EVALUATION OF AGRICULTURAL LANDSCAPE HETEROGENEITY APPLYING THE SATOYAMA INDEX TO PROMOTE SUSTAINABLE REGIONAL PLANNING IN RURAL AREAS OF CENTRAL VIETNAM

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ABSTRACT: Habitat diversity is an important factor influencing biodiversity in agricultural landscapes. In recent years, a lot of efforts have been put into developing indicators for monitoring biodiversity to address the issues regarding the conservation and sustainable use of natural resources. Agricultural landscape mosaics have been increasingly threatened in recent years by rapid socio-economic changes and, especially in developing countries, they are gradually or rapidly being converted into more uniform landscapes. Therefore, appropriate land-use planning at a local level is needed to increase landscape heterogeneity and enhance habitat diversity in developing countries. To establish the appropriate way of diversity evaluation in rural area of developing countries, we investigated the patterns of agricultural landscape mosaics in a rural area of Vietnam by applying the Modified Satoyama Index (M-SI). To evaluate the diversity of agricultural lands including the small-scale farming and home-garden which are found in various areas in Asian countries, we employed the new method to calculate the M-SI value for each cell. By this, the border between spatial units was dissolved, and the detailed and critical analysis was realized. From the results of calculation, we determined the M-SI value for each cell and the spatial distribution of areas which have high value of M-SI. This paper discusses the possibility of applying M-SI in the rural areas of Vietnam, which have complicated contexts, as well as the validity of M-SI evaluation results. This investigation includes a case study and indicates the possibilities to construct proper land-use planning based on concrete evidence which could contribute to biodiversity conservation under agricultural development.

1. INTRODUCTION

1.1 Biodiversity indicator for agricultural landscapes

One of the important factors influencing biodiversity in agricultural landscapes is habitat diversity (Benton et al., 2003; Katoh et al., 2009). Previous studies have indicated that a diverse mosaic of agricultural and nonagricultural lands, such as forests, grasslands, farmlands, fish ponds, and paddy fields, provided a variety of habitats for wildlife and plants (Robinson and Sutherland, 2002; Billeter et al., 2008; Firbank et al., 2008; Vickery et al., 2004). Conservation of multiple habitats which can be found at limited space containing diverse land use is important in terms of the global environmental issues. The Convention on Biological Diversity (CBD) provides an international framework for addressing issues regarding the conservation and sustainable use of natural resources and the fair sharing of benefits from genetic resources. The framework asserts the necessity of significant reduction of the rate of biodiversity loss. One of the major concerns of the parties of CBD is the development of indicators for monitoring biodiversity (CBD, 2003).
A number of indicators for monitoring the status of diversity in different level and scales have been established and developed. Especially in recent years, there has been a growing interest in the landscape heterogeneity of agricultural area. Satoyama Index (SI) developed by Kadoya and Washitani (2011) is one of the diversity indicator commonly used in Japan. *Satoyama* is the name of traditional common rural landscape in Japan. The most conspicuous ecological feature of *Satoyama* landscape is the diverse mosaic of agricultural and non-agricultural lands, including woodlands, grasslands, farms, ponds, and creeks. This kind of landscapes provides a variety of habitats for wildlife and plants (Washitani, 2001; Kadoya and Washitani, 2011; Katoh et al., 2009; Kobori and Primack, 2003). Kadoya and Washitani (2011) described the potential as a biological diversity assessment approach through the calculation of the diverse mosaic of *Satoyama* landscapes.

1.2 Loss of agricultural landscape mosaics in developing countries

Although agricultural landscape mosaics which is like *Satoyama* in Japan are still found worldwide, they have been increasingly threatened in recent years by rapid socio-economic changes and, especially in developing countries, they are gradually or rapidly being converted into more uniform landscapes (Krebs et al., 1999; Robinson and Sutherland, 2002; Vickery et al., 2004; Scherr and McNeely, 2008). In many cases, this occurs in accordance with the introduction of large-scale production systems, which often cause environmental degradation and loss of culture and tradition (McNeely and Scherr, 2002). Therefore, appropriate land-use planning at a local level is needed to increase landscape heterogeneity and enhance habitat diversity in developing countries.

SI is still under being developed and there has been ongoing debate regarding the localized SI especially for Asian countries. In the process of calculation of SI, Kadoya and Washitani (2011) used 1×1 km grid as the elementary spatial unit because they conformed land-cover data unit available on the World Wide Web. However, it is difficult to evaluate the diversity of agricultural lands including the small-scale farming and home-garden which is found in various areas in Asian countries by the same scale of conventional methods. Thus, localized calculation which is suited to local livelihood and geographical situation is needed for developing countries especially in Southeast Asia (Imai et al., 2013).

1.3 Objectives

The work described here had two main objectives. First is to investigate and visualize the patterns of agricultural landscape mosaics in a rural region of developing country by applying the SI. We chose a rural area of Vietnam as the study site. Second is to find key factors to examine the land-use features among areas which have high value of SI in the study site. Our motivation was to establish the appropriate way of diversity evaluation in rural area of developing countries.

2. STUDY AREA

The study area was southern-east part of Nam Dong district where is a rural district of Thua-Thien Hue province in the central region of Vietnam (Fig. 1). This area has experienced rapid socio-economic changes and drastically land use changes through the FLA (Forest Land Allocation) and the settlement policy for local people. The Co Tu people, one of the ethnic minorities, live primarily in the mountainous inland of Central Vietnam, including Quang Nam Province and Thua Thien-Hue Province along the border with Laos (Truong and Kobayashi, 2013). Although they used to be farmers engaging mainly in slash-and-burn cultivation, paddy-field rice cultivation and continuous upland farming have become popular with the local communities of mountainous regions since the styles of slush-and-burn cultivation was prohibited and all forest areas were nationalized. These agricultural developments have seemingly created a diverse mosaic of agricultural and nonagricultural lands in this area, however, acacia forests have been expanding in recent years due to the central government's encouragement of the plantation of fast-growing trees, and land-use diversity has been decreasing as a result (Tokito et al., 2015). Land-use planning based on appropriate evaluations of environmental conditions is needed to mitigate or solve these problems.

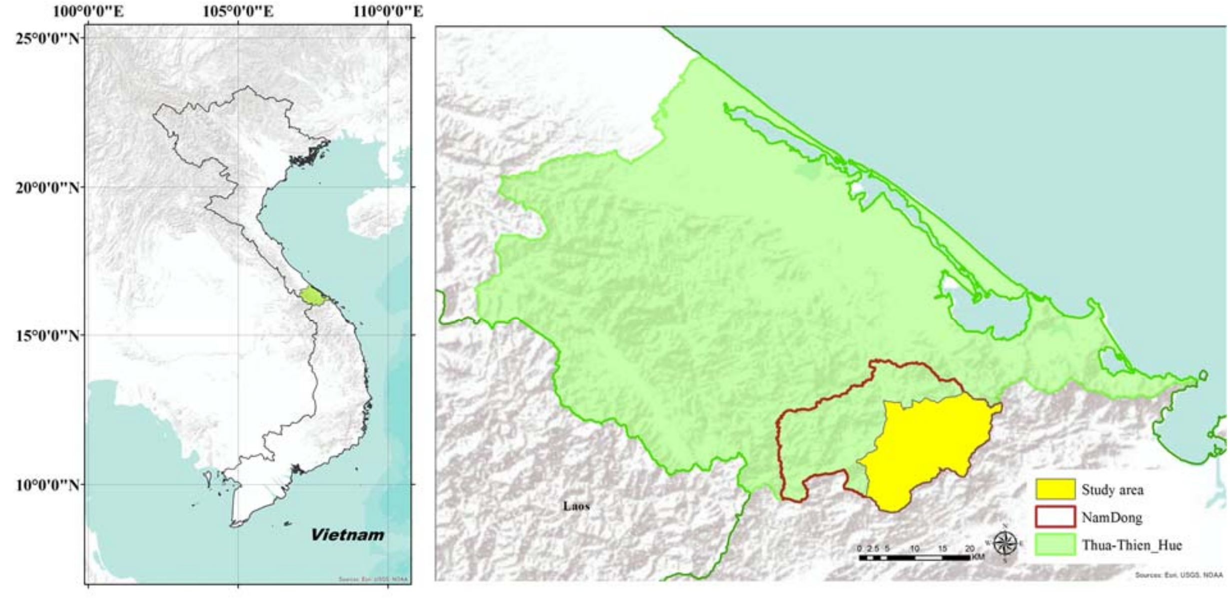


Figure 1 Study area

Table 1 Land-use type and classification

	Land use	Target	Agricultural
1	Production forest (Acacia plantation)		
2	Protected forest	O	
3	Special use forest (National Park)	O	
4	Perennial crops	O	O
5	Annual crops	O	O
6	Paddyfield	O	O
7	Upland rice field	O	O
8	Other cultivation field	O	O
9	Irrigated field	O	O
10	Aquaculture pond	O	O
11	River	O	
12	Unused range of hills	O	
13	Road (Agricultural road)	O	
14	Water area for specific purpose	O	O
15	Local government office		
16	Post office		
17	Educational facility		
18	Sports facility		
19	Medical facility		
20	Waste disposal site		
21	Pablic use land		
22	Cemetery		
23	Residential area		
24	Religious area		
25	Religious facility		
26	Defence facility		
27	Open space		
28	Other land for non-agricultural products		

Sources: *Ogawa et al. (2013)*

3. MATERIALS AND METHODS

3.1 Land-use data

We analyzed land-use data with a scale of 1:50,000 which provided by the local government in 2013 for the classification of land use and the evaluation of SI value (Fig. 2). The area size is 294.23 km^2 distributed across 4 communes in Nam Dong district. We used 10m × 10m grid size which is the minimum unit of land use map as the elementary spatial unit for calculating the diverse mosaics of agricultural landscape in the study area where the small-farming was mainly practiced.

In this study, we applied the Modified Satoyama Index (M-SI) (Yoshioka et al., 2013) which is a kind of SI. Among conventional SI approach, production forests were included in the category of "forest" as same with natural and secondary forests. However, the areas covered with single kind of trees don't have much value as the biological diversity assessment. As an improvement index, M-SI distinguish between production forests and natural or secondary forests, and set the additional classification. M-SI makes it possible to take into account the production forests such as forest plantation of fast growing tree which have been expanding in Southeast Asia.

The land use types consist of 28 kinds of land uses (Table 1), and we classified these land-use types into 4 types based on land-use category defined in Yoshioka et al. (2013). They are "wilderness land use," "rural land use," "production forest," and "urban land use". The calculation targets in this study is

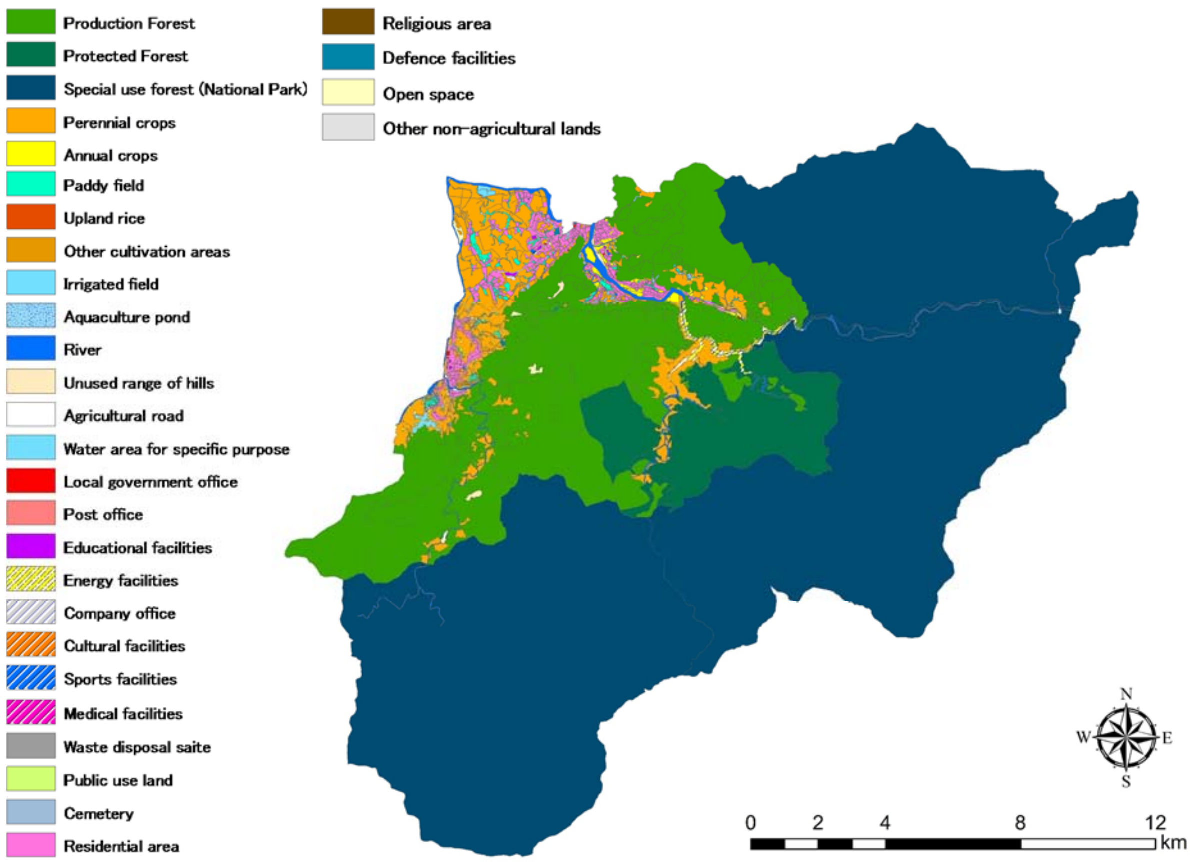


Figure 2 Land-use map

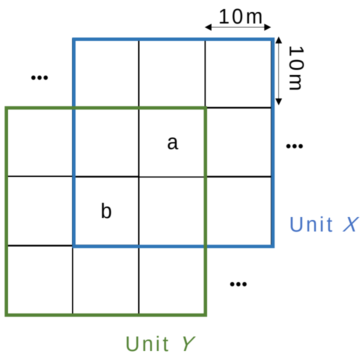


Figure 3 Calculation method

set to be “rural land use” which is including the agricultural land uses indicated in Table 1 as well as is including land uses constituting *Satoyama* landscapes as mentioned above, and the other land uses were not utilized for the analysis in order to distinguish potential habitat areas from non-habitat areas clearly.

3.2 Calculation of the M-SI

At first, we determined individual basic land-use spatial units for each cell, and eliminated the cells of “wilderness land use”, “acacia plantation”, or “urban land use”. Secondly, we calculated the landscape heterogeneity using the Simpson’s diversity index (SDI) among 9 cells comprising each agricultural landscape unit. SDI was calculated as:

$$SDI = 1 - \sum_{i=1}^{S} p_i^2 \qquad (1)$$

where S is the number of different land-use items in a given spatial unit and p_i is the proportion of item i to the 9 elementary cells. At this time, SDI of 9 cells (e.g. Unit X in Fig.3) was calculated and the value of SDI was given to cell (a) as attribute information. As well as, SDI value of Unit Y was calculated with 9 cells including cell (b) and given to (b). Similarly, each cell was given each SDI value calculated with surrounding 8 cells and cell itself.
Thirdly, we calculated the M-SI by multiply SDI and the ratio of nonagricultural land use. M-SI was calculated as:

$$M - SI = SDI \times (1 - P_{agrigulture}) \qquad (2)$$

where $P_{agrigulture}$ is the ratio of agricultural land use among one unit consisting of 9 cells. The M-SI value varies from 0 to 1. The more land-use mosaic is diverse or the higher the ratio of agricultural land use is, the higher M-SI value is calculated.

4. RESULTS

4.1 Spatial pattern of the M-SI

From the results of calculation, we determined the M-SI value for each cell and the spatial distribution of areas which have high value of M-SI (Fig.4). In here, “0” means homogenous landscape, and “1” means highly heterogeneous landscape including a minimum of agricultural cover.
To clarify where features with either high or low values cluster spatially, we calculated statistically significant hot spot using the hot spot analysis by ArcGIS (Fig. 5). Areas with high value of M-SI were shown in red, and areas with low value of M-SI were shown in blue.

4.2 Relationships between land use patterns and M-SI

To clarify the factors that contribute to high M-SI value, we choose the typical areas based on features of land use distribution, and examine the relationships with observed patterns of land use. At first, 3km × 3km grids covering all of study area were created and chose three grids as target areas, named Area 1, Area 2 and Area 3, considering the ratio of areas covered with red color (hot spot) (Fig. 6). Figure 7 and 8 show the land-use map and the result of hot spot analysis for Area 1, Area 2 and Area 3.
From the result of hot spot analysis, it was observed that the distribution of blue color (cold spot) at Area 1 is narrowest among three areas. According to the average, maximum and minimum value of M-SI among three areas which were

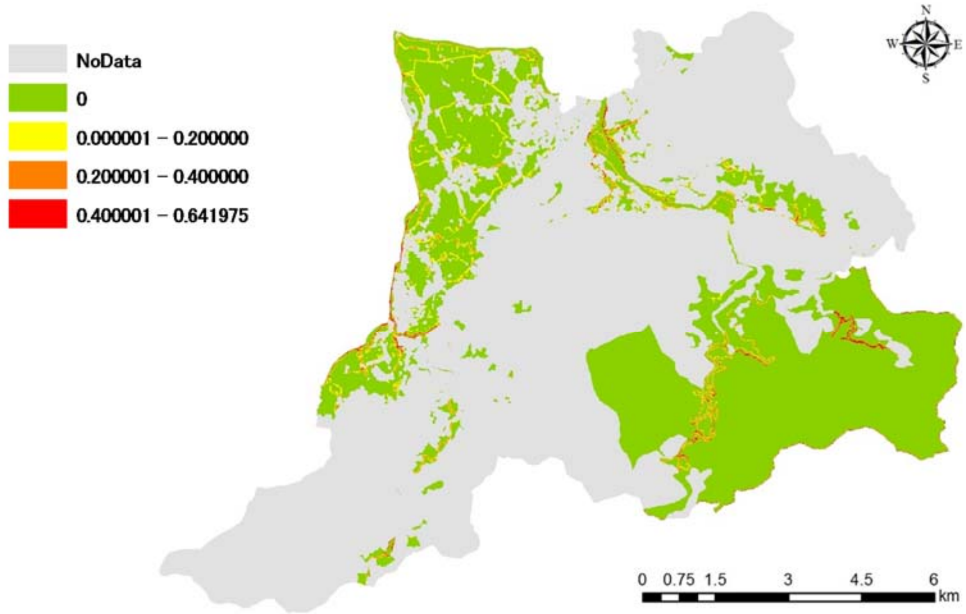


Figure 4 Spatial distribution of areas which have high value of M-SI

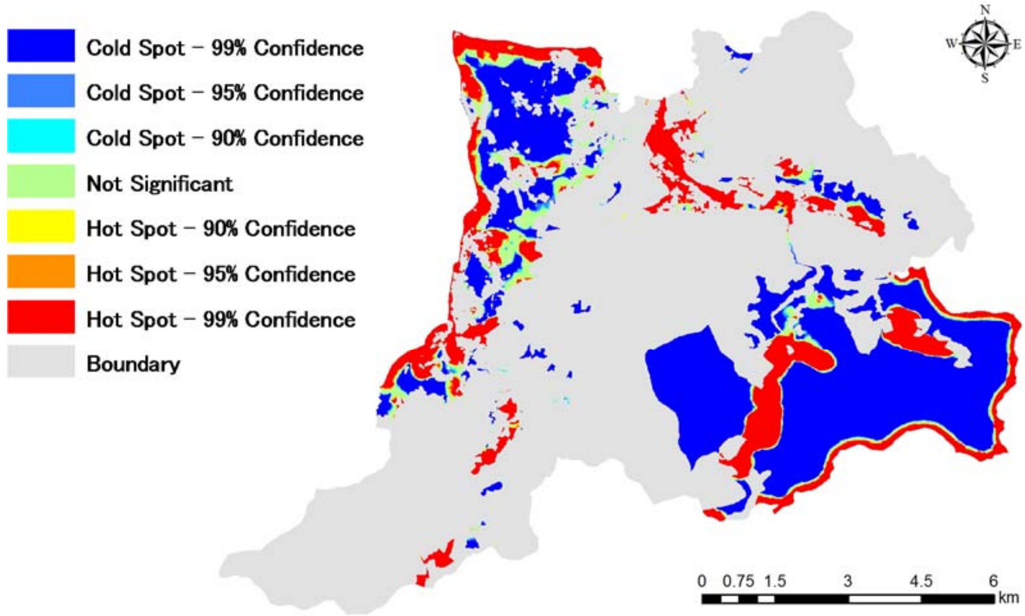


Figure 5 Result of Hot Spot Analysis

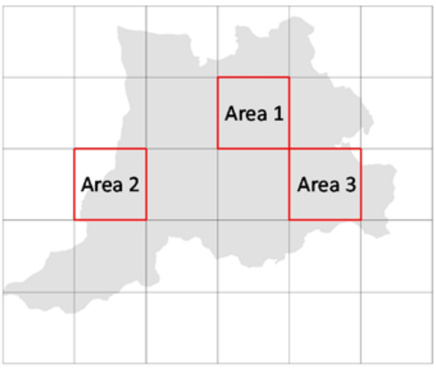


Figure 6 The location of target areas

shown in Figure 9, it was found that high value of M-SI were observed frequently at Area 1. By contrast, there are great variations of M-SI in Area 2, and large deviations of the M-SI in Area 3.

We examined and compared each land-use features among these three target areas. Area 1 is located near the river which flows from north to southeast, and contains two villages which were surrounded by the land of acacia forestry. Area 2 is also residential area located near the river. There are huge mountainous area which have been used for the acacia plantations between Area1 and 2. Area 1 and 2 are seemingly similar to each another. On the other hand, Area 3 is located nearby the protected forest, and far away from residential area. Average elevation of Area 3 is relatively higher than other areas which have high value of M-SI (The highest area of all cells is forest area which has homogenous land use).

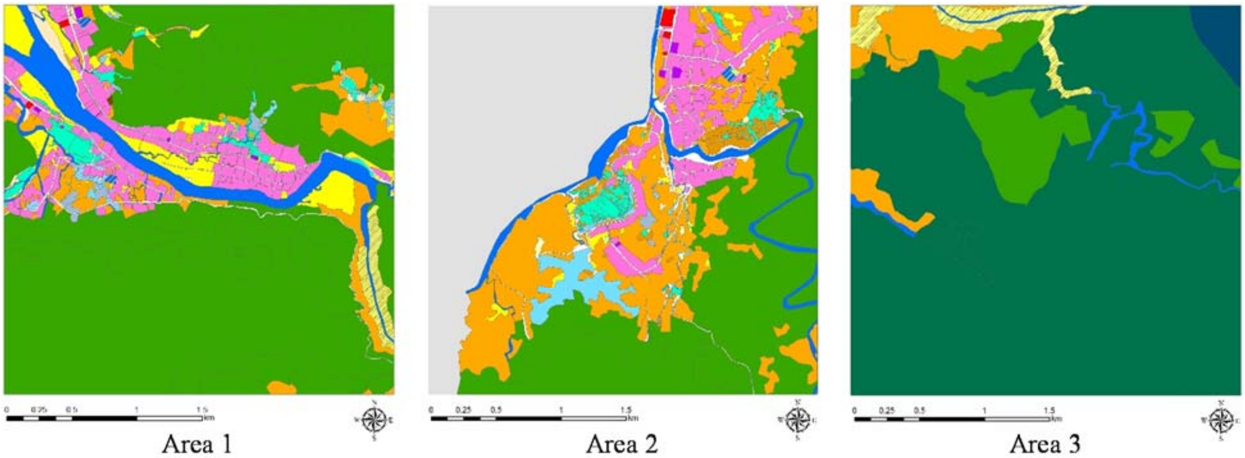


Figure 7 Land use map

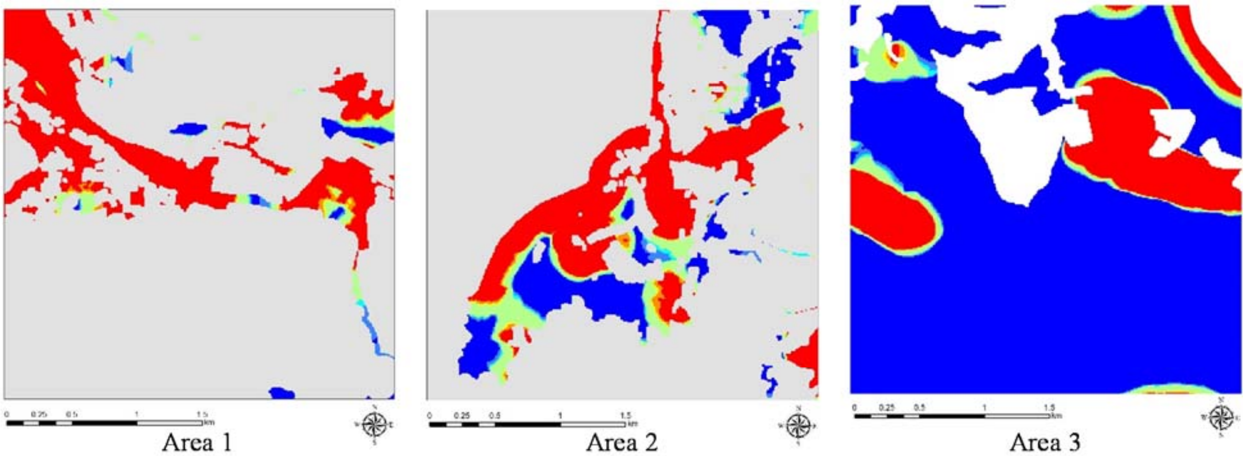


Figure 8 Hot Spot distribution map

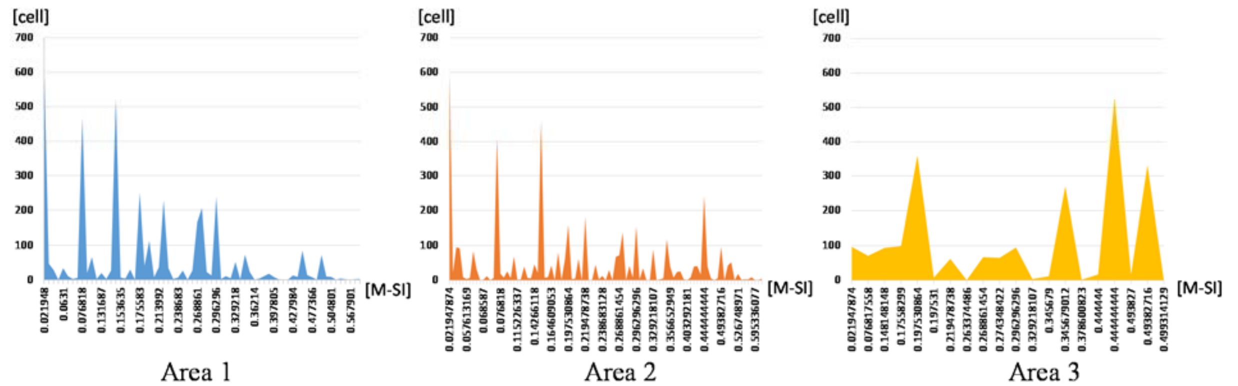
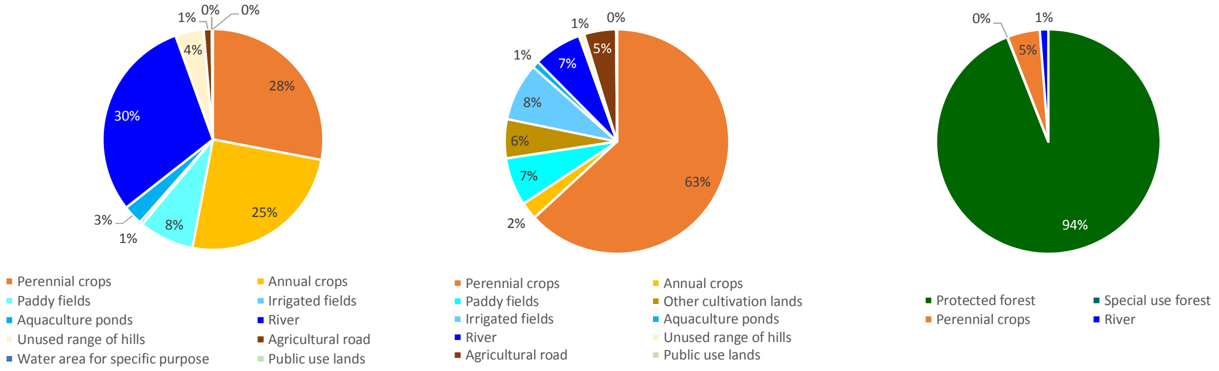


Figure 9 Frequency distribution chart of M-SI

Figure 10 show the constitution of “rural land use” in each of three target areas. Comparing these three figures, it was found that every area is including water-related land use, like a paddy field, irrigated area, aquaculture pond, river, and so on. Especially Area 1 and Area 2 consist of many variety of land for water use. Although the variety of land-use types in Area 1 and Area 2 is same, this study revealed that M-SI values are different in each area. This results would indicate that differences in combination or constitution of land use could be factors of M-SI values so that we need to find out the mechanisms of decision making for land use which contribute to high M-SI value. Additionally, as remarkable aspects of land use differences, Area 3 doesn’t have land for annual crops while Area 1 and 2 has land for perennial crops. This is presumably linked to the fact that people tend to choose the land for annual crops at low land or near residential area. From the above, variables of decision making for land use, for example elevation or distance from water area, has potential to be independent variable to identify the driving forces that are contributing to high M-SI value.



Area 1 Area 2 Area 3

Figure 10 The constitution of "rural land use"

5. DISCUSSION AND CONCLUSIONS

This paper discusses the possibility of M-SI application in the rural areas of Vietnam, which have complicated contexts, as well as the validity of M-SI evaluation results. In Southeast Asia, people commonly enhance their resilience by practicing multiple and small-scale agriculture. In recent years, some studies have pointed out that the higher was the diversity of habitats in the landscape, the higher was the diversity of diet (Kauhala and Ihalainen, 2014) so that the diversity of habitats must be important index for human living environment and should be conserved sustainably. To make a land-use planning with keeping or enhancing the resilience of livelihood in rural area, appropriate method of land-use diversity evaluation is needed. However, it was difficult to evaluate the land-use patterns in Southeast Asia especially in mountainous regions because conformed land-cover data on the World Wide Web was only available and their data units could not grasp individual paddy or cropland patches. So some previous studies could not classify 'paddy field' and 'cropland' while these differences were quite important in describing the nature of land uses and diversity of habitats (Kadoya and Washitani, 2011). In this study, as a counterapproach, we used the small cell size distracted from land-use map and conducted micro-scale calculation. Consequently, the agricultural landscape mosaics within a small-scale agriculture were successfully evaluated by the M-SI. This study pointed out that the combination or constitution of land use could be factors of M-SI values and that proper land-use planning can realize the conservation of biodiversity through consideration about the generation trend of land-use types, such as annual crops and perennial crops formulation mentioned above. For the next step, we'd like to try to identify the driving forces that are contributing to rich heterogeneity of agricultural landscapes towards the biodiversity conservation under agricultural development.

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