 years, most land use was for residential purposes, for example, detached houses with private areas, and housing estates. The center of the research area was changed land-use, for example, department stores, dormitories, and public spaces. Land-use in the form of buildings in 2019 was calculated to be 17.12% of total research areas whereas that of 2023 was calculated to be 26.81% of total research areas. The analysis results revealed that change of land cover in the form of buildings in 5 years was increased by 9.56% of total areas.

- Land-use change of lands with water was changed in 2019 and 2023. During 5 years, land-use change was as follows: land-use in the form of water use in 2019 was calculated to be 2.43% of total research areas whereas that of 2023 was calculated to be 3.09% of total research areas. Land-use change in the form of water use during 5 years was increased by 0.66% of total areas.

CONCLUSIONS

Maha Sarakham Province is one of the important provinces of Thailand because it is the center of the central northeastern part with various natural resources and land-use in the form of agriculture, forest, and urban, plus many important cultural sources. For this research, it could be concluded that land-use change in 2 periods, i.e., 2019 and 2023, showed that the proportion of agriculture was reduced whereas the proportion of urban was increased to respond to economic and social expansion that met with the hypothesis of this research.

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