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THE IMPACT OF TOURISM DEVELOPMENT ON THE STRUCTURE OF AGRICULTURAL LANDSCAPE OF THE DONGSHAN RIVER BASIN, TAIWAN

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Abstract. After the establishment of the Dongshan River Scenic Area of Yilan County in Taiwan, land use in the Dongshan River Basin has undergone dramatic change, from agricultural areas to recreational settings, in the past decades. The purpose of this study was to apply the approach of landscape ecology to analyze the spatiotemporal transition of the agricultural landscape of the river basin after tourism development. The study aimed to examine the landscape change in the river basin and its ecological implications. Maps of the Dongshan River Basin in 1987 and 2003 were generated, and the land uses were grouped into six land-use types: paddy fields, high-density vegetation, low-density vegetation, water, built-up land, and sandy beaches. A set of landscape metrics were computed with FRAGSTATS. The results showed that, from 1987 to 2003, the major change in the river basin landscape was a rapid increase in the area of built-up patches, while the areas for all other land use decreased. As for paddy fields, although their overall structure was not significantly altered over the study period, 5% (301 hectares) of the paddy fields had been replaced by urban settlements, which included the river park, the booming country house scene, and a traditional arts center. These changes were the main contributors to the increasing patch edge of paddy fields. Viewing paddy fields in Dongshan River Basin as unique man-made habitats, attention is then given to both the dispersion of built-up patches and the increase in size of the patch edge of paddy fields.

Keywords: Tourism development, Paddy fields, Landscape ecology, Land-use changes, GIS

1. Introduction

As the economy develops rapidly, it accelerates changes in land use. The landscape is transformed and the original characteristics of the environment are altered (Harren, 2002). Change in land use can have a significant impact on the surrounding ecological environment; therefore, it is necessary to understand the spatial dynamics of an ecosystem to ensure its ecological functions (Fang *et al.*, 2005). Landscape ecology has become the fastest growing sub-discipline of ecology, ever since Carl Troll, a German geographer, first proposed the concept in 1939 (Wu, 2003). It has been extensively applied to explore the relationship between land-use changes and ecological processes in specific ecosystems. Over the past decades, the approach of landscape ecology has been applied to a wide range of problems, including the change of a single landscape pattern,

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landscape and biodiversity protection, nature reserve management, and urban planning. It provides an important methodology for studying the relationship between land use and ecological consequences. By using quantitative methods, it allows the analysis of the spatiotemporal transition of a landscape pattern or ecological processes (Turner and Gardner, 1991).

Since landscape pattern has been linked to biodiversity and other ecological values of landscapes, changes in a landscape can be regarded as an integrative tool for assessing ecological sustainability (Renetzeder *et al*., 2010). Landscape fragmentation is the main consequence of the disturbing process of land development on ecosystems. It can be induced by either natural or human agents, and has a negative impact on many species of plants and animals and on ecological processes (Farina, 1997). It increases the vulnerability of isolated patches to external disturbance, and threatens the sustainability of habitats and biodiversity (Nilsson and Grelsson, 1995). Hemeroby (naturalness), defined as the magnitude of the deviation from the potential natural vegetation as influenced by human activities, is another important concept for describing ecological sustainability (Renetzeder *et al.*, 2010). Human influences tend to result in a simplification and geometristation of landscape structure that reduces biodiversity and adversely affects ecological sustainability (Peterseil *et al*., 2004; Zechmeister and Moser, 2001). As Weins (2002) points out, all of the central themes of landscape ecology apply equally to terrestrial and riverine ecosystems. He asserts that whether the change is on land or in aquatic systems is of minor importance in the context of landscape ecology, and it is the spatial patterns and processes that are important.

Agriculture is usually viewed as one of the major threats to hemeroby and biodiversity in Europe, whereas agricultural land use may provide benefits to biodiversity conservation and ecological sustainability in Asia. The rice paddy, the dominant agricultural land-use in monsoon Asia, is considered a form of "man-made" wetland, providing the benefit of multi-functionality. Wise use of rice paddy fields can partially compensate for the loss of natural wetlands (Yoon, 2009). Paddy fields can provide significant ecosystem services just as wetlands do. In Japan, the ecosystem services of paddy rice cultivation were estimated to US$72.8 billion (Science Council of Japan, 2001; cited in Natuhara, 2013). The ecosystem services of paddy field include supplying wildlife habitats, supporting migratory bird species along their flyways, recharging the groundwater, retaining storm water and aiding flood control, air purification and cooling, the prevention of soil erosion and landslides, and the reduction of carbon dioxide (Huang *et al*., 2006; Kato *et al*., 1997; Liu *et al*., 2010; Wu, 2011; Yoon, 2009).

In Taiwan, as a result of the pressure from urban growth and competition from other land use development, the area for paddy fields has been decreasing in size. The total area of paddy fields in Taiwan decreased from 472,759 ha (1991) to 406,064 ha (2011), showing a 14% decrease over two decades (Council of Agriculture, 2010). Yilan County, an agricultural area located in the northeast of Taiwan, has been famous for its vast expanse of paddy landscape. However, the landscape has changed significantly in recent years due to tourism and housing development. One of the most significant cases is the change of the paddy landscape along the Dongshan River which was notorious for its frequent floods before the 1970s. After a river reconstruction project along its middle and downstream sections, the vicinity of these river sections was established as the Dongshan River Scenic Area in 1984. The Dongshan River Park, located within the scenic area, was opened in 1994; and the Yilan government further held the International Children's Folklore & Folkgame Festival on the park in 1996. The park soon became one of the most popular tourist destinations in Taiwan, and boosted the local economy significantly (Yilan County Government, 2002). The county was then transformed from a production-based agricultural environment into a tourist-oriented recreational setting. An evolution in economies and industry reflects the common development and evolutionary process of humans and landscapes (Naveh, 1995). In addition, the progression of a society often accompanies shifts in land use and changes in local landscape, resulting in changes to the original environmental characteristics (Haaren, 2002). Following the establishment of the Scenic Area, waves of land policy and landscape reforms had a far-reaching impact on the spatial and landscape characteristics of the area around the river basin, dramatically changing land use. Apart from the consideration of agricultural production, the preservation of the ecological, aesthetic, and cultural values of agricultural land in the basin has drawn much attention from the public.

As Apan *et al*. (2002) have pointed out, landscape structure is the result of the interactions between physical, biological, political, economic, and social driving forces, and changes in a landscape regarding the anthropogenic influence (e.g., agriculture) are a key indicator of sustainability. Rather than imposing a negative impact on ecological environments, the paddy fields in monsoon Asia can benefit sustainability. From the aspect of ecological sustainability, attention must be paid to the change in land use in the Dongshan River Basin and the environmental issues involved. The purpose of this study was to apply the approach of landscape ecology by conducting a GIS-based analysis of the spatiotemporal transition of land uses in the Dongshan River Basin after a period of tourism development in order to examine the whole landscape change in the river basin and to explore the implications for agricultural land management.

2. Methods

2.1. Study Area

Yilan County, located in the northeast part of Taiwan, rapidly transformed from an area based on agriculture to one based on tourism. The most obvious evidence of this was the development of the Dongshan River Basin into a scenic area. The Dongshan River Scenic Area was developed by transforming the areas along the upper, middle, and lower sections of the Dongshan River as the Forest Park, Water Park, and River Park, respectively (Wujie Global Information, 2012). The region along the middle and lower sections of the basin, where the River Park and the National Center for Traditional Arts were located, accommodates the most popular tourist destinations in Yilan County. The study area includes the middle and downstream areas of Dongshan River (Figure 1).

Dongshan River, with a length of 25.3 km, is the fifth longest river in Yilan County (Yilan County Government, 2002). The river basin contains some of the richest farming land in Yilan County. This area consisted mainly of agricultural areas for rice cultivation before the development of the River Park in the 1990s. It flows northeastward through the Lanyang plain before emptying into the Pacific Ocean. Elevation ranges from 3 to 15 meters above mean sea level. The existing landscape of the basin is made up of paddy fields, patches of vegetation, fish ponds, and other land uses such as recreational areas, industrial parks, and residential settlements.

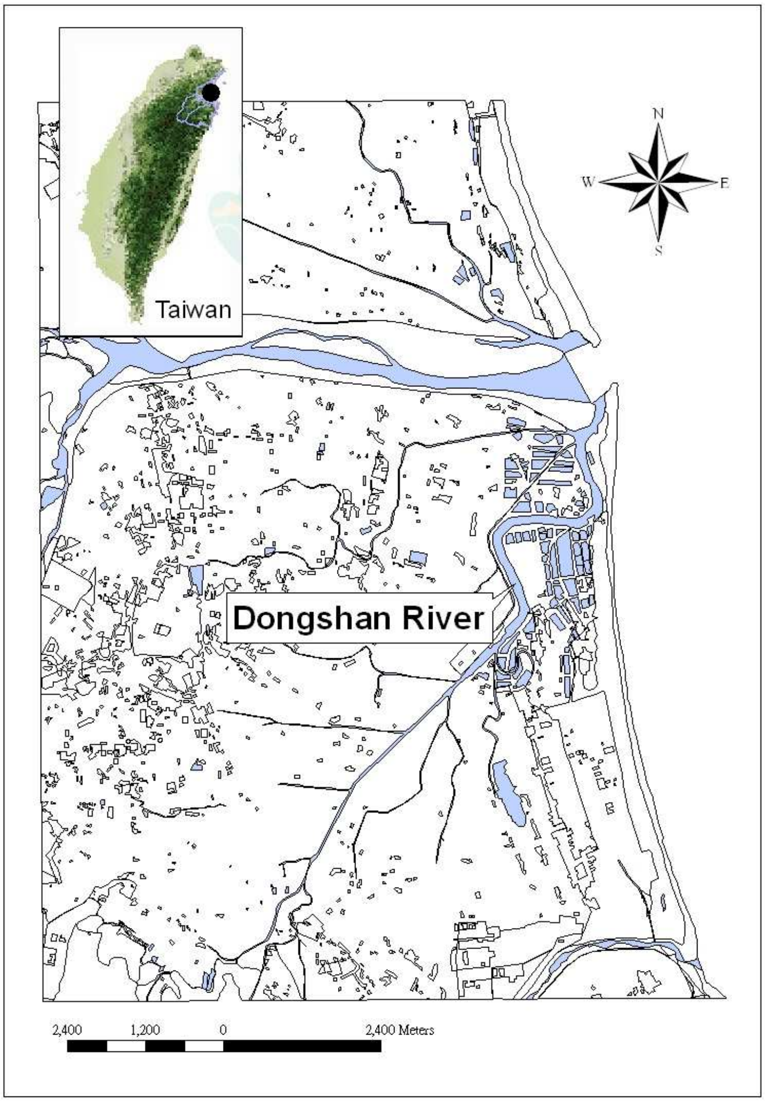

Figure 1. Location map of the study area

2.2. Data Acquisition and Processing

Since satellite images of the study area before the opening of the Dongshan River Park were not available, the hard copies of basic topographic maps, provided by Taiwan's Ministry of the Interior, were used as a data source for this study. These maps were produced with the orthographic projection methodology of analytical photogrammetry (Ministry of the Interior, 2011). With a scale of 1/25,000, these maps show not only the topography but also the different land usage in the area. Four versions of basic topographic maps were available for the study area. The first and last version, produced in 1987 and 2003, respectively, were selected as the data maps for the analysis of land use changes in the Dongshan River Basin.

The two hard copies of basic topographic maps were both digitized and converted into vector images with ArcView 9.0. According to the land-use information shown on the basic topographic maps, land use in the Dongshan River Basin includes: paddy fields, woods, wind-breaking forests, bush, dry farms, rivers, fish ponds, built-up land, and sandy beaches. Usage was further divided into six land-use types (Table 1): paddy fields, high-density vegetation, low-density vegetation, water, built-up land, and sandy beaches. Woods and wind-breaking forests were included in the land-use type of high-density vegetation (2), representing that these areas are mainly covered by trees. Bush and dry farms were included as low-density vegetation (3), and rivers and fish ponds were included as water usage (4). The land-use maps of 1987 and 2003 were generated as shown in Figures 2 and 3. They were further converted into ArcGrid format for metrics computation with FRAGSTATS (McGarigal *et al*, 2002), which is a computer software program designed to compute landscape metrics for categorical map patterns, and can work with the program Spatial Analyst (an extension of the ESRI ArcGIS system) to generate landscape indices.

Table 1. Land-use types

Type	**Land use**
1	paddy field
2	high-density vegetation (woods and wind-breaking forests)
3	low-density vegetation (bush and dry farms)
4	water (rivers and fish ponds)
5	built-up land
6	sandy beaches

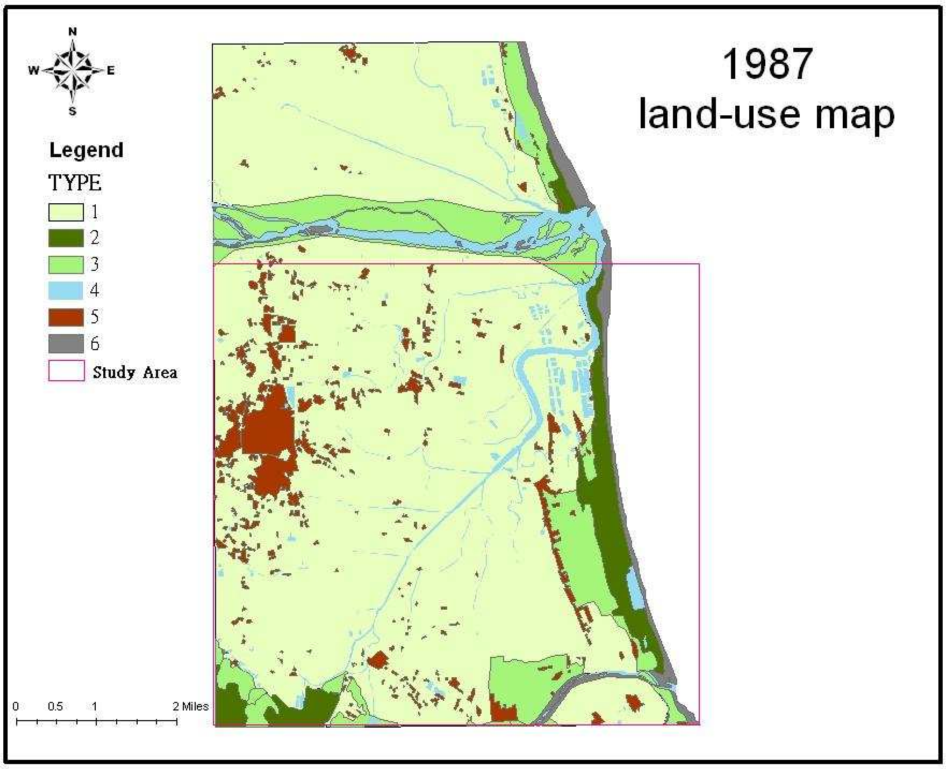

Figure 2. Land-use map of the study area in 1987

2.3. Analysis

A set of landscape metrics were computed with FRAGSTATS to conduct an analysis of the land-use changes in the Dongshan River Basin. Landscape metrics may be defined at three levels: patch, class, and landscape level. Patch-level metrics quantify the spatial character and context of individual patches; class-level metrics separately quantify the amount and spatial configuration of each patch type; and landscape-level metrics illustrate the spatial pattern of the entire landscape mosaic (McGarigal *et al.*, 2002). This study placed emphasis on class-level metrics as they can be utilized to quantify the extent and fragmentation of each patch type in the landscape. The computed metrics were selected from the group of area/density/edge metrics, which provide fundamental and valuable information for interpreting landscape fragmentation and structural change.

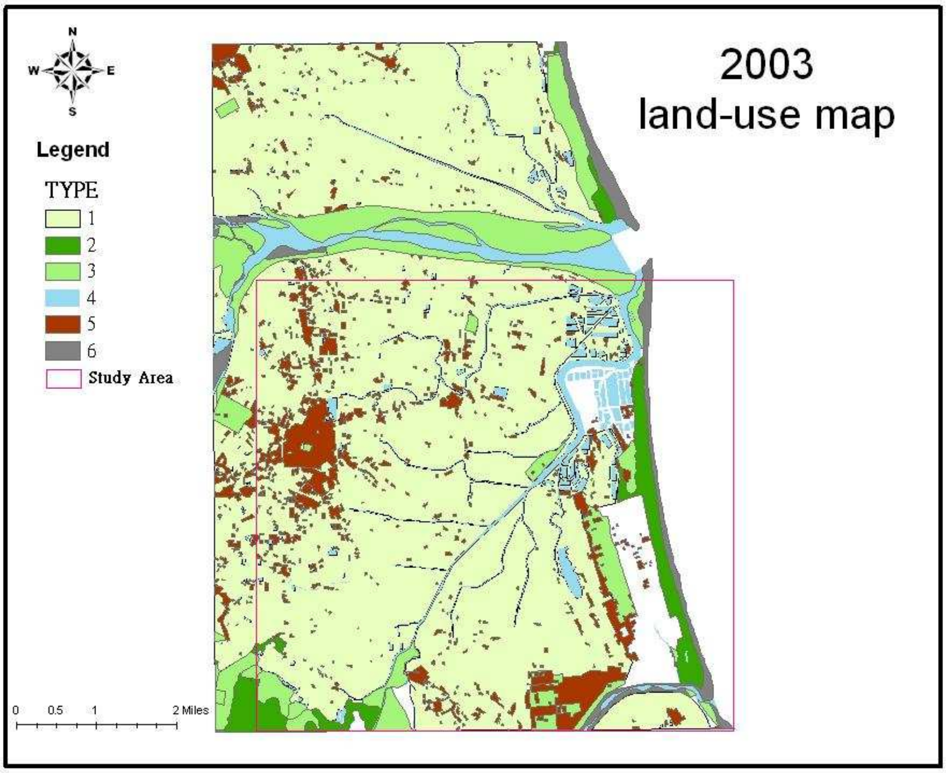

Figure 3. Land-use map of the study area in 2003

3. Results

3.1. Overall land-use changes

As shown in Table 2, all land-use types, with the exception of built-up land, have decreased in the area. The land-use type dominating the river basin consists of paddy fields, occupying almost three fourths of the landscape. However, it decreased from 74.93% to 71.13% of the landscape; that is, 301 hectares of paddy fields were lost between 1987 to 2003. The other significant land-use change was the rapid increase of built-up patches, dispersed across the paddy fields and increased by 576 hectares over the study period. Built-up land became the second largest land-use type in 2003, accounting for 8.88% of the Dongshan landscape.

3.2. Structural change of vegetative landscape

The paddy field contributes the primary land usage along the Dongshan River, occupying more than 70% of the total area of the landscape. The other vegetative land uses, classified as high-density and low-density vegetation, comprise only about 10% of the area. They include vegetation located in the Dongshan River Park and in two industrial areas, as well as the wind-breaking forest planted along the beach. As indicated in the previous section, all these three types of vegetative land use decreased in the class area and proportion of the landscape from 1987 to 2003. The data shown in Table 3 further delineates the structural change of the vegetative landscape.

Table 2. Change in Class Area (CA)[a] and Percentage of Landscape (PLAND)[b], 1987-2003

1987			**2003**		
Land-use type	CA (ha)	PLAND (%)	Land-use type	CA (ha)	PLAND (%)
Paddy fields	5943.61	74.93	Paddy fields	5642.31	71.13
High-density vegetation	314.53	3.97	High-density vegetation	307.09	3.87
Low-density vegetation	574.92	7.25	Low-density vegetation	440.05	5.55
Water	423.97	5.34	Water	408.19	5.15
Built-up land	128.19	1.62	Built-up land	704.22	8.88
Sandy beaches	547.28	6.90	Sandy beaches	135.41	1.71
Total landscape area	7932.5	100.00	Total landscape area	7637.27	100.00

[a] the total area of all patches for a particular land-use type
[b] the proportion of the landscape occupied by certain land-use type (class)
The above explanations were based on those of McGarigal, Cushman, Neel, and Ene (2002).

With regard to the paddy fields, while the values of the patch number, patch density, largest patch index, and mean patch area decreased slightly, there was a substantial increase in the patch edge. The total edge of the paddy fields increased by 15%, from 372,125 to 426,987.5 meters, and the edge density increased by 19%, from 46.91 to 55.91 (m/ha). In addition, there was also an increase in the landscape shape index, which provides a simple measure of class (land-use) aggregation (the increase of this value implies that the patch type has become more disaggregated). The LSI of the paddy fields increased from 12.63 to 14.91 (when normalized, from 0.0563 to 0.0647).

It can also be seen that there were different structural changes in high-density and low-density vegetation. All metric values, except for the largest patch index and the mean patch area, of the high-density vegetation decreased significantly. The patch number dropped drastically from 235 to 5 (with patch density decreasing from 2.9625 to 0.0655), although the class area lost only 7 hectares. In addition, the largest patch index and the mean patch area increased from 1.72 to 2.61 and from 1.34 to 61.42, respectively. All of these results suggest that high-density vegetation had become more aggregated by 2003. By contrast, the increase in patch number, edge and landscape shape index indicates that low-density vegetation underwent some degree of fragmentation during the study period.

Table 3. Structural change of vegetative landscape

Metrics	Paddy fields		High-density vegetation		Low-density vegetation	
	1987	2003	1987	2003	1987	2003
Class area (ha)	5943.61	5642.31	314.53	307.09	574.92	440.05
PLAND (%)	74.93	71.13	3.97	3.87	7.25	5.55
Number of patches[a]	20	19	235	5	13	19
Patch density (# / 100 ha)[b]	0.2521	0.2488	2.9625	0.0655	0.1639	0.2488
Largest patch index (%)[c]	72.73	72.13	1.72	2.61	2.70	1.12
Mean patch area[d]	297.18	296.96	1.34	61.42	44.22	23.16
Total edge (m)[e]	372,125.0	426,987.5	205,900.0	22,512.5	54,962.5	59,137.5
Edge density (m/ha)[f]	46.91	55.91	25.96	2.95	6.93	7.74
Landscape shape index[g]	12.63	14.91	29.12	4.96	6.35	8.40
Normalized LSI[h]	0.0563	0.0647	0.1998	0.0285	0.0280	0.0444

[a] the number of patches of the corresponding patch type
[b] the number of patches of the corresponding patch type divided by the total landscape area (converted to 100 hectares)
[c] the percentage of the total landscape area comprising the largest patch
[d] the total area of all patches of the corresponding land-use type, divided by the number of patches of the same type
[e] the sum of the lengths (m) of all edge segments of the corresponding patch type
[f] the sum of the lengths (m) of all edge segments of the corresponding patch type, divided by the total landscape area (hectare)
[g] the total length of edge (or perimeter) of the class, divided by the minimum length of the class edge (or perimeter) possible for a maximally aggregated class
[h] Normalized landscape shape index; the total length of edge (or perimeter) of the corresponding class minus the minimum length of class edge (or perimeter) possible for a maximally aggregated class, divided by the maximum minus the minimum length of class edge
The above explanations were based on the work of McGarigal, Cushman, Neel, and Ene (2002).

4. Discussion and Conclusion

4.1. Changes of the Agricultural Landscape

The change of rural landscape under the pressure of urban sprawl and economic development has been a key issue for agricultural land management in Taiwan. Council of Agriculture (2004a) conducted a project for the spatial allocation plan of agricultural land in Taiwan, in which the approach of Forman (1995) was used to analyze the changes of agricultural landscape on selected areas, including Yilan. It indicated that five major processes of landscape transformation were detected on the agricultural lands in Taiwan. They were perforation (formation of gaps), dissection (subdivision of patches by lines), shrinkage (reduction of patch size), fragmentation (breaking up of large patch into smaller parcels), and attrition (reduction of patch number). Focusing on a smaller scale, the results of this study shows that the agricultural land of the Dongshan River Basin have been gradually replaced by urban and tourism land uses.

According to the annual reports of Taiwan Tourism Bureau (2014), the park attracted an average of more than 1.3 million visitors each year until 2003, when the outbreak of severe acute respiratory syndrome (SARS) stroke down Taiwan's tourism, the visitors to the park decreased to 68.5 thousand. Despite the temporary depression of the park, the National Center for Traditional Arts built just across the park in 2002, soon became another hot tourist spot of Dongshan River Scenic Area. Now these two tourist spots are attracting more than 2 million visitors in total each year. From 1987 to 2003, the major change in the river basin landscape was a rapid increase in the area of built-up patches, while the areas of all other land uses decreased. The main factor for the decrease in areas of high-density and low-density vegetation was the construction of two industrial parks. As for the paddy fields, although their overall structure was not significantly altered over the study period, 5% (301 hectares) of the paddy fields had been replaced by urban settlements, which included the river park, the bulky farm houses, and the center of traditional arts. The significant increase of small parcels (mainly farm houses), which dispersed across the paddy fields, changed the landscape with the process of perforation. These changes were the main contributors to the increasing patch edge and edge density of the paddy fields.

4.2. Ecological and Environmental Concerns

Rice paddy fields are a unique ecosystem, rich in biodiversity and able to sustain a diverse assemblage of plants and animals (Edrisinghe and Bambaradeniya, 2006). The environmental and ecological multi-functionality of paddy fields has received much attention. Natuhara (2013) indicates that landscape and temporal change are two major characteristics of the ecosystem of paddy field, and the linkage between paddy fields and the surrounding environment plays an important role in biodiversity. Paddy fields, including irrigation ponds and canal networks, have provided substituting habitats for a large variety of wetland species after the loss of natural floodplain by development (Washitani, 2007). Thus, the loss and change of paddy fields may cause certain degree of impact on the ecosystem services they provide. Viewing paddy fields in the Dongshan River Basin as unique man-made ecosystem, attention can be given to some environmental and ecological concerns.

First, according to Taiwan's Regulations for Building Farmhouses on Agricultural Land (Council of Agriculture, 2004b), up to 10% of each agricultural area is allowed to be used for the building of a farmhouse by the landowner. The rapid development of rural tourism in Dongshan River Basin has induced the increase and dispersion of farmhouses (mainly home stay facilities) within the paddy fields, and it may be regarded as a potential environmental hazard. As pointed out by Chang *et al*. (2006), paddy fields play an important role in flood control because they can gradually mitigate flood movement and provide flood detention. Therefore, the increase of built-up patches within paddy fields may cause adverse and cumulative effects on the flooding patterns in the basin. In addition, environmental pollutants associated with home stay facilities, like household wastewater, may also impose impacts on the surrounding paddy fields (Council of Agriculture, 2004a). The increase of the patch edge of paddy fields is another significant structural change to the vegetative landscape, which is caused by the perforation of built-up parcels. This process usually occurs with the shrinkage of agricultural land, and may eventually result in the fragmentation of the landscape (Council of Agriculture, 2004a). There has been much research focusing on the edge effects on birds. As pointed out by Joan *et al.* (2000), bird species richness is positively correlated to agricultural areas, and negatively correlated to urban areas. However, McGarigal *et al.* (2002) believe that edge effects should be viewed from an organism-centered perspective as edge effects influence organisms differently; that is, some species benefit from edges and some are adversely affected or unaffected.

4.3. Implication for further research

In Taiwan, previous research on changes in agricultural land use has focused on the spatial differences of landscape pattern changes in different areas, and the patterns of changes under urban influences, such as perforation, cutting, fragmentation, reduction, and loss (e.g., Lin and Lin, 1999; Tsai *et al*., 2003; Tsai and Huang, 2007; Wu, 2011). The ecological effects of different landscape-pattern change on the flora and fauna within paddy fields have not been well investigated and analyzed. Therefore, long-term investigation is suggested to assess the impact that the dispersion of built-up patches poses on bird species and biodiversity in paddy fields in Dongshan River Basin, and the future policies of local land-use management must take the ecological impact of these changes into account.

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