Quantitative Evaluation Methods for Secondary Ecosystem Management Activities -For *Satoyama* Banking-

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1 Background and Purpose

A primary ecosystem has already disappeared in many countries, and much of the nature that remains is a secondary ecosystem fostered with traditional human activities. In Japan, these secondary ecosystems are called *satoyama*. Traditionally managed *satoyama* maintains biodiversity that is different from, but not inferior to, primary ecosystem.

However, secondary ecosystems, such as *satoyama* in Japan, continue to decrease due to human activities such as residential land development. And even if they remain, they face biodiversity degradation due to a lack of traditional management. The former problem is called "overuse" in terms of "space," and the latter is called "underuse" in terms of "quality."

To address the overuse problem, assessment of "no net loss" has started to occur by comparing the negative impact on nature and the positive impact of compensation mitigation such as biodiversity offsets. Such assessment is based on quantitative habitat assessments represented by HEP, which is part of the environmental impact assessment.

In this study, we devised a quantitative evaluation method based on the application of HEP. Then, it was demonstrated with a case of secondary ecosystem management activities by a non-profit organization. The results were compared with an overuse case of a land development project, for which a quantitative evaluation was performed based on environmental impact assessment. Based on this comparative analysis, we propose an effective quantitative assessment method to evaluate the impacts of future secondary ecosystem management activities.

２ Methodology

2.1 Quantitative assessment of the impacts of management activities in secondary ecosystems

We evaluated the ecosystem management activities in *satoyama* in Aichi Prefecture, using *Luehdorfia japonica* as an indicator. For the evaluation, SI and HSI models were constructed and calculated, focusing not only on the ecology of *Luehdorfia japonica* and its habitat but also on the quality of the habitat changed by the management activities. The management outcomes were assessed by comparing the THU before and after the management activities.

2.2 Quantitative assessment of the impacts of development projects in secondary ecosystems

We evaluated the impact of a land development project in a *satoyama* in Yokohama City using two species of fireflies (*Luciola cruciata* and *Luciola lateralis*) and two species of frogs (*Rana ornativentris* and *Rana japonica*) as indicators. SI and HSI models were constructed and calculated using the biological data on the ecology and habitat of these species. The development impacts were assessed by comparing THUs before development and THUs for three development scenarios, including no-action.

2.3 Issues in quantitative assessment of the impacts of management activities in secondary ecosystems

A comparison between the quantitative assessment of the impacts of management activities and development projects in secondary ecosystems revealed issues of consideration in the quantitative assessment of the impacts of management activities in secondary ecosystems.

The points of comparison were the type of human activity, the type of *satoyama* ecosystem, the purpose of the assessment, the species used in the assessment, the method of determining the assessment area, and the assessment results.

3. Results

3.1 Quantitative assessment of the impacts of management activities in secondary ecosystems

Habitat variables were selected as the availability of plants whose flowering season is from March to May, the availability of space for flight, and the availability of *Asarum* spp.

For the evaluation area, habitat evaluation was conducted using a 25m square evaluation grid.

Figure 1 shows the relationship between the habitat variables, SI models, and HSI model in the adult and larval stages of the *L. japonica*.

The respective SI models before and after the management activities in the experimental site are shown in Tables 1 to 4, and the HSI model is shown in Equation 1. Figures 2 to 7 show the respective evaluation results, and Figure 8 shows the graph of THU before and after the management activities.

For the SI2 model on the availability of flying space, two separate models (SI2α and SI2β) were developed to account for the consideration of spatial connectivity.

Some grids assessed in this study included areas where no management activities were conducted, and in such areas, the HSI values were lower than in areas where activities were conducted. Furthermore, the SI2β model, which took into consideration spatial connectivity, yielded a higher SI value than the SI2α model, even in the areas where management activities are not conducted in the surrounding grids. However, since the HSI model was constructed to change significantly depending on the availability of *Asarum* spp., the overall HSI value became low even when the SI2β value was high.

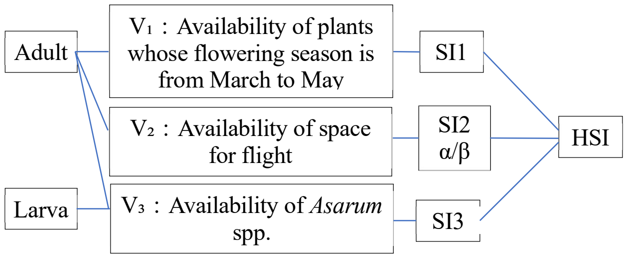

Figure 1: Relationship between the Habitat Variables, SI models, and HSI model of the *L. japonica*

Table 1: SI model for SI1 (the availability of plants whose flowering season is from March to May)

Condition	SI value
Have not seen any plants with purple or yellow flowers within a year.	0.0
Have identified plants with yellow flowers within a year.	0.5
Have identified plants with purple flowers within a year.	1.0

Table 2: SI model for SI2α (the availability of space for flight, without consideration of connectivity)

Condition	SI value
Type A (very high canopy density and forest density, thickets on the forest floor)	0.0
Type B (density with moderate sunlight in the forest)	0.5
Type C (very low canopy density and forest density, forest floor is not thicketed)	1.0

Table 3: SI model for SI2β (the availability of space for flight, with consideration of connectivity)

Condition	SI value
Evaluation grid is Type A and all surrounding 8 grids are also Type A.	0.0
Evaluation grid is Type A and any of the surrounding 8 grids contain Type B or C.	0.2
Evaluation grid is Type B and all surrounding 8 grids are also Type B.	1.0
Evaluation grid is Type B and any of the surrounding 8 grids contain Type A or C.	0.5
Evaluation grid is Type C and all surrounding 8 grids are also Type C.	0.0
Evaluation grid is Type C and any of the surrounding 8 grids contain Type A and B.	0.8

Table 4: SI model for SI3 (the availability of *Asarum* spp)

Condition	SI value
No growth of *Asarum rigescens var. brachypodion* or *Asarum takaoi*.	0.5

Growth of *Asarum rigescens var. brachypodion* or *Asarum takaoi* can be seen.	1.0

$$HSI = \frac{SI1 + SI2}{2} \times SI3$$

Equation 1: HSI model for evaluating the outcomes of *Satoyama* management activities

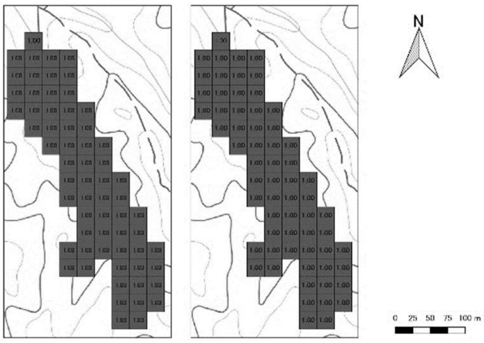

Figure 2: SI1 values before and after management activities

Figure 3: SI2α values before and after management activities

Figure 4: SI2β values before and after management activities

Figure 5: SI3 values before and after management activities

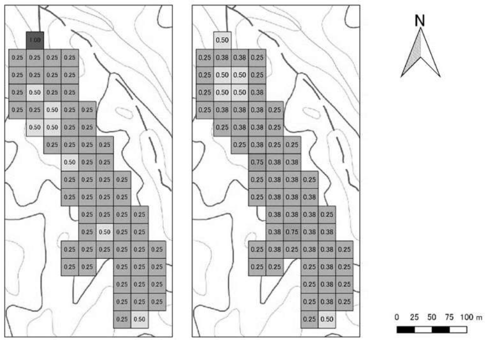

Figure 6: HSI values before and after management activities when SI2α model is used

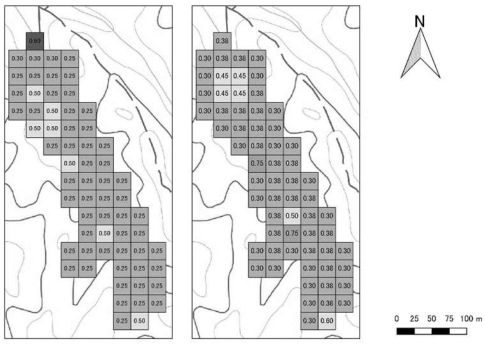

Figure 7: HSI values before and after management activities with SI2β model is used

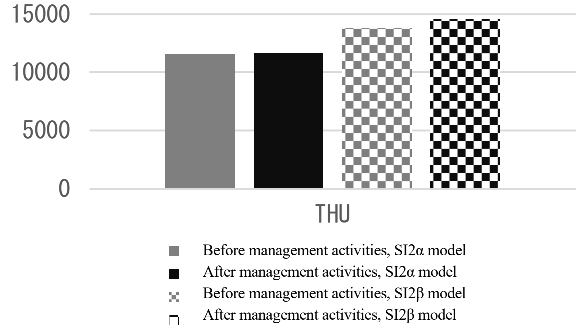

Figure 8: THU before and after management activities

3.2 Quantitative assessment of the impacts of development projects in secondary ecosystems

The habitat assessment results of the four species are shown in Figures 9 to 12. Except for *R. ornativentris*, THU decreased in all scenarios, including no-action.

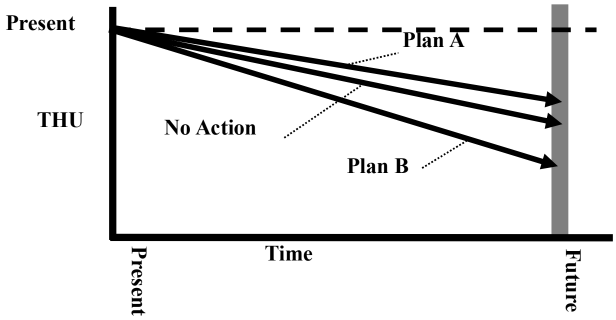

Figure 9: Change in THU of Genji Firefly (*Luciola cruciata*)

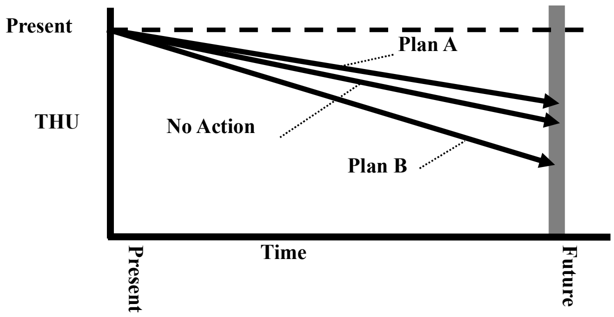

Figure 10: Change in THU of Heike firefly (*Luciola lateralis*)

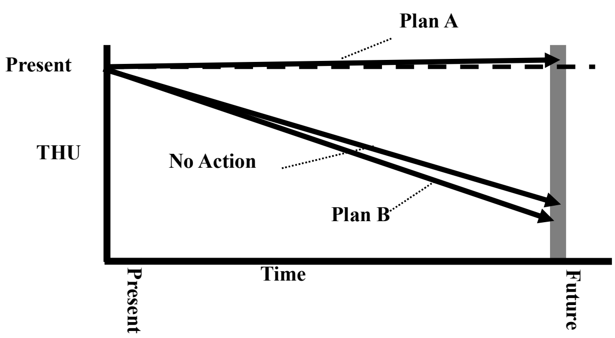

Figure 11: Change in THU of Montane Brown Frog (*Rana arnativentris*)

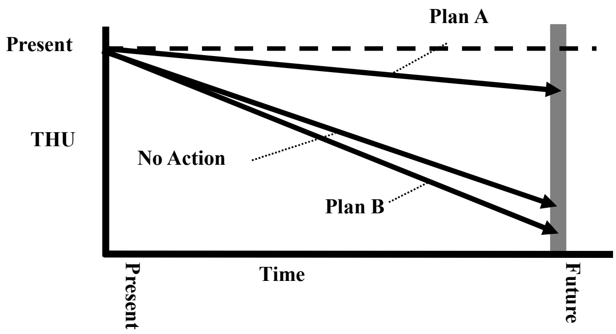

Figure 12: Change in THU of Japanese Brown Frog (*Rana japonic*a)

4. Discussion

The results of the two case studies are summarized in Table 4 according to the perspectives on quantitative biodiversity assessment.

We identified five issues to consider when developing a quantitative evaluation method for the impacts of secondary ecosystem management activities.

First, the method should be designed to be utilized by those who do not have expertise in biology. Since HEP is a quantitative biological assessment, which is time-consuming and costly, it needs to be conducted by experts in biology and ecology. It requires detailed and diverse data for decision-making, including a selection of target species, construction of SI and HSI models, and estimation of SI values. To effectively conserve *satoyama* ecosystems, it is necessary to develop a simple assessment method that can be utilized by non-specialists in biology and ecology.

Second, the method should convey the causal relationship between specific management activities and the conservation impacts on ecosystems and habitats. HEP is a quantitative biological assessment and cannot directly evaluate the impacts of human management activities. However, in the case of species in *satoyama* ecosystems whose habitats have been maintained through human involvement, the management activities themselves are directly related to the quality of the habitat.

Third, the method should evaluate human management activities themselves since HEP evaluates the biological status of the target area as a habitat and not the management activities directly.

Fourth, the method should evaluate the impacts of continuous management activities. HEP evaluates the biological status of a target area at a certain point in time. In constant human management activities, such as in *satoyama* ecosystems, extensive research efforts become necessary to effectively evaluate the changes over time.

Lastly, the method should be simple and yet the ecological health aspect of HEP should not be compromised. The results of HEP are quantitative evaluations from an ecological perspective. Therefore, it may not be easy to translate the value of ecosystems and incorporate it into the cost of activities in s*atoyama* ecosystem management planning and trade-offs involving biodiversity offsetting and banking in the future. It would be possible to better integrate the benefits of conservation activities holistically through developing a method to evaluate the management activities themselves in a simple and quantitative manner without compromising the perspective of evaluating the ecological health of the HEP.

Table 5: Perspectives on quantitative biodiversity assessment and the results of the case studies

Perspectives	3.1. Yokohama Project	3.2. Aichi Project
Type of human activities	Residential development business	Satoyama conservation activities
Type of *satoyama* ecosystem (Area)	Deciduous broad-leaved forest, paddy field (33.6ha)	Deciduous broad-leaved forest (4.0ha)
Evaluation target	Impacts of development project and mitigation measures on the habitat of evaluation species	Impacts of conservation activities on the habitat of evaluation species
Evaluation species used for HEP	Genji firefly (*Luciola cruciate*), Heike firefly (*Luciola lateralis*), Japanese brown frog (*Rana japonica*), Montane brown frog(*Rana ornativentris*)	Japanese luehdorfia (*Luehdorfia japonica*)
Evaluation area division method	Polygon	Mesh
Evaluation results	Negative impacts of the development project could be evaluated biologically and quantitatively for each evaluation species	Positive impacts of outcomes of the conservation activities could be evaluated biologically and quantitatively for each evaluation species

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