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Metrics analysis and evaluation of landscape mosaic changes to monitor the identity of forest monastery green space, Northeast Thailand

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Abstract Forest monasteries are significant Buddhist sites that serve as hubs for ecological services and forest habitats. These monasteries are dispersed throughout urban and community landscapes in Thailand, but have been facing a decline in green space due to land-use changes and urban expansion. This study discussed the assessment of the situation and changes in the structure and pattern of forest monastery green spaces through the application of geo-information technology and principles of landscape ecology. The study classified green and non-green areas in 2022, with proportions of 39.40% and 60.06% respectively. Accuracy and Kappa were 80.21% and 0.92, respectively, reflecting near-perfect agreement. The most significant ecological landscape structures of forest monasteries were green spaces with a core area surrounded by edges, supporting habitats and ecological services, accounting for 19.50% and 10.12%, respectively. These forest monasteries were found across all four settlement patterns: nucleated, linear, dispersed, and isolated, distributed in urban, suburban, and natural areas, each facing different landscape mosaic changes. Forest monasteries located within developed landscapes tended to have lower green space retention and persistence compared to those in agricultural, mixed, and natural landscapes, respectively. However, in terms of maintaining contiguous green spaces, analysis of landscape metrics such as patch area, percentage of landscape, core area, and patch context revealed that Wat Pah Nanachat and Wat Pah Nong Pa Pong had the highest values. These metrics most strongly reflected the green space identity of forest monasteries, even though these monasteries are located in areas undergoing urban development, compared to other forest monasteries. The findings of this research can be used to analyze and assess the green space potential of monasteries dispersed throughout the landscape system. This is helped to understand the dynamics of change in forest monastery green spaces, which must be surrounded by forested areas—an essential cultural landscape element vital to social ecology and contributing are to expand the urban green spaces for future environmental sustainability.

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Keywords: Forest monastery, Green area classification, Landscape ecology, Landscape cover change, Geo-Informatics

Introduction

Spatial interactions brought on by an increase in land use demand result in changes in land use and land cover. It brings about changes that have an impact on the environment, society, and economy in both beneficial and negative ways. (Kutintara, 2012). Such changes can be empirically observed as changes in the landscape (Forman and Godron, 1986), urbanization, settlement, occupation, and different types of space, leading to the reduction of natural and world forest areas from 5.32% (4,236 million hectares) in 1990to 1.31% (4, 059million hectares) in) 2020FAO, 2020). Meanwhile, about 100 years ago, Thailand used to have 70% of its forest area (Baimai, 2007), but it remained only 31.57% in 2022 (Royal Forest Department, 2022). The northeastern region has the least remaining area, accounting for 14.99%, with most of it being distributed in conservation areas (Santisuk, 2012). Changes in diverse land use outside the conservation area also affect the region, resulting in a reduction in natural areas or a decrease in the size of green space in the landscape of Thailand.

Geo-informatics technology is now used in tracking to research conditions, variations, and dynamics of land use/land cover. In order to improve the accuracy of land cover classification, acquire land use information that is helpful for environmental management, conservation, protection, and planning, as well as for fostering the nation's sustainable well-being, a range of techniques and methods can be used in conjunction with photographic features that have wavefront, spatial, and temporal details and field data (GISTDA, 2009). To provide highly accurate classification findings and receive land cover information in a timely manner, research has been conducted to construct classifications. There are techniques for analyzing land use/cover, such as using mathematical equations/ models, regression equations predicting land cover, segmentation-based classification, Support Vector Machines for Classification, classifying data using satellite image features, creating proportional images, vegetation index, physical index, built-up cover index, and classifying the objects/ land cover of interest, or using the time period feature to study spatial changes, and integration of such techniques and methods with geographic information such as the Normalized Difference Vegetation Index (NDVI), sentinel satellites to extract green area information from other land cover (Lu and Weng, 2007), application of land use data for urban area planning (Cavur *et al*., 2019), application of multi-index imaging from sentinel images to increase the accuracy of classifying mixtures of objects with indexes of vegetation, soil, water, and built-up that can distinguish similar reflection values between soil and

built-up with the NDTI index (Osgouei *et al.,* 2019). Moreover, those techniques are used to monitor changes in the ecosystem and study the composition of green space in order to decide on conservation and management plans for urban green space (Do *et al.,* 2018) and create connections between green space within the city and space planning for conservation and use around the city (Guo *et al.*, 2018). Additionally, as a result of the ecological impacts, cities and their surrounding context are being watched as they grow. This monitoring is applied in a variety of fields to track changes in the environment over a large area and display spatial information about how things are arranged, distributed, and grouped in space to explain land use components using landscape ecological principles (Tangkitngamwong, 2012). This is thought to be the possibility of using geoinformatics technology to design and maintain green spaces in landscape ecosystems by analyzing and comprehending changes in land use.

Landscape ecology is a theory used to explain the relationships of ecological processes in terms of structure, pattern, and role in a given area with the aim of creating an understanding of the environment in relation to living things through the landscape system structure (Forman and Godron, 1986) by describing spatial patterns through analysis based on metric measures or landscape indices, developed by McGarigal *et al*. (2012). It also helps to gain a holistic understanding of the landscape (Makhzoumi, 2000). This understanding can lead to the design of areas through area planning, such as researching the pattern and structure of land use in conjunction with sustainable urban development (Krnacova and Hrnciarova, 2006) and using landscape ecology principles when designing areas to rebuild the ecological system and create new environments (Ahmadi *et al*., 2018). In order to propose guidelines for managing green spaces at the provincial level and planning guidelines for conservation and management of remaining forest areas, conservation and management of areas in Thailand has applied principles to assess the ecological diversity of wasteland areas (Majandang, 2015; Srikhunmuang *et al.*, 2015). The goal is to restore the traditional natural areas to regain abundance and serve as a forest habitat. Due to the need to restore the country's forest ecosystem, the government has implemented laws and initiatives to conserve lands in order to raise the nation's percentage of green space to 55% (NESDC, 2023). Both in situ and ex situ measures are implemented in declared conservation areas. Meanwhile, plans are underway to increase green areas both inside and outside the city limits, beyond the declared conservation areas. In order to establish an ecological balance of natural green space, green space for services, green space for the environment, and green space for thoroughfares, steps have also been determined for the development and design of green areas that take into account the planning and management of the water system (ONEP, 2005). Those are any areas covered by

plants. It's an outdoor or semi-outdoor area with boundaries both inside and outside the city limits that people can use. Some areas are still connected to the traditional forest regions, despite their modest size, like the forest monastery area, while some may be public areas that are available for use by individuals involved and are being disrupted by the surrounding land use activities of the community. The religious site is surrounded by a valuable forest community and has an ecological landscape. It serves as a location for Dhamma practice as well as a forest ecosystem that keeps the forest intact (Sornsakda *et al.,* 2013). On the other hand, there have been some alterations to forest monasteries. They were once a location with one kilometer of forests all around it; however, due to use and tree-cutting by communities both inside and outside the area, they have lost their surrounding forest area and have finally turned into a regular temple (Chaisuwan and Charoonseang, 2018). It is crucial to comprehend the ecological elements of the forest monastery green area landscape as well as how land use has changed within the forest monastery landscape system. The reason for this is that over 90% of Thais are Buddhists, and forest monasteries are regarded as an element of the landscape system that is situated in the middle of a community. This concept has long been present in Thai society (Kanyalak *et al*., 2015). There are around 1,848 temples in the province of Ubon Ratchathani, and there are 43,562 temples nationwide, with the Northeastern area having the greatest number of temples (The National Office of Buddhism, 2021). There are 936 forest monasteries among them, 375 of which are recognized by law (Sornsakda *et al.,* 2013). Numerous forest monasteries, including Wat Pah Nong Pah Pgong, Wat Pah Nanachat, Wat Pah Prom Titanusorn, Wat Pah Hua Don, Wat Pah Non Sawan, Wat Pah Nam Bun, and Wat Pah Nong Bua Hee, are examples of places where a variety of plants are still preserved. These temples are dispersed throughout the province landscape system, encompassing urban, rural, and even natural settings. They feature plants that are critically endangered and endangered as well as areas with the Species Diversity Index and Importance Value Index (Jumpasingha *et al.*, 2018). Studying forest monasteries helps understand how patches of green space maintain their identity based on the ecological landscape. It will give an understanding of its layout, arrangement, and ecological landscape change (Fahrig, 2013; Galán-Acedo *et al*., 2019) in the context of community expansion and land use that may affect the forest monastery landscape.

In this study, the principles of landscape ecology were combined with the application of geo-information technology as a framework for examining the green spaces of forest monasteries distributed within the landscape context of Ubon Ratchathani Province. This area is undergoing land-use changes and the expansion of communities and urban society, which may impact the decline and

loss of the distinctive identity of forest monastery green spaces within a 1-kilometer radius. The objectives of the study were to classify and assess the structure, patterns, and changes in the landscape ecology of forest monastery green spaces using Sentinel satellite imagery and high- resolution satellite images, through the application of the Morphological Spatial Pattern Analysis (MSPA Model) and the Landscape Mosaic Model (LM model) and to analyze the landscape matrix and patch metrics of forest monastery green spaces as a case study for understanding the components and spatial arrangement within a 1-kilometer radius, in order to reflect the unique identity of forest monastery green areas.

Materials and methods

Study area

Ubon Ratchathani Province is partly located in the basin (Korat-Ubon Basin) (Figure 1). There are two rivers flowing through it: the Mun River and the Chi River. The average height above sea level is approximately 120 meters. It is a plateau that slopes from west to east. The average annual rainfall is 1597.16 mm, with the highest amount in September (304.25 mm) and the lowest in January (3.21 mm). Average monthly temperature is 27.60 °C, with the lowest temperature in December (24.28 °C) and highest in April (30.37 °C), Soil has different origin materials and birth processes according to landforms, consisting of sedimentary rocks amd igneous rock that is a volcanic rock of the basalt type (Department of Mineral Resources, 1991).The forest area consists of two wildlife sanctuary areas: Yod Dome and Buntharik-Yodmon Wildlife Sanctuary and 4 national park areas, namely Phu Chong-Nayoi National Park, Kaeng Tana National Park, Pha Taem National Park, and Khao Phra Wihan National Park. Forests can be divided into dry evergreen forest, deciduous dipterocarp forest, freshwater swamp forest, and mixed forest (Santisuk, 2012).

Methodology

It is a study of the structure and pattern of green space in forest monasteries in Ubon Ratchathani Province. There are 3 main steps: 1) classification of green and non-green area data; 2) classification of the ecological structure and pattern of the green area of forest monasteries through the application of geo-informatics technology; and 3) evaluation of changes in the ecological landscape of the forest monasteries' green areas in Ubon Ratchathani Province, with the details of operations as follows:

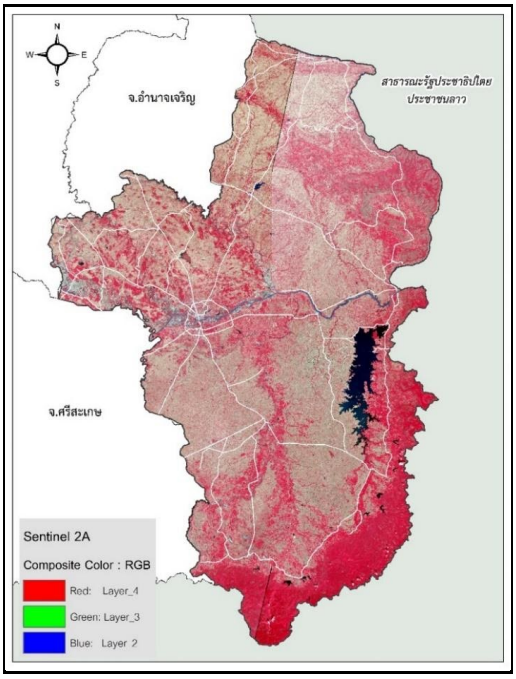


Figure 1. Study area in Ubon Ratchathani

Classification of green area and non-green area data in Ubon Ratchathani Province

***Data collection and procedures*:** The study used pre-processing cloud-free Sentinel-2A satellite imagery recorded in March 2022, with 10-meter spatial details from the Copernicus Open Access Hub (https://scihub.copernicus.eu/). We performed resolution resampling on the images using the Nearest Neighbor method to achieve an image resolution of 10 meters in every band and combined the image data in each band (stack layer). Then the image data were cut to the extent of the study area, which is Ubon Ratchathani Province, and secondary data were collected in the form of documents, research, and geographic information system data, such as temple location, city plan, buildings/constructions, land use, forest area, etc.

Classification of green areas and non-green areas in Ubon Ratchathani Province

Together with field data on the different types of green areas, green areas were identified using the proportionate image of the range of reflectance values in each band of the Sentinel-2A image, including NDVI, NDWI, NDBI, and NDTI (Table 1). Data types were specified as follows: 1) Green areas, including

forest areas, grasslands, coppices, and areas covered by vegetation, 2) Non-green areas, including land areas, buildings, and water areas. Then reflectivity data from the training area were compared in terms of spectral profile to extract information that is a component of green areas separated from non-green areas from the image, according to the research of Osgouei *et al*. (2019). Additionally, utilizing a hybrid interpretation between the support vector machine approach and visual classification, land covers were divided into 5 categories: forest areas, agricultural areas, miscellaneous areas, community areas, buildings, and water areas. The total accuracy was then assessed using the data, and it was found to be at 85% (Congalton and Green, 2008). After calculating the Kappa Index (Cohen, 1968), a confusion metric was produced.

Table 1. Index for classifying elements of green and non-green areas

Index Name	Index	Formula	Application	Reference
1.Normalized Different Vegetation	NDVI	$\frac{NIR–Red}{NIR+Red}$	Measure of photo-synthetic activity/ density of vegetation	Rouse *et al*, 1974
2.Normalized Different Water	NDWI	$\frac{GREEN–NIR}{GREEN+NIR}$	Water Classification and separate them from terrestrial land	McFEETERS, 1996
3.Normalized difference built-up	NDBI	$\frac{SWIR–NIR}{SWIR+NIR}$	Automatically mapping urban areas	Zha *et al*., 2003
4.Normalized Difference Tillage	NDTI	$\frac{SWIR1–SWIR2}{SWIR1+SWIR2}$	Automatically urban area and Separate them from bare land	Osgouei *et al*, 2019

Classification of ecological structures and patterns in the green areas of forest monasteries, Ubon Ratchathani Province

Forest monastery structure classification: The model "Morphological Spatial Pattern Analysis (MSPA)," created by Soille and Vogt. (2009) was used to evaluate green forest area data for ecological landscape. MSPA is a segmentation technique that measures foreground and background agreas. The shape, connectivity, and arrangement of the forest areas were the main topics of our metric-based description of the data. The forest area's edge width was set to 3 (30 meters) and the forground connection parameter to 8, which allowed for the classification of the forest area's ecological landscape into 7 forms: core, edge, perforation, bridge, loop, branch, and islet. Then the information on the location of forest monasteries was overlayed to analyze the structure group of forest monasteries in the Ubon Ratchathani landscape system.

Forest monastery landscape ecology analysis: It is an analysis of the settlement characteristics, the location of forest monasteries, and an explanation of the relationship between the green area pattern of the forest monasteries in

order to select the forest monastery area that is a good representative of the plant community of the forest monasteries with area size and presence of core area according to the BioCondition V2.2 method (Eyre *et al.*, 2015). Purposive sampling was employed to select samples for analysis based on aerial photographs and high-resolution photographs as well as the landscape location within a one-kilometer radius (Tucker *et al*., 2014; Nicu and Stoleriu, 2019) as a framework to explain the structure, pattern, and dynamics of the forest monastery landscape system according to the following method:

Landscape mosaic change: between 1998 and 2021 was measured by comparing the landscape dominance through the Landscape Mosaic Model. (Wickham and Norton, 1994) define landscape types as follows: Natural dominance, agricultural dominance, developed dominance, and mixed dominance from the mosaic group of 19 classes from the tri-scene diagram according to the proportion criteria of 0.1, 0.6 and 1.0 along the three axes of the mosaic type (Figure 2). Landscape axial values closer to 0.1 indicate presence, values closer to 0.6 indicate dominance, and values closer to 1.0 indicate uniqueness of the landscape cover type. Out of the 19 landscape classes represented by lowercase letters -- a-agricutlure; d-developed; n-natural, in the landscape frame is a landscape proportion that is between 0.1 - 0.59, while capital letters (A, D, N) are a landscape proportion with a value of 0.6 - 0.99. Meanwhile, unique landscapes (AA, DD, NN) are those with a value of 1. This serves as a framework for classifying and understanding changes in the forest monastery landscape in the landscape ecosystem structure of Ubon Ratchathani Province between 1998 and 2021, etc.

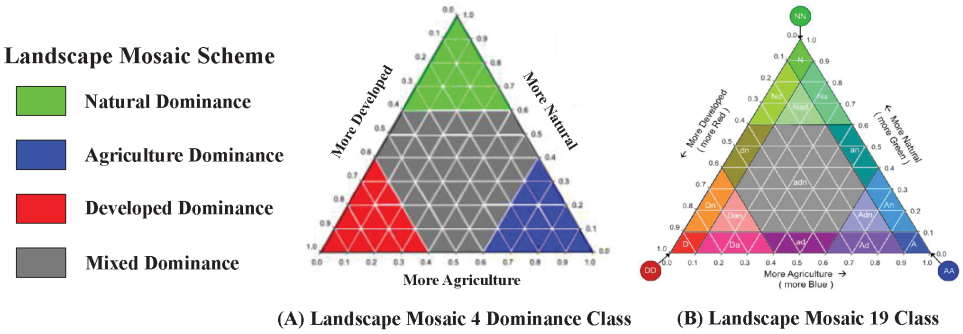


Figure 2. Classification of the forest monastery landscape system (A) into 4 dominance landscape groups based on (B) 19 landscape classes defined by the Landscape Mosaic Model

Table 2. List of landscape measurement indexes for analyzing the structures and patterns of forest monastery green space

Metrics	Abbrev.	Description
1.Percentage of Landscape	PLAND	Measurement of the composition and dominance of the landscape to find out the proportions of landscape- level elements, classes, and land- use patches, presented in percentage.
2.Patch Number	PN	Measurement of the total number of patches present at the level of landscape, class, and green space, and it is used to measure the dispersion of land use components in the landscape system, presented in cardinal numbers
3.Size of Patch	Size patch	Measurement of the size of land use components and the forest monastery green area patch in sq. km. The size of forest monastery patches is divided into 3levels: 1. large patches (area > 2 sq. km.) 2. medium sized patches (area 2 - 25sq.km.) and 3. small patches (area < 25sq.km.) (Eyre *et al.*, 2015) (Tucker *et al*., 2014)
4.Core Area	CA	Measurement of the core area of forest monastery green area patches. The border width of the area patch is 30m. The unit of measurement is sq.km.
5.Patch Context	Patch Context	Measurement of the value of green space patches in the landscape system (proportion of patch size to total area or area with a radius of 1km). The context of the patch is classified into 4levels: 1. very high level 2. high level 3. moderate level 4. low level according to the method of Eyre *et al*., (2015)
6.Mean Shape Index	MSI	Measurement of the average shape of land use type components and green areas. It is used to describe the shape of all land use elements within a landscape system.
7. Shannon's Diversity Index	SHDI	An index measuring the diversity of elements present in a landscape. Values closer to 0 mean the landscape has a single type of area and low diversity. If the value increases, it means that the landscape has more patches in the landscape system and has increased diversity. It is used to measure the complexity of all land use types in a landscape.
8. Shannon's Evenness Index	SHEI	The index measures the diversity and even distribution of components present in a landscape system and the health of the patch.

Analysis of landscape metrics: It is conducted to evaluate the characteristics of the patch structure in the forest monastery landscape. The metrics selected for this study include the ones from the research of Botequilha Leitão and Ahern (2002), which are used in monitoring and planning for sustainable landscape management; BioCondition V2.2 (Eyre *et al*., 2015), which is a metric used to assess the forest habitat; (Nicu and Stoleriu, 2019), which is a metric used to track landscape changes and impacts on cultural conservation areas. there were designed the metrics for analyzing the forest monastery landscape as follows (Table 2).

Results

Classification of the ecological structures of the forest monastery green area landscape in Ubon Ratchathani Province

The topography of Ubon Ratchathani Province is shaped like a plateau and slopes eastward. In the center of Mueang District and Warin Chamrap District, there are mountains to the northeast and south that cause upstream areas, water support areas, and river flows to connect with the waterways in the Chi and Mun river basin systems. The Mun River is the main river that flows through the middle from the west and flows out into the Mekong River in Khong Chiam District. Thus, the province's physical geography—which includes mountainous regions, foothill slopes, flood plains, and stream terrace plains— creates a landscape ecosystem. Cities, communities, and settlements are scattered throughout the plain terrain on both sides of the river and in the upland regions. The majority of the provincial green space environment is made up of agricultural land that is dispersed throughout communities and suburbs in different districts along plains to low plains behind rivers and river terraces. The second mostly found landscape is forests that stretch from the foothills to the mountains along the southern edge of the region where the northeastern Phu Phan Mountain range meets the Phanom Dong Rak Mountain range. Most of them are in protected forest areas and along the waterfront coastline of the Mun, Chi, Lam Se Bok, and Lam Se Bai rivers. They are patches and corridors that are divided into agricultural areas with mostly perennial trees scattered among meadows, woodlands, and scrub. Meanwhile the urban settlement is clustered in the city centers of Ubon Ratchathani and Warin Chamrap. The chequer board settlement pattern spreads out along the main and secondary roads and along the banks of the Mun River; linear and rural settlements concentrated in communities in various districts of the province; nucleated settlements are dispersed or isolated, etc.

Results of classification of green and non-green areas by interpreting the sentinel satellite images have an overall accuracy of 94.87 % and a Kappa coefficient of 0.92 or almost perfect agreement (Table 3) Agriculture and plantation are the highest, accounting for 8,333.33 km^2 (53.33 %), followed by forest and shrub/ grass, accounting for 6,158.22 km^2 (39.40 %), and miscellaneous or barren area, accounting for 80.21 km^2 (0.51 %), water area, accounting for 639.49 km^2 (4.07 %), and urban and built-up area, accounting for 420.30 km^2 (2.69 %) (Figure 3).

Landscape ecological patterns in the green areas of forest monasteries, Ubon Ratchathani Province

From the analysis of the MSPA model, it was found that the green space pattern found the most is core, with an area of 3,046.01 km^2, accounting for 19.50 %, followed by edge, with an area of 1,581.42 km^2, accounting for 10.12%. Meanwhile, bridge, branch, islet, perforation, and loop were 453.19, 453.02, 434.43, 137.52, and 107.82 km^2 (2.90, 2.90, 2.78, 0.88, and 0.69%), respectively, and a non-forest area consist of 9, 87.413km^2 (60.24%) (Figure 4.) The forest monastery green area is mostly in the core area with the function as a forest habitat, totaling 125 forest monasteries, followed by the islet area in the form of stepping stone, totaling 65 forest monasteries, and bridge, loop and branch, which are forest monastery green area in the form of a corridor that connects to patches of natural forest and/or other landscape metrics, accounting for 65, 60, 11 and 5 forest monasteries, respectively. As for the monastery settlement, they are located in community centers both in the city, outside the city and in natural areas ranging from the plains, uplands to mountains, along Noen, Non, Khok, and Don. They can be classified into 2 groups: urban settlements and rural settlements, consisting of 1) Linear 2) Nucleated or Clustered 3) Dispersed or Isolated (Figure 5).

Table 3. Accuracy evaluation and Kappa index of green space classification

		Hybrid interpretation Classification							
		F[/1]	**A[/2]**	**M[/3]**	**U[/4]**	**W[/5]**	**Total**	**PA (%)**	**EC (%)**
Ground Truth	**F[/1]**	**468**		2			470	99.57	0.43
	A[/2]	16	**82**	**23**			121	67.77	32.23
	M[/3]	10		**106**	39		155	68.39	31.61
	U[/4]			2	**266**		268	99.25	0.75
	W[/5]					**39**	39	100	0
	Total	494	82	133	305	39	**961**		
	UA (%)	94.74	100	79.70	87.21	100			
	EO (%)	5.26	0	20.30	12.79	0			

Overall Accuracy: 94.87 / Kappa Index : 0.92

[1]/F**:** Forest Class, [2]/A**:** Agriculture Class, [3]/M**:** Misscellaneoues Class, [4]/U**:** Urban and Built-up Class, [5]/W**:** Water Class

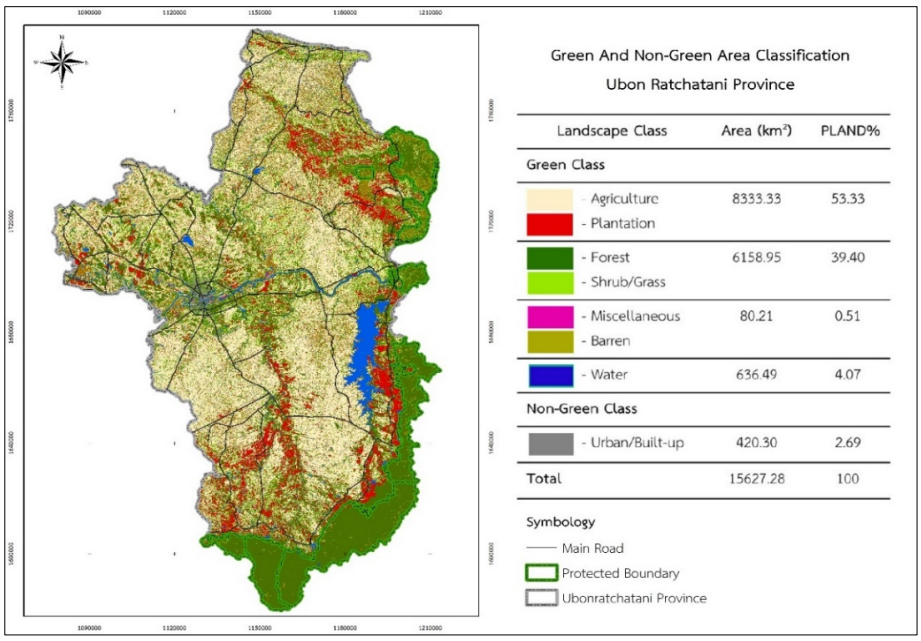


Figure 3. Results of classification of green and non green areas in Ubon Ratchathani Province

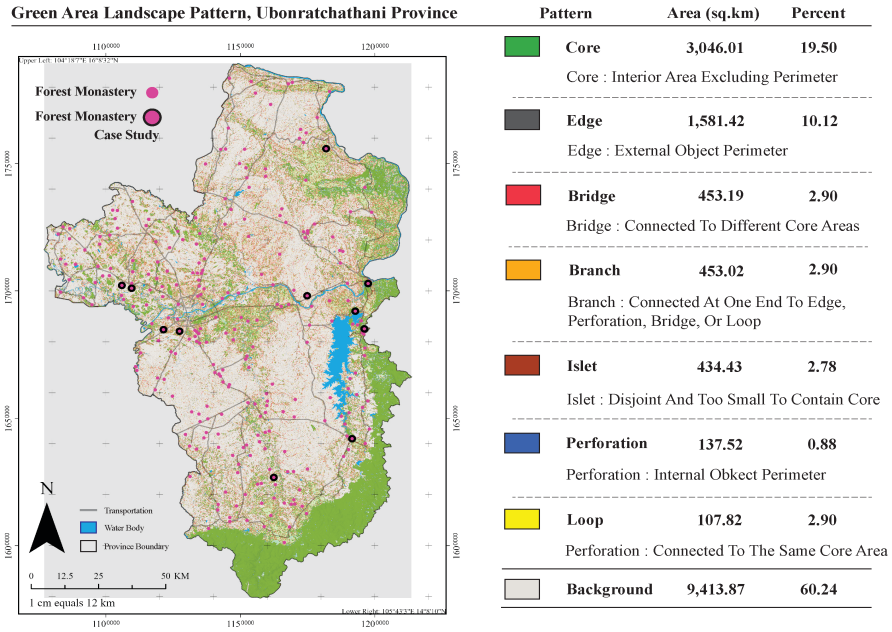


Figure 4. Landscape ecological patterns and distribution of green space of forest monasteries in Ubon Ratchathani Province

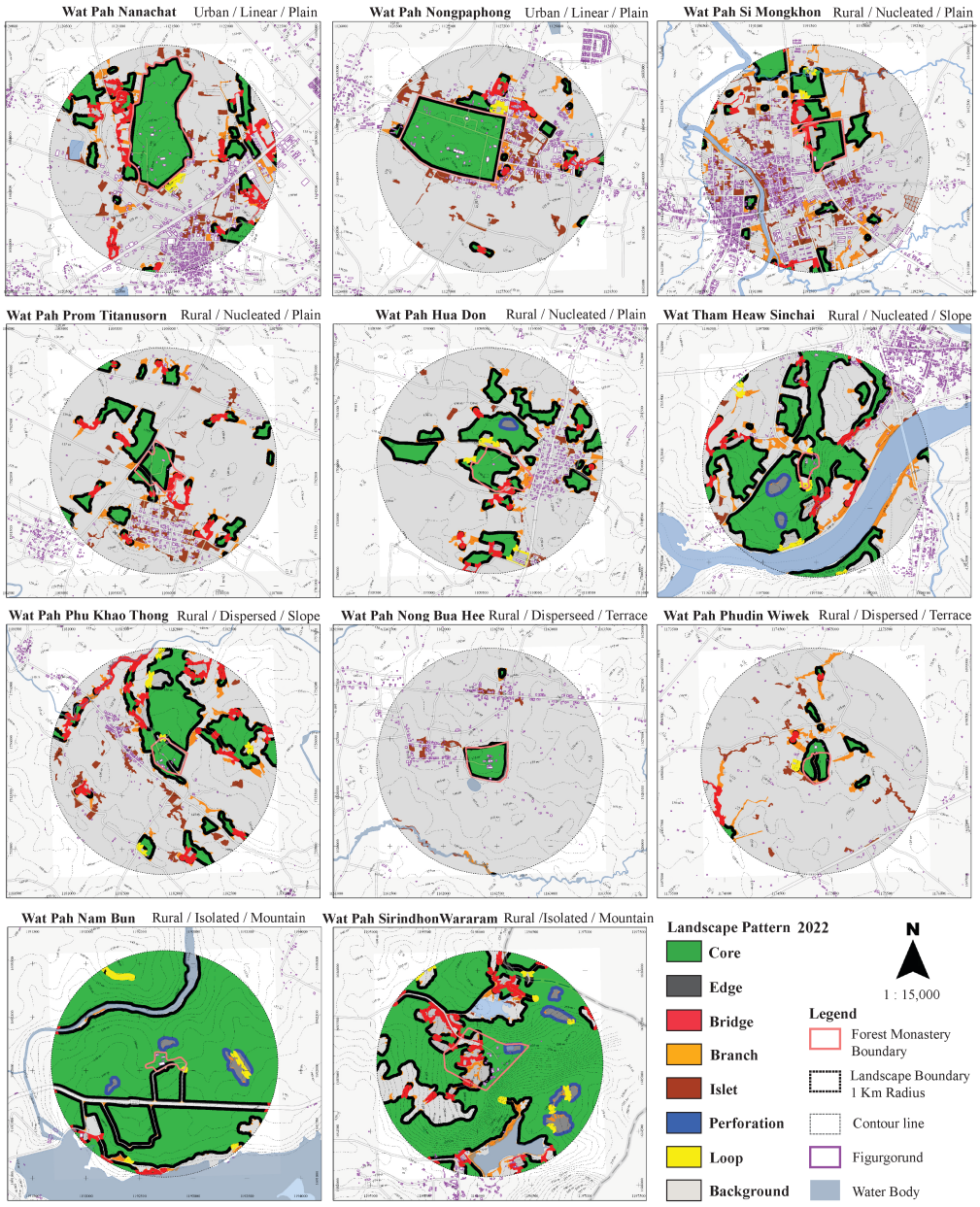


Figure 5. Landscape ecological patterns of the green space of forest monasteries, a case study in Ubon Ratchathani province

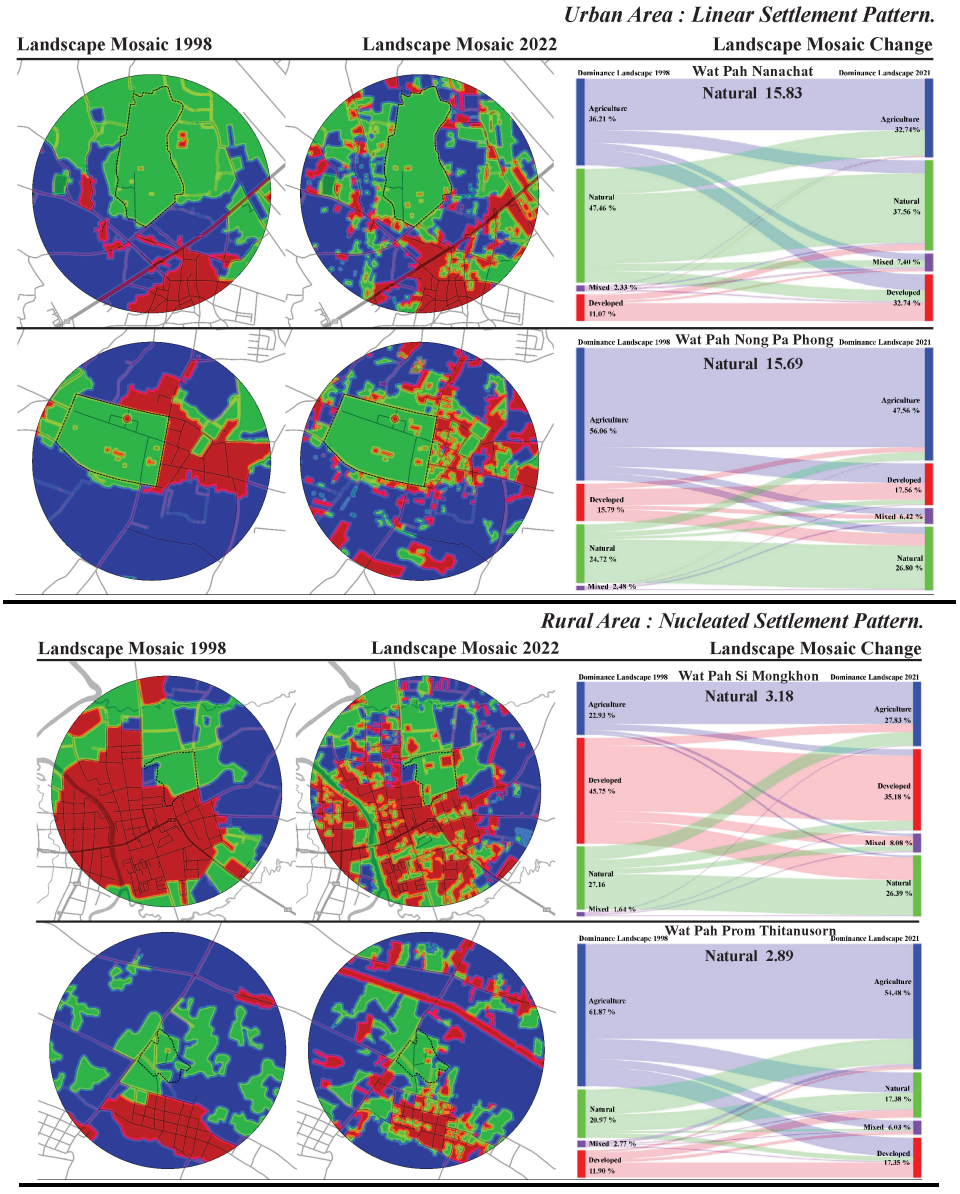
Changing the landscape ecology of the green area of forest monasteries, a case study

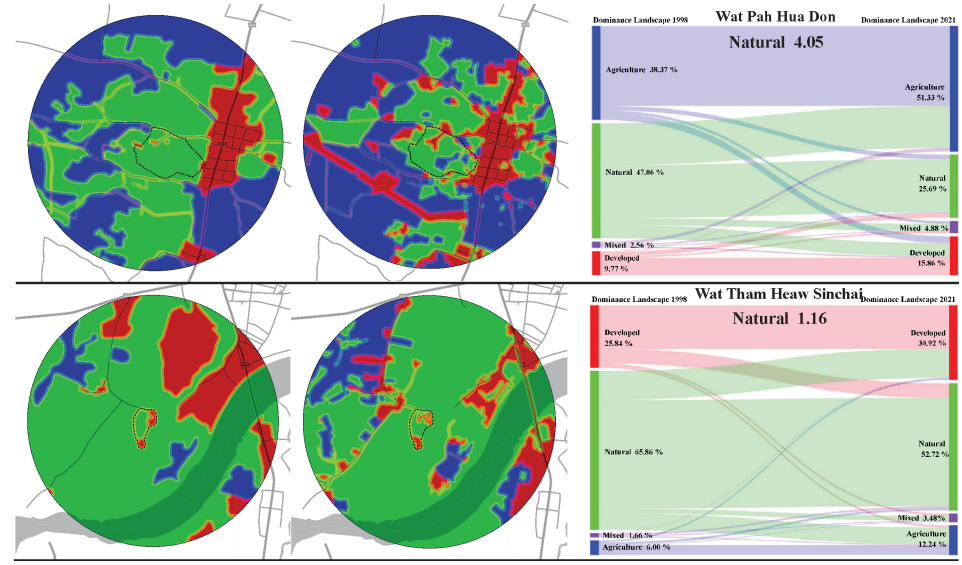
Regarding changes in the green area landscape system of forest monasteries from 1998 to 2022 (Figure 6), there was an increase in coverage and changes in the landscape mosaics of forest monastery clusters with the linear rural settlement pattern in developed and mixed areas. Meanwhile, natural areas and agricultural areas are decreased in proportion. In the Wat Pah Nanachat, developed areas and mixed areas increased from 11.07 % and 2.33 % to 74.32 % and 40.7 %, respectively, while natural areas and agricultural areas decreased from 47.46 % and 36.21 % to 56.37 % and 74.32 %, respectively. As for Wat Pah Nong Pa Pong, natural areas, developed areas, and mixed areas increased from 24.72 %, 15.79 %, and 2.48 % to 47.56 %, 17.56 %, and 6.42 %, while agricultural areas decreased from 56.06 % to 47.56 %.

For the nucleated or clustered rural settlement pattern, the overall coverage and landscape mosaic changes increased in agricultural areas, developed areas, and mixed areas while there was a decrease in natural areas. In Wat Pah Si Mongkhon, agricultural areas and mixed areas increased from 22.93% and 1.64 % to 27.83 % and 8.08 %. For developed areas and natural areas, they decreased from 45.75 % and 27.16 % to 18.35 % and 39.26 %. In Wat Pah Prom Titanusorn, developed areas and mixed areas increased from 11.90 % and 2.77 % to 17.35 % and 6.03 %, while agricultural areas and natural areas decreased from 87.61 % and 97.20 % to 48.54 % and 38.17 %. In Wat Pah Hua Don, agricultural areas, developed areas, and mixed areas increased from 37.38 %, 77.9 %, 56.2 % to 33.51 %, 86.15 %, and 88.4 %, while natural areas decreased from 06.47 % to 69.25 % In Wat Tham Heaw Sinchai, developed areas, agricultural areas, and mixed areas increased from 25.84 %, 6.00 %, and 1.66 % to 30.92 %, 12.24 %, and 3.48 %, while natural areas decreased from 65.86 % to 52.72 %, etc.

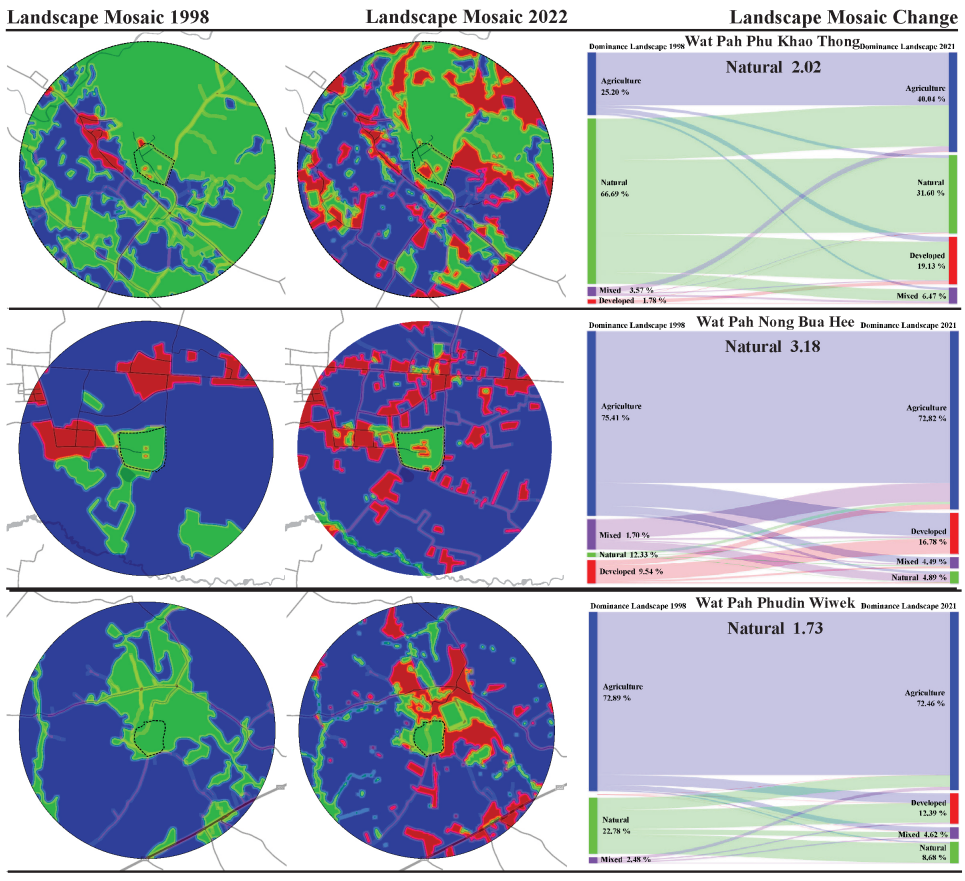
For the dispersed or isolated rural settlement pattern in community areas, the overall coverage and landscape mosaic changes increased in agricultural areas, developed areas, and mixed areas, while there was a decrease in natural areas. In Wat Pah Phukao Thong, agricultural areas, mixed areas, and developed areas increased from 20.25 %, 57.3 %, and 78.1 % to 04.40 %, 47.6 %, and 13.19 %, while natural areas decreased from 69.66 % to 60.31 %. In Wat Pah Nong Bua Hee, developed areas and mixed areas increased from 9.54% and 1.70 % to 16.78 % and 4.49 %, while natural areas and agricultural areas decreased from 12.33 % and 75.41 % to 4.89 % and 72.82 %. In Wat Pah Phudin Wiwek,

developed areas and mixed areas increased from 00.0 % and 48.2 % to 39.12 % and 62.4 %, while natural areas and agricultural areas decreased from 78.22 % and 89.72 % to 68.8 % and 46.72 % etc. In forest monastery groups, natural area coverage and landscape mosaic changes were found the most in Wat Pah Nam Bun, which decreased from 95.85% to 97.24%, and Wat Pah Sirindhorn Wararam, which decreased from 99.07 % to 96.11 %. In addition, relatively low changes in agricultural areas, developed areas, and mixed areas were found.





Rural Area : Dispersed Settlement Pattern.



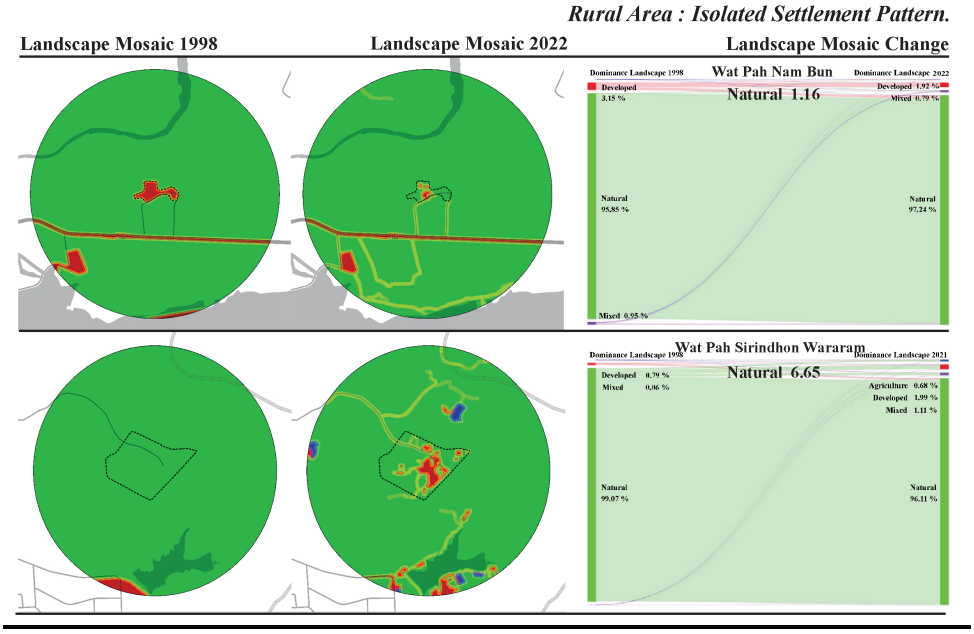


Figure 6. Data flow diagram of changes in the landscape system in the forest monastery area, a case study of Ubon Ratchathani Province

Ecological metrics, landscape, green space of forest monasteries, a case study

The results of the analysis of landscape metrics in a 1-kilometer radius area revealed that forest monasteries in the landscape system close to urban and rural areas were characterized by developed uniqueness (Table 4). They occupied an area surrounded by communities and built-ups. The landscape had high values of SHDI and SHEI. This could be found in Wat Pah Si Mongkon, Wat Pah Nanachat, Wat Tham Heaw Sinchai, Wat Pah Hua Don, and Wat Nong Pah Phong, with the SHDI values of 1.88, 1.71, 1.61, 1.61 and 1.54 and SHEI values of 0.90, 0.82, 0.77, 0.77 and 0.74, respectively. The second mostly found landscape is agricultural uniqueness and mixed uniqueness in Wat Pah Phukao Thong, Wat Pah Prom Titanusorn, Wat Pah Phudin Wiwek, Wat Pha Nong Bua Hee, with SHDI values of 1.54, 1.53, 1.41 and 1.00 and SHEI values of 0.74, 0.79, 0.68 and 0.48, respectively. Meanwhile, the natural uniqueness system was found in the landscape system of Wat Pah Sirindhorn Wararam and Wat Pah Nam Bun with SHDI values of 0.69 and 0.38 and SHEI values of 0.35 and 0.24, respectively. For the analysis of PN metrics, Wat Pah Si Mongkhon, Wat Pah Nanachat and Wat Nong Pah Phong had the highest values of 602, 379, 300, while Wat Pah Nong Bua Hee, Wat Pah Prom Titanusorn, Wat Pah Phukao Thong, Wat Pah Hua Don, Wat Pah Si Mongkhon, Wat Pah Phudin Wiwek, Wat

Pah Sirindhorn Wararam, and Wat Pah Nam Bun had PN values of 235, 221, 211, 184, 160, 159, 110, and 57, respectively. The PN values were shown to be high in landscape systems of forest monasteries that are close to urbanization, such as Wat Pah Si Mongkhon located in the center of Buntharik District; Wat Pah Nanachat and Wat Nong Pah Phong located on the outskirts of Warin Chamrap area with and average distance of 10km. The PN value decreases as it approaches the natural area, like the case of Wat Pah Sirindhorn Wararam and Wat Pah Nam Bun. Moreover, it had an inverse relationship with the mean shape index (MSI). In forest monasteries in natural areas such as Wat Pah Nam Bun, Wat Pah Sirindhorn Wararam, Wat Pah Phukao Thong and Wat Tham Heaw Sinchai, they had MSI values of 2.38, 2.32, 2.02, and 2.01, respectively. Meanwhile, the MSI value decreases when the area changes to agricultural area, mixed area, and urbanized area. The forest monasteries with the least MSI values were Wat Pah Si Mongkhon, Wat Pah Nanachat, and Wat Pah Nong Pa Phong, which are 1.70, 1.76 and 1.91, respectively.

Table 4. Analysis of the landscape ecological pattern of the green area of Wat Pah, a case study of Ubon Ratchathani Province

Monastery Site	Landscape Metrics				Forest Monastery Patch (Patch Metrics)					
	SHDI	SHEI	MSI	PN	PA	PD/1	SzP/2	Co/3	Pcont/4	Cont/5
WatPah Nanachat	1.71	0.82	1.76	379	0.54	18.54	Med/6	0.45	83.15	Med/6
Wat Nong Pah Phong	1.54	0.74	1.91	300	0.54	15.69	Med/6	0.45	15.69	Med/6
WatPah Si MongKhon	1.88	0.90	1.70	602	0.11	3.18	Sml/7	0.07	3.80	Low
WatPah Prom Titanusorn	1.53	0.79	1.84	221	0.10	2.89	Sml/7	0.05	2.58	Low
WatPah Hua Don	1.61	0.77	1.78	184	0.14	4.05	Sml/7	0.07	3.72	Low
WatTham Heaw Sinchai	1.61	0.77	2.01	160	0.04	1.16	Sml/7	0.02	1.18	Low
WatPah Phukao Thong	1.54	0.74	2.02	211	0.07	2.02	Sml/7	0.05	2.00	Low
WatPah Nong Bua Hee	1.41	0.68	1.67	235	011	3.18	Sml/7	0.08	3.51	Low
WatPah Phudin Wiwek	1.00	0.48	1.98	159	0.06	1.73	Sml/7	0.03	2.75	Low
WatPah Nam Bun	0.38	0.24	2.38	57	0.04	1.16	Sml/7	0.03	0.97	Low
Wat Sirin-dhorn Wararam	0.69	0.35	2.32	110	0.23	6.65	Sml/7	0.11	7.15	Low

1/PD: PLAND, 2/SzP: Size Patch, 3/Co: Core Area, 4/Pcont: Patch Context, 5/Cont: Context Level
6/Med: Medium, 7/Sml: Small,

From the metrics analysis of forest monastery patches in the area with a radius of 1kilometer (Table 4) with regard to patch size (PA), core area size (CA), and patch context (P-Context) per green area metrics, it was found that Wat Pah Nanachat and Wat Nong Pah Phong had the most patch area (PA) of 0.54 km^2 and 0.54 km^2, representing PLAND at 15.84 % and 15.69 %, respectively. While they had a core area (CA) of 0.45 km^2 and 0.45 km^2, classified as a group of forest monasteries with a medium patch size and a medium context. It is followed by forest monasteries with low patch size and low context, which include Wat Pah Sirindhorn Wararam, Wat Pah Hua Don, Wat Pah Nong Bua Hee, Wat Pah Si Mongkhon, Wat Pah Prom Titanusorn, Wat Pah Phukao Thong, Wat Pah Phudin Wiwek, Wat Pah Nam Bun, and Wat Tham Heaw Sinchai with an area of 0.23, 0.14, 0.11, 0.11, 0.10, 0.07, 0.06, 0.04 and 0.04 km^2, respectively, and a core area of 0.11, 0.07, 0.08, 0.07, 0.05, 0.05, 0.03, 0.03 and 0.02 km^2, respectively.

Discussion

In order to classify the primary components of green areas and non-green areas, aspect ratios were created, and the green and non-green areas in Ubon Ratchathani Province were classified using a combined classification approach. Indices, NDTI, and NDBI were used to build land cover categorization to separate non-green areas, including built-up areas and barren areas, from green areas, while the NDVI index was used to obtain data on land cover in green areas. According to the definition, green space refers to natural areas within cities and communities with vegetation as the main component (Office of Natural Resources and Environmental Policy and Planning, 2005). In order to plan and manage landscape systems and environmental ecosystems, land use maps and green space types were obtained based on the classification guidelines of Osgouei *et al.* (2019). These guidelines aid in understanding the urban context, building, expansion patterns, and settlement (Kopecká *et al.*, 2017). In the context of forest monasteries, it can be used to monitor the situation, distribution, changes in green space, and the loss of identity of forest monasteries (being surrounded by a forest area with a radius of 1 kilometer) (Chaisuwan and Charoonseang, 2018).

For landscape ecological structures and patterns of forest monasteries, urban and rural settlements have been found to be related to built-up density and clustering according to the surrounding land use environment (Muensee *et al.*, 2015; Chantako *et al.*, 2022). These included linear, nucleated, and dispersed settlements. From mosaic and landscape metrics analysis, the ecological landscape of forest monasteries can be divided into 3 groups: urban landscape,

rural landscape, and natural landscape, consistent with the patterns of land use in the cultural landscape in a 1-kilometer radius area (Nicu and Stoleriu, 2019). The forest monastery ecological landscape in an urban area has built-ups, residences, and roads, which fall under the category of developed uniqueness and linear and nucleated settlements, causing green areas to decrease. In addition, due to the outstanding landscape of community/residential areas and agricultural areas in natural areas, it results in the reduction of patches, creating isolation and dispersion of green areas in the forest monastery landscape system, such as Wat Pah Si Mongkhon, Wat Pah Nanachat, and Wat Pah Nong Pa Phong. Ecological landscape in the community area had agriculture uniqueness surrounding the community area, and patches of green space are in the form of clustered and dispersed settlements. There was an agricultural landscape metric that makes the green areas of forest monasteries look like isolated islands, such as Wat Pah Nong Bua Hee and Wat Pah Phudin Wiwek. The extent of dispersion of green areas in the landscape depends on topographic factors. As a result, the ecological landscape of forest monasteries may undergo a transition of land use as mixed uniqueness, developed uniqueness, agriculture uniqueness, and natural uniqueness, leading to changes in green areas in the landscape system, such as Wat Pah Prom Titanusorn and Wat Pah Hua Don, which are located on the upland near a developed area, with the distance from the city center of 30 kilometers, causing the green area of these forest monasteries to decrease and form a mixed uniqueness. This group therefore varies according to factors of use and the influence of proximity and distance of urbanization. For example, Wat Pah Heaw Sinchai and Wat Pah Phukao Thong had restrictions on the use of land within the conservation area. Also, the forest monasteries are located in an upland to mountain area, making them still a green area with natural uniqueness. The location of the forest monasteries is far from the community located in the area of steep slopes up to mountains, and some are in conservation areas. As a result, the landscape has large green areas clustered together with a natural shape and quite low dispersion of green space in the landscape system, such as Wat Pah Nam Bun and Wat Pah Sirindhorn Wararam.

For uniqueness of forest monasteries, landscape metrics can be used to assess the green space situation in forest monastery areas within a radius of 1km by classifying the uniqueness of the landscape using a landscape mosaic model. It facilitates planners' comprehension of the distinctive characteristics of forest monasteries situated in natural, developed, mixed, and agricultural areas, as well as the mosaic changes that transpire throughout time. Using the landscape metrics, this aids in comprehending the situation as it stands now as well as its presence, growth, and decline (Riitters *et al.,* 2020). In this study, it is an analysis of patches of forest monasteries to represent their role as forest habitats and a

Buddhist place, as well as the uniqueness of forest monasteries that must be surrounded by forest areas. For example, forest monasteries with natural uniqueness, low diversity index values close to zero, and the mean shape index (MSI) of greater than 2 (circular shape) are Wat Pah Nam Bun and Wat Pah Sirindhorn Wararam. On the other hand, forest monasteries with dispersed and reduced green areas had high SHEI values and decreased MSI index, combined with PN values. For instance, Wat Pah Si Mongkhon has a PN value of 602 patches, with an average patch size of 0.8, while Wat Pah Nanachat has values of 379 and 1.53, respectively, and Wat Nong Pah Phong has values of 300 and 1.53, respectively. It is classified as a highly dispersed landscape ecosystem in a 1-km radius area with the number of patches approaching and exceeding 500 and the average patch shape being less than 1.7 (Nicu and Stoleriu, 2019). However, when considering only the green area of the forest monastery territory per 1 kilometer of the landscape system, Wat Pah Nanachat and Wat Pah Nong Pah Phong are representative forest monasteries that are unique in terms of location, area characteristics, area size, and shape towards being a forest habitat. They also have ecological diversity, with Shannon-Wiener's Index of 2.78, 2.63 and Important Value Index (IVI) of 2.63 and 2.78, respectively (Jumpasingha *et al.*, 2018). Furthermore, the area's function as a healthy ecosystem that provides ecological services (Wonglangka and Han, 2018) and sizable green spaces aid in lowering the temperature of the nearby community areas. From the results of the said study, it provides a quantitative overview of the ecological relationships in the landscape of forest monastery green areas, with structures and patterns that preserve their ecological richness. Future research should therefore focus on understanding how to manage and conserve the green space of forest monasteries in order to maintain the quality of the structure, shape, and function of these institutions at the local level. Qualitative research is also necessary to understand the factors that contribute to the sustainability and richness of Wat Pah Nanachat and Wat Pa Nong Pah Phong today.

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Conflicts of interest

The authors declare no conflict of interest.

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