Comparison of land use spatial model for economy zone and urban growth expansion forecast according to “Phuket Smart City” development plan

Pattarapong Ngansakul[1]

Faculty of Humanities and Social Sciences Suan Sunandha Rajabhat University

E-mail: pattarapong.ng@ssru.ac.th

Abstract.

Comparison of land use spatial model for economy zone and urban growth expansion forecast according to “Phuket Smart City” development plan. It identifies the most suitable spatial model for forecasting the expansion of economic zones and urban areas in Phuket Province.

Three spatial models Land Change Modeler (LCM), Future Land Use Simulation (FLUS), and Modules for Land Use Change Simulations (MOLUSCE) were evaluated using Sentinel-2 satellite imagery of Phuket from 2016 to 2020 as the base years for accuracy assessment against land use data for 2024. The findings reveal that the MOLUSCE model exhibited the highest accuracy among the three models, with a precision of 90 percent, followed by the FLUS model with 70 percent, and the LCM model with 67.4 percent. Subsequently, the MOLUSCE model was employed to project the growth of economic zone and urban areas in Phuket for the year 2028. The projection indicates that by 2028, Phuket is expected to experience a growth of 29.93 square kilometers in economic zone and urban areas, representing a 5.73 percent increase, with an accuracy rate of 85.4 percent.

Keywords: Urban growth, Spatial model, LCM, FLUS, MOLUSCE

1. Introduction

The development of urban areas under the concept of Smart City is an initiative aimed at transforming cities into special economic zones, which began in 2003. The three provinces selected as pilot areas were Chiang Mai, Khon Kaen, and Phuket. Since then, efforts have been continuously made to promote Phuket as a Smart City under various names, such as the "Phuket ICT Innovation Paradise" project in 2008 and the "Smart Province Model Project in Phuket" in 2014. However, no project has yet achieved significant tangible outcomes (E-leader, 2016). Subsequently, with support from the "Digital Economy" policy in 2017 and Phuket's readiness in terms of infrastructure, it was chosen as one of 24 pilot provinces aimed at attracting investors to use Phuket as a base for various technology-related businesses (Phuket Development Plan 2023-2027, 2022). This will become a labor market attracting workforce from outside the province, significantly benefiting the promotion and stimulation of the national economy. However, the rapid development of various areas to meet this policy has resulted in urban congestion and suboptimal land utilization, which may complicate future urban management (DEPA Southern Region, 2022).

Currently, a popular tool for monitoring urban expansion is the creation of spatial models (Liu, X. et al., 2020; Srishti G. & Rajendra S., 2023). Numerous types of models exist, and data sources can vary, including land surveys, aerial photography, or remote sensing methods,

particularly suitable for large study areas with limited time, such as using satellite imagery (Kulpanich, 2020). Among the satellite imagery sources available for spatial modeling is Sentinel-2, part of the Copernicus program, which is an Earth Observation Program with spatial resolution ranging from 10 to 60 meters, providing image data to ground stations every 5 to 7 days (GISTDA, 2018).

Therefore, the researcher is interested in comparing spatial models suitable for the growth of economic zone and urban areas in Phuket using Sentinel-2 satellite imagery. The results will be summarized to identify the most suitable spatial model for predicting future growth trends in the economic zone and urban areas of Phuket, serving as a basis for management and development planning according to the Phuket Smart City initiative.

1.1 Research Objective

1.1.1 To compare the spatial models suitable for the growth of economic zone and urban areas in Phuket.

1.1.2 To forecast the growth trends of economic zone and urban areas in Phuket for the year 2028.

2. Methodology

In this research, three spatial models will be employed to compare the forecasting results for the economy zone and urban growth expansion according to “Phuket Smart City” plan including: LCM (Land Change Modeler), FLUS (Future Land Use Simulation) and MOLUSCE (Modules for Land Use Change Simulations) and satellite imagery data from Sentinel – 2 was selected as input data because the image data has high resolution and covers the study period as shown in Table 1.

Table 1: Sentinel – 2 bands specifications

Sentinel-2 bands	Sentinel-2A		Sentinel-2B		Spatial resolution (m)
	Central wavelength (nm)	Bandwidth (nm)	Central wavelength (nm)	Bandwidth (nm)	
Band 1 – Coastal aerosol	442.7	21	442.2	21	60
Band 2 – Blue	492.4	66	492.1	66	10
Band 3 – Green	559.8	36	559.0	36	10
Band 4 – Red	664.6	31	664.9	31	10
Band 5 – Vegetation red edge	704.1	15	703.8	16	20
Band 6 – Vegetation red edge	740.5	15	739.1	15	20
Band 7 – Vegetation red edge	782.8	20	779.7	20	20
Band 8 – NIR	832.8	106	832.9	106	10
Band 8A – Narrow NIR	864.7	21	864.0	22	20
Band 9 – Water vapour	945.1	20	943.2	21	60
Band 10 – SWIR – Cirrus	1373.5	31	1376.9	30	60
Band 11 – SWIR	1613.7	91	1610.4	94	20

Band 12 – SWIR	2202.4	175	2185.7	185	20

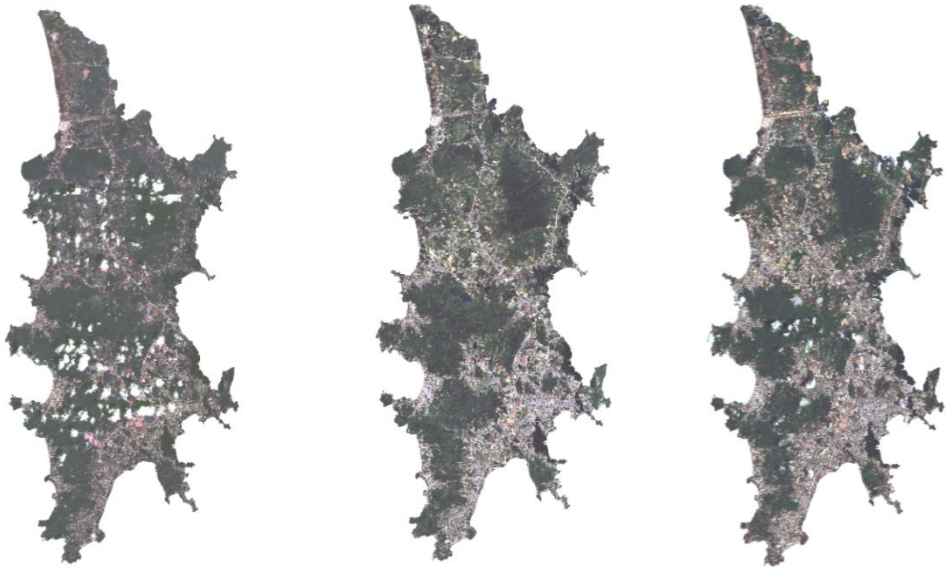
Source: European Space Agency, 2020

The Study area is Phuket province are in the upper southern region of Thailand, situated between latitudes 7 degrees 45 minutes to 8 degrees 15 minutes north and longitudes 98 degrees 15 minutes to 98 degrees 40 minutes east. It is the largest island in Thailand, located to the west of the southern region in the Andaman Sea of the Indian Ocean. The widest part of Phuket Island measures 21.3 kilometers, while the longest part measures 48.7 kilometers, covering a total area of 543.034 square kilometers, or approximately 339,396.25 rai. Phuket Province also comprises 32 smaller surrounding islands.

2.1 Data Collection

The time periods will be divided into three phases: before, during, and after the development plan. Accordingly, three periods of Sentinel-2 satellite imagery have been selected, representing the years 2016, 2020, and 2024. These years will serve as representatives for the different stages of the policy's implementation as shown in Figure 1.

Figure 1: Satellite imagery from Sentinel-2 of Phuket for the years 2016, 2020, and 2024.



2.2 Data Analysis

2.2.1 In this research, the following data has been selected:

- Satellite imagery from Sentinel-2 covering the area of Phuket for the years 2016, 2020, and 2024, to be analyzed using spatial models.
- Land use data for Phuket in the year 2024, from Department of Land Development using for verifying the accuracy of supervised classification result.

2.2.2 Interpretation of Sentinel-2 satellite imagery will be conducted for the years 2016 and 2020 using a supervised classification method, categorized into three types with 100 sample points each:

- Economic zone and urban areas
- Green areas (including agricultural and all types of forested land)
- Water bodies

Subsequently, the accuracy of the data will be verified using a random point sampling method, in conjunction with Land use data for Phuket in the year 2024, ensuring that the overall accuracy is no less than 80%.

2.2.3 Once the classification results are obtained, satellite imagery from both periods will be used to analyze three types of spatial models: FLUS, LCM, and MOLUSCE. The results will reflect changes in land use types compared to the actual changes occurring in 2024. The evaluation will consider overall accuracy; the model with the highest values for both will be deemed the most suitable for forecasting and monitoring the growth of economy zone and urban areas in Phuket.

2.2.4 The spatial model determined to have the highest accuracy will be used to forecast growth trends for economic zone and urban areas in Phuket for the year 2028.

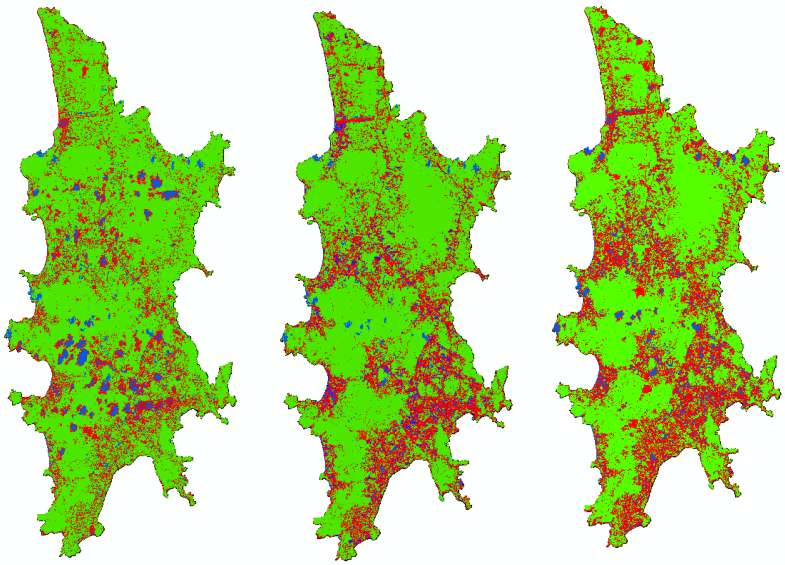
3. Result

3.1 The land use classification results from Sentinel-2 satellite imagery of Phuket for the years 2016, 2020, and 2024 were conducted using computer-based Supervised Classification. Land use is categorized into three types, namely:

- Economic zone and urban areas (represent as red color area)
- Green areas (including agricultural and all types of forested land) (represent as green color area)
- Water bodies (represent as blue color area)

The overall accuracy values are 81.1%, 89.4%, and 83.6%, respectively as shown in Figure 2.

Figure 2: The land use classification results from Sentinel-2 satellite imagery of Phuket for the years 2016, 2020, and 2024 (from left to right)

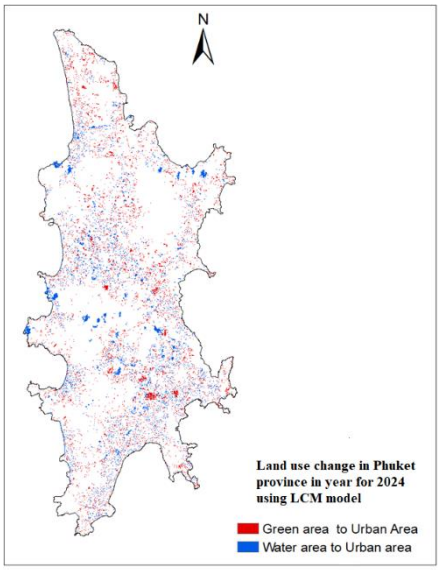


3.2 Using Classification results from the year 2016 and 2020 as input for spatial model analysis and comparison.

3.2.1 LCM (Land Change Modeler)

The analysis indicated that using the satellite imagery of Phuket from 2016 as the baseline and the imagery from 2020 as the trend data, the results from forecasting with the LCM model revealed that by 2024, Phuket is projected to experience growth economic zone and urban areas of approximately 6.51 square kilometers, representing an increase of 4.04%. The accuracy of the LCM model was found to be 67.4%. The results are displayed in figure 3.

Figure 3: The results of the growth trend simulation for economic zone and urban areas in Phuket for the year 2024, using the LCM model

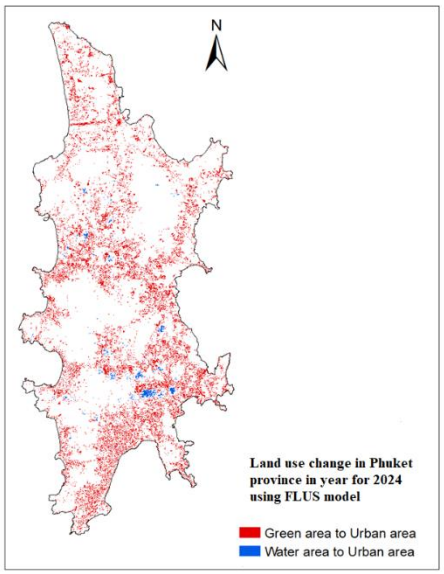


3.2.2 FLUS

The analysis revealed that using the satellite imagery of Phuket from 2016 as the baseline, the results from forecasting with the FLUS model indicated that by 2024, Phuket is projected to experience growth in economic zone and urban areas of approximately 3.64

square kilometers, representing an increase of 2.26%. The accuracy of the FLUS model was found to be 70%. The results are displayed in Figure 4.

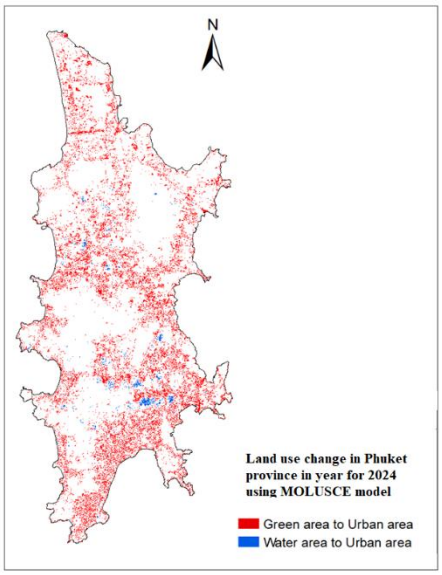
Figure 4: The results of the growth trend simulation for economic zone and urban areas in Phuket for the year 2024, using the FLUS model



3.2.3 MOLUSCE

The analysis indicated that using the satellite imagery of Phuket from 2016 as the baseline and the imagery from 2020 as the trend data, the results from forecasting with the MOLUSCE model revealed that by 2024, Phuket is projected to experience growth in economic zone and urban areas of approximately 8.71 square kilometers, representing an increase of 5.40%. The accuracy of the MOLUSCE model was found to be 90%. The results are displayed in Figure 5.

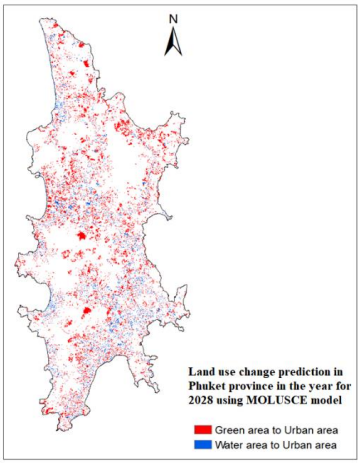
Figure 5: The results of the growth trend simulation for economic zone and urban areas in Phuket for the year 2024, using the MOLUSCE model



From the analysis of the three models—LCM, FLUS, and MOLUSCE—it can be concluded that the model with the highest accuracy of 90% is MOLUSCE, making it the most suitable for forecasting the growth trends of economic zone and urban areas in Phuket for the year 2028. The FLUS model follows, with LCM ranked last in terms of accuracy.

3.3 Based on the analysis from the previous steps, the MOLUSCE model is deemed the most suitable for forecasting the growth trends of economic zone and urban areas in Phuket. Using the Sentinel-2 satellite imagery from 2020 as the baseline and the imagery from 2024 as trend data, the results indicate that by 2028, Phuket is projected to experience growth in economic zone and urban areas of approximately 29.93 square kilometers, representing an increase of 5.73%. The accuracy of this forecast is 85.4%. The results are displayed in Figure 6.

Figure 6: The results of the growth trend simulation for economic zone and urban areas in Phuket for the year 2028, using the MOLUSCE model



4. Discussion

Comparison of land use spatial model for economy zone and urban growth expansion forecast according to “Phuket Smart City” development plan involved the use of three models: Land Change Modeler (LCM), FLUS, and MOLUSCE. Satellite imagery from Sentinel-2 for Phuket was analyzed across three time periods: 2016, 2020, and 2024, to identify the model with the highest suitability and accuracy for predicting growth trends.

The results indicated that the MOLUSCE model was the most suitable, achieving an accuracy of 90%. This was followed by the FLUS model with an accuracy of 70%, and the LCM model with an accuracy of 67.4%. These findings align with the research conducted by Nattchapa Suyatha (2019), which studied changes and forecasts in corn cultivation areas impacting the environment in the Pua District of Nan Province using the MOLUSCE model. The study found that corn cultivation areas increased the most, followed by agricultural areas, while natural forest areas saw the most significant decline.

Additionally, the work by Thitiya Patkhamtan (2020) assessed carbon sequestration from biomass and future change trends in Bang Kachao. This research utilized land use classification data from Sentinel-2 imagery for the years 2016, 2019, and 2021 in conjunction with the MOLUSCE model to predict land use changes by 2029, revealing that residential and built-up areas are projected to increase the most.

5. Conclusion

To summarize, this research found that MOLUSCE model is the most suitable model for using in land use prediction in Phuket province and the growth trend simulation for economic zone and urban areas in Phuket for the year 2028. So, this data can be used as information for decision-making in planning and management for government agencies in Phuket Province. such as public utilities, road planning and green areas management

Acknowledgment

We would like to express our gratitude to the Faculty of Humanities and Social Sciences and Suan Sunandha Rajabhat University for their valuable support throughout this research.

References

Clark Labs. (2024). Land Change Modeler in TerrSet. Clark Labs. Retrieved December 20, 2023, from https://clarklabs.org/terrset/land-change-modeler/

Digital Economy Promotion Agency, Southern Region. (2022). Smart City Phuket: A livable city for sustainable economy. Retrieved December 15, 2023, from https://www.phuket.go.th/webpk/file_data/plan2/6.SmartCity.pdf

E-leader. (2016). How did Phuket Smart City originate? Retrieved December 1, 2023, from https://www.theeleader.com/news-enterprise/smart-city-in-phuket/

European Space Agency. (2020). Sentinel-2 sensor specifications. Retrieved December 20, 2023, from https://sentiwiki.copernicus.eu/web/s2-mission

Geo-Informatics and Space Technology Development Agency. (2018). Components of geographic information technology. Retrieved April 14, 2024, from http://www.gistda.or.th/main/th/node/817

Kulpanich, N., Worachairungreung, M., & Chaysmithikul, P. (2020). Surveying for built-up areas in Nakhon Pathom Province with remote sensing from Landsat 8 and Sentinel 2 imagery. Suan Sunandha Asian Social Science, 14(2), 44–55. https://so05.tci-thaijo.org/index.php/ssajournal/article/view/251459

Liu, X., Liang, X., Li, X., Xu, X., Ou, J., Chen, Y., ... & Pei, F. (2020). A future land use simulation model (FLUS) for simulating multiple land use. Landscape and Urban Planning, 94, 94–116. https://doi.org/10.1016/j.landurbplan.2017.09.019

Nattchapa, S. (2019). Forecasting changes in corn cultivation areas affecting the environment: A case study of Pua District, Nan Province. Naresuan University. Retrieved December 15, 2023, from https://ww2.agi.nu.ac.th/nred/Document/is-PDF/2562/geo_2562_039_FullPaper.pdf

Phobkarn Awasakanakarn. (2017). Phuket city development model for urban development towards smart city. Retrieved December 25, 2023, from http://rs.mfu.ac.th/obels/?p=2339

Phuket Provincial Office. (2023). Phuket Provincial Development Plan 2023-2027. Retrieved December 6, 2023, from https://ita.phuket.go.th/assets/upload/o4%20แผนพัฒนาจังหวัดภูเก็ต%20พ.ศ. 2566-2570.pdf

Gaur, S., & Singh, R. (2023). A comprehensive review on land use/land cover (LULC) change modeling for urban development: Current status and future prospects. Sustainability, 15(2), 903. https://doi.org/10.3390/su15020903

Thitiya, P. (2020). Assessment of carbon storage from biomass and future change trends in Bang Kachao area, Samut Prakan Province, using the MOLUSCE model. Thammasat University. Retrieved December 15, 2023, from https://digital.library.tu.ac.th/tu_dc/frontend/Info/item/dc:185892#

Chen, X., He, X., & Wang, S. (2022). Simulated validation and prediction of land use under multiple scenarios in Daxing District, Beijing, China, based on GeoSOS-FLUS model. Sustainability, 14(18), 11428. https://doi.org/10.3390/su141811428

Zhang, C. (2021). Spatial pattern simulation of land use based on FLUS model under ecological protection: A case study of Hengyang City. Sustainability, 13(18). https://doi.org/10.3390/su13181256