Applying Landscape Ecological Metrics on Land Use Change in Lanyang Plain

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Abstract

Land use is the human activity affecting by economical, cultural, political and historical factors and presents complex, uncertainty and spatiotemporal characteristics. Understanding of land use change and its trend is necessary for understanding the environmental problems.

Nestled between the Pacific Ocean in the east and the Central and Snow Mountains in the north and southwest, Lanyang Plain is one of Taiwan's most picturesque and secluded geographical areas. However, due to the great construction, Taipei-Yilan highway, the regional landscape structure on a large scale in this area has been directly changed. The original ecological function was thus deteriorated a lot. Conflicts between ecological and socio-economic aspects tend to obstruct the implementation of traditional landscape policy instruments.

In this study, land use data in 1982, 1984, 1994, and 2002 surveyed by the government were collected to analyze land use change. After classifying land use categories from the original data, landscape structure at class and landscape scale levels are quantified by calculating landscape metrics. The quantified indices as well as the possible related events or driving forces are discussed further as the suggestions for future management.

Key Words: landscape structure, land use change, landscape metrics

INTRODUCTION

Landscape (land use) comprises various aspects of natural and socio-economic environment. Landscape structure refers to the spatial relationship among distinctive ecosystems or landscape ‘elements’—more specifically, the distribution of energy, materials and species in relation to the size, shapes, numbers, kinds and configurations of the ecosystems. Quantifying landscape structure is a prerequisite to the study of landscape function and change.

The processes of the transformation of the land use reveal the contradictions of the actual process of the nature use. It is necessary and useful to account for landscape structure in land management decision processes based on the land use map using geographic information systems.

Nestled between the Pacific Ocean in the east and the Central and Snow Mountains in the north and southwest, Lanyang Plain is one of Taiwan’s most picturesque and secluded geographical areas. Its abundance in natural and ecological resources brings the richness of avian community. However, due to the great construction, Taipei-Yilan highway, the regional landscape structure on a large scale in this area has been directly changed. The original ecological function was thus deteriorated a lot. The objectives in this study were to analyze landscape structure of Langyang Plain. Various landscape metrics, including area, patch density and size, edge, shape, and diversity aspects were calculated using the landscape structure analysis program FRAGSTATS. The quantified indices as well as the possible related events or driving forces are discussed further as the suggestions for future management.

STUDY AREA

Taiwan is located one hundred and fifty kilometers off of the southeast coast of mainland China, between cool-temperate Japan to the north, sub-tropical south China to the west, and the tropical Philippines islands to the south (Fig. 1).

The study area is located in the northern-east Taiwan with Pacific Ocean in the east and the Central and Snow Mountains in the north and southwest, at elevations ranging from 0 m to 3555 m. Monthly mean temperature ranges from 16.0°C to 28.4°C, annual precipitation is about 2827.7 mm, and the relative humidity averages 84%. In this study, Lanyang Plain (elevation under 100 m) is focused.

Figure 1 Study area and location of Lanyang Plain

METHODS

Data processing

Land use data in 1982, 1984, 1994, and 2002 surveyed by the government organizations were collected in this study to analyze the land use change for understanding the landscape structure. Since the original data were collected from different organizations, the geographical surveyed range and the standard of the identifications of the land use types are somewhat different, data processing as follows is thus needed before analyzing the landscape structure.

(1) Acquire the focused area (the elevation under 100 m) by using the function 'clip' in Arcview 3.2;

(2) Formulate a classification system of the landscape patch types in Lanyang Plain. 8 types were identified (Table 1);

(3) Re-classify the data in different years into 8 landscape patch types in accordance with their properties and the corresponding accessible aerial photos;

(4) Give a new attribute (patch type) to each polygon in the land use map, combining polygons with the same patch type.

The above procedures were performed using ArcView GIS software. Figure 2 shows the landscape (land use) map of Lanyang Plain.

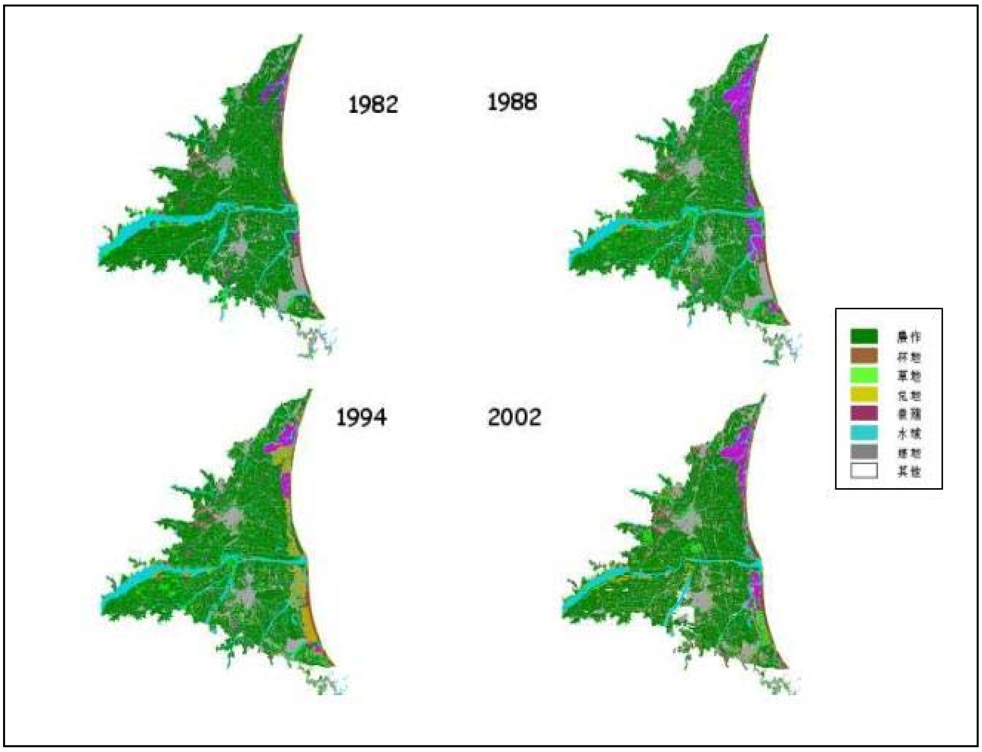

Figure 2 landscape (land use) map of Lanyang Plain

Table 1 Patch types and ID for the Lanyang Plain

Patch type	Patch ID
Agriculture field	1
Forest	2
Meadow	3
Abandoned area	4
Aquaculture use	5
Water area	6
Construction Area	7
Others	8

Calculation of landscape metrics

FRAGSTATS, developed by the Forest Science Department, Oregon State University, U.S.A., is a program for quantifying landscape structure. There are two versions of FRAGSTATS, Vector (ARC/INFO) and Raster (Image Maps) versions. Both versions produce a number of metrics: areas, patch density, size and variability, edge, shape, core area, and diversity.

More than 40 landscape metrics can be calculated by FRAGSTATS. However, many of them are highly correlated (USEPA, 1994; Riitters *et al*., 1995). In the analysis of the landscape structure of Lanyang Plain, 6 indices at class level were selected, including class area (CA), number of patches (NUMP), mean patch size (MPS), edge density (ED), area- weighted mean shape index (AWMSI), and area-weighted mean patch fractal dimension (AWMPFD), while 8 were selected at the landscape level, including total landscape area, largest patch index, number of patches, mean patch size, edge density, area-weighted mean shape index, area-weighted mean patch fractal dimension, Shannon's diversity index (SDI), and Shannon's evenness index (SEI). Even though many of the class and landscape indices represent the same fundamental information, class indices represent the spatial distribution and pattern within a landscape of a single patch type; landscape indices represent the spatial pattern of the entire landscape mosaic, considering all patch types simultaneously. The definition and description of these indices that used in FRAGSTATS are given by the FRAGSTATS user's guide (McGarigal and Marks, 1994).

RESULTS AND DISCUSSIONS

The calculated landscape metrics at the class and the landscape levels are shown in Table 2 and 3 respectively.

Table 2 Indices at class level

Patch ID	years	CA	NUMP	MPS	ED	AWMSI	AWMPFD
1	1982	221301515.05	2717	81450.69	0.011	1.99	1.10
	1988	181850276.44	4840	37572.37	0.014	2.19	1.11
	1994	181026356.68	4718	38369.30	0.014	2.24	1.11
	2002	180365336.08	4566	39501.83	0.014	1.83	1.10
2	1982	7739175.29	240	32246.56	0.001	2.34	1.12
	1988	10031084.49	1092	9185.97	0.001	2.78	1.14
	1994	9996704.59	1084	9222.05	0.001	2.79	1.14
	2002	17619470.28	3167	5563.46	0.003	2.31	1.14
3	1982	6755358.31	531	12721.96	0.001	1.60	1.08
	1988	22474349.80	4504	4989.86	0.005	1.78	1.10
	1994	22897238.30	4365	5245.64	0.004	1.79	1.10
	2002	14295471.16	1528	9355.67	0.002	1.99	1.11

4	1982	5996411.06	187	32066.37	0.001	3.63	1.17
	1988	8779817.65	813	10799.28	0.001	2.70	1.14
	1994	22659020.77	1140	19876.33	0.002	2.02	1.10
	2002	18349967.67	1728	10619.19	0.003	2.10	1.12
5	1982	7477838.32	600	12463.06	0.001	1.47	1.06
	1988	19427391.79	972	19987.03	0.002	1.46	1.06
	1994	8989491.24	667	13477.50	0.001	1.45	1.06
	2002	11764411.66	379	31040.66	0.001	1.52	1.07
6	1982	34609344.51	410	84413.04	0.003	6.62	1.25
	1988	34278828.05	566	60563.30	0.004	6.67	1.26
	1994	34263336.87	565	60643.07	0.004	6.66	1.26
	2002	26115671.76	1267	20612.21	0.004	3.58	1.19
7	1982	57710640.22	1175	49115.44	0.009	81.99	1.45
	1988	64794288.52	2451	26435.86	0.011	94.39	1.47
	1994	61801747.01	2501	24710.81	0.011	95.20	1.47
	2002	66982723.59	2766	24216.46	0.014	127.69	1.51

Indices at class level

CA is a measure of landscape composition. From the results in Table 2, the area of agriculture field decreased by years, while construction area increased. However, agriculture area remains the majority in Lanyang Plain. The area of aquaculture use fluctuated without certain trend, which may result from the undefined corresponding policy of the government. Aquaculture use along the coastline of Lanyang Plain was flourished in 1980s because the soil salinity problem was getting tough for farming work. However, a big proportion of the area was abandoned then in 1990s because of the threatening shrimp-disease. The policy of planning these areas to other purposes is remaining undefined, hence, the land use type identification by different organizations may be different.

NUMP is considered as representing landscape configuration, while MPS shows that a landscape with a smaller mean patch size for the target patch type than another landscape might be considered more fragmented. The NUMP values of construction use in Table 2 increased by years accordingly with the economic development trend. MPS values of each type decreased by year, except the aquaculture use. The decreasing MPS values represent the fragment trend of the land use in Lanyang Plain.

Edge metrics, as NUMP, usually are considered as representing landscape configuration. From the ED results in Table 2, there is no big difference between years. Patch shape has been shown to influence inter-patch processes. AWMSI index show that larger patches are weighted more heavily than smaller patches in calculating the average patch shape, and it is considered as measures of overall shape complexity. AWMSI and AWMPFD values of construction use increases obviously as the patch shapes become more irregular.

Table 2 Indices at landscape level

years	TLA	NUMP	MPS	ED	AWMSI	AWMPFD	SDI	SEI
1982	342027717.26	5873	58235.92	0.027	15.97	1.17	1.37	0.66
1988	342027717.26	15245	22435.40	0.038	20.07	1.19	1.59	0.72
1994	342027717.26	15050	22726.09	0.038	19.43	1.19	1.58	0.72
2002	342027717.26	15913	21493.26	0.042	26.65	1.19	1.64	0.79

Indices at landscape level

From the results in Table 3, the whole NUMP shows the increasing trend. MPS decreases while ED and AWMSI increased by year, which means the land use in Lanyang Plain is becoming fractal, irregular, and the inter-patch edge is becoming longer.

As for the diversity index, diversity reflects to the number of patch types present; evenness refers to the distribution of area among different types. SDI increases as the proportional distribution of area among patch types becomes more equitable, and SEI approaches 1 as the distribution of area among the different patch types becomes increasingly even. From Table 3, SDI is 1.37 in 1982 to 1.64 in 2002, and SEI is 0.66 to 0.79, which means the level of heterogeneity is enhanced.

CONCLUSIONS

Land use data of Lanyan Plain in 1982, 1984, 1994, and 2002 surveyed by the government were collected to analyze land use change in this study. Landscape structure at class and landscape scale levels are quantified by calculating landscape metrics.

From the results, there is no big difference of the proportion of the landscape composition during the decades of the development in social, economic, cultural, and political aspects. Agriculture field remains the majority, though its proportion decreased slightly. As a whole, the land use in Lanyang Plain approaches diversity and evenness.

At the class and landscape level, some of the metrics quantify landscape composition, and others quantify landscape configuration. Composition and configuration can affect ecological processes independently and interactively. Thus, it is especially important to understand for each metric what aspect of landscape structure is being quantified. Here in this study, part of the metrics were discussed, it is then suggested more could be analyzed further to get more comprehensive implication of changes of landscape structure.

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