Индикаторы разнообразия для ландшафтной экологии в национальном парке Пумат, Нгеан, Вьетнам

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Аннотация

На структуру и разнообразие ландшафтной экологии влияют не только многие экологически значимые процессы, но и оценка плана, политики в отношении управления ресурсами. Используя ландшафтные индикаторы, можно выяснить связь между компонентами ландшафта и пространственным распределением. В данной статье индикаторы разнообразия используются для расчета площади национального парка Пумат во Вьетнаме. Индикаторы включают в себя *индекс числа выделов* (Number of patches – NP), *процент ландшафта* (Percentage of Landscape – PLAND), *форму объекта* (Shape – SHAPE_AM), *индекс формы ландшафта* (Landscape Shape Index – LSI)*, индекс контраст границы* (Edge Contrast – ECON_AM), *индекс распространения ландшафта* (Contagion – CONTAG), *индекс связности ландшафта* (Cohesion – COHESION), *индекс возможности соединения ландшафта* (Aggregation index – AI), *индекс разнообразия Симпсона* (Simpson Diversity Index – SIDI). Эти индикаторы были рассчитаны на единицах ландшафтной экологии, созданных из составных карт, которые включали геоморфологию (топографические и геологические карты), почвенные карты, карты биоклимата и карты растительного покрова. Результаты, которые представляют собой измеренные и проанализированные индикаторы, показывают, что разнообразие ландшафтной экологии будет способствовать планированию сохранения разнообразия и социально-экономического развития на территории исследования.

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Diversity Indicators for landscape ecology in the area of Pumat National Park, Nghean, Vietnam

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Abstract

Landscape ecology structure and diversity are not only influenced by many ecologically relevant processes but also by assessing the plan, policy about the management of resources. Using landscape indicators can find out the connection between landscape components and spatial distribution. In this article, the diversity indicators are used for calculating the area of Pumat National Park, Vietnam. These include *Number of patches (NP), Percentage of Landscape (PLAND), Shape (SHAPE_AM), Landscape Shape Index (LSI), Edge Contrast (ECON_AM), Contagion (CONTAG), Cohesion (COHESION), Aggregation index (AI), Simpson Diversity Index (SIDI).* These indicators were calculated on landscape ecology units created from component maps that included geomorphology (topographic and geological maps), soil maps, bioclimate maps, and vegetation cover maps. The findings which are indicators measured and analyzed then show the diversity of landscape ecology will contribute to planning diversity conservation and socio-economic development in the research area.

1. Introduction

1.1. Introduction

As system models, indicators and indices simplify systems, functions, forms, and processes. However, a set of meaningful and representative indicators would facilitate knowledge, decision-making, monitoring, and evaluation of planned interventions in terms of policy and management objectives [1]. The landscape indicators were developed and calculated in a manner that lends itself to hypothesis testing and associated statistical analysis whenever resource managers think such analyses would be informative and helpful [2]. landscape metric and indicator values can provide information on the trends in the condition of the ecosystem components. The information about trends helps to determine: 1) if it is necessary to intervene,2) if so, which intervention will yield the best results, and 3) how successful interventions have been [4].

Landscape metrics applications allow objectively and expeditiously assess landscape diversity and present an appropriate model for optimized allocation of lands in agro-landscapes [8]. In fact, the biotope assessment provided no information about the landscape's spatial distribution or structural composition. As a result, landscape metrics were used to examine structural and biotope diversity at the landscape scale [7].

We can analyze two of the most important features of a landscape using Landscape Ecology metrics: composition and configuration. The composition of a landscape refers to the richness and abundance of the various elements that comprise it, without taking into account their spatial distribution; however, even if the composition metrics are not explicitly spatial, they have significant spatial effects. Landscape

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configuration, on the other hand, refers to the spatial properties of the elements, such as distribution, position, orientation, and shape [1].

Landscape ecology indicators can be used to describe a landscape's composition as well as its spatial arrangement. They can be applied at different levels to describe single landscape elements by such features as size, shape, number or for whole landscapes by describing the arrangement of landscape elements and the diversity of landscape [6]. A number of landscape metrics has been developed for investigation, monitoring and evaluation of landscape structure [8]. On another hand, landscape ecology unit is considered as an ecosystem which its functions depend on the spatial context and composition of the ecosystem (landscape context), landscape diversity conservation (including areas with natural vegetation) reduces negative impacts on the environment and enhance natural capital. The fact that the current international debate on landscape indicators is strongly ‘driven’ by the agro-environmental policy angle has quite naturally led to a somewhat biased selection [3].

Some studies represent landscape more as an ‘object’, that is in terms of the physical arrangements of various types of features. Thus, in the landscape ecological literature ‘landscape’ is often defined in terms of the structure and pattern of a land cover mosaic and its relationships with physical and biotic elements such as terrain, geology, soils and vegetation, and cultural factors associated with people’s use and management of the land over time.

Some land-use plans for public lands consider landscape ecology concepts such as fragmentation and connectivity [9]. Resource managers also see clear value in understanding the landscape context of decisions and assessments conducted at local levels (e.g., Wood et al. 2016). However, regular use of landscape metrics to inform planning and management decisions on public lands is lacking. On another side, by considering landscape scales and using resource information collected at multiple spatial scales that is understandable and accessible to all stakeholders, landscape approaches to resource management can help achieve sustainable, multifunctional landscapes [2].

1.2. Research area

Pumat National Park is located in three districts of Anh Son, Con Cuong Tuong Duong, Nghean province, approximately 130 kilometres from Vinh City, and is part of the Western Nghean Biosphere Reserve. The park, formerly known as the Pumat National Reserve, has a total area of 194,804ha, divided into 94,804ha of the core zone and 100,000ha of the buffer zone. *(Figure 1.)*

Pumat National Park has high biodiversity, with 2,500 plant species belonging to 160 families and nearly 1,000 animal species, where wild and rare genetic sources are conserved.

Many programs and projects on conservation, scientific research, sustainable livelihood development, and environmental education are being implemented; the values and cultural characteristics of the ethnic communities in the western region of Nghe An are being preserved, restored, and promoted...

Purpose of the research

Analysis diversity indicators of landscape ecology units at the area of Pumat National Park, Vietnam

Contents of the research:

- Create a landscape ecology map by overlay geomorphology map (topographic and geological maps), soil maps, bioclimate maps, and vegetation cover maps.

- Measuring diversity indicators of landscape ecology units in the Pumat National Park area, Vietnam

-Analyzing the results of a measuring indicator for landscape ecology units in the Pumat National Park area of Vietnam for priority spatial planning.

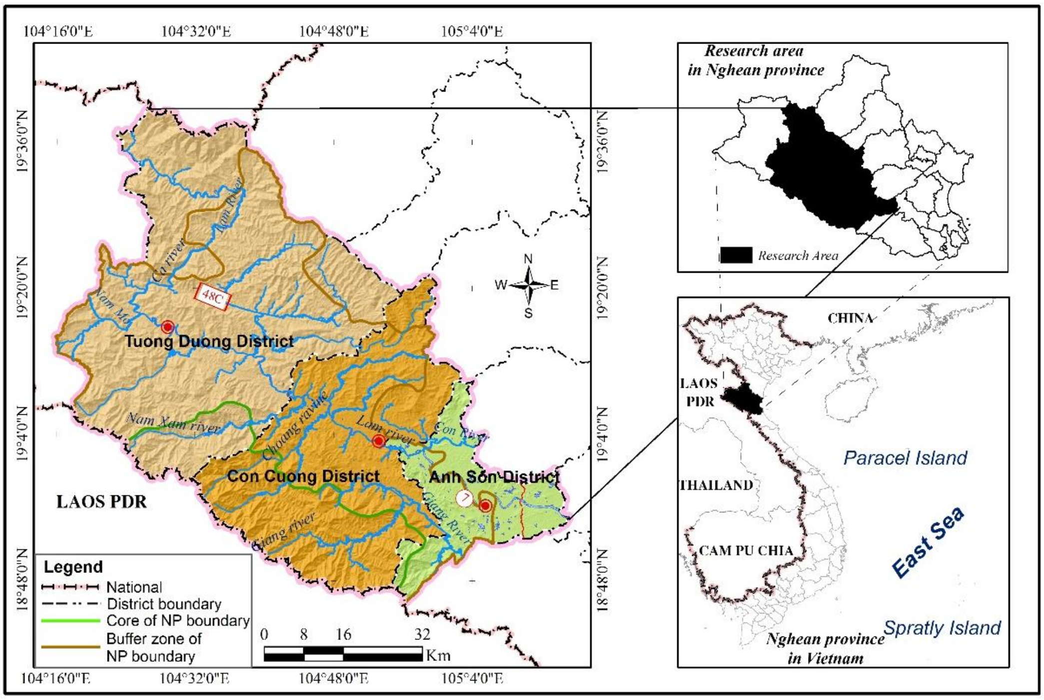

Figure 1. Map of the research area

2. Material and Methods

2.1. Material

The input maps used for creating landscape ecology map in the research area are geomorphology maps (topographic and geological maps), soil maps, bioclimate maps, and vegetation cover maps at a scale of 1:50.000. The landscape ecology map created from them in Pumat National Park consists of 110 landscape ecology units, with 32 landscape ecology units located in average mountains (1200-1700m), 30 landscape ecology units located in low mountains (700-1200m), 37 landscape ecology units located in hills (200-700m), and 11 landscape ecology units located in plain (200m).

2.2. Methods

Using ArcGIS 10.5's overlay tool to create a landscape ecology map from input maps listed in the material part. “Union” and “Intersect” are the two tools that can be used to complete this task. In this article, however, input data created from other total boundaries will be used. As a result, when using union tool, the output data is joined to maintain all features *(Figure 2)*. When using the intersect tool, the output data will match the smallest input data boundary, and all other data will be erased outside of it.

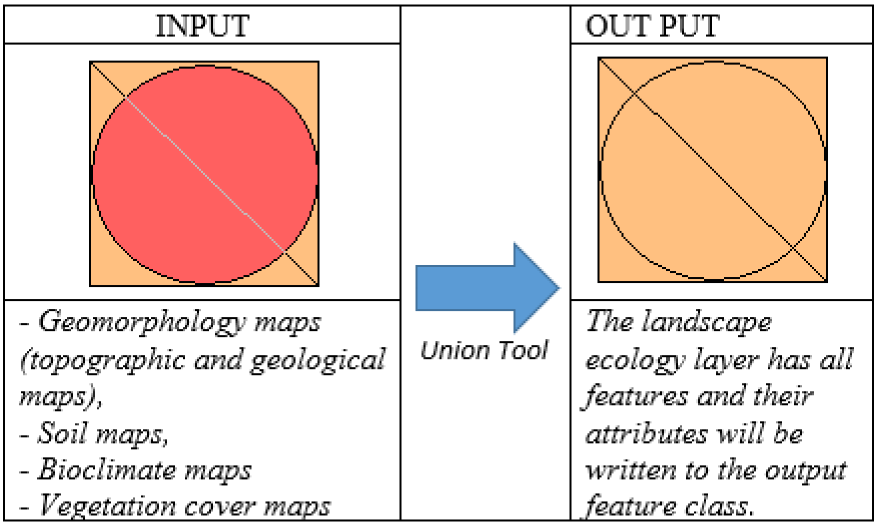

Figure 2. Translation method of creating landscape ecology map

Using the structure and diversity analysis method, GIS, Fragstat software measures, Number of patches (NP), Percentage of Landscape (PLAND), Shape (SHAPE AM), Edge Contrast (ECON AM), Contagion (CONTAG), Cohesion (COHESION), Aggregation index (AI), – Simpson Diversity Index (SIDI). Table 1 shows the definition, equation, and description of each indicator. Table 1 describes the indicator chosen to measure each concept (a more detailed description of the use of the indicators, as well as a complete description of the ecosystem concepts, can be found in McGarigal and Mark (1995). Figure 3 shows an overview of the approach used to construct the indicators.

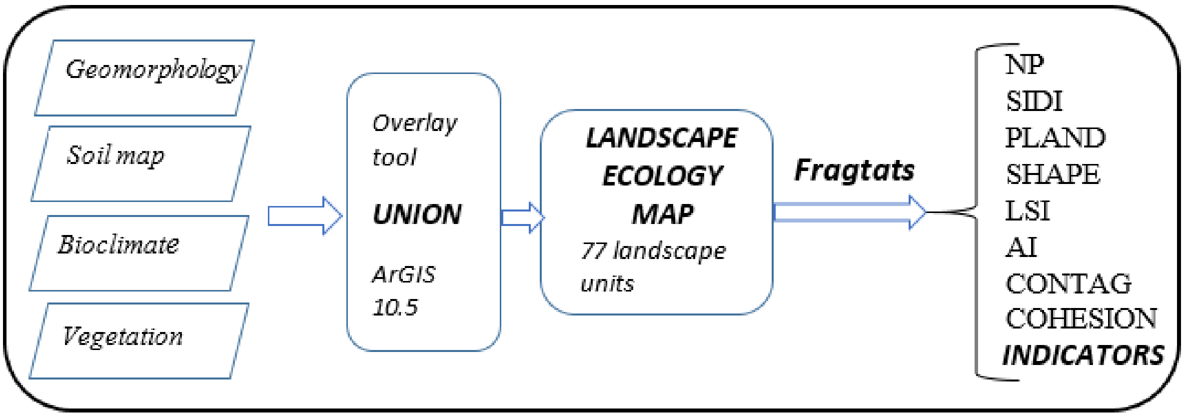

Figure 3. Outline of the methodology used to calculate the indicators.

2.3. Data processing

Table 1: Indicators go with their parameters and meaning

Indicator		**Parameters**	**Meaning**
1. Number of patches (NP)	$NP = n_i$ *Unit: None* *Range: NP ≥ 1, without limit.*	n_i = number of patches in the landscape of patch type (class) i.	Patch metrics for relative landscape ecology structure comparisons are provided by the number of patches.

2. Simpson Diversity Index (SIDI).	$\mathrm{SIDI} = 1 - \sum_{i=1}^{m} \mathrm{P}_i^2$ *Unit: None*	P_i = proportion of the landscape occupied by patch type (class) i.	Simpson Diversity Index (SIDI) is a measure of the diversity of homogeneous spatial units.
3. Percentage of Landscape (PLAND)	$\mathrm{PLAND} = \mathrm{P}_i = \frac{\sum_{j=1}^{n} a_{ij}}{\mathrm{A}}(100)$ *(Unit: Percent)* *Range: 0 < PLAND ≤ 100*	P_i = proportion of the landscape occupied by patch type (class) i. a_{ij} = area (m^2) of patch ij. A = total landscape area (m^2).	Percentage of Landscape (PLAND), describes in percentage terms the composition of a given landscape ecology
4. Shape (SHAPE)	$SHAPE = \frac{p_Y}{\min p_y}$ *(Unit: None)* *Range: SHAPE ≥ 1, without limit.*	p_{ij} = perimeter of patch ij in terms of number of cell surfaces. min p_{ij} = minimum perimeter of patch ij in terms of number of cell surfaces (see below).	Shape (SHAPE_AM) is a measure of the geometric complexity of the landscape elements of a given land cover categor
5. Landscape Shape Index (LSI)	$LSI = \frac{E}{\min E}$ *Unit: None* *Range: LSI ≥ 1, without limit.*	E = total length of edge in landscape in terms of number of cell surfaces; includes all landscape boundary and background edge segments. min E = minimum total length of edge in landscape in terms of number of cell surfaces.	LSI has a direct interpretation, in contrast to total edge, for example, that is only meaningful relative to the size of the landscape. LSI can also be interpreted as a measure of patch aggregation or disaggregation, similar to the class-level interpretation.
6. Aggregation index (AI)	$\mathrm{AI} = \left[\frac{\mathrm{g_{ii}}}{\mathrm{max{\to}g_{ii}}}\right](100)$ *Unit: Percent* *Range: 0 ≤ AI ≤ 100*	g_{ii} = number of like adjacencies (joins) between pixels of patch type (class) i based on the *single-count* method. max-g_{ii} = maximum number of like adjacencies (joins) between pixels of patch type (class) i (see below) based on the *single-count* method.	Aggregation index (AI), as the previous one indicates the tendency of the types of coverage to aggregate
7. Contagion (CONTAG)	$CONTAG = \left[1 + \frac{\sum_{i=1}^{m}\sum_{k=1}^{m}\left[P_i\left(\frac{g_{ik}}{\sum_{k=1}^{m} g_{ik}}\right)\right]\cdot\left[\ln P_i\left(\frac{g_{ik}}{\sum_{k=1}^{m} g_{ik}}\right)\right]}{2\ln(m)}\right]100$ *(Unit: Percent)*		Contagion (CONTAG) measures the level of aggregation of the landscape ecology classes and it is

	0 < CONTAG ≤ 100 P_i = proportion of the landscape occupied by patch type (class) i. g_{ik} =number of adjacencies (joins) between pixels of patch types (classes) i and k based on the *double-count* method. m =number of patch types (classes) present in the landscape, including the landscape border if present.	calculated at the landscape ecology level;
8. Cohesion (COHESION)	$COHESION = 1 - \left(\frac{\sum_{j=1}^{n} p_{ij}}{\sum_{j=1}^{n} p_{ij}\sqrt{a_{ij}}}\right) * \left(1 - \frac{1}{\sqrt{Z}}\right)^{-1} * 100$ *(Unit: None)* *Range: 0 ≤ COHESION < 100* p_{ij} = perimeter of patch ij in terms of number of cell surfaces. a_{ij} = area of patch ij in terms of number of cells. Z = total number of cells in the landscape.	Cohesion (COHESION) indicates the tendency of landscape ecology types to aggregate

(Source: Fragstat metrics research at Umass)

3. Results and Discussion

3.1. Landscape ecology structure

The research area consists of 77 units of landscape ecology which lie in 8 terrain types. (Figure 4)

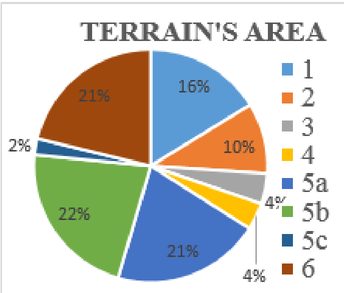

Figure 4: Total landscape ecology's area in terrain types

In which,

1: *Average and low mountains develop on metamorphic rocks* which are divided into nine landscape ecology units (LE1-9). Their entire area is 84143.91ha, accounting for 16.23% of the total. These habitats are made up of six different plant types, the most common of which are 11. Closed evergreen forest with broadleaf trees and 18. High-altitude dry formation.

2. *Low mountains develop on limestones* are separated into eleven landscape ecology units (LE10-19). They cover 50852.59 hectares or 9.81% of the total land area. The plant cover of 15. Closed evergreen subtropical forest with broad leaves (along with coniferous) on limestones and 16. Secondary mixed wood and bamboo in the rainy humid subtropical on limestone are the principal plant covers in these units.

3. The landscape ecology units of *low mountains with denuding structures developed on sedimentary rocks* are divided into seven landscape ecology units (LE20-26). They occupy a total area of 21834.79 hectares or 4.21% of the total land area. The most prevalent plant types found in these habitats are 11. Closed evergreen forest with broadleaf trees, 12. Rainy humid forest with secondary Mixed wood and bamboo, and 13. Rainy humid subtropical with secondary shrubs.

4. *Hills with denude structures develop on sandstone, siltstone* are divided into seven landscape ecology units (LE27-33). They occupy a total land area of 19454.33 hectares or 3.75% of the total land area. These ecosystems consist of four plant types: 5. Closed evergreen subtropical forest with broad leaves (go with coniferous) on limestones; 16. Secondary mixed wood and bamboo in the rainy humid subtropical on limestone;17. Secondary grasslands in the rainy humid subtropical on limestone and 19. Agricultural plants.

5a. High hills developed on metamorphic rocks are divided into eleven landscape ecology units (LE34-44). They cover a total of 107579.6 hectares, accounting for 20.52% of the total land area. In these environments, there are six different plant covers. The most common plant cover types in these areas are 2: Secondary tropical rain forest with timber and bamboo and 19. Agricultural plants.

5b. Low hills developed on metamorphic rocks are divided into thirteen landscape ecology units (LE45-57). They cover a total of 114145.8hectares, accounting for 22.02% of the total land area. The most common plant types observed in these ecosystems include 2: Secondary tropical rain forest with timber and bamboo; 3: Secondary shrublands grassland in a wet tropical climate; 5: Tropical dry semi-deciduous broadleaf closed forest, and 19. Agricultural plants.

5c. *Valleys among high hills developed on metamorphic rocks* are divided into nine landscape ecology units (LE58-66). They cover a total of 11658.72 hectares, accounting for 2.25% of the total land area. There are four different plant coverings in these habitats. 5: Tropical dry semi-deciduous broadleaf closed woodland and 19. Agricultural plants are the most common plant cover categories in these places.

6. *Assemble valleys develop on other rocks* are split into eleven landscape ecological units (LE67-77). They take up a total of 109953.2 hectares or 21.21% of the total land area. These habitats have four different plant covers. The principal plant covers are 19. Agricultural plants, 5: Tropical dry semi-deciduous broadleaf closed forest, and 6: Tropical bamboo and mixed wood.

The landscape map of the research region is illustrated in Figures 5 and 6, with its components listed in Figure 3.

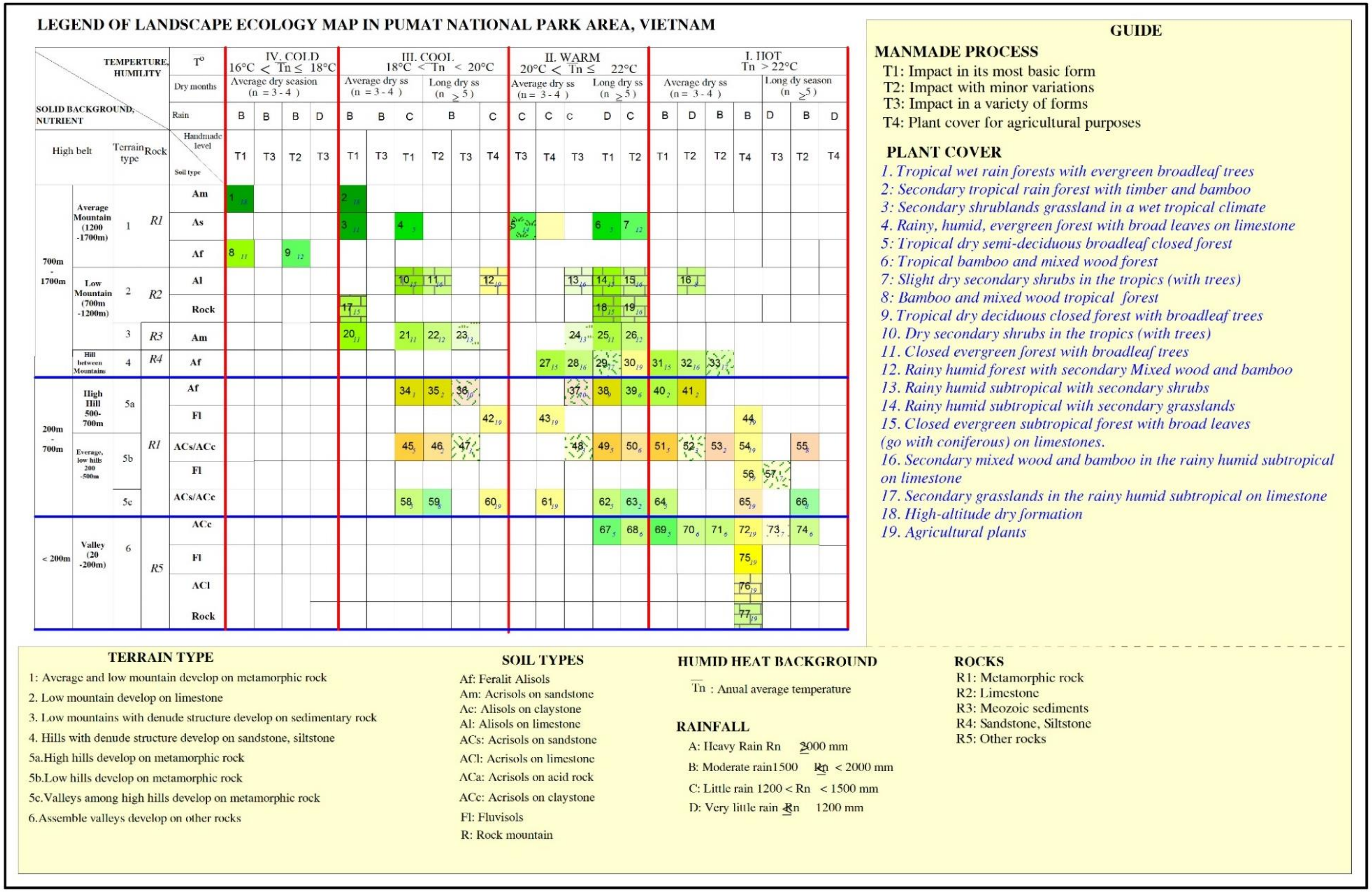

Figure 5: Legend of landscape ecology map in PuMat National Park, Vietnam

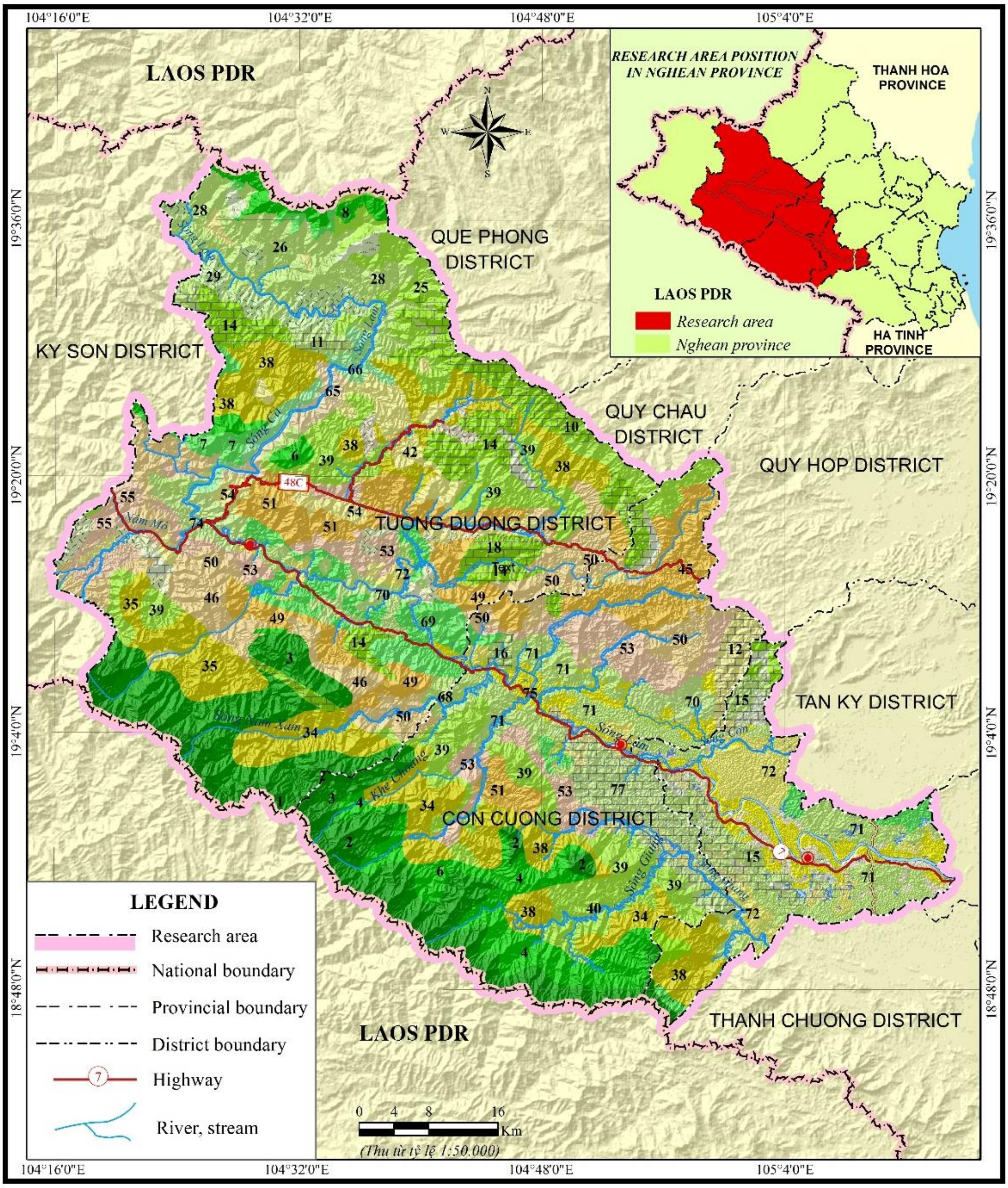

Figure 6: Map of landscape ecology in Pumat National Park, Vietnam

3.2. Indicator for landscape ecology’s structure and diversity

a. Number of patches and Simpson Variety Index (SIDI)

The number of patches (NP) and Simpson Variety Index (SIDI), which describe the numerical density and diversity of landscape ecological patches, both grew as the spatial scale increased, as did the correlation. The patch aggregation level information in NP is a little more detailed than the number of patch types information.

In landscapes with 50–10 percent native cover, the number of patches (NP) had a detrimental influence on habitat availability, whereas patch size had a beneficial effect in landscapes with less than 10% native cover. The NP indicator values in the research area range from 1 to 18. The landscape units have the maximum value (for example, landscape number 71 73 39 50, which is in a hilly and valley terrain). Low mountains and hilly terrain have the lowest value of landscape units. *(Figures 7 and 8)*

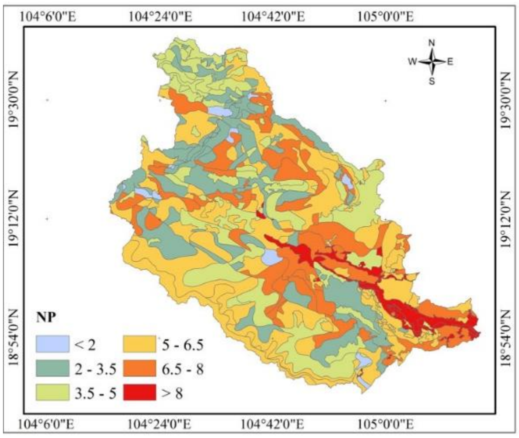

Figure 7: Map of NP indicator value distribution

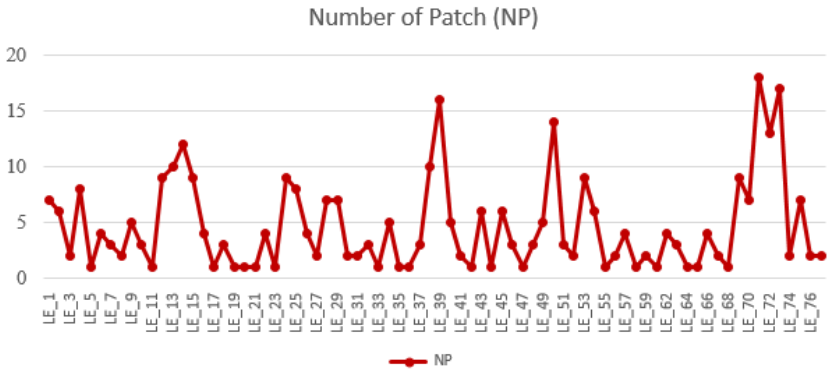

Figure 8: Number of Patch chart for landscape ecology units

The Simpson Diversity Index (SIDI) is a well-known community ecology-based diversity statistic. The study area's SIDI is 0,968. The proportional distribution of area among patch types becomes more equal as the number of different patch types (i.e., patch richness, PR) grows, and SIDI approaches 1.

b. Percentage of Landscape (PLAND)

PLAND, as opposed to total landscape ecology area, is a relative measure that can be used to compare landscapes of various sizes. The spatial distribution or configuration of habitat fragmentation has no effect on PLAND. The PLAND in the study area varies per landscape unit, ranging from 0.01 to 6.4. This signifies that all landscape units of the related landscape type are small and infrequent. *(Figures 9 and 10)*

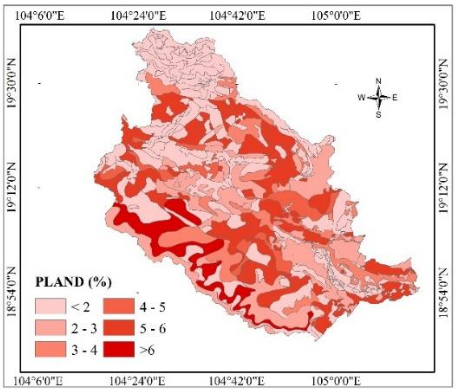

Figure 9: Map of PLAND indicator value distribution

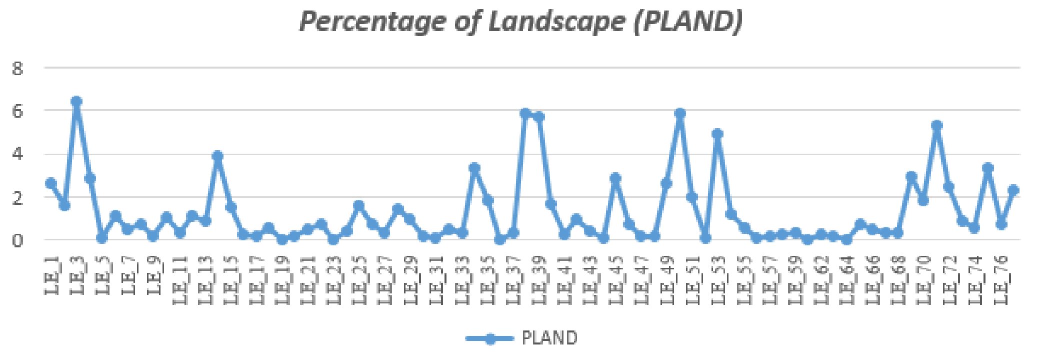

Figure 10: Percentage of Landscape (PLAND) chart for landscape ecology units

c. Shape (SHAPE)

The geometry of patches whether they're simple and compact or uneven and convoluted is what shape is all about (McGarigal and others 2002). A normalized ratio of a patch's perimeter to its area is computed using a basic shape index. An increased SHAPE index, in this case, suggests increasingly irregular patches that resemble a circle or square less and more. More complicated shape index determines the fractal dimension of whole landscape ecology or the mean fractal dimension of a single landscape ecology unit. The SHAPE index varies per landscape unit in the research area, ranging from 1.33 to 6.92. Only a few landscape units have a fast-increasing SHAPE index value (6 units per 76 units). It demonstrates that the landscape ecology unit in the study area is as compact as possible (i.e almost square). *(Firgures 11 and 12)*

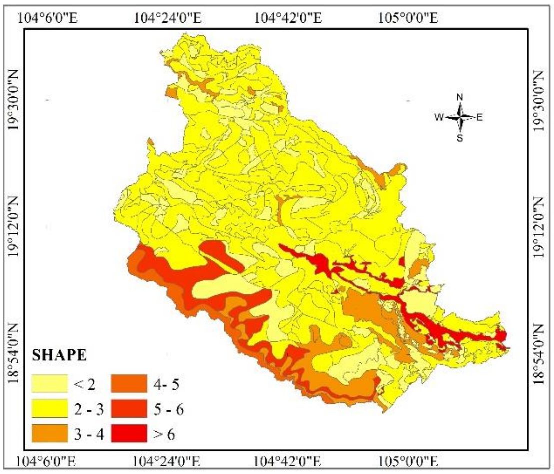

Figure 11: Map of SHAPE indicator value distribution

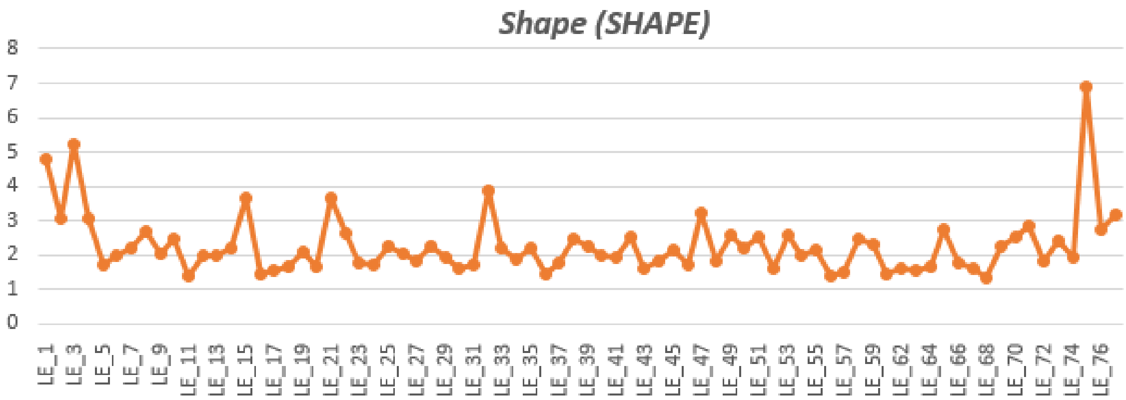

Figure 12: Percentage of Shape (SHAPE) chart for landscape ecology units

d. Landscape Shape Index (LSI)

Similar to the class-level interpretation, LSI can be regarded as a measure of patch aggregation or disaggregation. In particular, when LSI rises, the patches become more disaggregated. The LSI values in the research area vary greatly between landscape ecology units, ranging from 1.3 to 9.2. However, the fact that the median LSI value is just 3.3 (almost 1) indicates that the landscape ecology is made up of a single square (or nearly square) patch. *(Figures 13 and 14)*

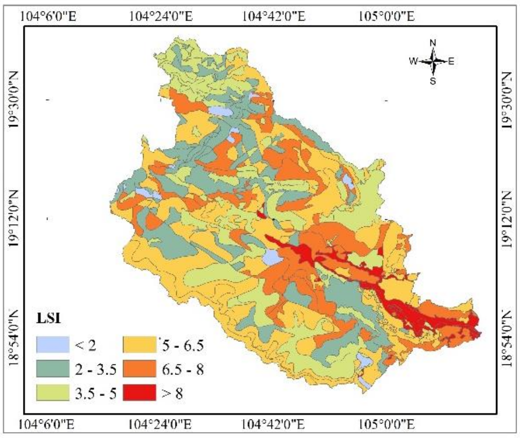

Figure 13 Map of LSI indicator value distribution

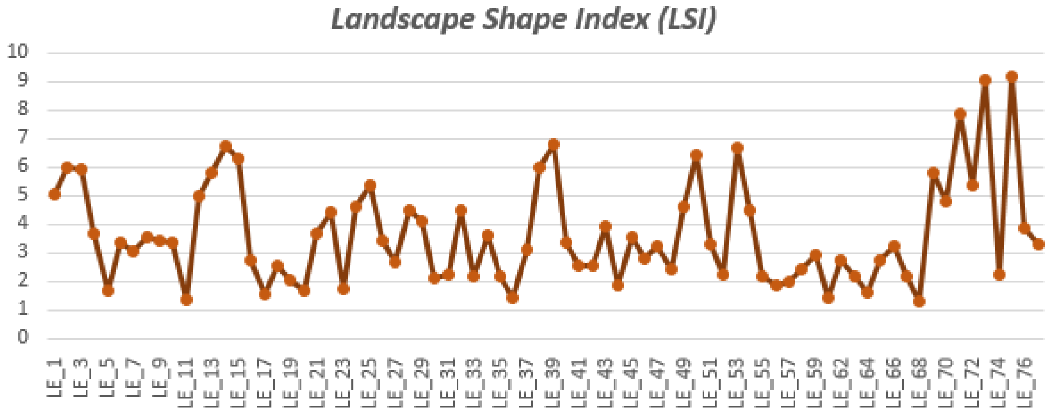

Figure 14 Percentage of Landscape Shape Index (LSI) for landscape ecology units

e. Aggregation Index (AI)

To measure spatial patterns of landscape ecology, an Aggregation Index (AI) is used. A class-specific Aggregation Index (AI) that is unaffected by landscape composition. A class with the maximum amount of aggregation (AI = 100) is made up of pixels that share the most conceivable edges, according to AI. The lowest level of aggregation (AI = 0) is a class in which no pixels share any edges (totally disaggregated). In the research area, the AI index values are about 98-99, indicating that the landscape ecology unit has been maximally aggregated into a nearly single, compact patch. *(Figures 15 and 16)*

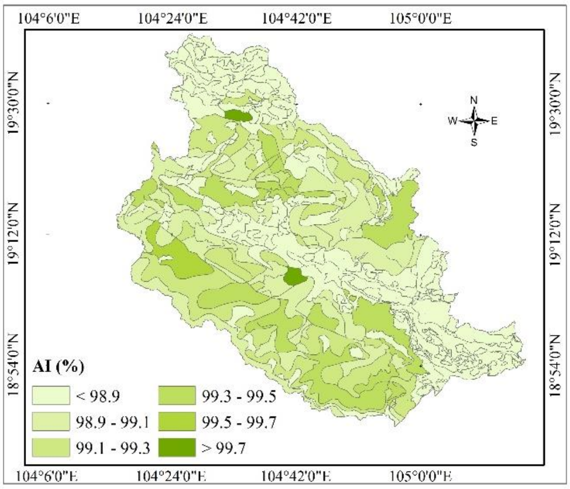

Figure 15: Map of Aggregation Index (AI) value distribution

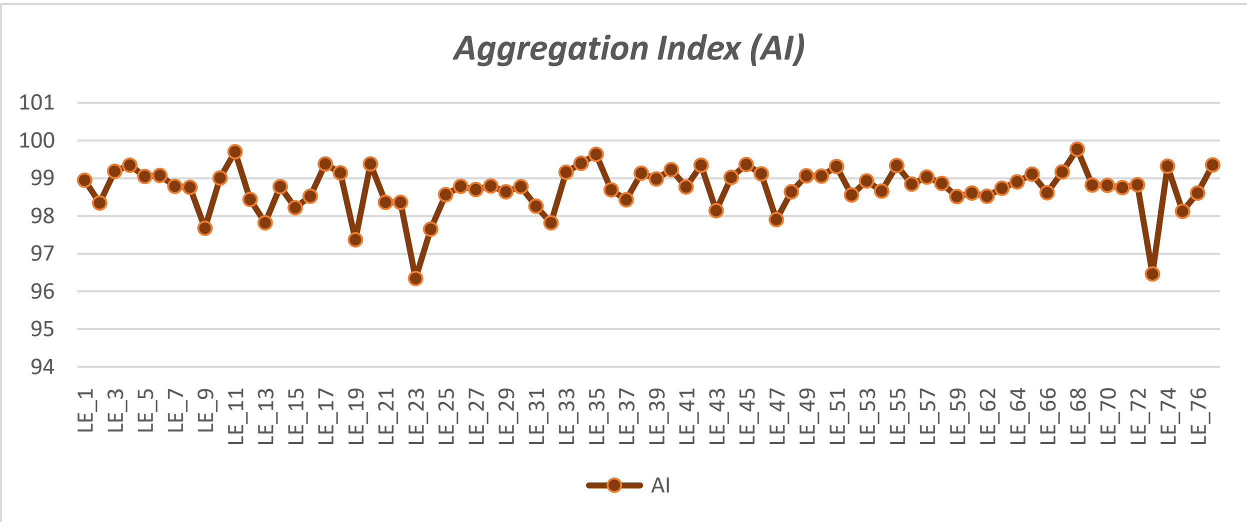

Figure 16: Aggregation Index (AI) chart for landscape ecology units

f. Contagion (CONTAG)

When the landscape ecology units are maximally disaggregated (i.e., every cell is a different landscape ecology unit) and interspersed, CONTAG approaches 0. (equal proportions of all pairwise adjacencies). When all landscape ecological units are maximally aggregated, i.e., when the landscape consists of a single patch, CONTAG equals 100. The Contagion value of 55.75 in the research region indicates that the degree of aggregation is normal.

g. Cohesion (COHESION)

COHESION is referred to as an “aggregation metric”. It describes the interconnectedness of the landscape ecology components in question. As the proportion of the landscape occupied by the focus class diminishes, COHESION approaches zero, and the landscape becomes increasingly segmented and less physically connected. COHESION rises in lockstep with the proportion of the landscape ecology occupied by the focal class, until it reaches an asymptote at the percolation threshold. COHESION values ranging from 95.47 to 99.85 indicate that landscape ecology units are interconnected at a high level. *(Figure 17)*

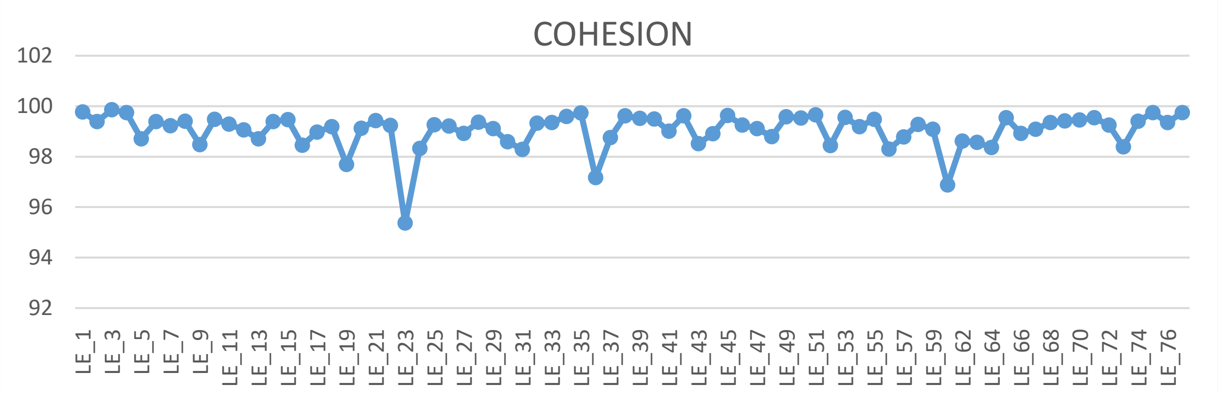

Figure 17: Cohesion (COHESION) chart for landscape ecology units

Conclusion

Eight indicators are measured in this article for 77 landscape ecology units derived from four input maps (geomorphology, soil, bioclimate and vegetation map). These indicators are calculated by GIS, Fragstats sofware which are Number of patches (NP), Simpson Diversity Index (SIDI), Percentage of Landscape (PLAND), Shape (SHAPE), Landscape Shape Index (LSI), Aggregation index (AI), Contagion (CONTAG), and Cohesion (COHESION) are the indicators in consideration in Pumat National Park, Vietnam. These indicators can be used to evaluate the landscape for specific reasons like land use planning and function zoning....

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