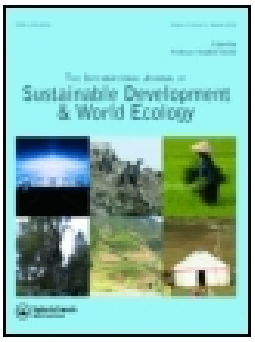

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Rural industrial structure and landscape diversity: Correlation research

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Rural industrial structure and landscape diversity: Correlation research

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Key words: Rural industrial structure, landscape diversity, hierarchical correlation, cluster correlation, Yongsheng county

SUMMARY

Landscape diversity reflects the integrated natural characteristics of rural areas, to some extent, while industrial structure shows the regional social economic characteristics. Therefore, correlation research on rural industrial structure and landscape diversity may couple the natural environment and social economy, which is of great importance to rural sustainable development. In this paper, we carried through this research from two aspects. First, we made a qualitative analysis of the hierarchical correlation beween rural industrial structure and landscape diversity, and the correlation during different historical periods was also summarized. Second, taking Yongsheng County, Yunnan Province, China as a case study, we applied the method of hierarchical clustering to make a quantitative analysis of the clustering correlation between rural industrial structure and landscape diversity. The results show that there are correlations between rural industrial structure and landscape diversity. That is, different industrial structures may result in similar landscape diversity in developed rural areas; while in developing rural areas industrial structure cannot exclusively determine landscape diversity, which is also influenced by natural factors, such as landform, physiognomy and climate.

INTRODUCTION

As a natural attribute of ecosystems and the product of interactions between social and natural systems (Sajise 1995), biodiversity closely links local ecological, economic and socio-cultural functions (Xu and Wilkes 2004). The concept of biodiversity has a hierarchical structure, from gene to landscape (Noss 1990). Landscape diversity, which is defined on the broadest scale, closely affects the lower classes in the hierarchy (Nagaike and Kamitani 1999). As Turner (1989) and Forman (1995) pointed out, in order to consider biodiversity at a lower level than landscape, it is important to clarify the roles of structure, function, and spatial and temporal changes in a landscape. So, landscape diversity is significant for biodiversity conservation. There are many studies focusing on the relationship between species diversity and landscape diversity (Eduardo and Ávila 2000; Jeanneret *et al.* 2003; Krause *et al.* 2004; Leimbeck *et al.* 2004).

Rural industrial structure implies the composition and correlation of all industries in a regional economy of rural areas. Industrial structure is an

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important factor affecting landscape diversity because it differs in various social-economic development periods, with different demands for natural resources and corresponding regional land-use/-cover change, which inevitably leads to a change in landscape patterns and landscape diversity. Landscape diversity indicates the natural characteristics of rural areas on the whole, while industrial structure shows the social-economic characteristics in economic structure and development level, therefore, correlation research between them can couple the natural environment and social economy in rural areas. This is of great importance to rural sustainable development.

Although the research paradigms on landscape diversity and industrial structure have been formed, few focus on correlation analysis between them. There are few primary research studies on the impact of a single industry on biodiversity. For example, Mander *et al.* (1999) analysed possible impacts of ecological farming and low-intensity conventional agriculture on landscape values such as biodiversity, landscape diversity and nutrient flows. Jeffrey (1999) investigated the mechanism balancing agricultural development and biodiversity conservation. Bengtsson *et al.* (2000) focused on how to manage and develop European forestry, giving attention to forestry production value and biodiversity conservation. No one has mentioned the relationship between industrial structure and landscape diversity.

The research reported in this paper aims to understand the relationship between landscape diversity and industrial structure in rural areas. We first made a qualitative analysis on the hierarchical correlations beween them; followed by correlations between rural industrial structure and landscape diversity (CRISLD) during different historical periods. Using a case study in Yongsheng County in northwest Yunnan, a global biodiversity 'hotspot' in China (Mackinnon *et al.* 1996; Mayers *et al.* 2000; Xu and Wilkes 2004), we then applied hierarchical clustering to make a quantitative analysis of the correlations between rural industrial structures and landscape diversity.

HIERARCHICAL CORRELATION ANALYSIS

Hierarchical correlation between rural industrial structures and landscape diversity

The concept of rural industrial structure has a hierarchical structure, from planting structure to agricultural structure, and to three-industry structure. Defined on the broadest scale, the three-industry structure divides regional industries into three types, primary, secondary industry and tertiary industry, and deals with the composition and correlations between them. Agricultural structure means the proportions and correlations between planting, forestry, livestock raising and fishery, while planting structure relates to the proportion beween cereal crop planting and economic crop planting.

Corresponding to rural industrial structure, landscape also has a hierarchical structure with different landscape diversity, where landscape at higher scales is comprised of those at lower scale. There are obviously hierarchical correlations between rural industrial structure and landscape diversity (see Table 1). With increase in the scale of industrial structure, the diversity of the corresponding landscape increases. Relevant to planting structure, farm landscape is defined on the smallest scale in rural areas, which generally uses crop ecosystems of different sizes as landscape patches (Wen 1991). The diversity in farm landscape is low, and is mainly influenced by the quantitative proportion and spatial structure of different crops, together with the impact of environmental factors. Corresponding to agricultural structure, agricultural landscape is higher than farm landscape in the hierarchical structure, and is composed of farmland, grassland, woodland, wetland, etc. Natural conditions and agricultural development level are the main factors

Table 1 Hierarchical correlation beween rural industrial structure and landscape diveristy

Rural industrial structure	*Landscape type*	*Landscape diversity*
Planting structure	Farm landscape	Low
Agricultural structure	Agricultural landscape	Moderate
Three-industry structure	Rural landscape	High

influencing the structure and diversity of an agricultural landscape. Relevant to the three-industry structure, rural landscape is the broadest scale, and is composed of agricultural land, industrial land, residential land, etc. As natural restriction on the development of industry and real estate is far lower than that on agriculture, the spatial allocation of rural industries varies with high landscape diversity.

CRISLD in different historical periods

During the historical development of humans from the hunter-gatherer era, to the cultivation era, industrialization era and information era, the relationship between humans and nature changed, and human disturbances on natural landscapes also changed with the development of human productivity. Accordingly, landscape diversity and rural industrial structures differ during different historical periods (Table 2).

Hunter-gatherer era

At the beginning of human history, in the hunter-gatherer era, there was no differentiation between village and city. The industrial structure was particularly simple, relying on gathering and hunting entirely from nature. Therefore, natural factors dominated the rural industrial structure. The impact of human activities on the natural landscape was also low because humans did not have the ability to change nature for their livelihoods. As a result, natural and semi-natual landscapes were the dominant landscape types at that time, and the formation and dynamics of low-landscape diversity were mainly affected by natural ecological process, with little human disturbance.

Cultivation era

In the cultivation era, humans began to change nature on their own initiative, which resulted in the appearance of planting, livestock raising, forestry and fishery. However, as agriculture was an industry that used natural resources to satisfy human demands, its production depended heavily on natural conditions, such as soil, climate, water and landform. For example, fertile land produced high yields from agriculture, but a catastrophic flood or insect pest would leave humans without a harvest. Therefore, rural industrial structure was influenced by natural factors more than by humans.

With the development of planting, livestock raising, forestry and fisheries, many agricultural and semi-agricultural landscapes consisting of artificial homogenous patches appeared. There were also many roads and canals built for transportation. The introduction of artiificial landscape patches and corridors greatly changed the structure and function of the landscape, and inevitably increased landscape complexity and diversity. As these introduced agricultural landscape elements basically

Table 2 CRISLD for different historical periods

Historical period	*Rural industrial structure*	*Landscape type*	*Landscape diversity*
Hunter-gatherer era	Hunting and gathering entirely relying on the natural environment	Natural landscape and semi-natural landscape	Low-landscape diversity affected mainly by natural factors
Cultivation era	Agriculture affected by natural factors more than by humans	Agricultural landscape and semi-agricultural landscape	Moderate landscape diversity affected by natural factors more than by human activities
Industrialization era	Three-industry structure with specialization affected mainly by humans	Cultural landscape and natural landscape with confrontation	High-landscape diversity with a decreasing trend affected by human activities
Information era	Three-industry structure with new information industry and genetic industry affected mainly by humans	Cultural landscape and natural landscape harmonious	High-landscape diversity with an increasing trend affected by human activities

came from nature, they were also restricted by the natural environment. Therefore, landscape diversity in this period increased, and was affected by natural factors more than by human activities.

Industrialization era

In the industrialization era, agriculture was managed as an industry and specialization, and township enterprises and tertiary industries appeared in rural areas. Improved technology played a more important role in agriculture, industry and tertiary industries. Natural factors were no longer the determinants of rural industrial structure.

In contrast to the cultivation era, landscape structure and function changed greatly. Agricultural mechanization and specialization caused the simplification of the rural landscape and the appearance of large homogenous patches (Yu 1991), and natural remnants such as woodlands and swamps were often turned into farmlands. Meanwhile, a complex traffic system divided the natural landscape into pieces, which slowed the flow of energy and matter. Therefore, due to the replacement of the natural landscape by various cultural landscapes, landscape diversity in the industrialization era was a little higher than in previous societies. But there was a decreasing trend resulting from the fragmentation of the landscape structure. Furthermore, as introduced landscape elements in this period were always complexes of artificial materials, contrary to the assimilation of natural processes, human activities counteracted nature. Although humans took measures to restore natural landscapes, the fragmentation of landscape structure and decrease in landscape diversity are still threatening human survival.

Information era

After the industrialization era, the information era arrived with the information and genetic industries. Humans began to protect nature when exploiting natural resources. With the development of science and techonology, such as system science, information technology and bioengineering, humans were able to deal with various ecological and environmental problems in the landscape resulting from the development of industries. In rural areas, industrial structure tends to be optimized under the precondition of environmental protection and economic production. Therefore,

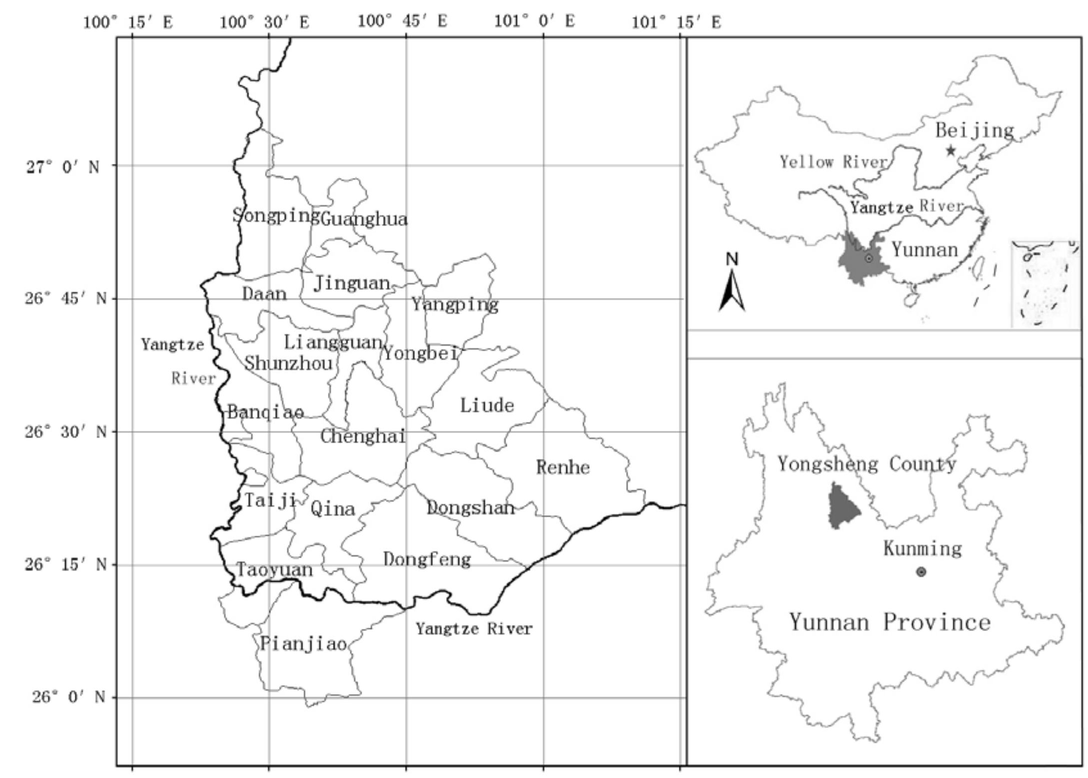

Figure 1 Sketch map of the study area in Yongsheng county, northwest Yunnan, China

we can see that all landscape elements are formed through a harmonious interaction between man and nature. Although some artificial landscape elements are introduced, they are compatible with nature and have few adverse effects. This ensures the integration of structure and function and the flow of energy and matter in a landscape. There is an increasing trend towards landscape diversity.

CLUSTERING CORRELATION ANALYSIS

Materials and methods

Study area

Yongsheng County, the case study area, is situated in the northwest of Yunnan Province, which has been internationally identified as a globally significant region for its rich biodiversity, rare ecosystems and high concentration of endemic biodiversity (Convention on Biological Diversity 2001; Xu and Wilkes 2004). It is located between longitude 100°22′–101°11′E and latitude 25°59′–27°04′N, with the Yangtze (Jinsha) River flowing through it (Figure 1). The distances from east to west and from south to north are 82 km and 140 km, respectively, and the elevation descends from north to south. The total land area is 4950 km^2, with 92.42% mountainous. Yongsheng County has a low-latitude, plateau monsoonal climate with four clearly demarcated seasons: dry in winter and spring and wet in summer and autumn.

As Yongsheng County is in the transition zone extending from the low altitude of the Yunnan-Guizhou plateau to the high altitude of the Qinghai-Tibet plateau, natural conditions are quite poor, with rugged terrain, poor soil, heavy water and soil erosion, low mean annual precipitation of about 1000 mm, low mean annual temperatures between 7.9°C and 10.5°C, and low light and heat resources. That is to say, the eco-environment in Yongsheng County is fragile.

Agricultural development in Yongsheng County exists, but secondary and tertiary industry are under-developed. In 1999, GDP per person was only RMB2,033, and poverty affected 83,000 people, about 22% of the population. The agricultural population was 93.5%, with 30.46% minority peoples, mainly the Hui and Yi ethnic groups. There are 18 towns in the county, including Yongbei, Jinguan, Liangguan, Qina and Renhe, Yuchenghai, Taoyuan, Pianjiao, Taiji, Shunzhou, Banqiao, Songping, Guanghua, Liude, Dongshan, Yangping, Daan and Dongfeng, which include a total of 147 administrative villages and 1375 natural villages.

Indices for hierarchical clustering

Hierarchical clustering is a multi-statistical method which classifies samples by the similarities and differences in clustering indices. In this paper, we first chose a series of indices for clustering of landscape diversity and the rural industrial structure. Then, taking the 18 towns of the county as samples for hierarchical clustering, we classified rural industrial structure and landscape diversity in 1999. Finally, by contrasting the clustering map for landscape diversity with that for rural industrial structure, we made a quantitative analysis with CRISLD.

Landscape diversity can be classified into three types (Fu 1995b; Fu and Chen 1996):

1. **Patch diversity**, defined as the diversity and complexity of the number, size and shape of landscape patches and measured by a fragmentation index (FN) and fractal dimension index (FD*i*);
2. **Type diversity**, which identifies distribution richness and proportions of patch types, and is often measured by the Shannon-Weaver diversity index (H); and
3. **Pattern diversity**, which is the diversity of spatial patterns of landscape types and the complexity of the connectivity, spatial linkage and neighbourhood effects between patches, measured by a contagion index (RC).

These landscape metrics were chosen as the indices for clustering of landscape diversity (Table 3). Definitions and more explanations of these metrics were given by Fu (1995a), Gustafson (1998) and Hargis *et al.* (1998).

Pi: area proportion of the type of landscape element i; m: number of landscape elements type; *Qij*: the area proportion of landscape element i adjacent to landscape element j; NP: number of patches; NC: area of the study; A*i*: area of the patch; *pi*: perimeter of the patch; C: an adjustment constant

According to development of the industrial structure in Yongsheng County, we chose the

Table 3 Indices for clustering of landscape diversity

Types of landscape diversity	*Landscape metrics*	*Mathematical model*
Patch diversity	Fragmentation index (FN)	$FN = (NP - 1)/NC$
	Fractal dimension index (FDi)	$FDi = 2Log\,(pi/4)/Log(Ai)$
Type diversity	Shannon-Weaver diversity index (H)	$H = -\sum_{i=1}^{m}(Pi)Ln(Pi)$
Pattern diversity	Contagion index (RC)	$RC = 1 - C/Cmax$ $Cmax = 2mLn(m)$ $C = -\sum_{i=1}^{m}\sum_{j=1}^{m}QijLn(Qij)$

indices for hierarchical clustering of rural industrial structure as follows:

1. GDP, which reflects the general level of rural economic development;
2. Production value of planting, forestry, livestock raising and fisheries, all of which comprise the interior structure of agriculture and influence rural industrial structure because of the important role of agriculture in the rural national economy;
3. Production value of industrial, manufacturing and business, which are representative of secondary and tertiary industry; and
4. The alteration index of industrial structure, which identifies the stability or change rate of rural industrial structure within a given period. This index is often calculated as follows:

$$D_t = \sum_{i=1}^{n}\left|S_{it} - S_{i0}\right|$$

where D_t is the alteration index of industrial structure, which represents the alteration extent of industrial structure in phase t compared with that in the basic phase; n is the number of industries; and S_{it} and S_{i0} are the proportion of production value of industry i in total industries in phase t and the basic phase, respectively.

Source data and data processing

The data for this study were derived from two sources. The values of indices for hierarchical clustering of rural industrial structure could be found or calculated from the *Statistics Yearbook of Yongsheng County in 2000.* The values of indices for hierarchical clustering of landscape diversity were calculated from remote-sensed images with the aid of landscape analysis software, FRAGSTATS.

Based on ERDAS 8.4 software, a LANDSAT-TM image (orbit 131/42, resolution 30 m) for August 12th, 1999, was interpreted with reference to field reconnaissance in July 1999, a land-use map of Yongsheng County in 1999 (scale 1:75,000), and a relief map of the county in 1995 (scale 1: 250,000). As a result, seven land-use types were classified: paddy field (irrigated land in the flat area), dry land (without irrigation or equipment, and relying on natural precipitation), forest land (including forest land, shrub land, open woodland, planted area with little forest and nurseries), harvested site (mostly herbs but does not meet the standards of open woodland, including slash-and-burn forest), water body (including rivers, lakes, reservoirs and ponds), urban land (including construction land, individual industry and mining land, enterprise land, showplace and historic site land, with its internal transportation, and green land) and unused land (unused and difficult to use land, including waste grassland, bare land, bare rock and sand land).

The method of maximum difference normalization was introduced to examine non-dimensional quantities of the original data. Data standardization of all the indices was as follows:

$$X'_{ij} = (X_{ij} - X_{jmin})/(X_{jmax} - X_{jmin})$$

where X_{ij} was the original value of index j of evaluation unit i, X'_{ij} was the non-dimensional quantity of X_{ij}, and X_{jmax} and X_{jmin} were the maximum and minimum, respectively, of index j in total evaluation units.

Figure 2 Clustering map of industrial structure in Yongsheng county, 1999

Figure 3 Clustering map of landscape diversity in Yongsheng county, 1999

RESULTS

Taking the 18 towns of Yongshen County as clustering units, we undertook hierarchical clustering of landscape diversity and industrial structure with a cluster method of between-groups linkage and measure interval of squared Euclidean distances. The results showed that, when the Euclidean distance was 10, we could divide Yongsheng County into five zones with different industrial structures (Figure 2): (1) Zone A: Yangping, Songping, Dongfeng, Dongshan, Taiji, Shunzhou, Taoyuan, Guanghua, Daan, Banqiao, Pianjiao, Renhe and Liude; (2) Zone B: only Liangguan; (3) Zone C: Qina and Chenghai; (4) Zone D: only Yongbei; and (5) Zone E: only Jinguan.

When the Euclidean distance was 10, we could also divide Yongsheng County into seven zones with different landscape diversity (Figure 3): (1) Zone I: Liude, Renhe and Shunzhou; (2) Zone II: Pianjiao, Taiji and Banqiao; (3) Zone III: Daan, Yongbei and Dongfeng; (4) Zone IV: only Jinguan; (5) Zone V: Chenghai, Liangguan, Qina and Taoyuan; (6) Zone VI: Dongshan and Songping; and (7) Zone VII: Guanghua and Yangping.

Furthermore, according to GDP in 1999, we could divide the 18 towns of Yongsheng County into two types: developed and developing areas. The former included five towns with GDP higher than RMB10,000,000, viz.Yongbei, Jinguan, Liangguan, Qina and Chenghai, and the latter included the remaining towns.

DISCUSSION

From Figures 2 and 3, we find three kinds of relationship between zones of landscape diversity and rural industrial structure:

1. A zone of landscape diversity is the same as a zone of rural industrial structure, such as Zones IV and E;
2. A zone of landscape diversity involves several zones of industrial structure. For instance, Zone V involves Zones B and C; and
3. A zone of industrial structure involves several zones of landscape diversity. For example, Zone A involves Zones I, II, VI and VII.

These relationships between zones exactly represent the relationships between landscape diversity and rural industrial structure in Yongsheng County.

Relationship between landscape diversity and rural industrial structure

The overlap of Zone IV and Zone E shows that there is a relationship between landscape diversity and rural industrial structure. In developed areas, such as towns in Zones B, C, D and E, industrial structures are diverse, with change evident. In these zones, the role of agriculture, especially planting, is relatively low in the overall national economy, with the rapid development of fisheries, livestock raising and industry. Accordingly, landscape diversity of towns in these zones is relatively high. Because of a high proportion of farmland and urban land, the impact of human activities on landscape is high, which results in high fragmentation and increasing complexity of landscape patterns. In contrast, in developing areas, such as towns in Zone A, agriculture is dominant in the rural economy, with undeveloped secondary and tertiary industry, and almost the whole labour force engaged in agricultural production. Moreover, forestry and livestock raising are a priority in the agricultural structure. Consequently, landscape diversity of towns in Zone A is relatively low. Because of a high proportion of forest land and unused land, the impact of human activities on landscape is low, which leads to low fragmentation and fractal dimensions.

Taking the 18 towns of Yongsheng County to represent different phases of social economic development, we find that, with the development of a social economy, the impact of human activities on the natural landscape will intensify more and more, and the proportion of cultural landscape will gradually increase, all of which will lead to an increase of landscape diversity. However, with further development of the rural economy, the intensification of human activities would have negative impacts on landscape diversity. This is mainly due to continuous development of secondary and tertiary industry, where more and more farmers become industrial workers, waiters and so on, leading to great transformations in other land-use types, which result in a decrease in landscape type diversity. On the other hand, further strengthening of human disturbance leads to high landscape fragmention and scattering, with a decrease in pattern and patch diversity of the landscape.

Similar landscape diversity with different industrial structure in developed areas

From Figures 2 and 3, we find that Liangguan, Qina and Chenghai have different industrial structures (Zone B and C) and similar landscape diversity (Zone V). This shows that, in developed areas, different industrial structures tend to have the same effects on landscape diversity and result in similar landscape diversities. Although different industrial structures display different characteristics, the mechanisms of their influence on landscape diversity are the same. With the development of a rural economy, the dominance of a primary industry is replaced by secondary and tertiary industries. More and more natural landscape is turned into semi-natural landscape or cultural landscape because of a continuous increase in the proportion of urban land. The proportional difference among all landscape elements tends to decrease, leading to an increase in landscape type diversity. At the same time, in the process of rapid economic development, the disorder of human disturbance results in an increase of landscape fragmentation and complexity.

Variable landscape diversity with similar industrial structure in developing areas

From Figures 2 and 3, we also find that the 13 towns in developing areas have similar industrial structures (Zone A) and different landscape diversities (Zone I, II, VI and VII). It can be concluded that, in developing areas, industrial structure will not exclusively determine landscape diversity. In developing areas, agriculture plays a leading role in the national economy because of the slow development of secondary and tertiary industries. Furthermore, there is often an unbalanced agricultural structure dominated by planting to forestry, fisheries and livestock raising. Therefore, industrial structure in developing rural areas is changeless; it can only induce a minor change in the proportion of some artificial landscape elements, such as farmland and urban land, but cannot determine landscape structure, which finally results in variable landscape diversity in different towns with similar industrial structures.

The formation and change in landscape diversity is mostly infuenced by natural factors, such as landform, physiognomy and climate. For example, as the three towns in Zone I, viz. Liude, Shunzhou and Renhe, are located in plateau plains with flat topography, mild and warm climate, and plenty of rainfall, there is a high degree of land use and various land-use types with little difference between their proportional areas. The features of landscape diversity in Zone I are represented by high Shannon-Weaver diversity and fragmentation indices. Contrary to towns in Zone I, Guanghua and Yangping in Zone VII, are located in high-mountain gorge areas with rugged topography, which imposes a great limitation on land use. Forest land and unused land are dominant with few other land-use types. Therefore, the landscape in Zone VII is mainly made up of several large contiguous patches with a high contagion index.

CONCLUSIONS

As landscape diversity is a kind of biodiversity defined on the broadest scale, while industrial structure can reflect the extent of human disturbance, the research using CRISLD is important to biodiversity conservation and management. Our study of hierarchical correlation analysis demonstrates that, in rural areas, there are corresponding hierarchical structures of industrial structure and landscape with different landscape diversity, and a high CRISLD occurs at different periods in history. The case study of clustering correlation analysis also proves the existence of CRISLD in Yongsheng County. Furthermore, the results show that different industrial structures could result in similar landscape diversity in developed rural areas; while in developing rural areas, industrial structure cannot exclusively determine landscape diversity, which is more infuenced by natural factors such as landform, physiognomy and climate.

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