Effect of landscape structure on functional biodiversity

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Abstract

We discussed the relation between agriculture and biodiversity in rice paddy landscape, especially focusing on both effects of landscape structure on functional biodiversity for agricultural production and effects of agricultural activities on biodiversity in farmland. As the conclusion, it were suggested that landscape mosaic around paddy fields is very important for the habitation of natural enemies, and landscape support the functional biodiversity for rice production. On the other hand, the landscape structures have been changed by both increasing and decreasing of human activities in rural area. Therefore, to use ecosystem services by agriculture in sustainable way, we need to consider not only agricultural practices inner fields, but also farmers' activities around fields which maintain the landscape structure.

1. Introduction

Agriculture is the typical human activity to use biodiversity and ecosystem services. Crops, vegetables, live stock and other agricultural productions are genetic resources of biodiversity which have been selected for human lives. Also agriculture needs many types of ecosystem services such as microorganism for fertile soil, insects and other animals as pollinators or natural enemies, forest for groundwater occurrence. Therefore farmers have adequately maintained biodiversity and ecosystem in and around farmland.

But in recent years, agriculture become a major threat to biodiversity in the world because many farmlands for agricultural export have been established by destroying natural ecosystem, for example, soybean and sugarcane fields in Amazon, palm plantations in South-east Asia and so on. Also modern and intensive agriculture in the countries where have long histories of agriculture have reduced biodiversity in farmland by both chemical material use and field improvement.

From these view points, in last January, Japanese government (2010), the chair country of The Tenth meeting of the Conference of the Parties (COP10) of the Convention on Biological Diversity (CBD), made a proposal for post 2010 target of CBD. The Japanese proposal includes a target to increase the ratio of production that is managed in sustainable manner in agriculture and other activities which utilize biological resources. This target has two sub-targets; promotion of agricultural production methods that reduce adverse impacts on ecosystems, and providing habitats to wildlife in agricultural lands or its surrounding areas. These sub-targets show two different spatial scales influenced on relations between agriculture and biodiversity, in fields and farmland landscape.

Landscape is one of the key words in recent years to study the relation between

agriculture and biodiversity in farmland. For example, Bianchi et al.(2006) suggested that diversified landscapes hold most potential for the conservation of biodiversity and sustaining the pest control function. Other studies pointed out the importance of landscape structure and conditions, such as landscape complexity, existence of non-crop habitats in field boundary (Coeur et al., 2002, Schmidt et al., 2007, Devictor & Jiguet, 2007, Aviron et al., 2007, Aavik & Liira, 2010). These studies mainly focused on pasture and other semi-natural vegetation, or hedgerows and other field boundaries in European countries. And their results are supporting some European attempts for agro-environmental policies such as Environmental Stewardship in England (Natural England, 2010), Ecological Infrastructures in Swiss (Boller et.al., 2004), High Nature Value Farmland by European Committee (Parachini et al., 2006).

But in Monsoon Asia in where rice paddy landscape is dominant, we have only few knowledge about the relation between agriculture and biodiversity in landscape level. Therefore we want to discuss about the relation between agriculture and biodiversity in rice paddy landscape, especially focusing on both the effect of landscape structure on functions of biodiversity for agricultural production and the effect of agricultural activities on biodiversity in farmland.

2. Landscape structure around rice paddy fields

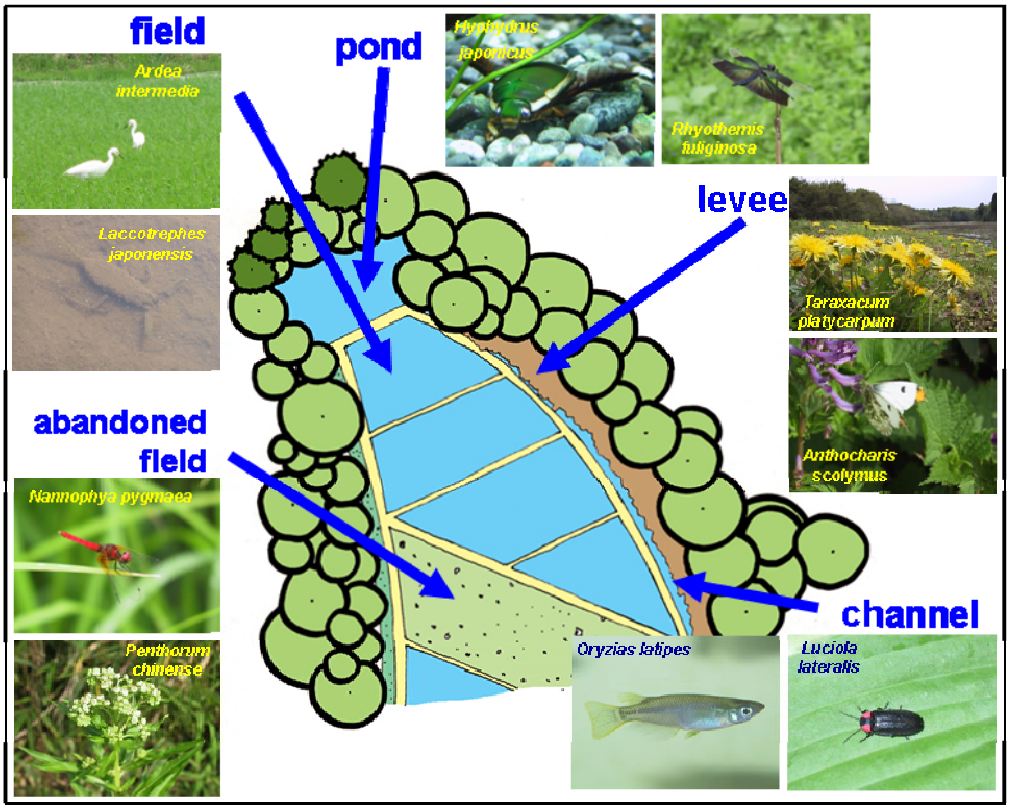

Fig. 1. Landscape elements around *Yatsu* rice paddy as habitats for wild-lives

In Monsoon Asia, we have high heterogeneous landscape in rural area. The main feature of the rural landscape is rice paddy fields. Rice paddy production needs not only “fields” but also many types of landscape elements such as paddy banks (levees), irrigation and drainage

canals, irrigation ponds, forest covering water catchment. Therefore paddy landscape is composed by many type elements necessarily, and there are mosaic of these elements (Fig.1). As the result, rural landscape in Monsoon Asia is highly heterogeneous.

These landscape elements have different role for wildlife habitation (Moriyama, 1997). Irrigated paddy fields have functions as shallow standing fresh water habitats for aquatic plants, aquatic insects, fishes, water birds and other aquatic animals. On the other hand, irrigation ponds are relatively deep standing fresh water habitats, and irrigation and drainage canals are running water habitats for many aquatic plants and animals. Banks of paddies, canals and ponds are terrestrial habitats as the same as forest covering catchment. But banks are covered by grasses or herbs in contrast to forests or woodlands. Furthermore, mosaics of aquatic and terrestrial elements provide habitats for amphibiotic animals such as frogs and dragonflies.

These landscape elements are not natural ecosystems. These elements had been formed and have been maintained and used by farmers for rice production. These human maintained ecosystems are called as “semi-natural ecosystem”. The mosaics of semi-natural ecosystems are very important for biodiversity in farmland. One of 3 types of HNV (high nature value) farmland in EU (Parachini et al., 2006), type 2, is defined as farmland with a mosaic of low intensity agriculture and natural and structural elements, such as field margins, hedgerows, stone walls, patches of woodland or scrub, small rivers etc.

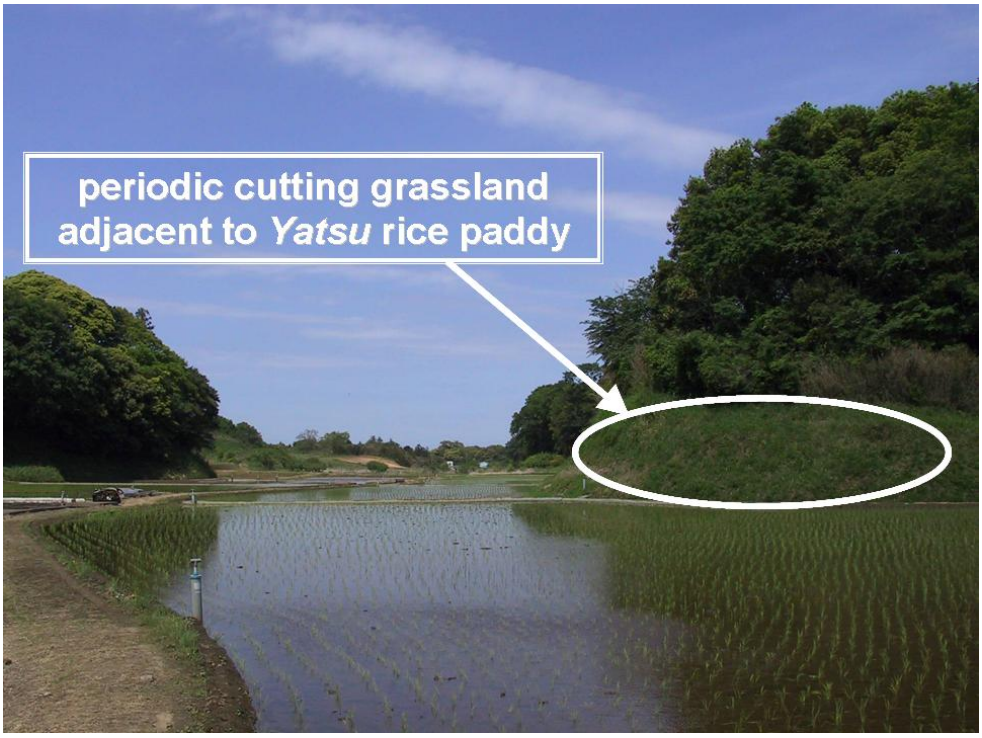

Fig. 2. Periodic cutting grassland adjacent to *Yatsu* rice paddy

In some cases, the mosaics of landscape are sustained by farmers' activities on the outside of fields. In the case of "***Yatsu*** Landscape" in Japan, in where paddy fields locate in the bottom of small valley with forest in surrounding slopes, periodic cutting grasses by farmers in adjacent slope to rice paddy fields conserve plants and butterfly diversity (Yamamoto et al., 2006). In traditional ways, gentle slopes had been used as grassland to take grasses as foods for cows and natural fertilizer for rice production in traditional ways. After energy revolution in 1950s, modernization and motorization of agriculture make grassland in no need, and most of grassland in rural area in Japan had changed into forest or urban land use. As the results of changes, many plants and insects which depend on grassland have declined. But small and liner grassland are sustained by periodic cutting grasses to prevent vegetation from casting shade over the paddy rice fields in ***Yatsu*** landscape (Fig.2). Diversity of plants and species richness of butterflies are very high in the slopes with cutting grasses (Fig.3, table 1). This result shows the effect of landscape structure with a mosaic of grassland, wetland (paddy) and forest.

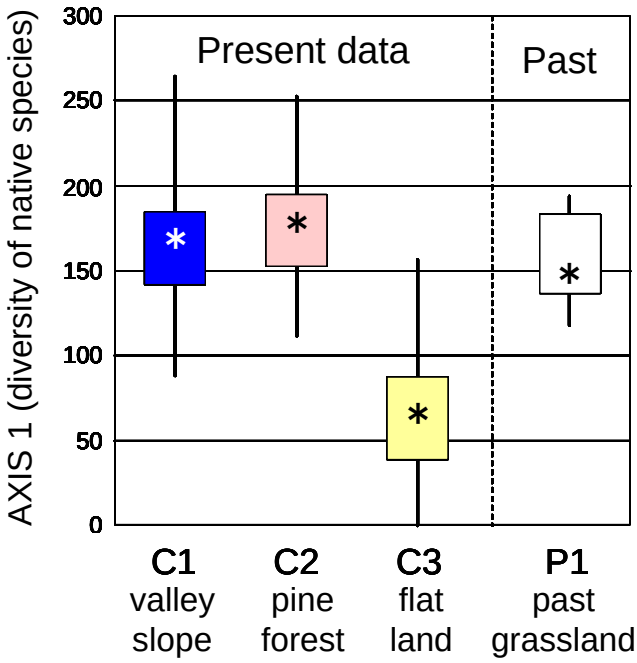

Fig. 3. Diversity of native herbs in *Yatsu* valley slope (C1) to compare with past semi-natural grassland (P1) and forest (C2)

Table 1. Relation between Butterfly Species richness and Landscape Structure in *Yatsu*

Land Use on One-side of Sences Root	Land Use on Another-side of Sences Root															
	(P)	●		●	●											
	(A)		●	●												
	(U)						●		●					●	●	
	(S)				●	●			●	●	●	●			●	
	(G)					●	●	●	●	●			●			
	(F)									●	●	●	●			
	(E)															●
(P) paddy rice field		18			25	23	24	12	25	7	43	29	36	37	2	13	21
(A) abandoned paddy			23		18	17	16		9		16	20	25	23	8		21
(M) rice + abandoned				34	24		11		11								
(U) upland field						8	5				15	24	13	10			20
(F) forest																	16
(G) grass in slope																	15

∗ (S) stream, (E) else
∗ number in tabel is amount number of butterfly species in each segment type

3. Changes of Landscape Mosaic around Rice Paddy

In European countries, modernization of agriculture has lead to simplofocation of landscape structure (Persson et al., 2010). On the other hand, rice paddy landscape in Monsoon Asia is originally heterogeneous because paddy rice production needs many elements, such as banks of paddies and canals. But we have no estimation and monitoring data of small and liner elements in paddy landscape, such as banks and canals. Therefore, in this reports, we wanted to analyze the changes of paddy landscape structure by using an indicator of land use level mosaic.

We selected the JOIN index (Krishna Iyer, 1950) as the indicator of land use mosaic. JOIN is an index to estimate the distribution of grid (lattice) data whether agglomerated or dispersive. JOIN is counted as the number of bordering lines between grids. For example, in a sample grid data shown in Fig.4, paddy grids are adjacent to wood grids in 6 lines, also paddy grids are adjacent to other paddy grids in 4. We counted JOIN number of paddy – paddy, paddy – forest and paddy – buildup area in each 1km grid of whole Japanese national land (370 thousands girds) by using land use data of each 100m grid in 1976 and 1997. If a 1km grid has large number of paddy – paddy JOIN then landscape in the grid is simple landscape dominated by paddies. On the contrary, if there is large paddy – forest JOIN then the grid is high mosaic landscape with paddies and forests. After counting JOINs in whole Japanese land, we calculated the average JOIN in each landscape type which classified by RuLIS (Yamamoto and Kusumoto, 2008, Fig.5), and also we analyzed changes of JOIN from 1976 to 1997 in each landscape types (Fig.6).

The result shows that we have many differences in heterogeneity of landscape and in changing patterns of the landscape structure. In paddy dominated landscape types which have high ratio of paddy area in 1km grid, the heterogeneities of landscape have increased because of decreasing of paddy – paddy JOIN and of increasing paddy –buildup area JOIN. These changes are results of urbanization. On the other hands, in high heterogeneous landscape types with large ration of paddy – forest JOIN in 1976, the heterogeneities of landscape have decreased because of decreasing of paddy – forest JOIN.

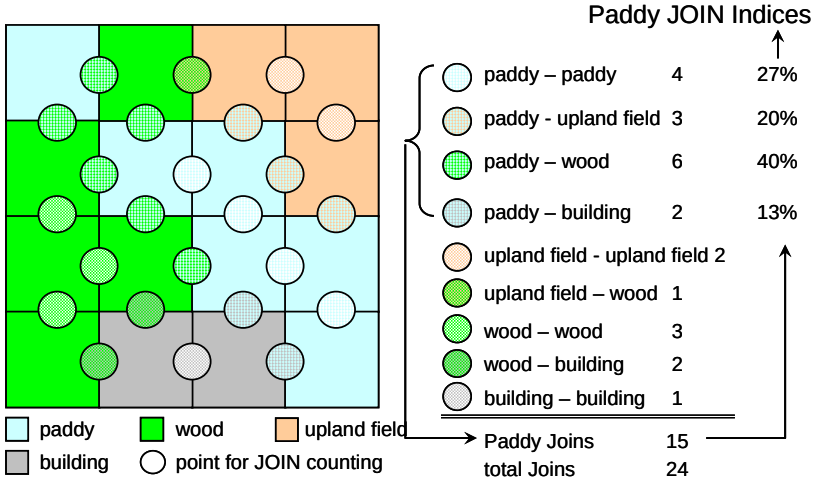

Fig. 4. Counting JOIN in a sample landscape mosaic

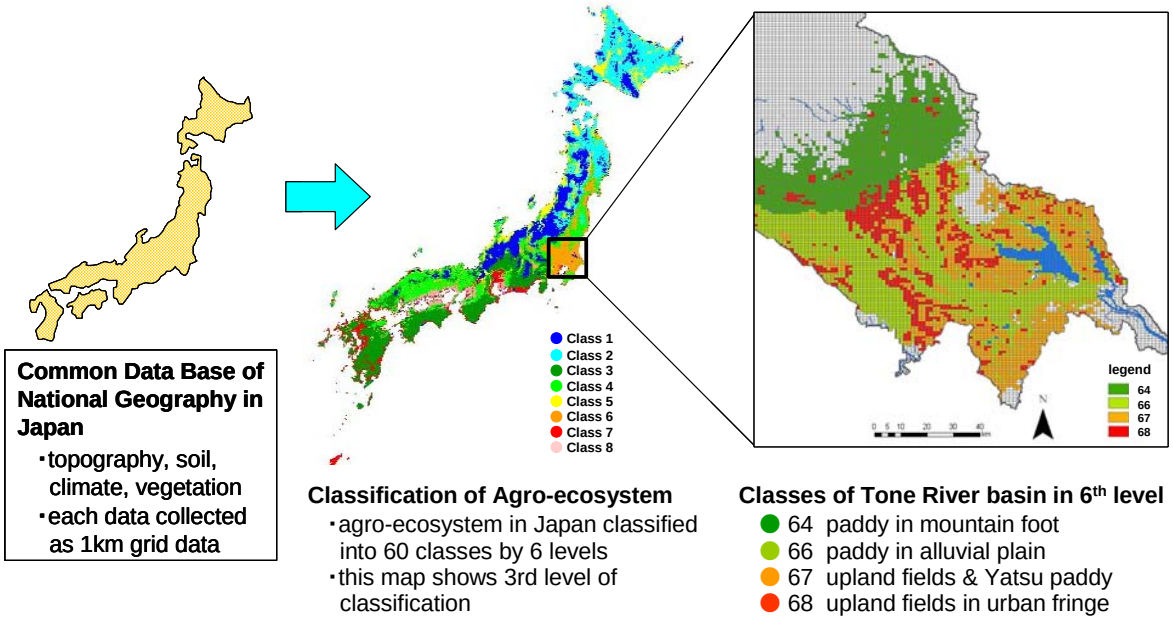

Fig. 5. Classification of Ecosystem by Rural Landscape Information System

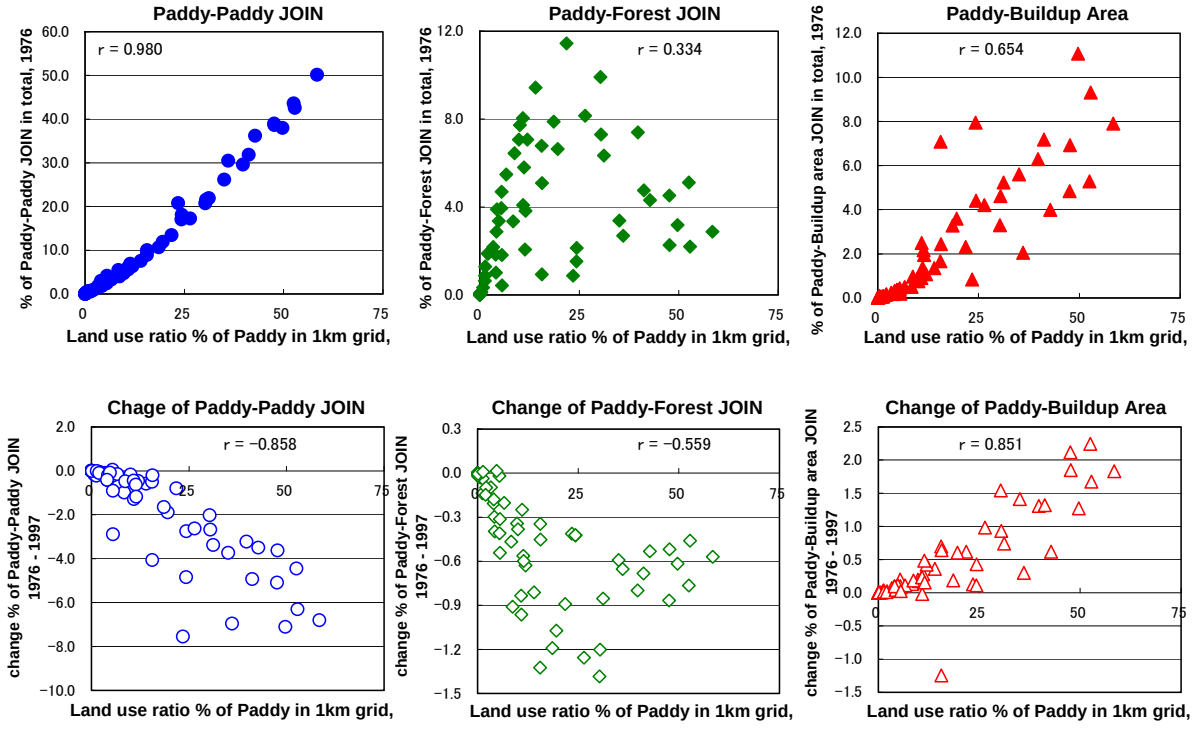

Fig. 6. Changes of landscape mosaic around paddy explained by using JOIN indices

These changes might occur by both destruction of the forests and abandonment of paddy fields. This result suggested that changes of landscape mosaic around paddy will be caused by both increasing of human activities in rural area, such as urbanization and deforestation, and decreasing of human activities such as abandonment of paddy fields.

4. Importance pf Landscape Mosaic around Paddy on Rice Production

Above analysis shows the changes of landscape mosaic around rice paddies. The next issue is how influence these changes on paddy rice production. But we have no direct investigation about influences of landscape change on agricultural production. Hence, we tried to clarify the importance of landscape mosaic around paddy fields on Rice Production.

Japanese Ministry of Agriculture (MAFF / Ministry of Agriculture, Forestry and Fisheries) is now conducting a research project to develop some new indicators of functional biodiversity. In this research project, distributions of some indicator species, most of indicators are natural enemies, have been surveyed at many sites in Japan. We accumulated these distributions data of indicator species, and we analyzed the relation between individual numbers of indicator species and influence factor such as agricultural practices, climate and landscape structures. *Tetragnatha* spiders were selected as a model indicator which widely distribute in Japanese paddy fields, and their individual numbers were put into objective variable. Explanatory variables were agricultural practices (frequency of chemical materials use; pesticide, herbicides, chemical fertilizers) and environmental factors such as climate (maximum, minimum and average temperature, precipitation, solar radiation, snow), topography (land relief) and landscape structure (JOIN of paddy-paddy, paddy- forest, paddy-buildup area).

The relation between objective and explanatory variables were analyzed by using GLM,

Table 2. Agricultural and environmental factors influenced on *Tetragnatha* spiders

explanatory variables	estimation	significance
Agricultural Practicies		
Conventional agriculture type or not	−0.233	0.038 *
Environmental friendly agriculture or not	−0.533	0.000 ***
Pesticide (put in plantation boxes, fipronil)	−0.487	0.000 ***
Pesticide (put in plantation boxes, non−fipronil)	−0.603	0.000 ***
Pesticide (put in fields)	−0.369	0.000 ***
Chemical fertilizers	−0.557	0.000 ***
Organic fertilizers	−0.120	0.107
Environmental Factors		
Annual mean air temperature	−0.499	0.000 ***
Annual amount of precipitation	0.001	0.000 ***
Amount of solar radiation in summer	−0.213	0.000 ***
Maximum snow depth	−0.025	0.000 ***
Relief of land	−0.005	0.000 ***
JOIN in 1997/ Paddy fields−Forest	0.018	0.000 ***
JOIN in 1997/ Upland fields−Forest	−0.005	0.005 **
JOIN in 1997/ Buildup area−Forest	−0.008	0.127
constant	28.423	0.000 ***

AIC= 2837.1
explained deviance: 62.8
Agricultural Parcticies=28.5, Environmental Factors=20.5, interactions=13.7

and a best model of GLM was selected according to AIC (table 2). The model shows the effect of agricultural practices on individual numbers of *Tetragnatha* spiders is 28.5%, and the effect of environmental factors is 20.5%, and interaction is 13.7%. This means that distribution of spiders inner paddy fields is influenced by not only agricultural practices in fields but also environment around fields. Especially, paddy – forest JOIN is the only positive factor influence on spiders, on the contrast other factors are negative. This result suggested that the landscape mosaic around paddy is very important for the habitation of natural enemies. Thus, the landscape structures support the functional biodiversity for rice production.

5. Conclusion

In this study, we discussed the relation between agriculture and biodiversity in rice paddy landscape, especially focusing on both the effect of landscape structure on functions of biodiversity for agricultural production and the effect of agricultural activities on biodiversity in farmland. As the conclusion, it were suggested that landscape mosaic around paddy is very important for the habitation of natural enemies, and landscape support the functional biodiversity for rice production. But the landscape structures have been changed by both increasing and decreasing of human activities in rural area. Therefore, for sustainable use of ecosystem services supported by biodiversity in agriculture, we need to consider not only agricultural practices inner fields, but also farmers' activities around fields which maintain the landscape structure.

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