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SPATIAL EVOLUTION OF SMART CITIES FOR SUSTAINABLE TOURISM: A CASE STUDY OF PHUKET PROVINCE, THAILAND

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Abstract: In this research, the objective is to study the Spatial Evolution of Smart Cities for Sustainable Tourism in Phuket Province, Thailand from 2005-2024, using the Geo-informatic Technique as information for decision-making in determining the direction of Smart City. The study results found that land use patterns such as Urban and built-up land, Waterbodies, and Forest land have had an increasing trend over the past 20 years. In 2005, Urban and built-up land was found to cover 132.19 km2 (24.10% of the total area). In 2024, it was found to have greatly increased, covering 165.91 km2 (30.25% of the total area), especially in Thalang District, which is north of Phuket. The area has a wide plain landscape, and beautiful wide beaches such as Bang Tao Beach. There has been a change from agricultural land to housing developments, residential areas, restaurants, hotels, resorts and homestays. The results of this study have been prepared as a spatial database for supporting decision-making in monitoring and planning the development of areas to support the expansion of sustainable tourism in the future to become a smart city.

Keywords: spatial evolution, smart cities, sustainable tourism, Phuket, land use

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INTRODUCTION

Over the past few years, the concept of Sustainable Smart Cities has gained a lot of attention. Urban areas around the world prepare to cope with rapid population growth, enormous use of resources, and environmental degradation as a result (Siokas et al., 2021; Stamopoulos et al., 2024). Smart City focuses on leveraging technology, using innovative technologies and data-driven solutions, promoting economic prosperity in cities, and reducing environmental impacts (Lamba et al., 2019; Sahu et al., 2024). The smart city concept is a convergence of several important technological features, including the prevalence of advanced information and communications technology, high-tech urban infrastructure, the Internet-of-Things, environmentally friendly technologies (Bibri, 2021; Majeed et al., 2021; Huda et al., 2024). The confluence of these things is connected to each other, resulting in an efficient management and operation system, driving the quality of life of people within the city to be better and sustainable.

Thailand needs to adapt in order to have the potential to cope with the challenges that arise. The government has therefore pushed forward the policy "Thailand 4.0" to use as a model to raise the competitiveness of the country to compete with the knowledge base and bring in new innovations (Taweesaengsakulthai et al., 2019; Irvine et al., 2022). This makes it possible to distribute development opportunities evenly and take into account the natural environment in a sustainable way. This is to be in line with the development guidelines according to the Sustainable Development Goals (SDGs), especially Goal 9 and 11. Goal 9 is a goal that shows the development of Build resilient infrastructure, promoting inclusive and sustainable industrialization and foster innovation (Kutty et al., 2020; Clement et al., 2023). Goal 9, by 2030, aims to develop quality regional infrastructure, promote comprehensive and sustainable industrial development, upgrade infrastructure and improve industry to achieve sustainability, by increasing efficiency in the use of resources and using technology and industrial processes that are cleaner and more environmentally friendly. And importantly, it is increasing access to information and communications technology, and striving to provide universal and affordable Internet access. Goal 11 is a goal that shows the development of cities and human settlements inclusive, safe, resilient and sustainable (Kutty et al., 2020; Parra-Domínguez et al., 2022). The goal is to provide access to sustainable, accessible, safe, and affordable transportation for everyone; strengthen efforts to protect and protect the world's cultural and natural heritage; reduce negative environmental impacts per capita in urban areas; this includes paying special attention to air quality, and municipal waste management; provide access to safe, inclusive and accessible public green space. It can be seen that the guidelines of both SDGs goals are consistent with the spatial evolution of Smart Cities for sustainable tourism in Phuket province. Phuket is a famous province for world-class tourism. As Phuket is a city that is very attractive to tourists and investors, there is an important factor such as economic growth that comes from the arrival of both domestic and foreign tourists. This causes the expansion of the local economic

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system (Sinlapasate et al., 2020; Chaigasem and Kumboon, 2024). In addition, Phuket is a city that is ready for relatively high investment. It can be observed from the investment value from the development of various projects in both the public and private sectors, with a focus on infrastructure and real estate development which are good indicators of readiness to become a tourist city. Phuket has also been selected as a pilot province to be developed into a smart tourism city in the areas of Maritime Hub, Medical Hub and MICE City, with human resource development being an important aspect (Rittichainuwat et al., 2020). Phuket Province also has a Phuket Smart City action plan that has development in all 7 areas: Smart Economy, Smart Economy, Smart Safety, Smart Environment, Smart Healthcare, Smart Education and Smart Governance (Sontiwanich et al., 2022). Such development guidelines will inevitably affect the pattern of land use change.

In terms of urban planning and various structures within the city, land use patterns should be taken into account. Whether it is public transportation systems, energy sources, public utilities, management systems must be put in place to support future smart cities. Yamagata and Seya (2013) designed a futuristic smart city to address carbon dioxide reduction over the next 20 years in the Tokyo metropolitan area. The research approach involves planning land use in an integrated and consistent manner. In urban areas, buildings are being used to install photovoltaic panels to save energy, public transportation uses electric vehicles and smart grid systems. Anguluri and Narayanan (2017) analyzed the green index for the planning of smart cities in Gulbarga city, India. The results of this study preserve the space for green in urban planning for well-being in totality.

In addition, Land Surface Temperature analysis helps promote the search for appropriate areas for land use planning. The importance of land use also affects the operation of rail transit in the commercial zone of Xi'an city in China. Duan et al. (2020) evaluated the connection between rail transit station operating efficiency and land use. This research presents an approach for integrated land use planning that is consistent with parking facilities to continue travel by railway in the city. It is a response to the development plan of smart cities that allows people in the city to have convenient access to the infrastructure system. Additionally, Kumar and Agrawal (2023) studied land use change for a densely populated and developing smart city, Prayagraj, India. The study clearly shows the growth rate of such cities that will occur in 2040. Such smart city expansion is an outcome that will help city residents, planners, administrators, and government to create appropriate policy plans for the sustainable future growth of Prayagraj. It can be seen that the aforementioned researches recognize the importance of limited natural resources, causing the concept of urban development to be a smart city in order to apply technology and innovation to reduce the use of natural resources. This is the concept of the "smart city", describing a sustainable urban environment where information and communication technologies (ICT) are exploited to foster sustainable development across key urban sectors.

For this reason, it is necessary to apply geo-informatics technology in this research to track land use change patterns in smart city areas, especially to the city of Phuket in Thailand in order to understand the pattern and direction of change in such area patterns, and find ways to manage land use systematically and orderly and support the up coming smart city. This is to increase the potential for sustainable tourism.

The objective of this research is to study the spatial evolution pattern of Smart Cities for Sustainable Tourism in Phuket Province, Thailand from 2005-2024 by using Geo-informatic Technique as information for decision-making in setting the Smart City direction in spatial management, to support the expansion of sustainable tourism in the future.

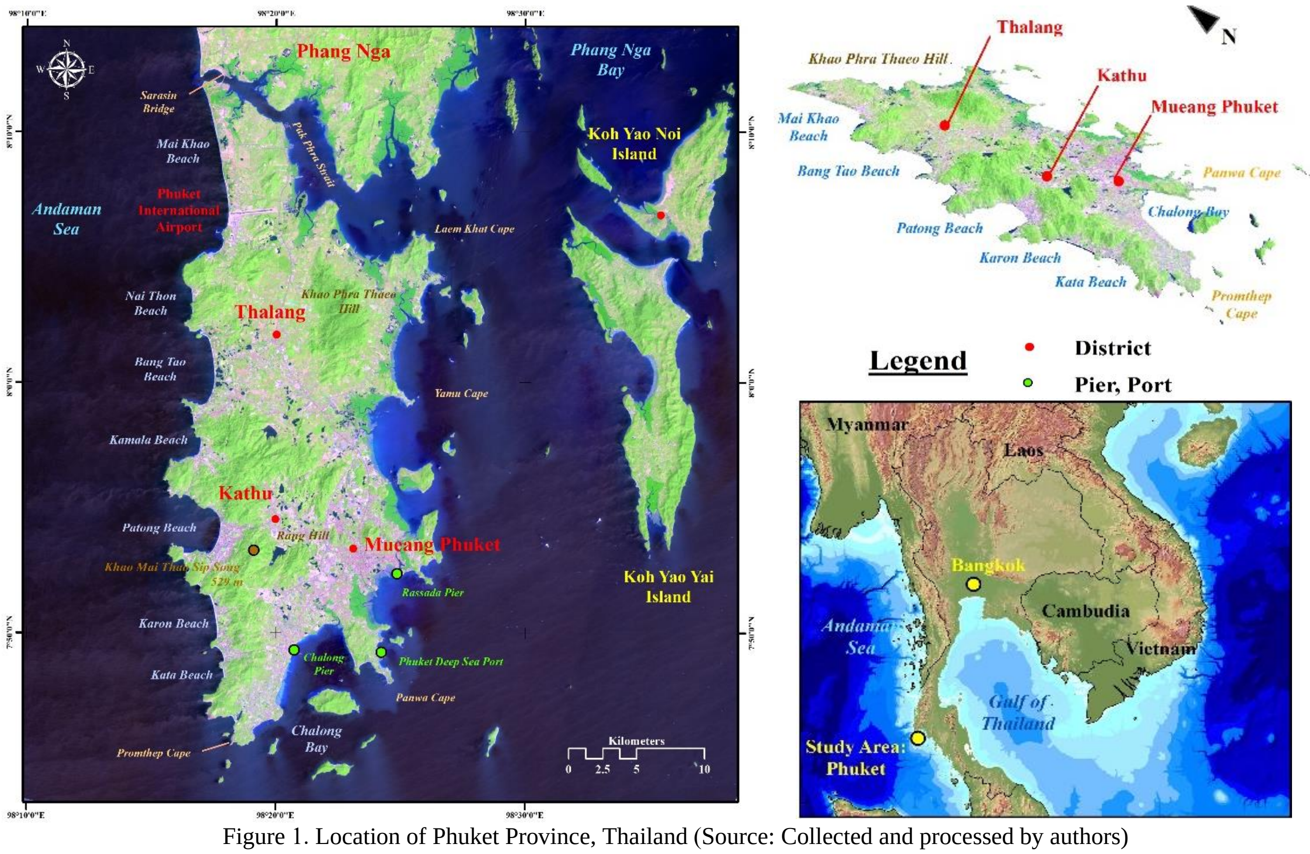

Figure 1. Location of Phuket Province, Thailand (Source: Collected and processed by authors)

MATERIALS AND METHODS

1. Study area

Phuket Province is a province in the southern-western region of Thailand. Phuket's geographic location is between 7°45' N and 8°15' N latitude and 98°10' E and 98°30' E longitude. The total basin area is 543.034 km^2 (Figure 1). Phuket's topography is characterized by the largest archipelago in Thailand, located in the Andaman Sea of the Indian Ocean. The area is mostly mountainous, approximately 70 % of the area. The highest peak is Khao Mai Thao Sip Song, 529 m high, in the southern part of Phuket Island, near Patong beach. There are also important mountains in the central part of the area, Khao Rang, and in the north, Khao Phra Thaeo, which is an important wildlife hunting area, and has been designated a protected area as Khao Phra Thaeo Non-Hunting Area. Phuket is approximately 30 % flat, appearing in the southeastern part of the island in Mueang Phuket. Such a flat area is vast. Once the largest agricultural and tin mining area in Thailand, most of the area is now a business and residential area. The area near the said flat area has a large indented coastline, namely Chalong Bay, a mangrove forest area located along the river mouth of Phuket Province.

North of Phuket is a small strait called Pak Phra Strait, but it also has a transportation network connecting it to the mainland with the Sarasin Bridge. The bridge is now no longer used as a transportation route and has become an important tourist attraction in Phuket, but has been replaced by the Thao Thep Krasattri Bridge and Thao Si Sunthon Bridge. The western side of Phuket has a north-south mountain range, interspersed with narrow coastal plains. But, it is a sea coast with fine white sand and beautiful beaches all along, including Mai Khao Beach, Nai Thon Beach, Bang Tao Beach, Kamala Beach, Patong Beach, Karon Beach, Kata Beach, and Kata Noi Beach respectively. The largest beach in this area is Patong Beach, a beach that both Thai and foreign tourists come to visit throughout the year.

2. Data Preparation and Methodology

The study of land use patterns and land use changes involves collecting data, analyzing the data, and displaying the findings systematically (Figure 2) as follows:

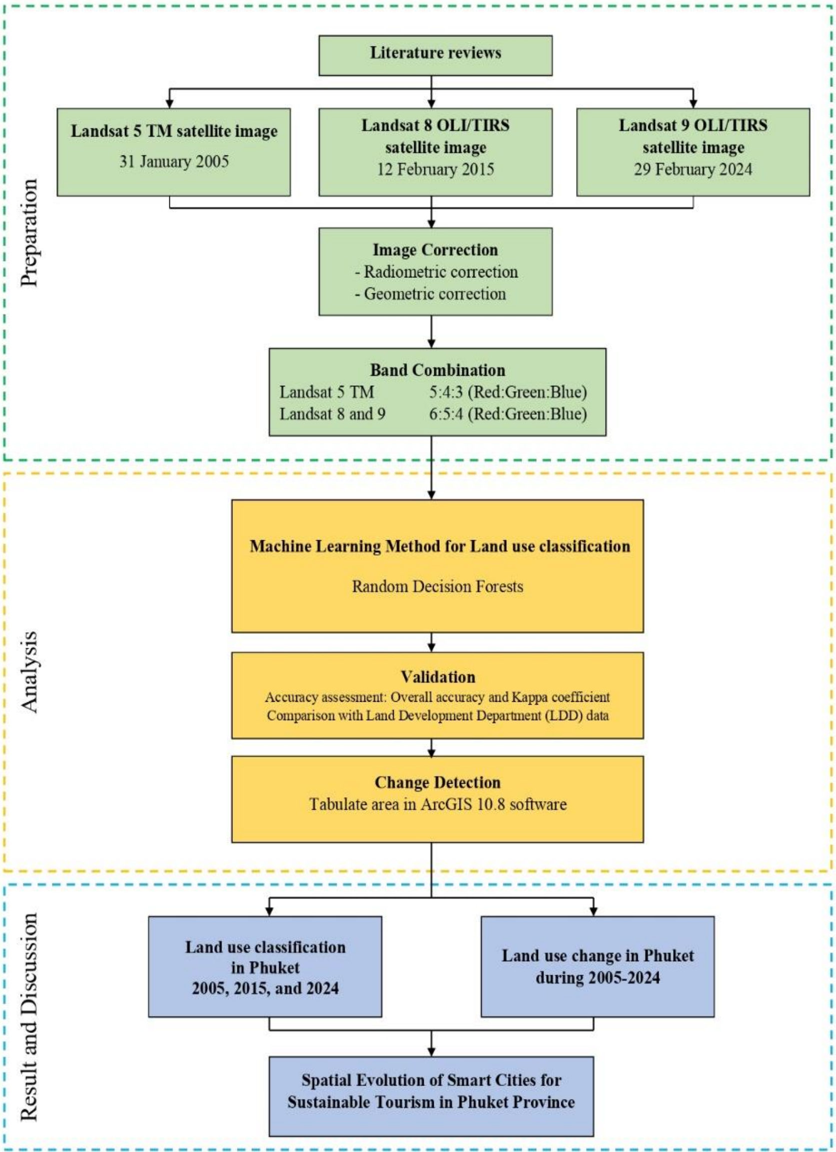

Figure 2. Flow chart of methodology

2.1. Collect spatial data and attribute data from relevant agencies and give permission for publication as shown in Table 1.

Table 1. Satellite imagery data and land use in Phuket province

Database	Acquisition date	Format	Sources
Landsat 5 TM Image Path 130 Row 054; Path 130 Row 055	31 January 2005	Image File	https://earthexplorer.usgs.gov/
Landsat 8 OLI/TIRS Image; Path 130 Row 054	12 February 2015	Image File	https://earthexplorer.usgs.gov/
Landsat 9 OLI/TIRS Image; Path 130 Row 054	29 February 2024	Image File	https://earthexplorer.usgs.gov/
Land use in Phuket Province 2005	2005	Shape file	Land Development Department (LDD), Thailand
Land use in Phuket Province 2015	2015	Shape file	Land Development Department (LDD), Thailand
Land use in Phuket Province 2024	2024	Shape file	Land Development Department (LDD), Thailand

2.2. Import image data from satellites including Landsat-5 TM system, Landsat-8 OLI/TIRS system and Landsat-9 OLI/TIRS system at each time period, using the satellite image data management program Erdas Imagine Version 8.5 and then perform band combination, by selecting band 5 (short-wavelength infrared), 4 (near-infrared), and 3 (red) for the Landsat TM system. As for Landsat, the OLI/TIRS system uses band 6 (short-wavelength infrared), 5 (near-infrared), and 4 (red). All 3 bands mentioned above have been brought into this Band combination method. When mixed, they can be used to detect city areas and buildings clearly. Such bands can well distinguish urban areas from areas covered by vegetation (Oon et al., 2019; Huang et al., 2023).

2.3. Interpret satellite image data to classify land use (land use and land cover classification) for the years 2005, 2015, and 2024 using ArcGIS 10.8 software based on the principles of Machine learning. This principle uses deep learning classification techniques in Random Decision Forests (or Random Forest) is an ensemble learning method for land use and land cover classification. The Random Decision Forests method is a popular method for interpreting land use efficiently (Phinzi et al., 2023). The results from interpreting land use patterns are presented as Overall Accuracy and Kappa coefficient coefficients (KHAT), to assess the accuracy of various classifications appearing on satellite imagery data (Congalton, 1988; Ababneh et al., 2019). Sampling points were determined in the study area, using data from the Land Development Department (LDD), Thailand, and validation was compared with data obtained from classification. The classification criteria are as follows:

< 0 means Unacceptable classification information
0.01 – 0.40 means Fair classification information
0.41 – 0.60 means Moderate classification information
0.61 – 0.80 means Good classification information
0.81– 1.00 means Very Good classification information

2.4. Use the obtained land use pattern data to create a database in the geographic information system, and check for errors in the spatial data. Using a geographic information system program, data were displayed at each time period to examine land use changes over time (Jia et al., 2014) as shown in Eq.

$\Delta = [(A_2 - A_1) / A_1 \times 100] / (T_2 - T_1)$; where Δ is the proportion of land use patterns that have changed (%); A_1 is the type of land use at time one (T_1) and A_2 is the type of land use at the second time (T_2); The results are displayed as the proportion of land use of each type on the map. It shows the pattern of land use change from 2005 to 2024 along with a comparison table of land use change (Change Detection) obtained from tabulate area analysis in ArcGIS 10.8 software.

2.5. Randomly inspect data from real areas to check the accuracy of data obtained from interpreting data from satellite images, including land use characteristics, factors and impacts of land use changes, and asking for explanatory information from people in the area etc.

2.6. Use the obtained land use pattern data to create a geographic information database and check for errors in spatial data and attribute data. Use ArcGIS 10.8 software to track land use changes, and store them as a Spatial database for various agencies to solve problems and plan land use in Phuket to properly support being a smart city.

Table 2. Land-use pattern for years 2005, 2015, and 2024 in Phuket obtained from Random Decision Forests method, showing overall accuracy and Kappa coefficient values

Land-use pattern	2005		2015		2024	
	km^2	**%**	**km^2**	**%**	**km^2**	**%**
Forest land	127.54	23.25	133.65	24.37	160.09	29.19
Agricultural land	233.68	42.60	195.02	35.55	157.48	28.71
Urban and built-up land	132.19	24.10	158.84	28.96	165.91	30.25
Waterbodies	18.65	3.40	25.79	4.70	30.76	5.61
Other land (Wetland, Mine abandoned, and Beach and sand bar)	36.46	6.65	35.22	6.42	34.28	6.25
Total	548.52	100.00	548.52	100.00	548.52	100.00
Overall Accuracy (%)	94.30		87.20		86.10	
Kappa coefficient (*KHAT*)	0.93		0.86		0.85	

RESULTS AND DISCUSSION

Phuket is an important province in Thailand with high investment and tourism potential, due to its geography conducive to investment and development and many natural and cultural tourist attractions. Over the past 5 years, Phuket has been developed to prepare for being a smart city. Various developments have occurred in many areas, causing unavoidable changes in land use patterns. The technique used to detect land use change for this study is the Random Decision Forests method, which is a type of machine learning process. The results show that processing satellite images for each time period, including 2005, 2015, and 2024, with the Random Decision Forests method, results in land use patterns in each time period effectively (Figure 3). Overall accuracy values as shown in Table 2 are as follows: 94.30 percent, 87.20 percent, and 86.10 percent, respectively. The criteria for classifying land use data are at a very good level. As for the Kappa coefficient coefficient (KHAT), it is a coincidence value of two sets of data from interpreting land use patterns. It was found that the KHAT values were as follows: 0.93, 0.86, and 0.85, respectively, which are also very good criteria.

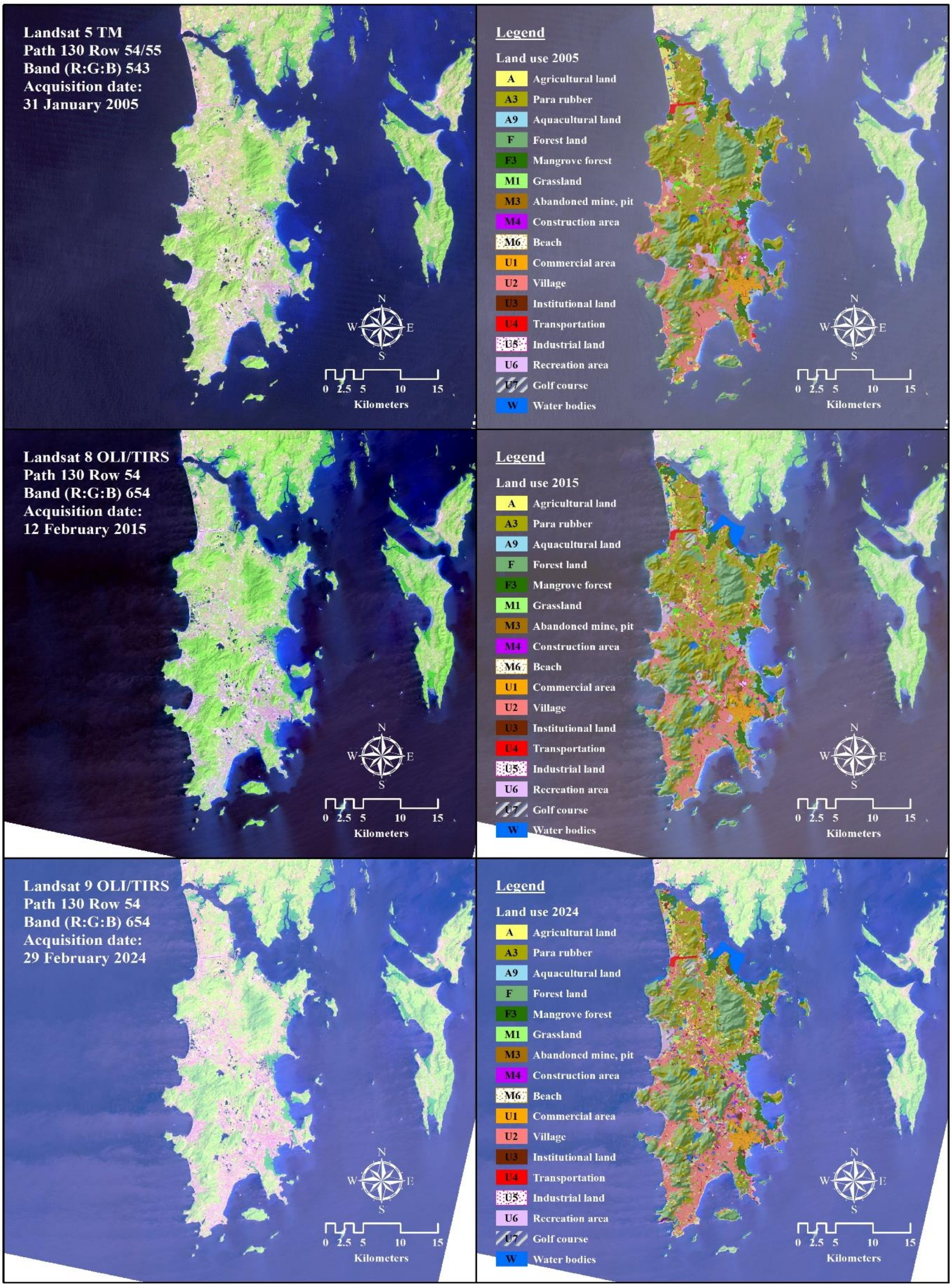

Figure 3. Land use pattern map of Phuket Province in 2005 (A), 2015 (B) and 2024 (C) (Source: Collected and processed by authors)

From the land use classification, it was found that the Phuket area over the past 20 years has had a greatly changed land use change pattern. In 2005, agricultural land was found covering 233.68 km^2 (42.6% of the total area). In 2024, it was found to have greatly decreased, leaving only 165.91.68 km^2 covered (28.71% of the total area). On the other hand, other types of land, such as Urban and built-up land, Waterbodies, and Forest land, tend to increase. In 2005, Urban and built-up land was found to cover 132.19 km^2 (24.10% of the total area). In 2024, it was found to have greatly increased, covering 165.91 km^2 (30.25% of the total area). The area of Waterbodies increased from 18.65 km2 (3.40% of the total area) to 30.76 km^2 (5.61% of the total area). Forest land area increased from 127.54 km^2 (23.25% of the total area) to 160.09 km^2 (29.19% of the total area). Over the past 20 years, other land areas have changed the least.

It can be seen that over the past 20 years, from 2005-2024, there has been a noticeable change in land use patterns in Phuket. Phuket has begun to develop the area to enter full urbanization (Prueksakorn et al., 2018). This causes some areas of Agricultural land to be replaced into Urban and built-up land areas to support a smart city. In particular, rubber plantations, an important economic crop of Phuket, have been transformed, with noticeable changes in land use around Thalang District, in the north of Phuket. The area has a wide plain terrain and beautiful wide beaches like Bang Tao Beach, making the area currently populated with many housing developments and residential areas. In this regard, the lifestyle of local people has changed from being a farmer to working in services or operating businesses such as restaurants, hotels, resorts, and homestays. This has caused some farmers to sell their land due to the current land value in Phuket being very high. Moreover, it can be seen that waterbodies have greatly increased as forests, agriculture and other areas have been transformed into water bodies such as reservoirs. Due to Phuket's high urban expansion, there is a need to use water for consumption. Therefore, such water sources have been developed to support a smart city. As for other areas in Phuket that have not changed much, they are mostly grassland areas; wetlands; sandy beach; an old mine that is now a tourist attraction such as the Kathu Mining Museum, which in the past was the main source of Phuket's tin mines. Phuket's land use change model shows the Transition Matrix of land use changes as shown in Table 3.

From the results of the study of changes in land use patterns expressed as a Transition Matrix, the Urban expansion model was created in the form of a map in this study, as shown in Figure 4. The study found that over the past 20 years, Phuket has clearly experienced urbanization. It can be seen from 2005 that there is a concentration of Urban and built-up land covering the southern part of the study area. It can be found in the Mueang Phuket District and along the western coast of Phuket Island, including Bang Tao Beach, Kamala Beach, Patong Beach, Karon Beach, Kata Beach, and Kata Noi Beach, respectively. In 2024, urbanization becomes evident along the main road connecting Thalang, Kathu, and Mueang Phuket districts, which is the main transportation route on Phuket Island. In addition, it was found in the southern area of Thalang District that there was an expansion of land use patterns such as village, golf course, recreation area, and institutional land covering the area. The Thalang area has high investment potential, with both Thai and foreign investors developing the area into housing developments and large hotels.

Table 3. Transition Matrix of land use changes in Phuket, 2005–2024 (km^2)

		2024				
	Land use change	**Agricultural land**	**Forest land**	**Other land**	**Urban and built-up land**	**Waterbodies**
2005	**Agricultural land**	142.58	43.15	13.28	32.45	1.10
	Forest land	7.80	103.85	2.01	6.30	1.12
	Other land	3.57	3.79	13.50	10.98	3.35
	Urban and built-up land	2.97	4.12	4.72	115.11	1.67
	Waterbodies	0.14	0.55	0.11	0.82	5.57

Since 2017, Phuket Province has set goals for developing into a complete Smart City by 2024. There are guidelines for development in 2 important issues: Smart Economy and Smart Living Community. They also set a vision for Phuket to be a tourism city with sustainable growth based on the creative economy for the happiness of everyone (Sontiwanich et al., 2022). Phuket's Smart Economy focuses on promoting the second industry, the digital industry, to support the tourism industry which is the main industry. Phuket's economy has always grown from the one-way tourism industry, so it is necessary to find new industries that will help the city grow sustainably. Such development focuses on investment in research and development of technology, emphasizing development in the form of a Research Center or Innovation Center. Promoting the current tourism industry to turn to Smart Technology to increase business efficiency, including providing opportunities for businesses and software developers both domestically and abroad to set up and operate businesses, with important measures such as an 8-year tax exemption. These Smart Economy creation processes will raise Phuket City to the level of being a center of knowledge and technology development. Ultimately, it will raise Phuket City to the level of being a center of knowledge and technology development. This will result in the city's products and services being created and developed until their quality and value increases.

Phuket's Smart Living Community focuses on enhancing the quality of life of people in Phuket. It can be divided into 3 areas: creating an application to facilitate tourism; creating a city-wide security technology system; and creating an Internet of Things (IoTs) mechanism to take care of the city's environment. In terms of building the city's security technology system, CCTV systems are planned to work with face detection solutions. Such technology will be used to monitor, monitor, and track illegal actors. In terms of water transportation, a security system has been put in place using the Vessel Tracking Management System (VTMS) and the Smart Band mechanism. The technology is a vessel tracking system to maintain water safety for tourists. As for the city's environment, there has been an initiative to apply Smart Sensors that combine IoT technology. These IoTs can monitor climate conditions, monitor seawater conditions, and detect potential environmental abnormalities, so that timely action can be taken to correct the situation.

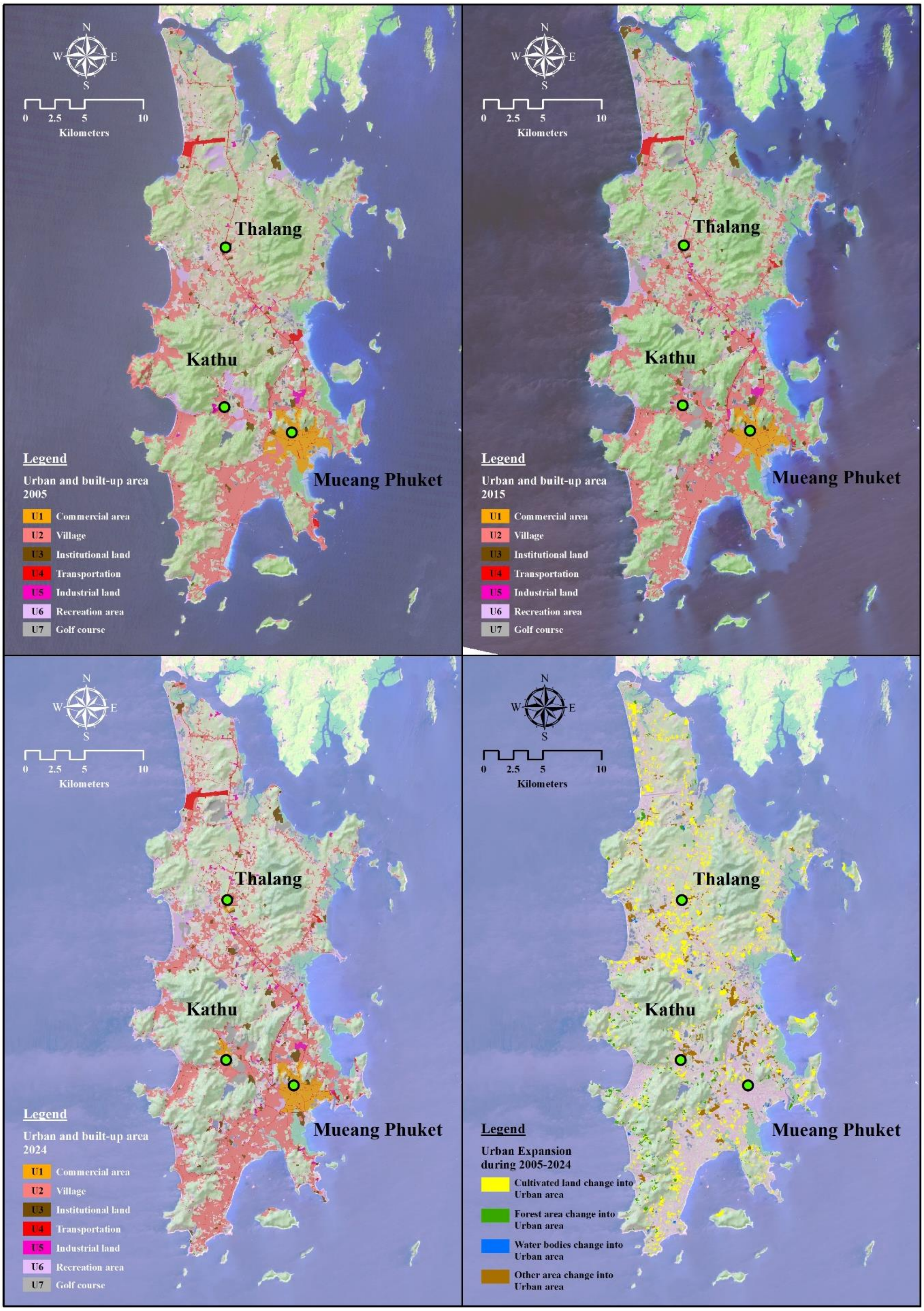

Figure 4. Urban Expansion Map of Phuket Province during 2005-2024 (Source: Collected and processed by authors)

In the future, Phuket will also promote the development of Smart Piers, the development of the City Data Platform, support and promote the application of digital technology in the tourism industry, and the Phuket Health Sandbox (Zhu and

Yasami, 2022; Siriluck Thaicharoen et al., 2023). There are also 5 other infrastructure development projects: expansion of Phuket International Airport Phase 2, expressway project (Kathu – Patong), expressway project (Muang Mai – Koh Kaew – Kathu), development of Phuket Airport No. 2 (Andaman Airport), and the mass transit system within Phuket City or Tram development project (Sirikijpanichkul et al., 2017). The project is being developed and promoted in areas with urban potential in Phuket Island to cover the entire island. This is for the well-being of local people and visitors from abroad to access and enjoy Phuket. This is considered a guideline for sustainable tourism development.

CONCLUSION

Urbanization is a result of economic growth. This process has created growth concentrated in the Mueang Phuket, Thalang, and Kathu districts. There has been an increase in migration from rural areas to cities in search of better opportunities and higher incomes. The more the economy grows, the more people migrate to cities.

Increasing urbanization requires administrators to prepare to accommodate the increasing demands and problems of urban society. Therefore, the concept of Smart City development has been introduced, which has taken advantage of modern and intelligent technology and innovation to effectively manage the city.

This is to reduce costs and reduce the use of natural resources of the city. In Phuket, there are two important projects: Smart Economy and Smart Living Community. The said project was developed in three important districts, causing the urban expansion of the three districts to occur clearly. Moreover, areas with high tourism potential such as Phuket's western coast have undergone changes in land use, becoming villages, golf courses, recreation areas, and institutional land. This land use pattern can be found along the western coast of Phuket Island, including Bang Tao Beach, Kamala Beach, Patong Beach, Karon Beach, Kata Beach, and Kata Noi Beach, respectively. In this regard, the Geo-informatic Technique process can be applied to monitor changes in land use well, so that such spatial information can be used to plan land use in line with the smart city guidelines. In particular, the Thalang district is an area with high potential for development into a new city, and supports the expansion of sustainable tourism in the future.

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