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Urban Morphology and Development of Mae Hong Son Old City: A Geospatial Analysis for Sustainable Heritage Conservation

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Abstract

This study investigates the urban morphology and development of Mae Hong Son's old city through geospatial analysis to support sustainable heritage conservation. It focuses on spatiotemporal changes in urban expansion by utilizing aerial photographs, high-resolution satellite imagery, and geospatial techniques including Change Detection and Kernel Density Estimation (KDE), to analyze the city's development patterns from 1971 to 2023. The results indicate that the built-up area increased significantly from 0.47 km² in 1971 to 9.71 km² in 2023, while the number of buildings grew from 2,855 to 11,948 during the same period. These findings reveal significant physical transformations, primarily driven by economic growth and increased settlement in the early 20th century. Urban growth predominantly occurred in the northern part of the city, constrained by surrounding mountains and rivers. Despite modern urban development, Mae Hong Son has retained its unique identity through a combination of traditional wooden structures and contemporary architecture. The findings emphasize the need to balance modern urban expansion with the preservation of cultural heritage and offer insights for sustainable conservation planning in historic cities and it contributes to understand the historical urban dynamics of Mae Hong Son's old city and provides recommendations for sustainable heritage conservation planning.

1. Introduction

The study of old cities has become increasingly important as these areas are characterized by unique local features, encompassing architecture, social structures, lifestyles, and historical and cultural elements. These factors have shaped old communities into historically and culturally significant places, evident in their distinctive urban landscapes that persist to the present day. However, the expansion of urban areas to accommodate population growth and economic activities has led to changes and sprawl of old city centers into peripheral areas. This has raised concerns about the potential impact on the cultural heritage of these communities. Thus, the study of urban morphology and the historical development of cities is critical to understanding changes in urban areas in terms of physical, economic, and social dimensions. Moreover, these changes reflect the interaction between local communities and external influences, such as economic development, transportation, and tourism policies. UNESCO (2011) emphasizes the importance of conserving historic cities through effective management and development strategies that maintain the unique identity of these urban areas.

Mae Hong Son is recognized as a historic city under the `Prime Minister's Office Regulation on Rattanakosin and Old Towns (2021) by the Office of Natural Resources and Environmental Policy and Planning (ONEP). Mae Hong Son has a long history, evolving from a trading outpost along the Mae Hong Son River to its current status as a significant urban center. Its heritage includes tangible and intangible elements such as ancient monuments, architectural styles, artistic works, traditional lifestyles, and cultural practices.

This research explores the development and transformation of Mae Hong Son through historical documents, field surveys, and spatial analysis using Kernel Density Estimation within a Geographic Information System (GIS). The aim is to gain a deeper understanding of the city's urban development and the cultural and social dimensions associated with these changes. The findings will contribute to recommendations for sustainable conservation and development of Mae Hong Son as a historic city, ensuring its cultural identity is preserved for future generations.

The importance of studying historical cities and urban morphology lies in the preservation of culture and history, particularly in maintaining local identity, which is often affected by urban and economic development. Research such as Urban Morphology and Conservation in China (Whitehand et al., 2011) (Xie et al., 2020) and Urban Morphology and Historical Urban Landscape Conservation and Management (Zhang & Li, 2022) highlights the critical role of urban morphology in managing historical urban areas through sustainable development strategies. Similarly, studies like Urban Morphological Analysis Framework for Conservation Planning and Management (Mohamed et al., 2018) emphasize the importance of using urban morphology as a tool for conservation planning and management. Spatial analysis techniques are widely applied in urban morphology studies to analyze urban forms. Examples include Urban Build-Up Building Change Detection Using Morphology Based on GIS (Moe & Sein, 2016) and Urban Road Change Detection Using Morphological Processing (Win, 2021), which employ change detection techniques to study urban morphological changes. Other research utilizes Kernel Density Estimation to analyze the distribution and transformation of urban structures and economic activities, as seen in studies by Zehul et al. (2021), and King et al. (2015). These techniques have been extensively used to study urban morphology across various regions.

Understanding urban morphology contributes to contextual insights into the development of historical cities, ultimately leading to urban conservation (Whitehand, 2015). For instance, studies on the conservation of Kiruna, Sweden (Jennie & Erik, 2020), and the preservation of urban and architectural heritage (Umar et al., 2019) demonstrate the interplay between different factors and urban development impacts on historical areas. This review underscores the need for urban morphological studies that balance economic growth with cultural heritage preservation. It provides a foundation for investigating the urban morphology and development of Mae Hong Son to achieve a harmonious balance between economic development and the preservation of cultural identity.

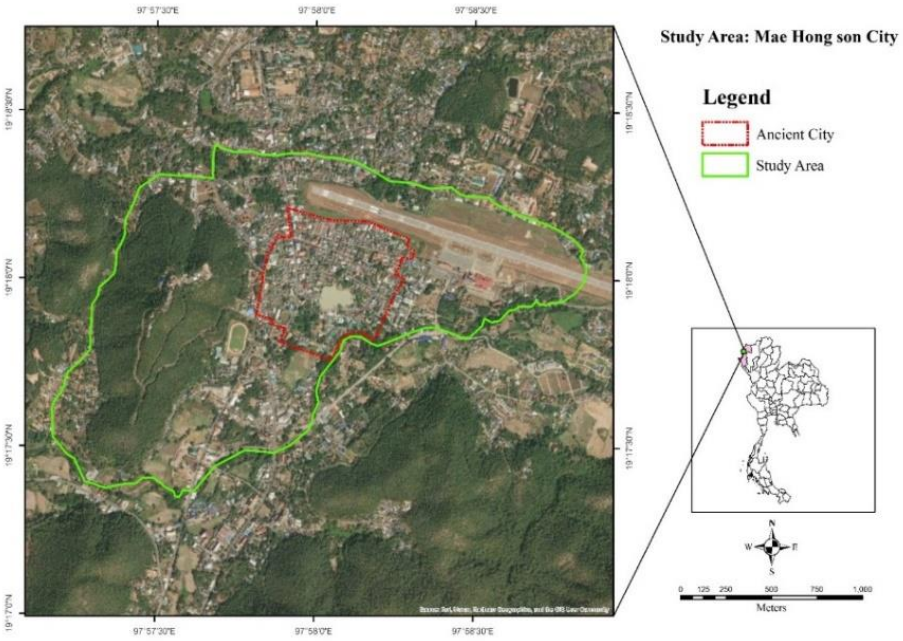
2. Data and Methods

2.1. Study Area

Mae Hong Son (Figure 1), a province in the northern of Thailand, is notable for its unique geographical features, cultural diversity, and multi-ethnic population. Mae Hong Son's old city is situated along the Mae Hong Son River, covering an area of approximately 6 square kilometers at an elevation of 250–400 meters above sea level. The city is located within a mountainous basin, flanked by two streams: the Mae Hong Son River to the south and the Bu Stream to the north. These streams converge at Ban Sop Pong before merging with the Pai River.

Historically, the original city was oval-shaped and relatively compact, with initial settlements covering an area of about 0.4 square kilometers near the riverbank. Over time, the community expanded along roadways, resulting in urban growth. Nong Chong Kham, a central feature of the area, is located to the south of the early settlement. The city's diameter extended to about 1 kilometer, encompassing an area of approximately 1.5 square kilometers. Evidence indicates that the city's ancient moat was completed in 1885 (BE 2428). However, remnants

of the moat no longer exist today, with some sections transformed into drainage channels. This historical and geographical context underscores the significance of Mae Hong Son's old city as a cultural and historical landmark.



Source: Author, 2025

Figure 1. Study Area: The Ancient City of Mae Hong Son

2.2. Data and Methodology

In this study, the researchers utilized aerial photographs and high-resolution satellite imagery from 1971 to 2023 within the WGS 1984 UTM Zone 47Q coordinate system. The data included black-and-white aerial photographs at a scale of 1:15,000 from the Royal Thai Survey Department in 1971 and 1984, color aerial photographs at a scale of 1:25,000 from the Ministry of Agriculture and Cooperatives in 2002, and high-resolution QuickBird satellite imagery from 2023. The selection of the time period was based on the availability of aerial photographic data and the major urban development periods of Mae Hong Son, with 1971 being the pre-urban expansion period prior to major infrastructure development in 1984, reflecting initial growth influenced by road expansion, 2002 corresponding to significant urban expansion under regional tourism initiatives, and 2023 being the latest development period for comparative analysis. The digitization process was performed to extract building structures and road networks from these images. These data were then analyzed to study the distribution and density patterns of built-up areas using Change Detection Techniques (Lu et al., 2004; Coppin et al., 2004) and Kernel Density Analysis. These methods were employed to examine the spatial patterns and expansion dynamics of urban development over time.

2.3. Change Detection and Kernel Density Estimation

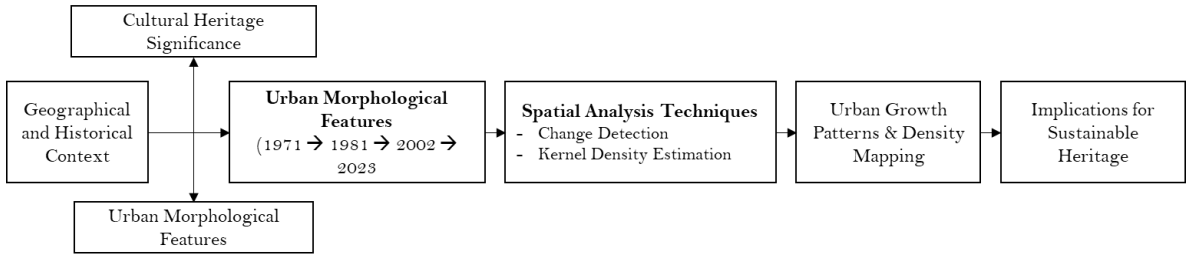
Change Detection is a process used to identify changes in data by comparing two distinct time periods. It is commonly applied in the context of satellite imagery or spatial data to analyze changes in landscapes, environments, or infrastructure (Picard, 1985; Ghaderpour & Vujadinovic, 2020). A widely used technique in this process is Classification Comparison, which involves comparing the classification results of imagery from two different time periods (Mas, 1999).

Kernel Density Estimation (KDE) is a method for analyzing point pattern distributions, falling under the principles of quantitative geographic analysis (Maurizio et al., 2007). It is a non-parametric statistical technique used to estimate the Probability Density Function (PDF) of a random variable. The method aims to approximate

the PDF of a dataset based on existing sample data. Spatial data points are analyzed using Geographic Information Systems (GIS), and the results are typically presented as a raster grid. KDE was chosen over other spatial density methods (e.g., Ripley's K-function or spatial autocorrelation indices like Moran's I) due to its ability to produce continuous surface density maps that visually represent urban intensity. KDE is particularly effective for identifying urban cores, expansion zones, and development hotspots (Figure 2). Its flexibility in setting bandwidth and kernel function makes it suitable for analyzing urban forms in compact, topographically constrained cities. The principle of KDE involves calculating the radius for each data point and connecting it with other points using a specified bandwidth to determine density. This approach can improve the accuracy of predictive models. The density function (Equation 1) is expressed as follows (Hastie et al, 2001):

$$\hat{f}(x) = \frac{1}{nh}\sum_{i=1}^{n} K\left(\frac{x - x_i}{h}\right) \ldots\ldots\ldots\ldots\ldots (Equation.1)$$

where: $\hat{f}(x)$ – the density of data at position x, n – number of samples, h– bandwidth, K – kernel function, x_i – sample data values



Source: Author, 2025

Figure 2. Conceptual Framework

3. Result and Discussion

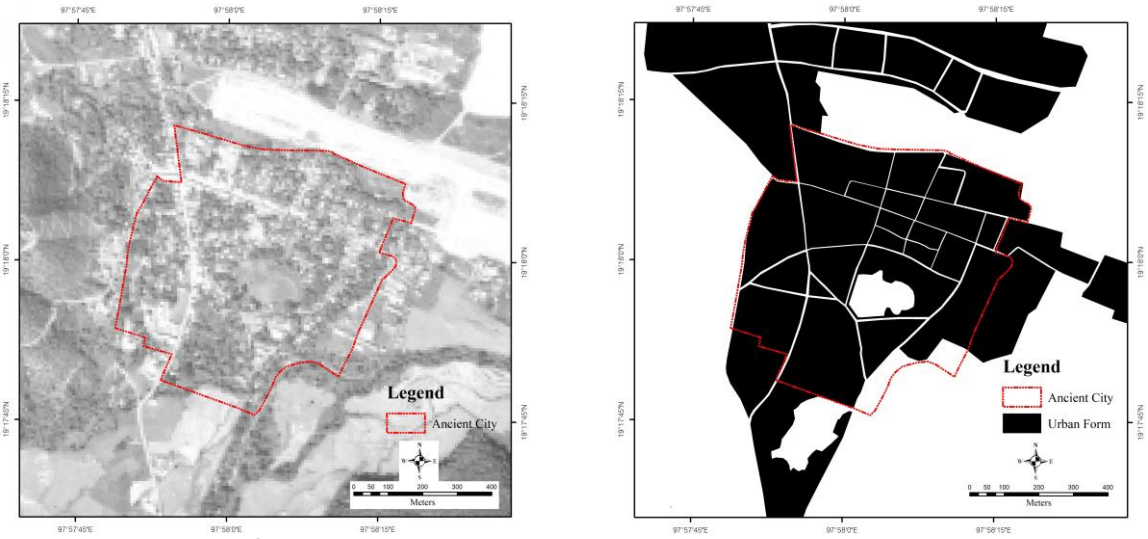
The study revealed that, based on historical aerial photographs and current satellite imagery, the city of Mae Hong Son has undergone urban expansion over time (Figure 3). The city has grown outward from its original center, which historically served as a trading hub for travelers. This area has since transformed into a residential zone, while still maintaining its historical significance. It continues to reflect the multicultural interactions of settlers, particularly the Tai Yai (Shan) community, who have preserved the city's history, architecture, and landscape. These characteristics provide a foundation for promoting cultural tourism in the region. Key historical sites include Sai Yut Market, the Old Market (Pok Kad Kao), the City Pillar Shrine, and Nong Chong Kham. These landmarks highlight the city's rich cultural heritage and its potential for sustainable tourism development.

1971 **1981** **2002** **2023**

Source: Author, 2025

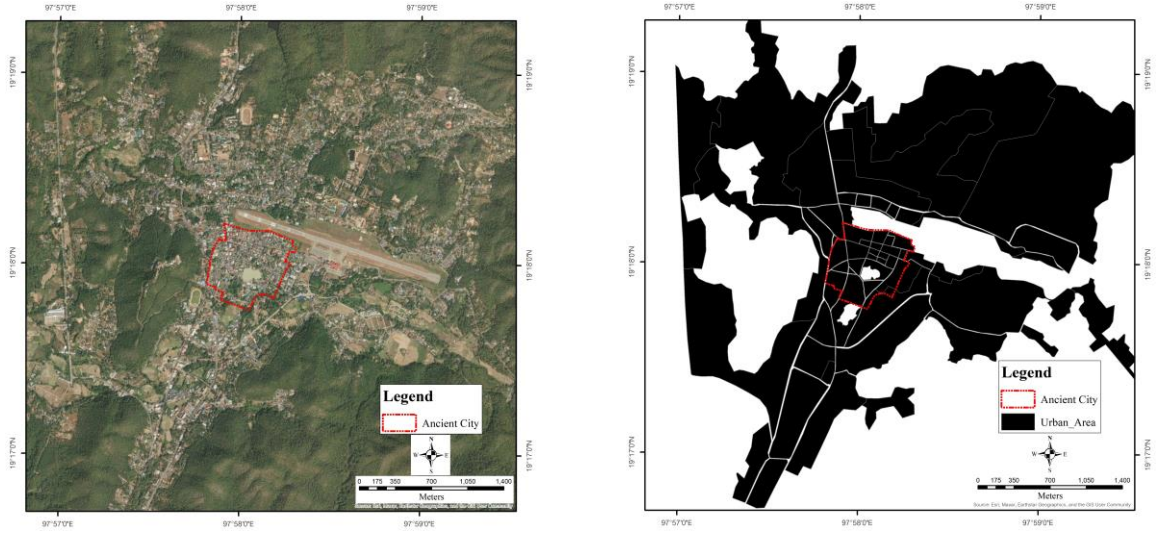
Figure 3. Aerial Photographs and High-Resolution Satellite Imagery from 1971 to 2023

When examining the urban morphology, it was observed that between 1971 (Figure 4) and the present (Figure 5), the city has significantly expanded outward from its original center (Table 1). The most notable growth occurred in the northern area near the airfield, due to the flat terrain located within a valley. In contrast, expansion in other directions has been limited by natural barriers such as mountains and rivers, which have constrained urban development in those areas.



Source: Author, 2025

Figure 4. Aerial Photograph and Urban Morphology of Mae Hong Son City in 1971



Source: Author, 2025

Figure 5. Aerial Photograph and Urban Morphology of Mae Hong Son City in 2023

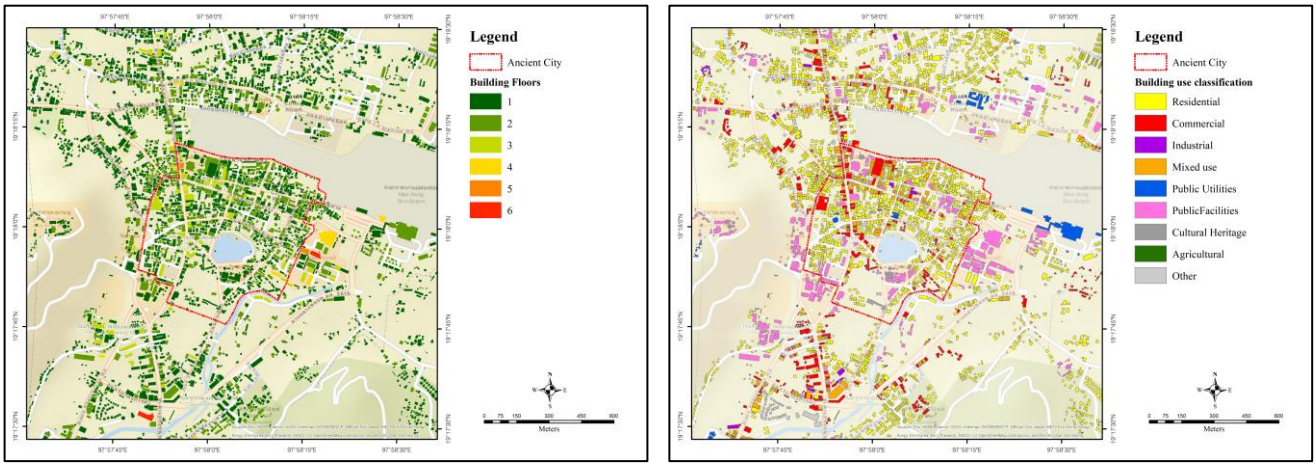
Table 1. Comparison of the Number of Buildings and the Area Size of Mae Hong Son City

	Before 1971	1971	1981	2002	2023
Building	1,328	2,855	6,002	10,053	11,948
Area (km²)	0.47	1.22	3.58	8.31	9.71

Source: Author, 2025

When examining the building patterns, it was found that Mae Hong Son city has a concentration of buildings in the center of the community, particularly along main road, covering an area of approximately 0.45

square kilometers (Figure 6 and Table 2 & 3). By 1984, the city had expanded to the northern outskirts along the road to the north of Mae Hong Son Airport, and to the west along the road leading south. In 2002, the city continued its expansion northward, reaching the area north of Mae Hong Son Airport. By 2013, development had extended further south and west. In terms of building characteristics, the old city area of Mae Hong Son primarily consists of one to two storey buildings clustered in the city center along the main roads. Taller buildings, ranging from four to five storeys, are located near the hospital, situated to the east of the area.



Source: Author, 2025

Figure 6. Building Usage Types and Number of Floors of Buildings in Mae Hong Son City in 2023

Table 2. Number of Floors of Buildings in Mae Hong Son City between 1971 – 2023

Year	Building floor							
	1	2	3	4	5	6	Frequency	Total
1971	1,918	844	83	7	2	1	2,855	2,855
1984	2,483	600	54	8	1	1	3,147	6,002
2002	3,692	348	7	3	1		4,051	10,053
2023	1,747	146	1	1			1,895	11,948
Total	**9,840**	**1,938**	**145**	**19**	**4**	**2**	**11,948**	

Source: Author, 2025

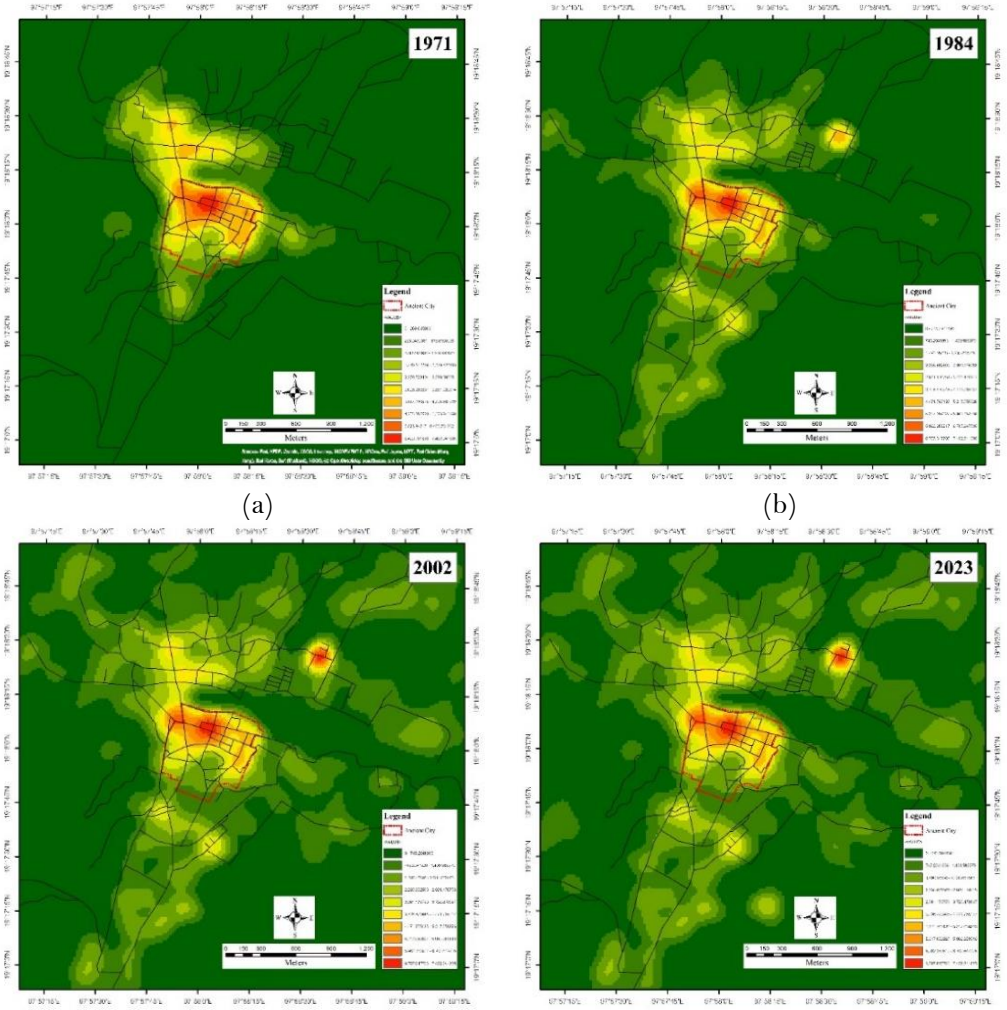
Table 3. Building Usage Types in Mae Hong Son City between 1971 – 2023 ty

Building Use	Building				
	1971	1984	2002	2023	Total
Residential	2,186	2,418	3,455	1,653	9,712
Commercial	28	50	6	2	86
Industrial	17	16	-	4	37
Mixed use	2		2	-	4
Public Utilities	543	580	383	93	1,599
Public Facilities	37	47	23	1	108
Cultural Heritage			1	1	2
Agricultural	19	24	86	136	265
Others	23	12	95	5	135
Total	**2,855**	**3,147**	**4,051**	**1895**	**11,948**

Source: Author, 2025

When analyzed using Kernel Density Estimation (KDE) to assess the distribution of buildings, it was found that between 1971 and 1984, the city expanded predominantly to the north and south (Figure 7). From

1984 to 2020, the expansion continued at an increased rate, with more buildings being constructed across a broader area. However, during the period from 2002 to 2023, the expansion slowed down considerably, and the city underwent minimal change compared to earlier periods. This suggests that urban development in Mae Hong Son became more stable, with limited growth and fewer new construction areas. This trend indicates a potential saturation of available land or a shift towards more sustainable urban planning strategies in the city.



Source: Author, 2025

Figure 7. Comparison of Urban Expansion Analysis Using Kernel Density Estimation (KDE) Technique.

4. Discussion

This analysis shows the changes in the urban morphology of Mae Hong Son City from the past to the present, utilizing data from aerial photographs and satellite imagery, along with analysis using Kernel Density Estimation and Change Detection techniques. This analysis results show the changes in morphological characteristics of Mae Hong Son City from the past to the present using data from aerial photographs and satellite images, along with analysis using Kernel Density Estimation and Change Detection techniques, which is consistent with the study by Guan et al. (2024) which examined three decades of urbanization in Qingdao City, China, as well as the research by Patel et al. (2024), which employed high-resolution satellite imagery to analyze land use changes in Ahmedabad City, India. The findings reveal that Mae Hong Son City has undergone significant physical changes and urban expansion from the 1970s to the present. In the past, urban growth primarily concentrated around the commercial center and gradually expanded into surrounding areas,

particularly to the north, due to geographic constraints such as surrounding mountains. The city's expansion is characterized by a combination of traditional buildings and modern architecture, while still maintaining the unique identity of Mae Hong Son City. This transformation reflects the interaction between urban development and external forces such as transportation, economy, and tourism.

The results of this study align with previous research on ethnic settlement patterns (Teerarojanarat, 2012), studies on the urban development of ancient cities in Grevana, Greece (Apostolou et al., 2024), and research on the settlement development of Batu, Indonesia (Witjaksono et al., 2023), all of which employed GIS and Remote Sensing techniques to study urban expansion. Additionally, this study is consistent with research on settlement distribution using Kernel Density analysis in Andean, Argentina (Lazzari et al., 2024), land-use classification within cities (Brandes, 2024), and spatial pattern analysis of rural towns such as Pingnan in Fujian, China (Chen et al., 2024). These studies highlight the significant contribution of this research in enhancing understanding of historical urban development and emphasize the importance of preserving the cultural and archaeological identity of the historic city of Mae Hong Son. The findings are in line with those of Li et al. (2023), who utilized GIS to delineate protection zones in response to increasing tourist pressure at the Wulingyuan World Heritage Site in China; Amato et al. (2017), who employed maps and aerial photographs to guide cultural heritage conservation amid urban expansion in Altamura, Italy; and Li et al. (2023), who used GIS-based planning to support the development and preservation of traditional villages in the Mentougou District of Beijing, China. The discussion of the results demonstrates that the findings of this study are consistent with numerous previous studies, reinforcing the role of Geographic Information System (GIS) technologies as an effective tool for supporting urban conservation research and planning.

5. Conclusion

The Kernel Density Estimation analysis further identifies the spatial distribution of buildings related to economic activities and residential areas, providing insights for sustainable preservation strategies for the historic city. One crucial consideration in conservation efforts is maintaining a balance between economic development and the preservation of the city's distinctive characteristics. Development policies should consider the cultural context and the needs of the local community to minimize the physical changes that could negatively impact the city's cultural heritage in the future. Further studies should investigate the impact of modern development on cultural and environmental values, as well as integrate Geographic Information System (GIS) technology in urban planning to support policy decisions aligned with sustainable development principles. This study underscores the need for careful planning to ensure that urban growth does not undermine the historical and cultural significance of Mae Hong Son City, while still accommodating the demands of modern development.

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