HNUE JOURNAL OF SCIENCE
Natural Sciences 2025, Volume 70, Issue 4, pp. 165-181
This paper is available online at http://hnuejs.edu.vn/ns
DOI: 10.18173/2354-1059.2025-0064

CHARACTERISTICS OF THE LANDSCAPE CLASSIFICATION SYSTEM OF COMMUNES: CHO RA, BA BE, PHUC LOC, THUONG MINH AND DONG PHUC, THAI NGUYEN PROVINCE

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Received April 3, 2025. Revised November 28, 2025. Accepted December 30, 2025.

Abstract. The paper builds a landscape classification system to clarify the characteristics of landscape units in the communes of Cho Ra, Ba Be, Phuc Loc, Thuong Minh, and Dong Phuc, Thai Nguyen province. The diversity and spatial differentiation of the landscape of the area are shown through the model diagram of the landscape classification system; four landscape component maps and landscape (synthesis) maps of the five communes at the same scale of 1:50,000. The landscape units of the area are arranged into a system of seven levels, including one landscape system, one landscape subsystem, one landscape type, three landscape classes, five landscape subclasses, six landscape classes, and one hundred and nineteen types of landscape. The research results provide a database for studies on the use of landscapes for local purposes and a basis to help managers develop planning, orientation for use, and conservation of the landscape here in a reasonable and sustainable way.

Keywords: landscape, landscape classification, landscape map, Thai Nguyen.

1. Introduction

Landscape classification (LC) is the basis for studies on landscape structures, processes, and functions, and is a prerequisite for landscape assessment, planning, protection, and management [1]. It is a method for determining the laws of development and distribution of landscapes [2], [3]. More specifically, LC is the arrangement of landscape units in a unified classification system based on the outstanding attributes of each landscape unit hierarchy [4]. According to Demek and R. Harvey, a landscape is a system of many constituent components, and between those components, there are mutual relationships, and each system consists of lower-order systems [3]. Naveh and Lieberman (1994) also argue that landscapes are divided into spatial-functional levels, each of which

is a "holon"—*an open system in a hierarchical whole*. Each contains holons at lower hierarchical levels and regulates them, and is also regulated by higher hierarchical levels [5], [6]. Landscape percentiles include spatial units ranging in scale from local to global; units below the lowest landscape percentile are refered to as landscape *morphological units* (Nguyen Thanh Long et al., 1992) or *landscape factors* (Forman and Godron, 1986; Forman, 1995) [7]. Depending on the purpose and extent of the study, the appropriate LC system is selected.

Globally, prior to 1940, the LC model did not have a complete system, but there was a perception that landscapes could be analyzed at different levels. Representatives include Alexander von Humboldt (Germany: 1769 - 1859), LC research methods shifted from traditional observation and description to system analysis and application of modern technologies. LC has expanded beyond mere natural geography to encompass many interdisciplinary approaches [5]. Since 2010, a number of new LC systems have been widely applied, particularly in Europe, China, and North America, such as LANMAP, MUFIC, and USFS [1], [2], [6]. Terms such as *system → sub-system → class → subclass* are a synthesis from the history of plant taxonomy, ecology, and functionally oriented landscape management [1], [6].

In Vietnam, LC research developed from the 1970s to the 1990s, and was strongly influenced by the (former) Soviet landscape geography school, while being adapted to suit Vietnamese conditions [3]. Some LC systems in Vietnam developed before 2000 are the main reference frameworks for this study such as the LC system proposed by Vu Tu Lap (1976) which includes eight levels, emphasizing the indicators of natural elements [8]; the LC system by the Center for Natural Geography – Institute of Geography (1992) including ten levels, combining the indicators of natural combination and indirect human impacts through land use [2]; the LC system by Pham Hoang Hai et al. (1997) consisting of seven levels, of which the human life index is one of the characteristic and outstanding indicators [3]. Since 2000, LC studies have made more contributions in terms of both theory and practical application. Typical representatives include Le Nam (2020), and Nguyen An Thinh (2013) [2], [7]; LC research has been applied in theses and publications in scientific journals at different regional and local levels such as those by Pham Huong Giang (2016) [9].

Ba Be is a mountainous district in Bac Kan province, established in 2003 with a total area of 684.09 km^2. According to Resolution No. 1683/NQ-UBTVQH15 dated June 16, 2025 issued by the Standing Committee of the National Assembly on the arrangement of commune-level administrative units of Thai Nguyen province, the entire area of Ba Be district, Bac Kan province, now belongs to the communes of Cho Ra, Ba Be, Phuc Loc, Thuong Minh and Dong Phuc of Thai Nguyen province; hereinafter referred to as "the five communes". The territory of Bang Phuc commune of Cho Don district, Bac Kan province (old), is not included in this study as it was recently merged into Dong Phuc commune of Thai Nguyen province. This place has a very rich and diverse environment, notably Ba Be National Park [9]-[11]. The research related to landscape in this area in the past, conducted by authors such as Chu Thi Van Anh (2017), Nguyen Thi Dong (2020) [12], [13] and some other authors are mostly concentrated in the Ba Be National Park area. Currently, there is no detailed landscape classification system for the five communes.

This study builds an LC system to clarify the law of landscape differentiation; builds an LC model, component maps, and landscape maps at a scale of 1:50,000; and analyzes and clarifies the outstanding characteristics of landscape units in the LC system of the five communes. The results of the study serve as a database to help managers and territorial planners orient the rational and sustainable use of the landscape in the locality.

2. Content

2.1. Databases and research methods

- *Database:*

(i) Administrative maps, geomorphological maps, topographic maps, soil maps, vegetation maps, and relevant forest status maps from the Department of Natural Resources and Environment of Bac Kan province, the Institute of Agricultural Planning and Design, the Forest Planning Investigation Institute - the Ministry of Agriculture and Rural Development, Institute of Geography, Institute of Geology - Vietnam Academy of Science and Technology.

(ii) Records, observations, photographs, and videos on the characteristics of landscape components and landscape differentiation of the five communes collected by the author from three routes and 17 field survey points during the research period (2021 - 2025).

(iii) Research works and scientific reports at domestic and overseas scientific conferences; reports on the status of socio-economic development, land use planning, and other documents of Bac Kan province and the former Ba Be district related to the topic.

- *Research methods:*

The project uses the following main research methods:

Methods of collecting, analyzing, and synthesizing documents: Applied to identify research problems, collect input data to analyze the constituent factors of landscape, analyze dominant factors to clarify the law of landscape differentiation, determine the hierarchy of percentiles in the LC system, and synthesize indicators to clarify the characteristics of landscape units throughout the system.

Map method and geographic information system: Applied to build four landscape component maps and landscape maps of the five communes. The basis for superimposing the component map layers into a landscape map comes from the perspective of synthesis—all landscape components intersect and interact with each other to develop [2]. The human component is not built into a separate map layer, but the level of human impact is integrated as shown in the vegetation cover map (low-impact evergreen closed forests, planted forests, agricultural ecosystems). The ArcGIS software application implements techniques for superimposing component map layers to determine the boundaries of landscape units, combining spatial analysis and synthesis to give percentile levels, adjustment, and grouping of small spheres with relative uniformity together, establishing the landscape map of the five communes, including component maps and landscape maps at the same scale of 1:50,000. This ratio ensures consistency and a level of detail that is appropriate for the use of landscape in local practice. The total number of zones is 1,207, with an average area of 56.68ha per zone. The base unit of landscape maps of the five communes is *landscape type*, represented by symbols (landscape

numbers), with ordinal numbers from 1 to 119**.** The process of establishing landscape maps of the five communes is as follows*:* collecting databases → building component maps → stacking → grouping → rasterization → glossary → landscape map.

System classification method: Approaching system logic to identify, divide, and organize landscape units according to a hierarchy from higher to lower levels. This method is applied to build an LC system for the five communes, including hierarchical percentile levels reflecting the systematic spatial organization of the landscape, based on the following principles: synthesis-system, hierarchical principle, territorial principle, historical-arising principle, and quantitative-technology integration. These principles are flexibly applied in the process of establishing the LC system of the area. The process of building the LC system for the five communes is as follows: identifying researcg objectives and objects → collecting input data → selecting criteria for determining landscape percentiles and landscape units → overlapping the component map layers and coordinating map analysis, etc. →analysing field survey and statistics to determine the boundaries of landscape units → Naming and symbolizing landscape units → building LC system tables, LC model diagrams, and landscape maps → describing the characteristics of each landscape unit.

Survey method: Implementing three field routes: *Route 1 (South – North):* National Highway 3 → along Provincial Highway 258; *Route 2 (East – West):* National Highway 3 → National Highway 279 → Ba Be National Park, especially the section of Ba Be lake → Ao Tien → An Ma Island → Dau Dang waterfall with a total length of nearly 10 km; *Route 3 (core area of Ba Be National Park):* Provincial Highway 254 → Hua Ma Cave →the end point of Provincial Highway 254. Survey work includes observing, recording, and collecting samples and information on the status of the landscape in the field for research tasks and verification of research results.

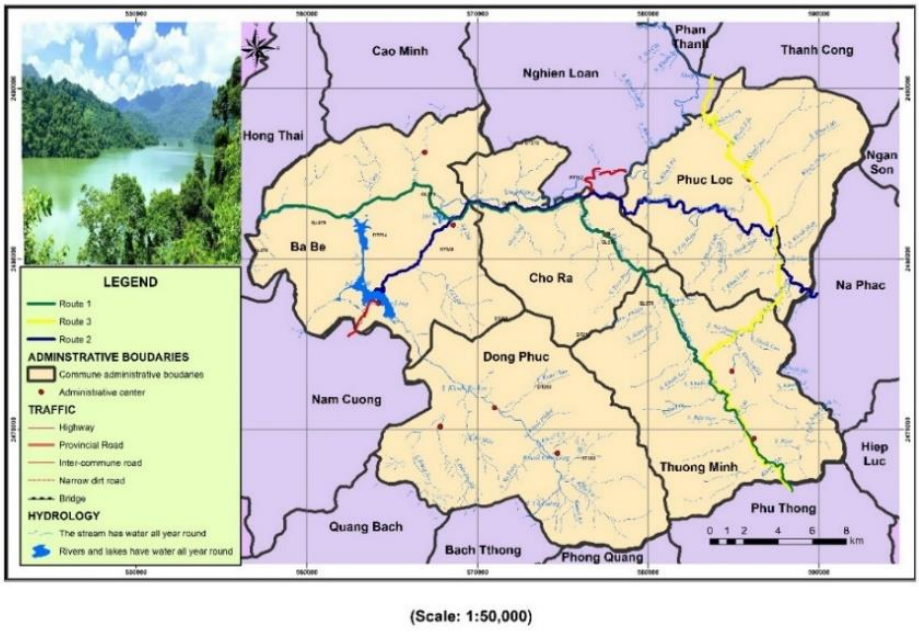


Figure 1. Diagram of field routes in the study area

In general, the construction of the LC system of the five communes uses a combination of many research methods, in which the methods of analysis – synthesis**,** mapping, and classification are the core.

Multi-system model: This study applies Cherkashin's multi-system model (2021) to present the hierarchical structure and systematic organization of landscape units. This model is a development from the theoretical foundation of geochemistry of the (former) Soviet Union, combined with the modern eco-spatial perspective that has been widely developed recently [5], [6].

2.2. Research results

2.2.1. LC criteria and characteristic signs of the LC system of five communes

Based on the selection of criteria and characteristic signs of LC of the five communes, including: referring to the system of LC indicators of previous research works in the world and in the country, mainly by the authors: Vu Tu Lap (1976) [8], Pham Hoang Hai & et al. (1997) [3], the Center for Natural Geography – Institute of Geography (1992) and Pham Huong Giang (2016), [9]; characteristics of landscape of the five communes; research objectives and map scale.

The main criteria selected to build the LC system for the five communes include: topography (terrain type, elevation, and topographic morphology); climate (average annual temperature, rainfall, and humidity); soil (soil type, mechanized composition, and land use capacity); plant cover (less affected closed forests, secondary plant cover, etc.); hydrology (river density, and flow regime); human life components (population, types of economic production, current land use status, and infrastructure works), natural disasters and climate change.

Combining the use of research methods, the topic of determining the LC system for the five communes, including seven levels, characteristic signs of landscape percentile levels are presented in the table below:

Table 1. Landscape levels and typical signs of the LC system in the five communes

No	Landscape percentile	Characteristic signs	Names of landscape units in the five communes
1	Landscape system	Solar radiation, humid heat, and humidity regimes shape the entire region.	Monsoon humid tropical landscape system.
2	Landscape subsystem	The monsoon recirculation mode redistributes heat and moisture.	Subtropical landscape system, humid monsoon with cold winters.
3	Landscape Type	Climate differentiation according to rainfall and dry time of year.	The landscape style of the evergreen rainforest in the rainy season.

4	Landscape class	Determined by topographic morphological groups: hills, mountains, valleys, and low-lying areas.	Mountain landscape layer; Hill landscape layer; Valley landscape layer.
5	Landscape subclass	Divided within the class range. Defined by the more detailed morphological hierarchy of the landscape class	Secondary grade of medium mountain landscape; Secondary low mountain landscape; Secondary layer of high hill landscape; Sub-layer of low-hill landscape; Sub-class landscape valley and valley in the middle of the mountain.
6	Landscape class	Determined by geomorphological signs mainly in the area	Riverbeds and alluvial beds (1); Ditches and low-lying bottoms erode rivers and streams, exposing bedrock (2); Karst surface (3); Ribs eroded, peeled off, landslides (4); Water surface (5); Special-use land (6).
7	Type of landscape	As a result of the interaction between the heat-moisture platform and the solid platform, landscape-type units are formed that exhibit homogeneous landscape characteristics in terms of both geothermal and non-geothermal characteristics.	119 types of landscape.

2.2.2. Main characteristics of landscape components of the five communes

The landscape of the five communes is associated with the history of natural territorial development of the mountainous region of Northeast Vietnam, with a geographical coordinate system of $22^0$27' to $22^0$35' North latitude - $105^0$44' to 105058' East longitude. This geographical location stipulates the percentile levels: landscape system, sub-landscape system, and common unified landscape type throughout the territory of the five communes. Based on this common characteristic, the diverse differentiation of the landscape of the five communes is the result of the impact of all landscape components: geology, topography–geomorphology, climate, soil, hydrology, biology, natural disasters, and human components of the five communes [9]-[11].

Geology → Formation of the solid foundation of landscape: In the area, there are three bending structures (Duong Phong concave fold complex belonging to the Phu Ngu structural zone; an arch-shaped convex fold in the Lo Gam structural zone; Ngan Son convex fold belonging to the Bac Son tectonic block); nine geological strata and three

magma intrusion complexes. The lava composition contains both ancient and modern elements, such as ancient gneiss, intrusive granite, limestone, and sandstone sediments.

Topography – geomorphology → Formation of the solid foundation of landscape: The territory of the five communes is located in the Northeast limestone mountain belt and belongs to the mountain ranges of the Gam river bow, with an average altitude of 600m above sea level; there are many limestone mountains interspersed with soil mountains, typically the Phja Bjóoc mountain range with a height of 1,578m. The main types of terrain include hills, mountains, and valleys. The terrain has high slopes; only 9.71% of the area of the district has slopes of less than 15^{o}, while the rest has slopes of more than 15°. The territory has six main geomorphological forms: Erosion slopes, erosion, landslides; Karst surface, ditches and low-lying bottoms erode rivers and streams, exposed bedrock; riverbeds and shoals; water surface; special-use land. Of these, the slopes of erosion and landslides account for 72.9%, and the karst surface accounts for 14.58% of the territorial area.

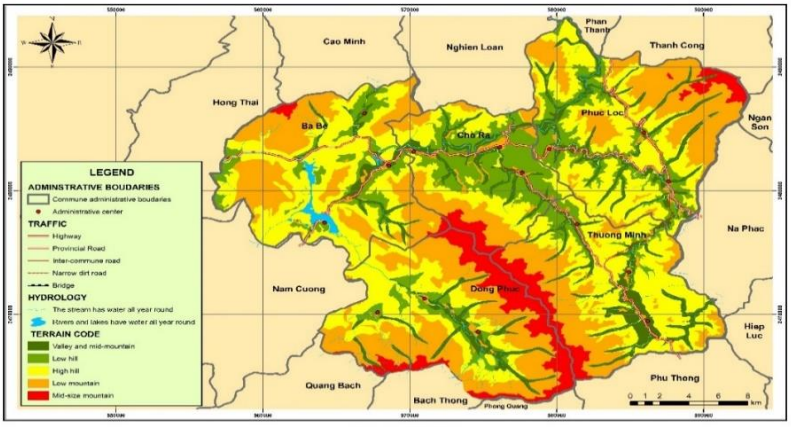
Climate → Direct impact on organisms, soil, and hydrology in the landscape: The area has a humid tropical monsoon climate. The average annual temperature is 23.7 ^{o}C, with the amplitude ranging from 13 ^{0}C to 15 ^{0}C. The average rainfall is 1,253 mm, the total average number of sunshine hours is 1,500 hours/year, and the humidity is quite high, with little fluctuation, averaging 84.6%. Cho Ra Valley – Ba Be Lake has low rainfall and has almost completely lost the typical early winter dry period of the Northern Climatic Region of Vietnam. This area has a monsoon regime, with the prevailing wind directions from the northeast, southwest, and south. Because it is located inland and is protected by high mountains, it is less affected by storms.

Soil → Habitat for organisms in landscape: The territory has seven main types of soils, all of which belong to the group of typical forest soils of the Northern mountains of Vietnam: Ferrite soils grow on acidic magmatic rocks, ferrite soils grow on clay and metamorphic rocks, reddish-brown soils on limestone, pale yellow soils on sandstone, reddish-yellow loamy soils on acidic magmatic rocks**,** river alluvial soils and brittle alluvial *soils.* Some types of soil are scattered over a small area, such as red-yellow humus soil on claystone, sloping soil for wet rice cultivation, feralite soil modified by rice cultivation, and yellowish-brown soil on ancient alluvium.

Hydrology → Source of life, climate regulation, and ecological functioning of the landscape: The Nang River and Ba Be Lake play the main role in the formation of the landscape here. Most of the region's rivers and streams are in the watershed area, and the beds of rivers and streams are deep and steep. People of all ethnic groups often build ditches, fade, north troughs, water reels, or take advantage of waterpower to serve production and daily life, such as rice mills, cotton machines, small-scale hydropower plants, and downstream fields. Ba Be Lake has both river and lake characteristics, with an area of about 500 hectares, located at an altitude of 150 m above sea level, with an average depth of 15 - 20 m, and the deepest place of 30 m.

Organisms → Living factors in the landscape ecosystem: Forest is a very typical landscape of the region, with a high forest cover rate (67.7%). Forest land area accounts for 84.71% of the natural area of the five communes, with indigenous and rare species such as Nghien, Lat, and Dinh, and temperate trees growing on the top of the Bjóoc

Mountains**.** Ba Be National Park belongs to the humid monsoon rainforest ecosystem in the Northern limestone mountains, characteristic of a primeval forest in the North of the country. In 2011, it was recognized as the 1938th Wetland Area (RAMSAR) of the world and the 3rd RAMSAR area of Vietnam, with the main types of ecosystems (ecosystem) including planted forests (51.83%), low-impact evergreen closed forests (26.55%), and secondary closed forests (8.84%). In addition, there are also ecosystems such as grass and shrubs, aquatic biomes, residential populations, special-use land, and agricultural ecosystems. The type of primeval forest that is less affected by the limestone mountains here is considered a standard model of the limestone mountain forest ecosystem typical of the Northeast region of Vietnam and the world.



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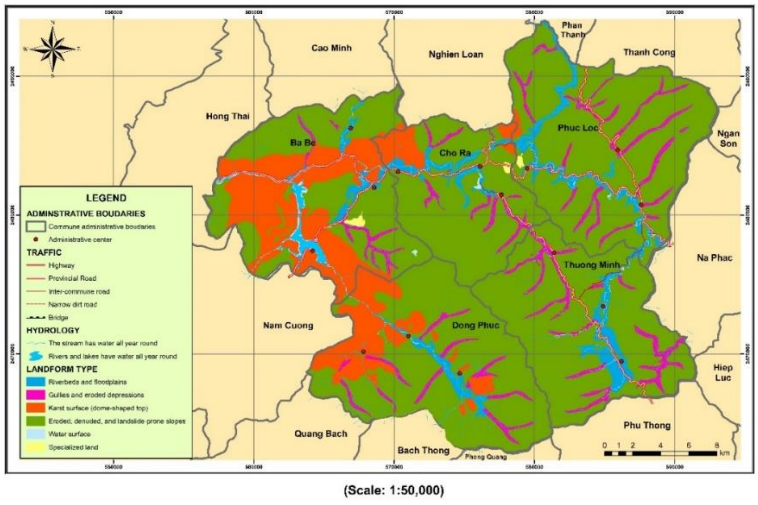

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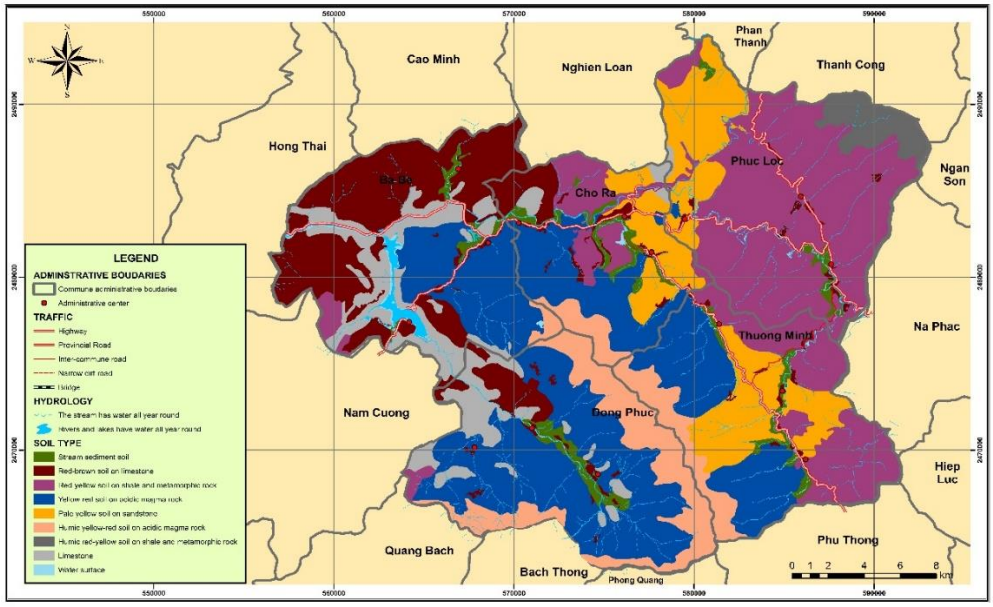
Figure 2. Landscape component maps of communes: Cho Ra, Ba Be, Phuc Loc, Thuong Minh and Dong Phuc, Thai Nguyen province, Thai Nguyen province (Miniature maps with a scale of 1/50,000): (a) Topographic map; (b) Geomorphological map



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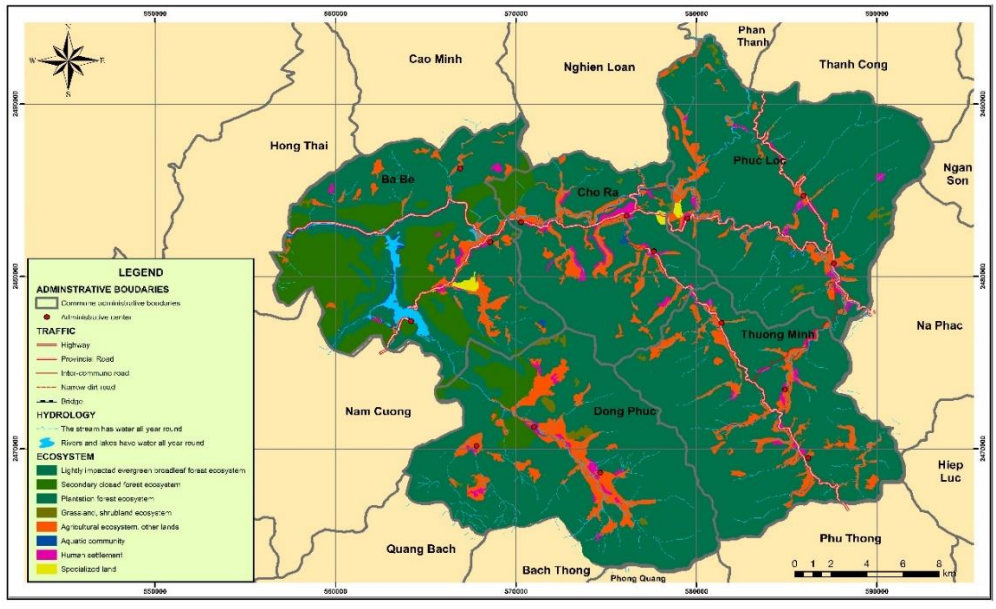

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Figure 3. Landscape component maps of communes: Cho Ra, Ba Be, Phuc Loc, Thuong Minh and Dong Phuc, Thai Nguyen province, Thai Nguyen province (Miniature maps with a scale of 1/50,000): (c) Soil map; (d) Ecosystem map of the study area

Human life component → Factors of great change, the emergence of human life crisis: In 2023, the population here was 49,934 people, of which the rural population accounted for 90.69%, and the average population density was 70/km^2. Over 95% of the population here are ethnic minorities: Tay, Nung, Dao, H'Mong, Kinh, Hoa, and San. Residential areas are quite concentrated along National Highway 279, and provincial roads 258, 254, and 212. The distribution is high: the lowest is Tay village; the highest is H'Mong village. Currently, most of the ethnic minorities of the five communes have human impacts, mainly agriculture and forestry combined with tourism in various forms: forest services, farming, ecotourism, and conservation projects. Only 0.03% of the land area has not been put into operation. The traffic system of the five communes has one national highway, four provincial roads, and six district roads. All of the communes have asphalt roads to the commune center. There are 45 schools at all levels (kindergarten, primary, and high school); one general hospital; eight solidly built rural markets, and one commercial and service center.

Disasters and climate change → impact on landscape sustainability: Up to 19% of ethnic minorities of the five communes have a very high risk of landslides, whereas the area with unknown or very low landslide risk accounts for only 14%. This area is also affected by the following phenomena: sedimentation of the bed of Ba Be Lake and Nang River, land degradation, a decline in area and diversity of forests, extreme weather events (hailstorms, severe and damaging cold spells, and salt fog) [9], [11].

Based on data sources collected and the mapping method, the study built four landscape component maps showing the diversity and spatial distribution laws of topography (a), geomorphology (b), soil (c), and ecosystems (d) of the five communes, shown in Figure 3.

2.2.3. Map of the landscape classification system and landscape map of 5 communes

- Diagram of the LC model of the five communes:

Based on the system of indicators and signs of identification of percentile levels and landscape units, along with the characteristics of landscape components of the five communes, the landscape grading method was used to identify landscape units and build the LC system of the five communes. The system consists of the following landscape units: one landscape system, one landscape sub-system, one landscape type, three landscape classes, five landscape sub-classes, six landscape classes, and 119 landscape types. These landscape units are arranged into a system of seven percentile levels, in order from high to low as follows: *one landscape system → one landscape subsystem → one landscape type → three landscape classes → five landscape subclasses → six landscape grades → 119 landscape types.* The hierarchical model of the LC system above is shown in Figure 4.

A landscape map is a composite map, fully and objectively reflecting the characteristics of nature, the relationships, and the mutual impact among landscape components [3].

The map of the communes of Cho Ra, Ba Be, Phuc Loc, Thuong Minh, and Dong Phuc, Thai Nguyen province, at a scale of 1:50,000 uses the base unit of type *of landscape*, reflecting the current landscape, the law of differentiation of landscape of the area, and is

the spatial basis to help assess the natural potential of the landscape for practical purposes of the locality.

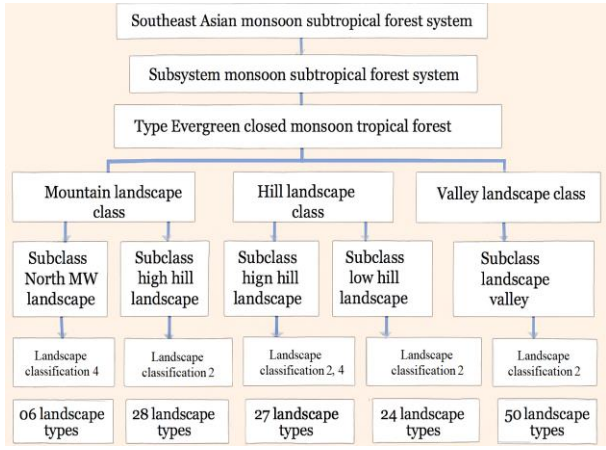

Figure 4. Diagram of the hierarchical model of the LC system in communes: Cho Ra, Ba Be, Phuc Loc, Thuong Minh, and Dong Phuc, Thai Nguyen province

The landscape map legend shows the LC system of the area, including all landscape percentiles. The legend is built according to *the matrix table*. The vertical columns on the left margin represent the solid foundation (terrain and soil types). The horizontal column on the right shows the heat-humidity platform (climatic type and plants). The intersection between the vertical and horizontal columns forms matrix cells with numbers (landscape numbers) and coloring characteristic of each landscape unit. The numbers and colors on the matrix cell of the annotation are recorded and colored according to the numbers and colors on the landscape map.

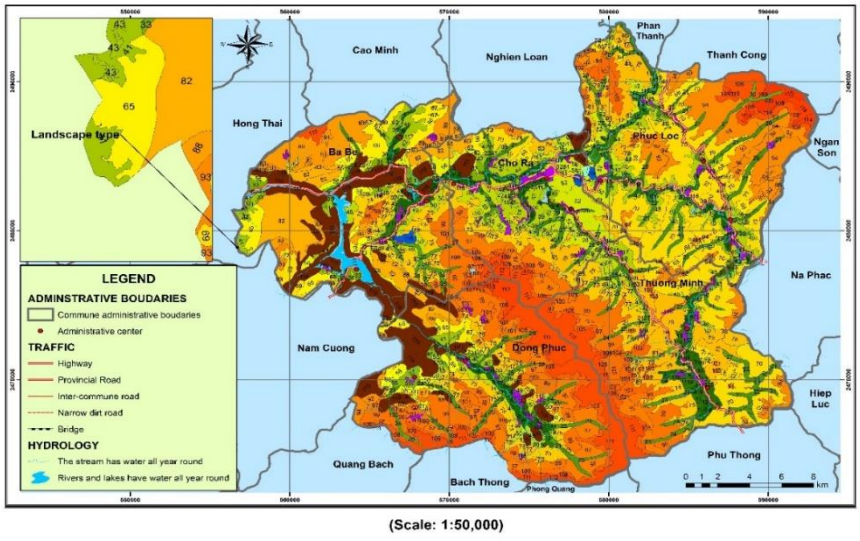

Figure 5. Landscape map of communes: Cho Ra, Ba Be, Phuc Loc, Thuong Minh, and Dong Phuc, Thai Nguyen province

THERMO-HYGROMETRIC PLATFORM / SOLIDE PLATFORM			LANDSCAPE SYSTEM	Tropical humid monsoon landscape system				
			LANDSCAPE SUBSYSTEM	Cold humid winter tropical monsoon landscape subsystem				
			LANDSCAPE TYPE	Tropical evergreen rainforest landscape type				
Landscape layer	Sub-landscape layer	Landscape category	LANDSCAPE CATEGORY / Types of Ecosystems / Soil type	Minimally disturbed secondary closed forest	Secondary closed forest	Planted forest	Grasslands and shrublands	Agroecosystems and other lands
Valley	*Valley*	*Riverbed and floodplains*	Alluvium	1	2	3		4
			Reddish-brown soil on limestone		5	6		7
			Red-yellow soil on claystone and metamorphic rock	8		9		10
			Red-yellow soil on acidic igneous rock			11		12
			Light yellow soil over sandstone			13	14	15
		Ravines and stream erosion basins, bedrock exposed	Alluvium			16		17
			Reddish-brown soil on limestone			18		19
			Red-yellow soil on claystone and metamorphic rock	20		21		22
			Red-yellow soil on acidic igneous rock	23		24		25
			Light yellow soil over sandstone	26		27		28
			Humic red-yellow soil on acidic igneous rock	29				
			Humic red-yellow soil on claystone and metamorphic rock	30				
Hills	*Low hills*	*Karst Surface*	Alluvium			31		32
			Reddish-brown soil on limestone		33	34		
			Red-yellow soil on acidic igneous rock		35	36		37
			Light yellow soil over sandstone			38		
		Eroded slopes with landslides	Alluvium			39		40
			Reddish-brown soil on limestone		41	42		43
			Red-yellow soil on claystone and metamorphic rock	44		45		46
			Red-yellow soil on acidic igneous rock	47	48	49		50
			Light yellow soil over sandstone	51		52	53	54
	High hills	*Karst Surface*	Reddish-brown soil on limestone	55	56	57		
			Red-yellow soil on acidic igneous rock	58	59	60		61
			Light yellow soil over sandstone	62		63		
		Eroded slopes with landslides	Alluvium			64		
			Reddish-brown soil on limestone		65	66		67
			Red-yellow soil on claystone and metamorphic rock	68	69	70	71	72
			Red-yellow soil on acidic igneous rock	73	74	75	76	77
			Light yellow soil over sandstone	78		79	80	81
Mountains	*Low mountains*	*Karst Surface*	Reddish-brown soil on limestone		82	83	84	
			Red-yellow soil on acidic igneous rock	85	86	87		
		Eroded slopes with landslides	Reddish-brown soil on limestone		88	89	90	91
			Red-yellow soil on claystone and metamorphic rock	92	93	94	95	96
			Red-yellow soil on acidic igneous rock	97	98	99	100	101
			Light yellow soil over sandstone	102		103		104
			Humic red-yellow soil on acidic igneous rock	105		106	107	
			Humic red-yellow soil on claystone and metamorphic rock	108		109		
	Average mountains	*Eroded slopes with landslides*	Reddish-brown soil on limestone			110		
			Humic red-yellow soil on acidic igneous rock	111		112	113	
			Humic red-yellow soil on claystone and metamorphic rock	114		115		
Residential land				116				
Water surface				117				
Special-use land				118				
Rocky mountain				119				

Figure 6. Glossary of landscape map of Ba Be district; 1/50,000 scale

2.2.4. Characteristics of landscape units in the PLCQ system of the five communes

- *Characteristics of landscape units in the LC system of the five communes*: The LC system of the five communes includes seven percentile levels. Each percentile level consists of one or more landscape units of the same level. For the first three percentile levels - landscape system, landscape subsystem, and landscape type - each percentile level consists of only one specific landscape unit. These commune units are formed mainly by

natural processes, which are territorial and govern the entire area of the five communes. Compared to lower-level units, they are less affected by human activities and have more stability, as described below:

Humid monsoon tropical landscape system of the five communes: Each landscape system is a natural unit with high uniformity, clearly distinguished from zones or subzones, and determined by the source of radiation (heat and humidity) and regional ecological laws. This is the highest landscape percentile in the LC system of the five communes, including one landscape unit, specifically "*humid monsoon tropical landscape system"* with outstanding characteristics: terrain type characterized by limestone mountains, interspersed with karst valleys; ferrite soil on limestone with strong drainage; the relatively intact primeval forests on the limestone mountains; a colder climate with pronounced winter; and Ba Be Lake as a very unique landscape. These characteristics differentiate this landscape unit locally while maintaining the general standard of the landscape system that is currently distributed throughout the localities in northern and north-central Vietnam [3], [8].

Tropical monsoon subsystem with cold and humid winters of the five communes: The landscape subsystem is at a lower percentile level than the landscape system. In the LC system of the five communes, the landscape subsystem includes one specific landscape unit, namely *the tropical monsoon landscape subsystem with cold and humid winters*. This landscape unit is widely distributed in many provinces in the north of Vietnam (e.g., Tam Dao, Cuc Phuong, Yen Bai, and Thanh Hoa) [3], [8], [9]. In the study area, this landscape subsystem has the following characteristics: complex terrain with limited strong impacts; cold, foggy winter affected by the microclimate of lakes and rocky mountains; caves, lakes, and karst underground streams in Ba Be National Park; and high biodiversity and many endemic species (white-cheeked black gibbons, toads, and big-headed turtles) [10].

Seasonal evergreen rainforest landscape of the five communes: According to most documents, the territory of Vietnam is divided into two main types of forests: tropical evergreen jungle landscape in the rainy season in hot and humid areas, and semi-deciduous or seasonal deciduous forest landscape in hot and humid areas with prolonged dryness [3], [8], [9]. The outstanding features of the tropical evergreen jungle landscape in the five communes are: Strong dominance of high belts, though those high belts share a relatively uniform heat-humidity mode; moderate rainfall and relatively high humidity with little fluctuation (average humidity of 84.6%); a short dry season; high forest cover; widespread evergreen elements across forest communities throughout the territory; multi-layered forests, interspersed with exposed rocks; vegetation growing in close association with rocks; and organisms living in caves and underground streams.

Landscape layers and landscape sub-layers of the five communes: From the 4th to the 7th percentiles of the LC system of the five communes, the landscape is differentiated and non-geographical. The lower the percentile level, the more diverse the differentiation of the landscape, and the easier the level of human impact is to identify.

The landscape class is an intermediate landscape unit in the LC system. The landscape of the five communes is divided into three main landscape classes and seven sub-landscape classes. The distinguishing criteria of hill class, mountain class, and valley

class in the middle of the mountain are mainly based on the quantitative differentiation of topographic morphology (shape, elevation, slit, and slope). Sub-landscape classes are established within the scope of the landscape class and are based on more specific differentiation markers than the main landscape class, namely:

* *Hill Commune Class*: This has the largest area, accounting for 49.7% of the total area of the five communes inhabited by ethnic minorities. The main terrain type consists of hills and mountains with a common altitude of 300 - 400m. The surface of the landscape layer is divided by streams, and transport is very difficult. Plant cover occupies the most dominant area of planted forests. This landscape class consists of the low-hill landscape sub-class and the high-hill landscape sub-class.

The low-hill sub-class accounts for 13.34% of the total area of the five communes inhabited by ethnic minorities. In addition to the main planted forest area, there are areas of rice fields, rice paddies, and terraced fields, where rice, corn, and annual crops are cultivated. This sub-class has two classes of landscapes (ditches and low-lying bottoms that erode rivers and streams with exposed bedrock; erosion, peeling, and landslides), with 24 types of landscape (from landscape type No. 31 to landscape No. 54). Of these, the current use status is dominated by planted forests, accounting for nearly 60% of the area of the sub-layer.

The sub-class of high hill landscape accounts for 36.39% of the total area of the five communes inhabited by ethnic minorities, distributed mainly at an altitude of 300 - 500 m, and 45.15% of the area of the sub-class with a slope of over 25º. This sub-layer includes two classes of landscape (trenches and low-lying bottoms eroding rivers and streams, bedrock roads, erosion, and landslides), with 27 types of landscape (from landscape No. 55 to landscape No. 81).

Mountain landscape class: This has the highest absolute altitude, commonly ranging from 600m to 1000 m; The terrain surface is strongly dissected, with slopes mostly exceeding 15º with terrain types of erosion-tectonic origin, many rugged limestone mountain ranges, thick layering, steep walls, quite common landslides, washing, and erosion**.** This landscape class consists of the medium mountain landscape subclass and the low mountain landscape subclass. The plant cover is dominated mainly by low-impact evergreen closed forests and planted forests. This place concentrates most of the district's mountain and rocky areas.

The low-mountain sub-layer accounts for 32.0% of the area's sub-soil; the average altitude is 500 - 700 m; 59.43% of the area of the sub-layer has a slope of over 25º; the soil is mainly loamy soil on rocks of different origins, thin soil layers, and many floating rocks. In addition to natural vegetation, there is also man-made vegetation, which includes planted forests and perennial trees. This sub-layer includes two classes of landscape (trenches and low-lying bottoms eroding rivers and streams, bedrock roads; erosion, peeling, and landslides), with 28 types of landscape (from type landscape No. 82 to type landscape No. 109).

The average mountain sub-class accounts for only 7.22% of the area's biodiversity; it is characterized by the highest absolute altitude, averaging 1000 m, with many high mountain ranges; 84.28% of the area of the sub-class has a slope of over 25º and the soil

layer is thin; the climate is tropical mountainous, with the cold season lasting five months, and the average temperature of less than 18 ºC. This sub-class has only the landscape class of erosion, peeling, and landslide, with six types of landscape (from landscape No. 110 to landscape No. 115). The current type of landscape is a rarely affected evergreen closed forest (number 111), accounting for 76.18% of the area of this subclass.

Valley landscape class: This accounts for 11.05% of the area of the five communes, with the lowest absolute altitude, usually located in low-lying areas between mountains or hills, with the average absolute altitude of 100m – 200m; the slopes are lower, but the terrain still belongs to the type of valley terrain with high slopes. Geological tectonic activities and the alluvial reclamation of rivers and streams have created a topography of trough valleys; basins distributed along rivers and streams, and ravines and low-lying bottoms exposed to bedrock. This class of landscape has the highest concentration of the agricultural ecosystems in the district (10 out of 30 types of landscape in the class).

Landscape classes of the five communes: Landscape classes are landscape units of lower percentile-level units than the percentile of landscape classes. The distinguishing signs of different landscape classes are based on the differentiation of microtopographic features, geomorphological processes, or landscape surface status. In the territory of the five communes, there are six main commune classes: Erosion, erosion and landslide rib classification occupies the largest area, accounting for 72.9% of the area of the five communes inhabited by ethnic minorities, present in 62 types of communes (39 - 54; 64 - 81; 88 - 115); Karst surface landscape class accounts for 14.58%, appearing in 23 types of landscape (31 - 38; 55 - 63; 82 - 87); Grade landscape of ditches and low-lying bottoms that erode rivers and streams, root rock roads account for 5.68%, appearing in 15 types of landscape (16 - 30); Riverbed and alluvial land landscape accounts for 5.37% and appears in 15 types of landscape (1 - 15); Water surface landscape class accounts for 1.24%, mainly present in landscape No. 117; The class of special-use land accounts for 0.23% of the district's urban area, where there are works for the construction of agency offices, non-business works, works for non-agricultural production and business and local public purpose works, mainly present in landscape type No. 118.

Types of landscapes of the five communes: In the LC system of the five communes, the landscape type represents the lowest percentile-level landscape unit, showing the correlation and a unique combination of all the criteria that have been used to build the LC system of the five communes, and is clearly demarcated on the landscape map. The natural territory of the five communes includes 119 types of communes. Among these, four types of landscape are specific and not classified according to landscape percentile levels, including: landscape type No. 116 (residential), No. 117 (water surface), No. 118 (special-use land), and No. 119 (rocky mountains). Landscape type No. 30 (Karst surface with planted forest) has the smallest area (6.5 km2). Type No. 70 (erosion, landslides; yellowish-red soil on claystone and metamorphosis; planted forest ecosystem), which is part of the high hill landscape sub-class, has the largest area (6889 hectares, equivalent to 10.07% of the five communes). On the landscape map, 119 landscape types are distributed across 1,207 polygons, with each polygon having an average area of 66.61 ha. Each landscape type has approximately 10 to 11 polygons. The landscape type, which

reflects the most comprehensive and specific entity of the landscape, is used as the basic unit to create the landscape map of the five communes (Figure 5).

Through a verification survey of 34 landscape types, the accuracy was 82.35%. Errors were found in landscape types with overly small polygons or those with "non-spatial" characteristics on the 1:50,000 scale landscape map. For example, within the landscape classification system of the the five communes: a location with coordinates 22°41'N-105°62'E belongs to landscape type No. 117 (water surface), but is actually located on a small island (An Ma Island); a location with coordinates 22°39'N-105°62'E belongs to landscape type No. 117 (water surface), but is actually located on the bridge south of Ba Be Lake; a location with coordinates 22°39'N-105°64'E belongs to the forest on rocky mountains landscape type No.119, but is actually located on the trekking route that runs through the core zone of Ba Be National Park. Furthermore, several experts have been consulted, and all believe that the results of building the landscape classification system for the study area are acceptable.

The research results presented here have successfully achieved the stated objectives of classifying and characterizing the landscape system of the five communes in Thai Nguyen province. However, there are still some limitations and shortcomings. These includethe isufficient clarification of the functions and ecosystem services of the landscape units and a lack of qualitative data to analyze landscape changes and development trends over time. Future research directions to further improve the study and enhance its practical application include integrating an analysis of ecosystem services into the landscape classification system and evaluating the ecological functions of the landscape for practical development purposes (forestry, tourism, and agriculture are fields with many natural advantages) within each landscape unit. This will help guide rational conservation, exploitation, and sustainable local development.

3. Conclusions

The communes of Cho Ra, Ba Be, Phuc Loc, Thuong Minh, and Dong Phuc, Thai Nguyen province, have diverse, rich and unique landscapes. The landscape classification system of the area consists of seven levels and landscape units are arranged in the following order: one landscape system → one landscape subsystem → one landscape type → three landscape classes → five landscape subclasses → six landscape classes → 119 types of landscape. The geography of landscape units at the high percentile level (landscape system, landscape subsystem, and landscape type) shows the unified relationship of the five communes in the overall landscape of the Northeast region of Vietnam. The landscape units at the lower percentile levels (landscape class, landscape subclass, landscape class, landscape type) clearly show the internal differentiation of the landscape of the region according to the landscape ecological and structural characteristics. Cherkashin's multi-system model is suitable for representing the landscape classification system of the five communes. Combined with the Component Maps and landscape maps of 5 communes, the scale of 1:50,000 is of great practical significance in planning and using the landscape for local socio-economic and environmental development purposes.

This research provides a scientific basis for the authors to conduct further studies on landscape assessment for agricultural, forestry, and tourism development in the area during the next research phase.

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