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SPATIO-TEMPORAL DEVELOPMENT OF COASTAL TOURIST CITY OVER THE LAST 50 YEARS FROM LANDSAT SATELLITE IMAGE PERSPECTIVE IN TAKUA PA DISTRICT, PHANG-NGA PROVINCE, THAILAND

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Abstract: The objective of this research was to study the land-use patterns through the Landsat satellite image perspective in order to see the spatio-temporal development of coastal tourist city in Takua Pa District, Phang-Nga Province, Thailand. The study found that there is a noticeable land-use change in the cassiterite (tin) mining area that has declined over the past 50 years, from 1973 appearing 55.82 km^2 (9.68%) until the current year 2022 without remaining, as it has been transformed into an agricultural area where rubber, palm, and coconut are planted. In addition, the mining area has become an urban area and buildings such as hotels and resorts, and a water source for shrimp farms. It can be seen that Landsat satellite imagery is very useful for land-use planning, especially in the coastal tourist city area. The results of this research can be classified as a spatial database for tourism planning in Takua Pa community by zoning into 3 areas for major tourism, Zone-1 Eco Tourism, Zone-2 Cultural Tourism, and Zone-3 High-end Tourism. This is important research data to support decision-making in regulating, monitoring, and controlling areas for further tourism business expansion in order to avoid negative impacts on the environment.

Key words: spatial assessment, built-up and recreation expansion, geo-informatic, Koh Chang Island, tourism

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INTRODUCTION

Spatial management in the coastal tourist city style is an economic activity that generates huge income for countries in the equatorial regions (Kay and Alder, 1999; Tan et al., 2018). The coastal city has a very high tourism potential because of its beautiful topography (Dvarskas, 2017; Patterson et al., 2004). The coastal region of the south west coast of Thailand has a high potential for tourism due to its diversity of natural resources, exotic landscapes, good service systems, and infrastructure that facilitates tourists holding (Gössling, 2002; Boavida-Portuga et al., 2016). It is another destination that both Thai and foreign tourists want to come and experience. One of the world-famous places is Phuket Island. With growth and bustle of Phuket Island like a city that never sleeps, as a result, Khao Lak beach, located in Takua Pa District, Phang-Nga Province, has been popular since 1994 as it is only 70 km from Phuket International Airport.

For this reason, it is important to tell from the perspective of the spatio-temporal development of coastal tourist city over the last 50 years via satellite imagery to help understand the context of the area and how it came to be for people in the community, government and private agencies understand the management of land-use planning to support the expansion of tourism business of Takua Pa District. Takua Pa District, Phang-Nga Province is one of the important cities in the south-west coast of Thailand. It covers an area of approximately 570.45 km^2. The study area is located between latitude 8°35' N to 9°5' N and longitude 98°10' E to 98°30' E (Figure 1). The topography is mostly hilly and low complexes appearing in the eastern part of the study area. The central part of Takua Pa is a sedimentary river basin of the Quaternary Period with the main river being the Takua Pa River (Feldens et al., 2022; Department of Mineral Resources, 2013). The west of the study area is a coastal plain, alternating with an undulating plain, spanning more than 70 km. And in the north, there is an estuary environment covered with mangrove forests and sediments washed by the Takua Pa River, resulting in this area being extremely fertile. There is also an important large island, Koh Kho Khao.

Takua Pa District, formerly known as “Takola”, is part of the Suvarnadwipa region (Ghosh, 2019). Takola is a Sinhalese word for cardamon fruit, which is an important spice product of the city that developed into a port since 500 BC (Srichampa, 2015; Ghosh, 2019). Takola is an ancient city of great historical significance. In 1890, Takola transformed from a spice trading port to a large mineral trading center, especially cassiterite which was an important raw material for the industrial manufacturing sector of the time **(**Gardiner et al., 2015**)**. The years 1935-1942 were the era of the cassiterite exploitation (Kongkeaw et al., 2019; Boonwanno et al., 2022). The tin mining activities were carried out day and night until it became a sleepless mining community like the Khuek Khak community, which means "energetic, upbeat" because all

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cassiterites were found anywhere near the town of Takola, such as Talat Yai or Big Market. It is an important historical evidence of prosperity and was a major exchange center of the south west coast in those days. But at present, tin mining has ceased to exist, forcing Takua Pa District to shift its status from tin mining and trading town to another form for the survival of the community. Therefore, nowadays it has become an important tourist city in the southern part of Thailand. Geo-informatics technology needs to be applied in this research to track land-use change patterns in order to create a database for systematic and methodical land-use planning that can tell about the past in 50 years ago, through satellite imagery of Landsat and tourism areas zoning in various ways to accommodate tourists in order to maintain the style of coastal tourist city maintaining the identity of the local community together with the development of sustainable modern tourist attractions in the future (Waridin and Astawa, 2021; Hadmoko et al., 2021; Waiyasusri et al., 2021).

The purpose of this research was to study land-use patterns in Takua Pa District, Phang-Nga Province from 1973 to 2022, and to study land-use changes to reveal spatio-temporal development of coastal tourist city over the last 50 years from Landsat satellite image perspective for information in decision making in setting the direction of spatial management to support the expansion of sustainable tourism in the future.

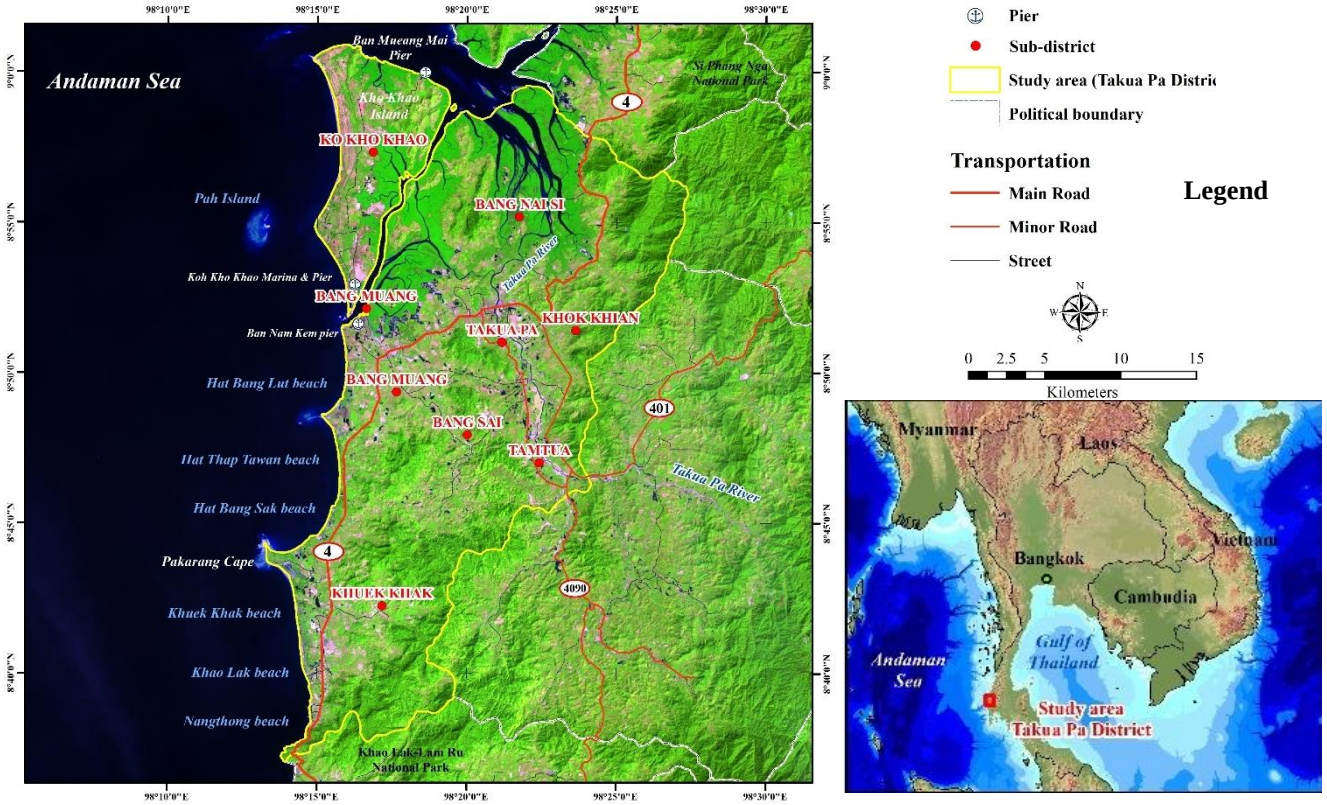

Figure 1. Location of Takua Pa District, Phang-Nga Province, Thailand (Source: collected and processed by authors)

MATERIALS AND METHODS

In the study of land-use patterns and land-use changes, data were gathered; analyzed; and showed in the results of the research systematically as follows:

1. Collect spatial data and attribute data from relevant agencies and grant permission to publish as follows:

Table 1. Satellite Image Data and Land-use data over the Takua Pa District for Analysis

Database	Acquisition date	Format	Sources
Landsat-1 MSS Image Path 130 Row 054	2 March 1973	Image File	https://earthexplorer.usgs.gov/
Landsat-5 TM Image Path 130 Row 054	17 January 1994	Image File	https://earthexplorer.usgs.gov/
Landsat-5 TM Image Path 130 Row 054	27 November 2004	Image File	https://earthexplorer.usgs.gov/
Landsat-8 OLI/TIRS Image Path 130 Row 054	24 January 2014	Image File	https://earthexplorer.usgs.gov/
Landsat-9 OLI/TIRS Image Path 130 Row 054	6 January 2022	Image File	https://earthexplorer.usgs.gov/

2. Import satellite image data including Landsat-1 (MSS system), Landsat-5 (TM system), Landsat-8 (OLI/TIRS system) and Landsat-9 (OLI/TIRS system) at each time interval, using the satellite image manipulation program Erdas Imagine Version 8.5, the satellite imagery bands were mixed by selecting the band: 5 (short-wavelength infrared), 4 (near-infrared), and 3 (red) for Landsat TM (Abuzar et al., 2020). Landsat OLI/TIRS uses band 6 (short-wavelength infrared), 5 (near-infrared), and 4 (red) (Barsi et al., 2014; Li et al., 2014; Lulla et al., 2021). And, Landsat MSS uses the following band combinations: Band 3 (near-infrared), 2 (red), and 1 (green) (Maul and Gordon, 1975; Wang et al., 2017).

3. Interpret satellite image data for land-use classification in 1973, 1994, 2004, 2014 and 2022 using image processing interpreting the land-use model with supervised classification (Everitt et al., 2010; Parida and Kumar; 2020). Results from the

interpretation of the land-use model are presented as Overall Accuracy and Kappa coefficient (KHAT) to assess the validity of the various data classifications that appear on the satellite imagery. Specifying a sample points to validate after land interpretation based on data from the Land Development Department of Thailand, additionally using random sampling method by selecting a sample point of land-use, each 30 locations for a total of 180 locations. Validation is performed to compare with the data obtained from the classification. The classification criteria are as follows (Jensen and Kiefer, 2007; Poursanidis et al., 2015):

< 0 means unacceptable classification data
0.01 – 0.40 means fair classification data
0.41 – 0.60 means moderate classification data
0.61 – 0.80 means good classification data
0.81 – 1.00 means very good classification data

4. Create data on the acquired land-use model as a database in the geographic information system and check for spatial errors by using the geographic information system program that displays the data at each time interval to check the land-use change for each period as shown in the equation (Jia et al., 2014).

$\Delta = [(A2 - A1) / A1 \times 100] / (T2 - T1)$

where Δ is the change in land utilization ratio (percent)
A1 is type of land-use at the first time (T1)
A2 is type of land-use at the second time (T2)

The results are shown as the proportion of each type of land-use on the map. It shows the land-use change pattern from 1973 to 2022, along with the Change Detection table from the Tabulate area analysis in ArcMap 10.3.

5. Randomly examine the data from the real area to verify the accuracy of the data interpreted from the satellite images, including land-use characteristics; factors and effects of land-use changes, asking for explanatory information from people in the area, etc.

6. Create land-use model area data as a geographic information database and check spatial data and attribute data errors, using ArcMap 10.3 geographic information system program to track land-use changes, and store it as a spatial database for agencies to solve problems and plan appropriate tourism land-use.

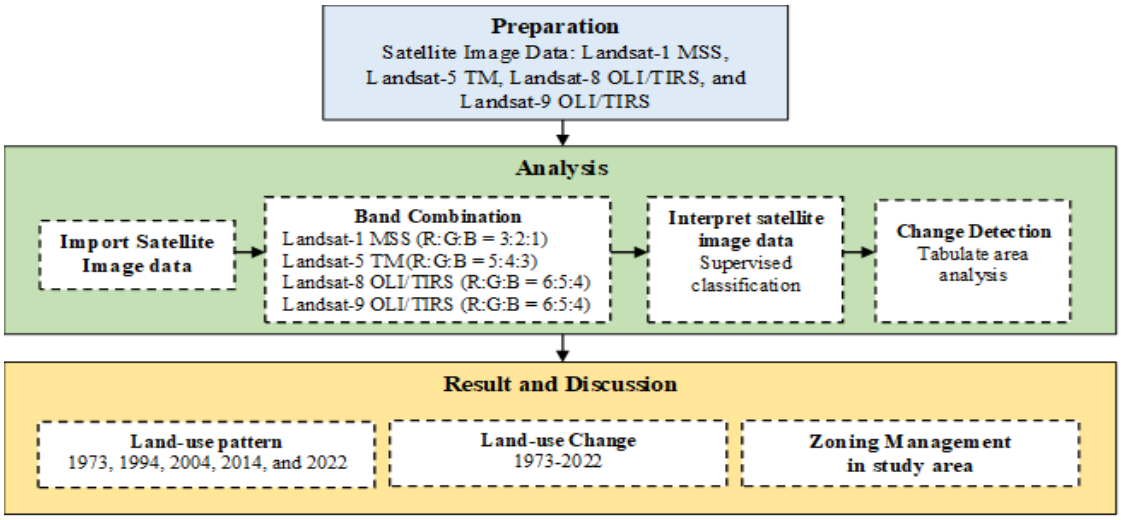

Figure 2. Flowchart of Methodology

Table 2. Land-use pattern of 1973, 1994, 2004, 2014, and 2022 in Takua Pa District, Phang-Nga Province, derived from Supervised classification showing overall accuracy and Kappa coefficient

Land-use pattern	1973		1994		2004		2014		2022	
	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%
Agricultural land	229.46	39.78	70.58	12.24	157.16	27.25	121.44	21.06	216.73	37.58
Beach	2.91	0.50	4.27	0.74	14.35	2.49	2.66	0.46	0.63	0.11
Forest land	278.18	48.23	465.74	80.75	343.3	59.52	384.66	66.69	292.45	50.71
Mine area	55.82	9.68	14.18	2.46	5.14	0.89	0	0.00	0	0.00
Urban and built-up land	8.19	1.42	8.9	1.54	31.03	5.38	39.88	6.91	35.25	6.11
Waterbodies	2.2	0.38	13.09	2.27	25.78	4.47	28.12	4.88	31.7	5.50
Total	576.76	100.00	576.76	100.00	576.76	100.00	576.76	100.00	576.76	100.00
Overall Accuracy (%)	75.30		76.80		81.70		84.20		87.60	
Kappa coefficient (KHAT)	0.65		0.73		0.76		0.79		0.82	

RESULTS AND DISCUSSION

Takua Pa district has been designated as a major tourist destination in the southern Thailand's west coast as a coastal tourist city, but the study area has not been zoning with the status of a coastal tourist city. In this research, the Landsat satellite image has been applied to study land-use patterns in order to understand land-use conditions from the past to the present. The satellite images were processed for each time period of 1973, 1994, 2004, 2014, and 2022 using a Supervised classification method.

The results of the research revealed that the results from the interpretation of the land-use model have overall accuracy as shown in Table 2 as follows: 75.30%, 76.80%, 81.70, 84.20 and 87.60%, respectively. The criteria for classification of land-use data are in good to very good. Kappa coefficient (KHAT), which is a coincidence of 2 sets of data, from the interpretation of the land-use model, it was found that the KHAT values were as follows: 0.65, 0.73, 0.76, 0.79 and 0.82, respectively, with good to very good criteria, and the land-use pattern for each period is shown in Figure 3 and Figure 4 as follows:

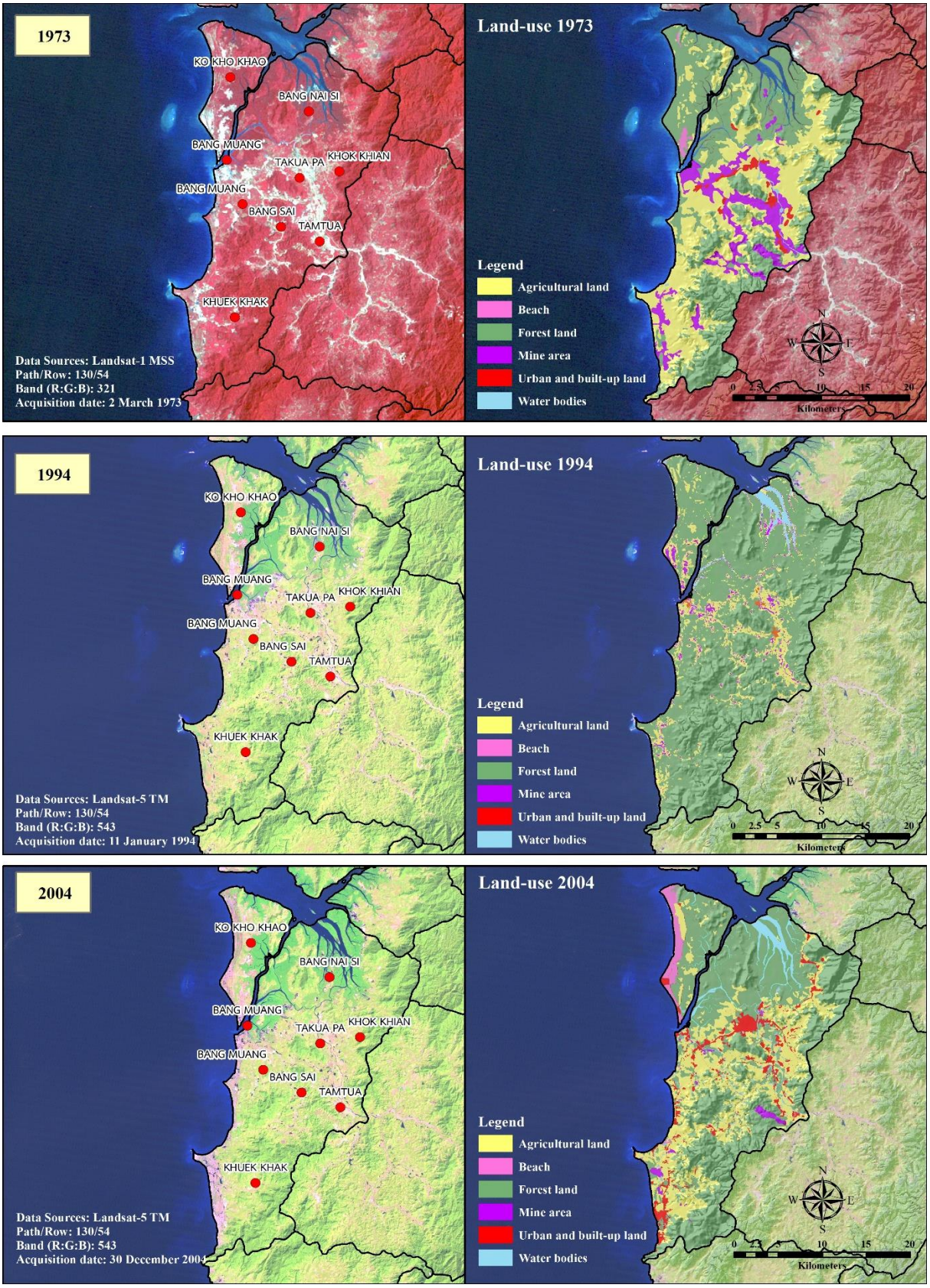

Figure 3. Land-use pattern map in 1973, 1994, and 2004 in Takua Pa District, Phang-Nga Province, Thailand
(Source: collected and processed by authors)

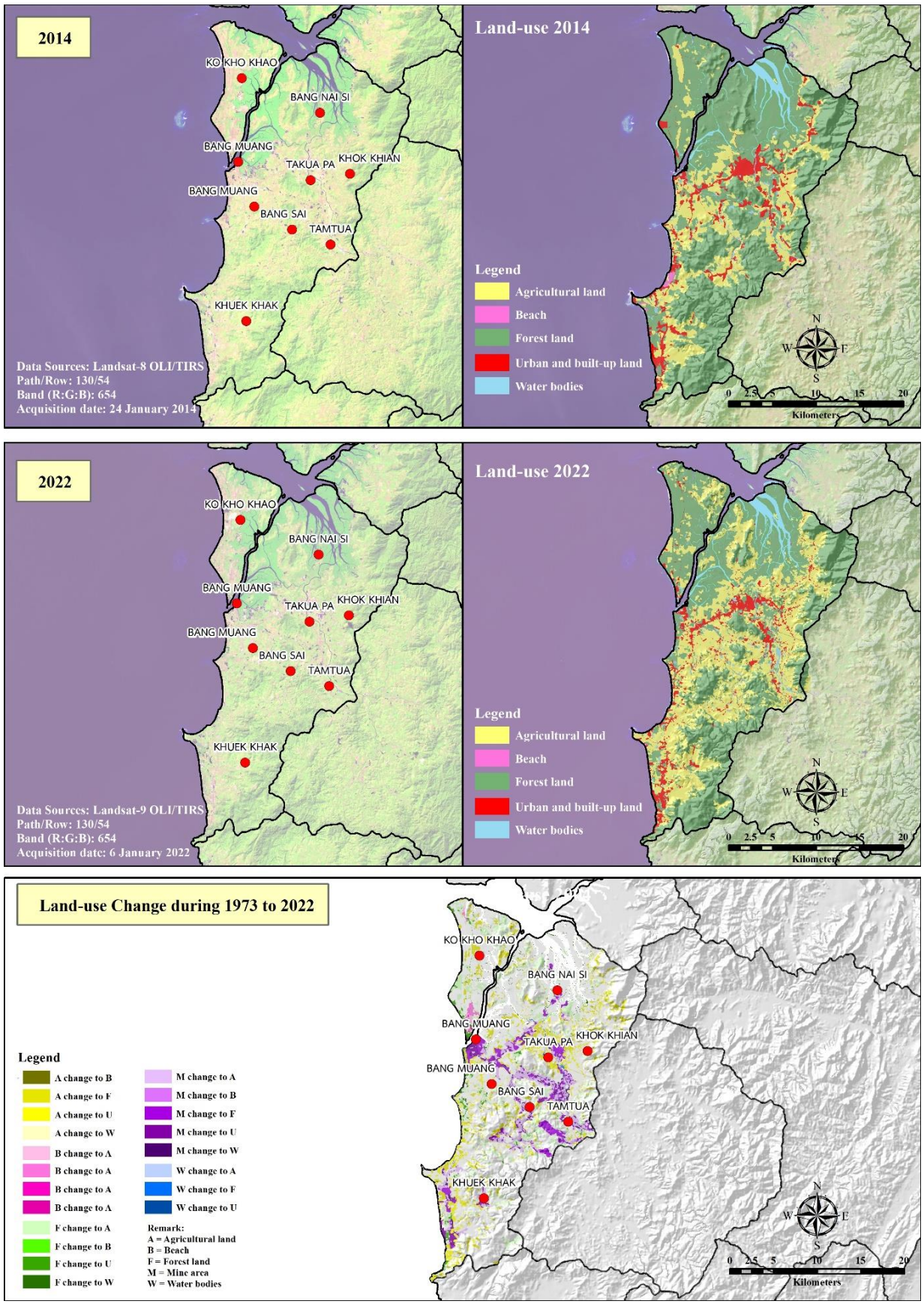

Figure 4. Land-use pattern map in 2014 and 2022. And Land-use Change Map during 1973-2022 in Takua Pa District, Phang-Nga Province, Thailand (Source: collected and processed by authors)

Interpretation of Landsat satellite images over the five time periods (1973, 1994, 2004, 2014, and 2022) shows the amount of land-use area that appeared over the period 1973-2022 (Table 2). The results showed that most of Takua Pa District was covered by forest, about half of the area. Most are tropical rain forest, mangrove swamp forest and beach

forest. Tropical rain forest covers the eastern part of the study area. Mangrove forests cover the estuary of the Takua Pa River in the northern part of the study area and east of Kho Khao island. The beach forest covers a small area in the western part of Kho Khao Island and the coastal area around Cape Pakarang. The agricultural land area is the secondary area that covers the study area, covering an area of approximately 25% of Takua Pa District. Most of the area is perennial crops and orchards such as rubber, oil palm, cashew, and coconut, which are the main cash crops of the study area. In addition, areas that have seen significant changes in Landsat satellite image processing over the past 50 years are land-use in the mine area, and urban and built-up land. Mine area in 1973 appeared 55.82 km^2 (9.68%) of the total study area, the trend has been decreasing over the past 50 years until now with no such area left.

Most of the mining areas that used to exist half a century ago were tin mines. Urban and built-up land-use tends to increase as shown in Table 2. In 1973, the area of urban and built-up land was only 8.19 km^2 (1.42 %). At present, in 2022, the aforementioned land-use reaches 35.25 km^2 (6.11%), most of which are community areas, hotels, resorts and government offices that are expanding to support tourism in the southern western region of Thailand. The results of this study are based on tracking land-use change patterns with Landsat over the past 50 years, since the application of Landsat-1 MSS, Landsat-5 TM, Landsat-8 OLI/TIRS. The development of the Landsat-9 OLI/TIRS satellite was launched on September 27, 2021 at 1:12PM CST from Vandenberg Air Force Base, California, under the direction of US Geological Survey (Lulla et al., 2021). This research therefore uses this satellite data to study land-use change in Takua Pa district. The study found that land-use change from 1973 to 2022, together with the change detection table obtained from the tabulate area analysis, is shown as spatial data to show the clarity of the transition of the area during that period (Figure 3B and Table 3). At present, the land-use of mine area has been changed until there is no more left. Land-use in urban and built-up land has an increase of 3.16.3%, and water sources have an increase in land-use 480.09%.

Table 3. Transition Matrix of land-use changes in in Takua Pa District, Phang-Nga Province, 1973–2022 (km^2)

Land-use change		2022					Change (%)
		Agricultural land	Beach	Forest land	Urban and built-up land	Waterbodies	
1973	Agricultural land	140.54	0.12	45.16	17.91	2.45	4.66
	Beach	0.88	0.02	1.61	0.34	0.06	-91.75
	Forest land	44.22	0.08	224.96	3.70	4.00	4.50
	Mine area	26.90	0.02	16.68	7.79	4.59	-100.00
	Urban and built-up land	2.58	0.00	0.72	4.64	0.34	316.30
	Waterbodies	0.67	0.00	0.31	0.09	1.09	480.09

Figure 4 (Figure below) in the period 1973–2022 shows a significant change in the mine area on the banks of the Takua Pa River in 1973, Tamtua, Takua Pa, Bang Muang and the coastal area of Khuek Khak sub-district. The Mine area was transformed into an agricultural area of up to 26.90 km^2 becoming forest land, urban and built-up land, and water bodies of 16.68 km^2, 7.79 km^2, 4.59 km^2 respectively. It can be seen that the proportion of the mine area being replaced is because the mines were shut down, as tin ore was mined in declining quantities, and the valuation of tin began to decline in the global market demand, and iron ore was increasingly used in industrial sectors as a replacement for tin. In addition, the government's policy directly affected the reduction of the tin mining area. The 4th National Economic and Social Development Plan (1977-1982) was the beginning of the transformation from a tin mining industry to a tourist city. The government has used the potential of the coastal areas and the Andaman Triangle provinces (Phuket, Phang Nga, Krabi) to link the development strategy of world-class tourism together with the conservation of marine attractions, resulting in a change in land use from mining areas to agricultural and tourist areas.

The condition of the study area shows mining traces of the dredged wells become mostly water bodies, appearing on both banks of the Takua Pa River and the coastal area near Khao Lak in Khuek Khak sub-district, which is now a resting place and Resorts. In addition, traces of a large ancient ore suction ship can be found at Ban Nam Kem pier (Figure 5A), which works like a large vacuum cleaner sucking minerals and sand on board, then filtering and separating tin, considered very modern 20-30 years ago. Traces of injected mining were found in the land, by spraying the soil with tin to collapse, thus appearing clay pits and wells in the present. However, due to environmental pollution and changing tin demand, the mining activity was canceled in 1993, thus transforming the mining area from being sold to resort hotels, palm and rubber plantations; various garden plants; and shrimp ponds widely in the area. Coastal tourist city of Takua Pa district that still maintains the identity of the local community can define zoning for tourism into 3 important areas: Zone-1 Eco Tourism, Zone-2 Cultural Tourism, and Zone-3 High-end Tourism, based on zoning classification criteria (Kay and Alder, 1999) (Figure 5) as follows:

Zone-1 Eco Tourism is the northern area of Takua Pa District. Due to the nature of the area which is mostly evergreen forest and mangrove forest, it makes biodiversity. Ecotourism is suitable for the northern area of Takua Pa, studying the mangrove nature path can be seen from the boat tour Sang Ne Canal community. It is a famous place for biodiversity of Takua Pa District, called The Little Amazon. This place has a hundred-year-old Banyan forest for tourists to canoe into the Sangne canal (Figure 5B). There is also a mangrove study trail in Kho Khao island and a walking trail in the savannah forest which is a beach forest, mangrove forest, swamp forest, grasslands, shrubs, alternative social plants, and rare orchids. Kho Khao island has a flat terrain formed by the deposition process of ancient tsunamis to become a bio-diverse sandy sediment island, becoming an eco-tourism destination community today. There is also important archaeological sites as the Khao Phra Noe Archaeological Site and the Thung Tuk Archaeological Site, both areas were the source of ancient civilization in the Dvaravati period 2500 years ago.

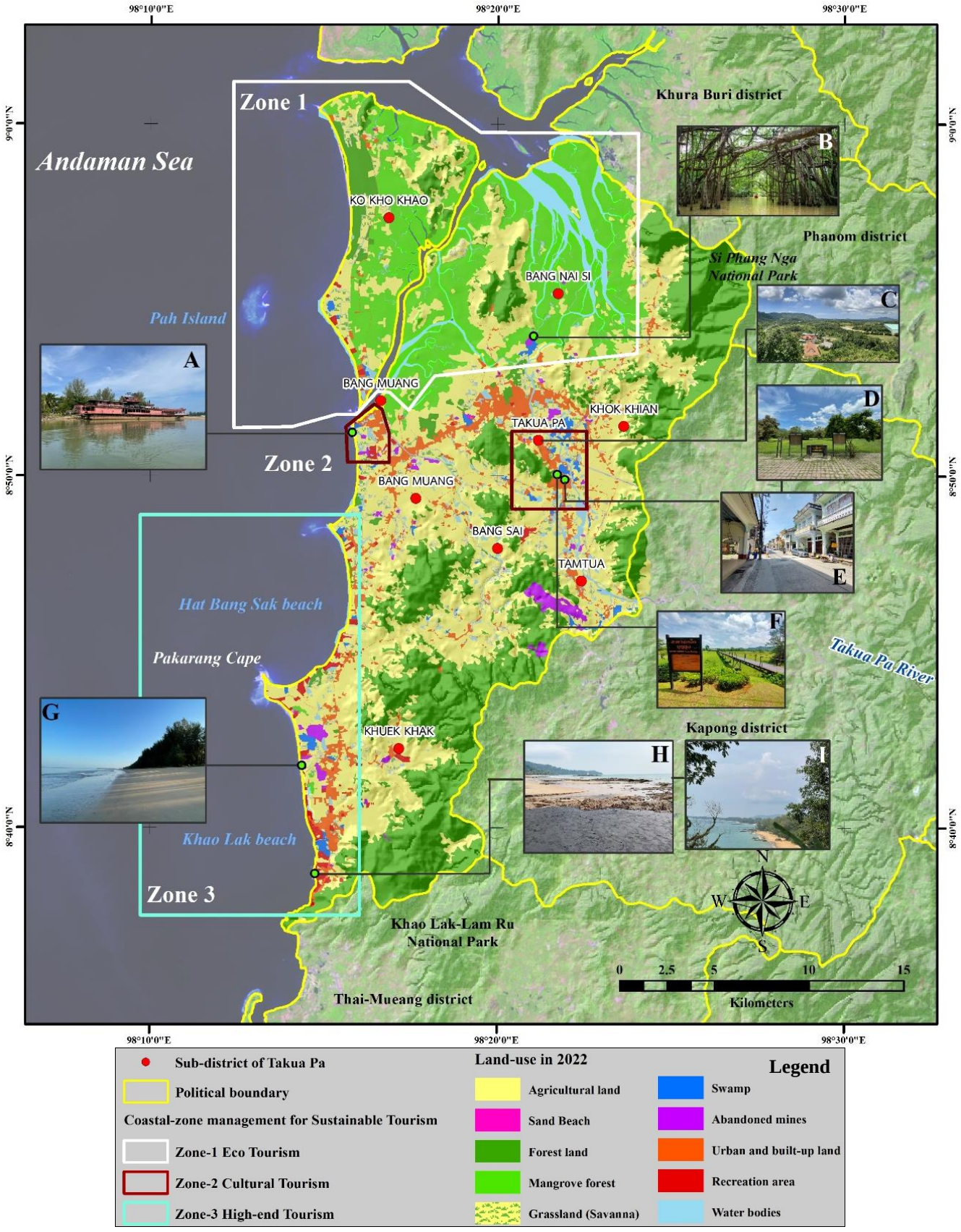

Figure 5. Zoning map for Takua Pa coastal tourist city spatial management planning (Source: collected and processed by authors). (A) Ore suction ship in Ban Nam Kem pier, (B) Sangne canal, (C) Takua Pa river, (D) Takala Old Town Wall, (E) Takala Old Town, (F) Boonsoong Iron Bridge, (G) Khuek Khak beach, (H) Nangthong beach, and (I) Khao Lak beach (Photo source: field survey, April 2022)

Zone-2 Cultural Tourism has two important areas: The Big Market and Ban Nam Kem, both areas have important highlights. The Big Market area, which is the site of the ancient Takola community, is located on the left bank of the Takua Pa River (Figure 5C). It is an ancient community developed from Chinese merchants in Takua Pa who came to trade, and

was an important source of tin mining since King Rama V era. There are many important places in this area, such as Takala Old Town Wall (Figure 5D), Sri Takua Pa road, which is a road in the middle of the big market community. It is the center of the community with the architecture of Sino-Portuguese buildings. There is also Tao Ming School, the first Chinese language school in Takua Pa District, and Guan Yu Shrine, a place of worship and the spiritual anchor of the Takua Pa community (Figure 5E). In addition, traces of tin mining from 30 years ago were also found, such as Boonsoong Iron Bridge (Figure 5F). Ban Nam Khem is an old community along the southern coast and is an important fishing community of Takua Pa. Ban Nam Khem Tsunami Memorial Center is also a place of remembrance and mourning for the great loss of the 2004 tsunami, and Ban Nam Khem pier is also an important port that can travel to Mu Ko Surin Marine National Park as well.

Zone-3 High-end Tourism is a regional zone in the southern part of Takua Pa District. The area has been developed from the former tin mining area into a world-famous recreational facility, Khao Lak. The area is home to many high-end hotels along the lines of Nangthong beach, Khao Lak beach, Khuek Khak beach, Hat Bang Sak beach, and Hat Thap Tawan beach (Figure 5G). These 5 beaches are very picturesque, especially Nangthong beach (Figure 5H) and Khao Lak beach (Figure 5I) which are very romantic as they have white beaches that are perfect for relaxing and watching the sunset all year round. And there are also fresh seafood restaurants spread widely along this coastline. In addition, Takua Pa District has an economic system that still has a very affordable cost of living, so it is popular with both Thai and foreign tourists.

Takua Pa District is also a place with high tourism potential. With Landsat satellite image processing techniques over the past 50 years, it presents the context of land-use change and past history by providing spatial data for tourism planning to support future visitor traffic. Organizing important tourism zoning for the Takua Pa community is to understand and realize the economic system that is changing from mining activities to become a world-renowned tourist city. In line with the principles of the United Nations Sustainable Development Goals (SDGs), in particular Goal 14, it addresses to conserve marine resources for sustainable development (Rees et al., 2018), scoped to sustainably handle with coastal ecosystems for the resilience restoration, to prepare for future changes of coastal tourist city as Takua Pa district that should have spatial evolution in conjunction with the conservation of coastal environments. This is for the government, the private sector and people in the Takua Pa community to participate in the management of the area to support tourism, especially the management of land-use in a systematic and orderly manner in the use of recreational areas. The land-use should be monitored to prevent expansion beyond its capacity to the extent that it may affect natural resources and coastal tourist city areas in order to maintain sustainable marine tourism in the future.

CONCLUSION

Over the past 50 years in Takua Pa District, there has been a huge change in land-use patterns. By tracking changes based on high-performance Landsat satellite imagery, land cover data can be extracted and analyzed to obtain land-use data to solve problems and plan land-use in Takua Pa District. Such spatial data can be used for effective tourism planning management and can be used to organize zoning to plan tourism in various ways in accordance with land-use. This is to allow the government, private sector and local communities to participate with each other in conserving the resources of the Takua Pa District area. Natural resources such as moist evergreen forests, mangrove forests, beach forests or estuary water bodies appearing in the Takua Pa River, in the north of the study area and east of the biodiverse Kho Khao islands, and man-made resources, whether it is the ancient community in Khao Phra Noe Archaeological Site and Thung Tuk Archaeological Site which is an ancient city over 2500 years old, Talad Yai community in the center of Takua Pa district with Sino-Portuguese architecture, and a memorial sites for the 2004 Tsunami. For this reason, Takua Pa or Takola has a long history of thousands of years. Participation in preserving local resources should be managed in land-use planning to be effective and consistent with the livelihood of people in the community supporting tourists to generate concrete income for the community with clear spatial goals for better actions in the future, in order to comply with the principles of the United Nations Sustainable Development Goals (SDGs) and to maintain tourism attractions in the future.

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