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Indicators for ecosystem diversity change in Con Cuong district, Nghe An province, Vietnam

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Abstract:

Efforts to preserve natural and human habitats through environmental conservation aimed at modifying their metrics always been made over the years. The goal of this research is to quantify changes in ecosystem indicators in Con Cuong district, Nghe An province, Vietnam from 2000 to 2015. This research area also has Pu Mat national park where the biodiversity-rich in habitat, species, genes as well as ecosystems. In this article, seven indicators are measured with GIS and Fragstats Software, including Shannon's Diversity Index (SHDI), Simpson's Diversity Index (SIDI), Number of Patches (NP), Patch Density (PD), Percentage of Like Adjacencies (PLADJ), Interspersion and Juxtaposition Index (IJI) and Edge Density (ED). The value for each indicator will be assigned for each observation to capture the character of the ecosystem. They will be compared with each other and considered changes in ecosystems of the forest, agricultural, artificial and others. The method of thematic overlays and transition matrixes has also been used to provide precise identification of the ecosystem changes that have taken place over the period under review. A detailed explanation and mapping of the dynamics of the ecosystem was obtained as a consequence. This work can be replicated and evolved into a methodological phase to show the indication of the ecosystem, because it adds a reference value for the study of differences in ecosystem characteristics. The findings show that the difference in the environment is mostly due to the decrease of naturalness and the increase in the complexity of agriculture ecosystems and urban growth.

Key words: indicators, ecosystem change, geographic information system, Con Cuong district, Vietnam

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Показатели изменения разнообразия экосистем в районе Кон Куонг, провинция Нгеан, Вьетнам

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Аннотация:

Усилия по сохранению естественной среды обитания и среды обитания человека посредством сохранения окружающей среды, направленные на изменение их показателей, всегда предпринимались на протяжении многих лет. Целью данного исследования является количественная оценка изменений показателей экосистемы в районе Кон Куонг, провинция Нгеан, Вьетнам, с 2000 по 2015 гг. В этой области исследований также есть национальный парк Пу Мат, где богато биоразнообразие среды обитания, видов, генов, а также экосистем. В этой статье семь индикаторов измеряются с помощью программного обеспечения ГИС и Fragstats, в том числе индекс разнообразия Шеннона (SHDI), индекс разнообразия Симпсона (SIDI), количество патчей (NP), плотность патчей (PD), процент подобных смежностей (PLADJ), индекс перемежения и сопоставления (IJI) и плотность края (ED). Значение для каждого индикатора будет присвоено для каждого наблюдения, чтобы отразить характер экосистемы. Они будут сравниваться друг с другом и учитываться изменения в экосистемах лесных, сельскохозяйственных, искусственных и других. Метод тематических наложений и переходных матриц также использовался для точной идентификации изменений экосистемы, произошедших за рассматриваемый период. В результате было получено подробное объяснение и картирование динамики экосистемы. Эта работа может быть воспроизведена и превратилась в методологическую фазу, чтобы показать индикацию экосистемы, потому что она добавляет эталонное значение для изучения различий в характеристиках экосистемы. Результаты показывают, что различие в окружающей среде в основном связано с уменьшением

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естественности и увеличением сложности сельскохозяйственных экосистем и роста городов.

Ключевые слова: индикаторы, изменение экосистемы, географическая информационная система, район Кон Куонг, Вьетнам.

Introduction

Ecosystem diversity is a vital issue for long time sustainability of ecosystems, contributing to biodiversity. The consequent transformations of urban-rural systems are one of the most important types of Land Use/Land Cover (LULC) changes that often determine negative effects on ecosystem functionality [3]. The structure and functioning of ecosystems can be affected by LULC changes dramatically [4, 15]. Besides, the forest canopy structure [16] is one of the basic indicators of the processes, key determinants, and community dynamics of ecosystems. Within the ecosystem service framework used by the Millennium Ecosystem Assessment [9], biodiversity is assumed to be the source of ecosystem services.

When studying ecosystem changes, a variety of indicators are carried out that have influenced each other. Because no single indicator will be able to address all potential dimensions of ecosystem resilience [6]. There is, therefore, a need for various metrics to address various answers to the question " “resilience of what to what”? [2]. In other words, it is vital that we clearly define what any indicator developed to assess change in ecosystem resilience is actually measuring – both in terms of the component or attribute of the ecosystem we are interested in maintaining [12].

Structural diversity is an important attribute of forest ecosystems and is related to ecosystem stability, adaptability and resilience as well as biodiversity and productivity [1]. Stand structural diversity is also reminded as an important forest ecosystem attribute that can be indicative of overall health, biodiversity, habitat value, resilience, and functioning of forest ecosystems [1, 5].

Measuring structural diversity of forest ecosystems is a challenging task, and several measures to quantify aspects of structural complexity have been proposed and evaluated [11, 13, 14]. Most of these indicators typically focus on tree-based characteristics such as tree size differentiation, diversity of diameter classes, or spatial patterns of tree positions. Commonly-used diversity indices have included Shannon index, Simpson index, Gini index, and diameter evenness index, which may result in similar, or sometimes different, interpretations of data [7, 8, 10, 14].

In this paper, we focus on measuring indicators for ecosystem changes. We compare the current ecosystem character in the year of 2000, 2005, 2010, 2015 and consider changes in 11 ecosystem units related to forest, agricultural, artificial and others. This work provides a methodological step for ecosystem indication, since it adds a reference value to an existing LCA method to analyse the differences, and can be used to explain landscape change. The set of ecosystem character indicators based on GIS techniques, Fragstats proposed by McGarigal and Marks (1995) The research area in this paper is Con Cuong district which is located in Nghean province belong to the Southern region, Vietnam. Con Cuong is one of three districts belonged core zone, the buffered zone of Pu Mat national park so its biodiversity is high. Therefore, research on ecosystem change here will be had strong value at biodiversity conservation.

Purpose of the research:

Measuring and comparing indicators for ecosystem diversity change in Con Cuong district, Nghe An province, Vietnam in the year of 2000, 2005, 2010, 2015

Contents of the research:

(a) Create distribution of ecosystem maps in Con Cuong district, Nghe An province, Vietnam in the year of 2000, 2005, 2010, 2015;

(b) Create a transition matrix for ecosystem changes in the year of 2000, 2005, 2010, 2015;

(c) Researching on results of measuring indicators for ecosystem diversity change in the year of 2000, 2005, 2010, 2015.

Material and Methods

Research area

Con Cuong District has located in the western mountains of Nghe An province, belonging to the Tay Nghe An biosphere reserve - considered as a biodiversity conservation corridor with species of national and international importance mentioned in the Red Book system of Vietnam and IUCN (North Truong Son biodiversity). Con Cuong‘s Natural area is 174.608 hectares in which have 128000 hectares forest lied in Pu Mat national park. The population in Con Cuong is 17.762 family with 170335 people who distributed in 8 ethnic groups of Thai, Kinh, Nung, Hoa, Kho Mu, Tay, Dan Lai, Mong. Therefore, ecology tourism and Community-Based Tourism is one of the suitable trends to create livelihoods as well as to keep conservation.

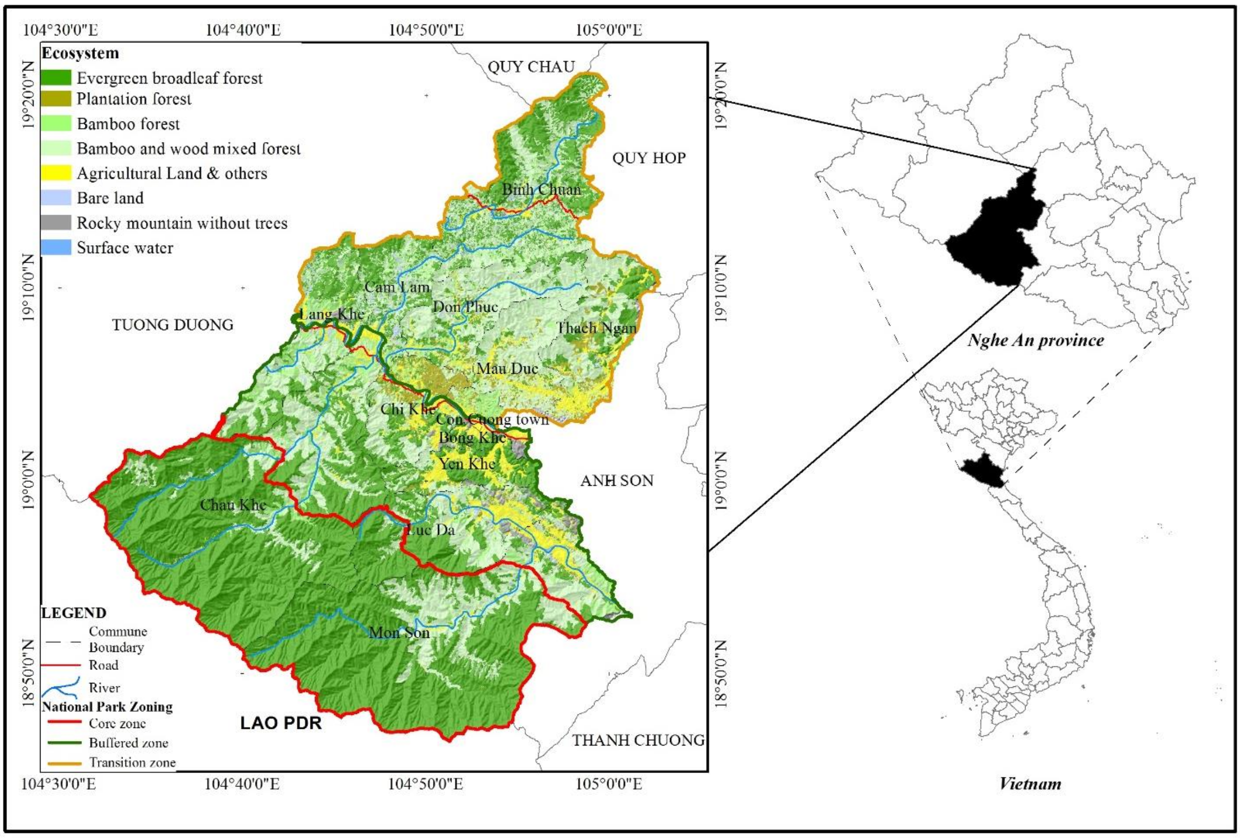

Figure 1. Map of the reasearch area

Material and Methods

Indicators for ecosystem diversity change in the research area is calculated and compare each other among ecosystem unit in 4 periods of time: 2000, 2005, 2010 and 2015. These indicators which indicators proposed in previous research by Martín et al. (2016) are Measured by GIS, Fragstat software; including Shannon's Diversity Index (SHDI), Simpson's Diversity Index (SIDI), Number of Patches (NP), Patch Density (PD), Percentage of Like Adjacencies (PLADJ), Interspersion and Juxtaposition Index (IJI) and Edge Density (ED). The define, equator and Description each indicator are shown in table 1. Table 1 explains the indicator selected to measure each concept (a more detailed description on the use of the indicators can be found in McGarigal and Mark (1995), as well as the complete description of the ecosystem concepts. The mapping materials necessary to calculate the indicators are the map of ecosystem distribution in 2000, 2005, 2010 and 2015.

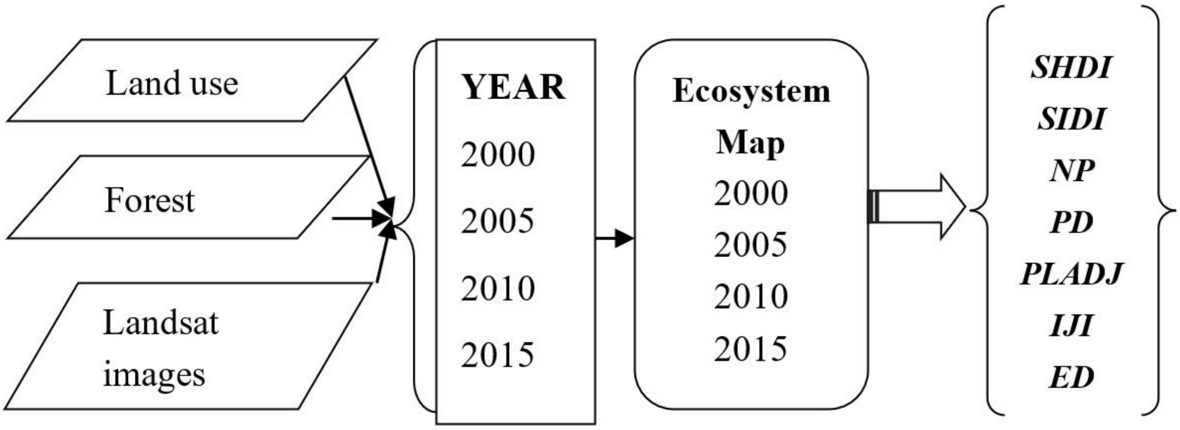

Figure 2. Outline of the methodology used to calculate the indicators.

Table 1. Indicators used for each landscape concept.

Indicator		**Parameters**	**Description**
Shannon's Diversity Index (SHDI)	$SHDI = -\sum_{i=1}^{m} P_i ln P_i$ *(Units: Information)*	P_i = proportion of the ecosystem unit occupied by patch type (class) i.	SHDI equals minus the sum, across all patch types, of the proportional abundance of each patch type multiplied by that proportion. In which, Pi is based on total ecosystem unit area (A) excluding any internal background present.
Simpson's Diversity Index (SIDI),	$SIDI = 1 - \sum_{i=1}^{m} P_i^2$ *(Units: None)*	P_i = proportion of the ecosystem unit occupied by patch type (class) i.	SIDI equals 1 minus the sum, across all patch types, of the proportional abundance of each patch type squared. Pi is based on total ecosystem unit area (A) excluding any internal background present.
Number of Patches	$NP = n_i$ *(Units: None)*	n_i = number of patches in the ecosystem unit of patch type (class) i.	NP equals the number of patches of the corresponding patch type (class).
Patch Density *Number per 100 hectares*	$PD = \frac{n_i}{A}(10{,}000)$ *(unit: Number per 100 hectares)*	n_i = number of patches in the ecosystem unit of patch type (class) i. A= total ecosystem unit area (m2).	PD equals the number of patches of the corresponding patch type divided by total ecosystem unit area (m2), multiplied by 10,000 and 100 (to convert to 100 hectares). Note, total ecosystem unit area (A) includes any internal background present.
Percentage of Like Adjacencies	$\left(\frac{g_{ii}}{\sum_{i=1}^{m} g_{ik}}\right)$ *(unit: Percent)*	g_{ii} = a number of like adjacencies (joins) between pixels of patch type (class) i based on the	PLADJ equals the number of like adjacencies involving the focal class, divided by the total number of cell adjacencies involving the focal class; multiplied by 100 (to convert to a

(PLADJ)		double-count method. g_{ik} = a number of adjacencies (joins) between pixels of patch types (classes) i and k based on the double-count method.	percentage)
Interspersion and Juxtaposition Index (IJI)	$IJI = \frac{-\sum_{k=1}^{m}\left[\left(\frac{e_{ik}}{\sum_{k=1}^{m} e_{ik}}\right)\ln\left(\frac{e_{ik}}{\sum_{k=1}^{m} e_{ik}}\right)\right]}{\ln(m-1)}(100)$ *(unit: Percent)*	e_{ik} = total length (m) of edge in ecosystem unit between patch types (classes) i and k. m = number of patch types (classes) present in the ecosystem unit, including the ecosystem unit border, if present.	IJI equals minus the sum of the length (m) of each unique edge type involving the corresponding patch type divided by the total length (m) of edge (m) involving the same type, multiplied by the logarithm of the same quantity, summed over each unique edge type; divided by the logarithm of the number of patch types minus 1; multiplied by 100 (to convert to a percentage)
Edge Density (ED).	$ED = \frac{E}{A}(10{,}000)$ *(unit: Meters per hectare)*	E = total length (m) of edge in the ecosystem unit. A = total ecosystem unit area (m^2).	ED equals the sum of the lengths (m) of all edge segments in the ecosystem unit, divided by the total ecosystem unit area (m2), multiplied by 10,000 (to convert to hectares). If an ecosystem unit border is present, ED includes ecosystem unit boundary segments representing ‘true’ edge only (i.e., abutting patches of different classes). If an ecosystem unit border is absent, ED includes a user-specified proportion of the ecosystem unit boundary.

(Source: Fragstat metrics research at Umass)

Data processing

The input data used on this research is ecosystem maps in the year of 2000, 2005, 2010 and 2015 which are created from a combination of land use map, forest current status map, and Landsat images in the same period. In which forest current status map is the main data which divided more detail at agricultural land and manmade forest by using land use map and Landsat images. The source of land use map is from Ministry of resource and environment, Vietnam which made in every five years. The Landsat images are downloaded from USGS with resolution 30x30m. After having the ecosystem maps for these input data, they are put on ArcGIS 10.5 to calculate the ecosystem units changes, matrix ecosystem changes and to measure ecosystem indicator by using Fragstat 4.2 software.

Results and Discussion

Ecosystem changes

On fig.3, it recognized that the ecosystem units have a huge change in evergreen broadleaf forest and agriculture. The evergreen broadleaf forest ecosystem converts from recovered and poor to rich/average in the west southern district in which presented the core area and buffered area of Pu Mat nation park. The agricultural ecosystems increase rapidly in the valley along Con river which is large river flow through the western mountainous region in Nghe An province in general, and Con Cuong in particularly, but its area does not change dramatically. This is also the place where concentrate residential and has advantage conditions for developing agriculture and agriculture-forestry combination. On another hand, the ecosystem of the secondary forest consists of a bamboo forest, bamboo and wood mixed forest has increase trend through the researched years. These belonged to the transition area at Pu Mat national park and due to the increasing forest cover policy in the research area for enlarging biodiversity and civil people livelihood. To get more clarity of ecosystem change, the transition matrix for ecosystem map in the period 2000 – 2015 is created (table 2). Relative and absolute changes for each of the 11 ecosystem units were calculated from 11x11 transition matrices (or cross-tabulation matrices). The transition matrices were built for the time interval 2000 to 2015, wherein rows display the categories of 2000 and columns display the categories of 2015. While row vectors show the evolution of an ecosystem type in the period 2000 - 2015, column vectors show the ecosystem unit in 2000, from which another ecosystem type was generated in 2015. The data of the main diagonal, shown in bold, indicate the area of ecosystem persistence.

Table 2. Transition matrix for the priod 2000 - 2015

2015 / 2000	1	2	3	4	5	6	7	8	9	10	11	*Sum2000*
1	**18476.84**	3348.67	296.31	0.16		78.58	1407.91	16.53	23.32		1.40	***23649.72***
2	15011.91	**4795.85**	1615.99	361.52	2.86	421.82	4377.58	55.41	13.81		8.82	***26665.57***
3	10877.57	6981.75	**3669.06**	1134.90	119.54	1089.54	8597.55	100.35	101.56			***32671.82***
4	1855.13	1166.09	2072.89	**3652.30**	636.98	1727.23	10136.56	842.57	241.40	473.44	68.40	***22872.99***
5	17.95	25.12	36.00	171.02	**172.75**	730.38	467.55	535.31	78.12	7.62	20.08	***2261.90***
6	100.59	255.36	1617.06	1306.45	299.15	**1575.94**	5273.33	255.03	274.77	14.68	32.76	***11005.12***
7	456.15	1044.44	1131.84	332.47	64.40	527.86	**3212.03**	66.39	33.04		9.43	***6878.05***
8		11.45	311.41	1198.60	796.31	1042.39	2881.35	**4516.78**	375.29	74.76	138.62	***11346.96***
9	29.49	235.62	2311.17	5424.89	2658.75	3286.19	14349.63	4794.70	**877.54**	775.26	212.33	***34955.57***
10			0.80	1543.45	4.87	36.94	46.80	140.33	1.40	**46.75**	0.19	***1821.53***
11				1.47	0.68	1.90	1.66	29.85	0.66	0.03	**442.77**	***479.02***
Sum 2015	***46825.63***	***17864.35***	***13062.53***	***15127.23***	***4756.29***	***10518.77***	***50751.95***	***11353.25***	***2020.91***	***1392.54***	***934.80***	**174608.25**

(1:Evergreen broadleaf forest – Rich; 2: Evergreen broadleaf forest – Average; 3: Evergreen broadleaf forest – Poor; 4: Evergreen broadleaf forest – Recovered; 5: Plantation forest; 6: Bamboo forest; 7: Bamboo and wood mixed forest; 8:

Agricultural ecosystem & others; 9: Bare land; 10: Rocky mountain without trees; 11: Surface water)

On table 2, the ecosystem of the evergreen broadleaf forest – Rich is the biggest amount increasing from 2000 to 2015 (*from 23649.72 hectares to 46825.6 hectares, about 98% increasing).* The main reason for this change is the transition from the average, poor and recovered one which sequence areas are *15011.91 hectares, 10877.57 hectares and 1855.13 hectares.* The secondary forest ecosystems have also transformed from others *(from 6878.05 hectares in 2000 to 50751.95 hectares in 2015)* which moved primarily from the ecosystem of poor and recovered evergreen broadleaf forest *(with 8597.55 hectares and 10136.56 hectares)*, the ecosystem on bare land *(14349.63 hectares)*, the ecosystem of agricultural Land & others *(2881.35 hectares)*. In agriculture and other ecosystems which converted from others to visa, but there is no significant change in the overall area of this ecosystem.

Calculate indicators for ecosystem changes.

Follow the formulas on table 1 is applied on arcgis 10.5, fragstats 4.2 software for calculating ecosystem indicators which are proposed in this paper in the year of 2000, 2005,2010, 2015. The ecosystem datasets were first converted into grid format (pixel size 10m×10 m) in order to perform synoptic metric analyses and further analyses using the FRAGSTATS package v.4.2 (McGarigal et al., 2012).

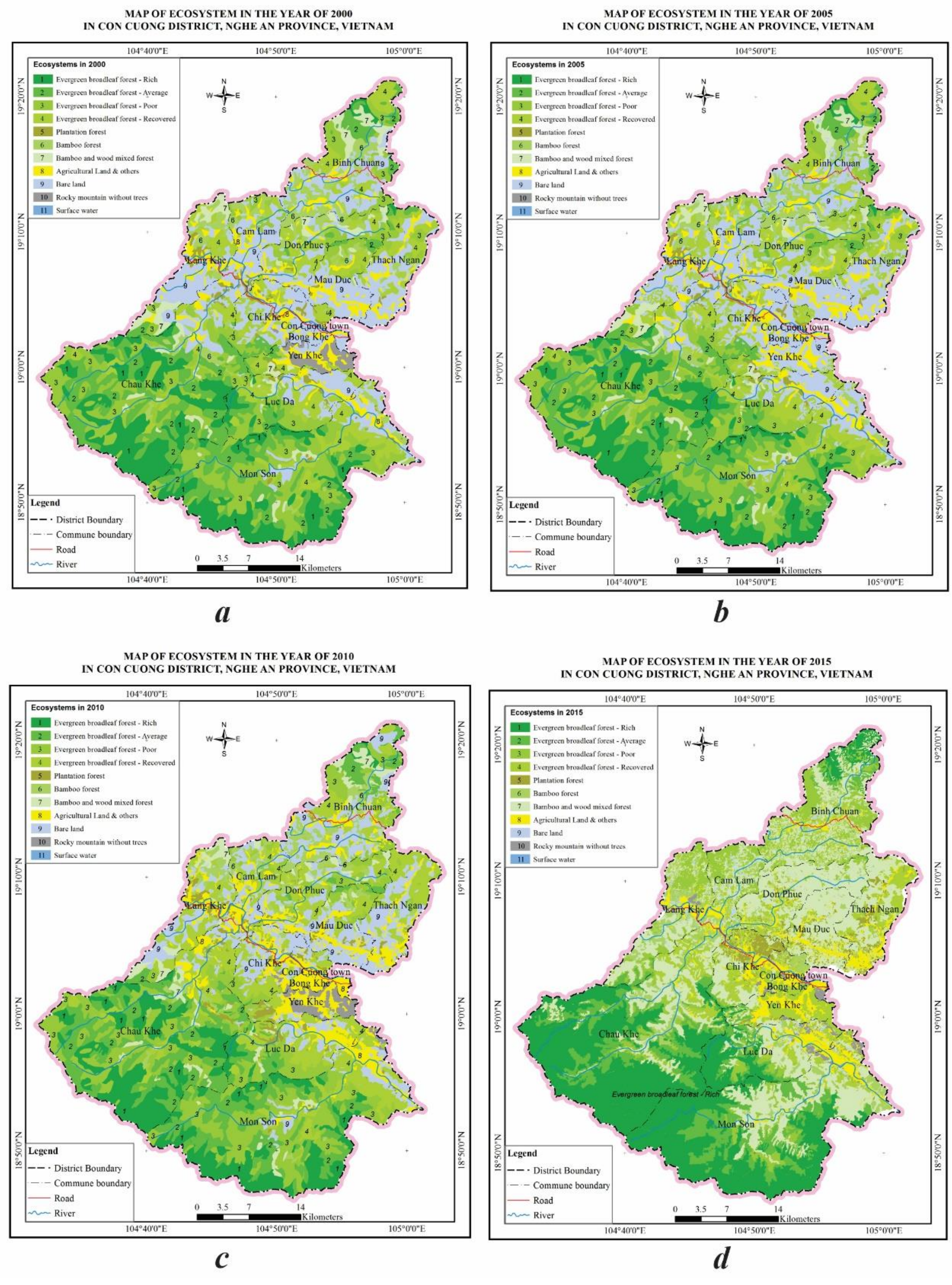

Figure 3. Ecosystem map in Con Cuong district, Nghe An province, Vietnam
(a: the year of 2000; b: the year of 2005; c: the year of 2010; d: the year of 2015)

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Table 3. Ecosystem indicator in Con Cuong district from 2000 to 2015

Ecosystem indicator	***Units***	***Years***			
		2000	***2005***	***2010***	***2015***
Shannon's Diversity Index (SHDI)	*None*	2.06	2.02	2.10	1.91
Simpson's Diversity Index (SIDI)	*None*	0.86	0.85	0.86	0.81
Number of Patches (NP)	*None*	803	982	1107	2543
Patch Density (PD)	*Number per 100 hectares*	0.46	0.56	0.64	1.46
Percentage of Like Adjacencies (PLADJ)	*Percent*	76.84	75.16	73.92	67.82
Interspersion and Juxtaposition Index (IJI)	*Percent*	75.67	76.02	76.86	76.36
Edge Density (ED).	*Meters per hectare*	20.14	21.66	22.79	28.32

Shannon's diversity index (SHDI) is a popular measure of diversity in community ecology, applied here to ecosystems. SHDI indicator in the research area has fluctuation around 2. From 2000 to 2010 and 2005 to 2010, SHDI increases with the rise in the number of different patch types (i.e., patch richness, PR) increases. However, from 2010 to 2015 the number of different patch types (i.e., patch richness, PR) decrease as a result of this index decrease.

Simpson's diversity index is another popular diversity measure borrowed from community ecology. Simpson's index is less sensitive to the presence of rare types and has an interpretation that is much more

Figure 4. Flow chart of the indicators \ from 2000 to 2015

Nguyen Van Hong, Dang Hung Cuong, Lai Vinh Cam, Vuong Hong Nhat, Tran Thi Nhung, Nguyen Phuong Thao, Nguyen Thi Thu Hien, Le Ba Bien, Kolesnikov Sergey Illich, Indicators for ecosystem diversity change in Con Cuong district, Nghe An province, Vietnam // «Живые и биокосные системы». – 2020. – № 33; URL: https://jbks.ru/archive/issue-33/article-2/. DOI: 10.18522/2308-9709-2020-33-2

intuitive than Shannon's index. This index has change trends like SHDI.

A single patch type's number of patches (NP) means a simple calculation of the degree to which a patch is subdivided or fragmented. Although the number of patches in a category maybe central to certain ecological processes, it often has minimal interpretive significance on its own because it does not convey any information concerning the area, distribution or density of the patches. The outcome of the NP indicator of the Con Cuong district ecosystem units is rising year after year. There are also great variations between the NP of the ecosystem units.

The patch density (PD) is an element of the ecosystem pattern that is limited but fundamental. The patch density has the same basic usefulness as the number of patches as the index, except that the patch density is expressed on a single unit basis, which enables the comparison between different ecosystem units. In Con Cuong District, PD indicator values grow from 2000 to 2015 over the years.

The amount of aggregation of patch types is measured by PLADJ. Thus, an ecosystem unit with larger patches with simple shapes would contain a higher percentage of adjacencies than an ecosystem unit with smaller patches and more complex shapes. Unlike the contagion index at the ecosystem unit level, this metric calculates only dispersion and not interspersion. The PLADJ indicator value declines over the years between 2000 and 2015 in the district of Con Cuong. Later, the level of dispersion of ecosystem units is lower. This is clearly seen in the ecosystem of the evergreen broadleaf forest – Rich and Agricultural ecosystem (see on Fig.3).

Interspersion and juxtaposition index are based on patch adjacency, not cell adjacency like the contagion index. As such, it does not have a class aggregation metric such as the contagion index, but rather isolates the interspersion or intermixing of patch types. From 2000 to 2005 and then 2010, the IJI rate increased. From 2010 to 2015 it declined, however.

Edge-density (ED) reports for a unit-based edge length that enables landscape comparisons of different dimensions. The ED Index has tended to rise marginally in 2000, 2005, 2010 and 2015 in Con Cuong district.

Conclusion

The main objective of this analysis is to quantify seven indicators of ecosystem units, which are rendered by a combination of land use maps, forest maps and Landsat images. These indicators are Shannon's Diversity Index (SHDI), Simpson's Diversity Index (SIDI), Number of Patches (NP), Patch Density (PD), Percentage of Like Adjacencies (PLADJ), Interspersion and Juxtaposition Index (IJI) and Edge Density (ED). To measure these metrics, we use the software Arcgis These seven indicators are combined, making it possible to simplify the complexity of the visual ecosystem units.10.5 and Fragtats 4.2 with the measurement formula suggested by

McGarigal and Marks (1995). Our approach has been shown to apply to the district of ConCuong, Vietnam, containing eleven ecosystem units. The methodological phase for these ecosystem indicators is proposed and the findings should be repeatable and clear. These metrics may be used to determine ecological diversity for specific reasons, such as protection of biodiversity, growing livelihoods, etc.

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