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Spatial Heterogeneity of Farmland Landscape in Tai'an County Based on GIS and FRAGSTATS

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Landscape heterogeneity is a hot topic in current agricultural ecology and farmland landscape research. The study of landscape heterogeneity is helpful to understand the basic characteristics and spatial combination of landscape patches, which can not only provide scientific and powerful reference for regional landscape planning, management and protection, but also reveal the influence of human activities and natural factors on landscape pattern and ecological benefits. Taking Tai ' an County as an example, this study quantitatively analyzed the heterogeneity of farmland landscape in Tai ' an County with GIS, Fragstats4.2 and GS + 7.0 as technical support. The research shows that : (1) the regions with high fragmentation degree are mainly distributed in woodland, transportation land, water area and water conservancy facilities land landscape, mainly because the distribution of these three landscape types is mostly presented in strips, resulting in high heterogeneity in the region. (2) The areas with high spatial mosaic degree are mainly distributed in woodland, transportation land, water area and water conservancy facilities landscape. (3) The high value area of spatial diversity is mainly distributed in the northern region, and the landscape types are mainly forest land, transportation land, water area and water conservancy facilities. Combined with the landscape index value, it also shows that the landscape diversity of the region is high and the heterogeneity level is high.

Keywords

Landscape ecology ; landscape heterogeneity ; farmland ; Tai ' an County.

1. Introduction

Landscape spatial heterogeneity is a specific manifestation of different sizes of various landscape patches at different scales, which affects the ecological process within the landscape. The study of landscape heterogeneity helps to understand the basic characteristics and spatial combination of landscape patches, which can not only provide scientific and powerful reference materials for regional landscape planning, management and protection, but also reveal the impact of human activities and natural factors on landscape pattern and ecological benefits . China is a large agricultural country. The stability and healthy development of agricultural ecosystem is of great significance to ensure food security and social stability in China. With the development of social economy, reasonable and effective agricultural ecological space planning

and ecological landscape construction play a positive role in farmland ecosystem protection and crop yield improvement [2–3].

With the promotion of large-scale management of cultivated land and the deepening of farmland intensification, there are few agricultural landscapes with strong heterogeneity at present. The growing demand for food by the population makes the agricultural landscape develop towards homogenization . Domestic and foreign scholars have done a lot of work on landscape heterogeneity. Christophe et al. took three rice producing areas in the Philippines as the research area, and analyzed the impact of farmland landscape heterogeneity on the surface arthropod community at the micro and regional scales. The study showed that the heterogeneity of farmland structure in high-altitude rice areas was low, and the regional scale effect could effectively explain the impact of landscape heterogeneity on the richness of arthropod community in rice fields . With the help of GIS technology, Wei et al. interpreted and classified the landscape of Shiyang River Basin, and analyzed the spatial heterogeneity of green landscape in the study area by using the landscape index method. The research results are helpful to provide the basis for the land use mode and ecological environment protection of arid inland rivers . Wang et al. took Gongyi City, a typical agricultural area in the middle and lower reaches of the Yellow River, as the study area to analyze the influence of farmland landscape heterogeneity on insect population diversity at multi-scale. The study showed that the landscape heterogeneity in hilly and mountainous areas had the most significant influence on insect pollination . Although most scholars have done in-depth research on landscape heterogeneity, the research on farmland landscape heterogeneity is extensive and insufficient. Therefore, this study takes Tai ' an County as an example, selects the typical farmland landscape, discusses the composition of farmland landscape and landscape heterogeneity, understands the heterogeneity level of landscape pattern in the study area, and provides opinions and suggestions for the construction and optimization of landscape pattern, the construction and optimization of ecological network, the protection of ecosystem and the management of agricultural production.

2. Regional overview and data sources

2.1. Overview of the study area

Tai ’ an County is located in the northwest of Anshan City, Liaoning Province, with geographical coordinates between 122°11 ’ – 122°40 ’ E and 41°01 ’ – 41°34 ’ N. The length of the whole country is 75km from north to south, 50km from east to west, and the total area is 1388km2. Tai 'an county is located in the hinterland of the Liaohe plain, water resources are very rich, there is no mountain, the terrain is flat, belongs to the warm temperate continental monsoon climate, and the four seasons are clear, rain and heat at the same time, dry and cold in the same season, warm, sunshine is sufficient, spring wind, winter cold. The county has 11 towns, 15 community committees and 204 village committees, with a population of 3547,000. At the same time in Shenyang, Liaoyang, Anshan, Yingkou, Panjin, Jinzhou and other large and medium-sized city economic circle, is an important node of Liaoning coastal economic belt and the northeast connecting north China traffic fortress.

2.2. Data sources

Based on the vector data of the second land use survey in Tai 'an County, the main types of data are point vector data, linear vector data and surface vector data.

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3. Research method

3.1. Fragstats Technology and Landscape Index Method

Landscape pattern index is a high concentration of landscape pattern information, which can quantitatively reflect the characteristics of landscape pattern. Fragstats (landscape pattern analysis software) technology is an integrated analysis environment for landscape index, which can calculate a variety of landscape pattern indexes. Landscape pattern index usually includes three levels, namely patch level, class level and overall landscape level. When selecting the landscape index, it is necessary to fully consider the relationship between the indexes and the ecological significance expressed, so as to avoid index duplication. Therefore, this study in the selection of landscape index, referring to the research process of many scholars, clear the meaning of landscape index, in the landscape level and plaque type level selected five categories of 10 landscape index [8-12].

(1) Number of patches (*NP*)

Ecological significance: the number of patches can usually be used to describe the heterogeneity of spatial landscape pattern, and the value range is $NP \geq 1$. The number of patches has a good positive correlation with landscape fragmentation. In general, the greater the number of patches, the higher the fragmentation ; on the contrary, the smaller the number of patches, the lower the fragmentation.

Calculation formula :

$$NP = N_i$$

In the formula : N_i represents the number of *i* landscape patches.

(2) Plaque density (*PD*)

Ecological significance : Patch density can be used to describe the fragmentation degree of spatial landscape, also can reflect the spatial heterogeneity of landscape, the value range is $PD > 0$. In general, the greater the plaque density, the more serious the fragmentation.

Calculation formula :

$$PD = Ni/A$$

In the formula : N_i represents the number of i landscape patches ; *a* Represents the total landscape area.

(3) Percentage of patches to landscape area (*PLAND*)

Ecological significance : equal to the total area of a patch type as a percentage of the total landscape area. It measures the components of landscape and is one of the basis for determining the dominant landscape. When the value tends to 0, it indicates that this patch type becomes very rare in the landscape ; when the value is 100, it indicates that the whole landscape is only composed of one kind of patches.

Calculation formula :

$$PLAND = CA / A$$

In the formula: *CA* represents the total area of a plaque type ; *A* Represents the total landscape area.

(4) Landscape shape index (*LSI*)

Ecological significance : Landscape shape index can reflect the rule degree of landscape patch elements, and it is also a measure of patch aggregation or dispersion, with the value range of $LSI \geq 1$. The larger the landscape shape index is, the worse the discrete aggregation degree of patches is.

Calculation formula :

$$LSI = \frac{\sum_{k=1}^{m} e_{ik}}{4\sqrt{A}}$$

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In the formula: m represents the number of plaque types ; e_{ik} denotes the total length of adjacent patches between type i and k.

(5) Polymerization index (AI)

Ecological significance : Describe the aggregation of different patches in landscape.

Calculation formula :

$$AI=\frac{g_{ii}}{maxg_{ii}}\times 100$$

In the formula: $maxg_{ii}$ denotes the number of edges of similar adjacent grids when the patch type i reaches the maximum aggregation.

(6) Dispersion and parallel index (IJI)

Ecological significance : IJI is one of the most important indicators to describe landscape spatial pattern. Various ecosystems in mountainous areas are seriously affected by vertical zonality, and their distribution is mostly circular, and the IJI value is generally low. Many transitional vegetation types in arid areas are subject to water distribution and proximity, and IJI values are generally high.

Calculation formula :

$$IJI=\frac{-\Sigma\left[\frac{e_{ik}}{\Sigma_{k=1}^{m}e_{ik}}ln\left(\frac{e_{ik}}{\Sigma_{k=1}^{m}e_{ik}}\right)\right]}{ln(m-1)}$$

In the formula: e_{ik} denotes the total length of adjacent patches between type i and k.

(7) Aggregation index ($CONTAG$)

Ecological significance : generally speaking, high aggregation value indicates that a certain dominant patch type in the landscape forms a good connection ; on the contrary, it indicates that the landscape is a dense pattern with multiple elements, and the degree of fragmentation of the landscape is high.

Calculation formula :

$$CONTAG=\left[1+\frac{\Sigma_{i=1}^{m}\Sigma_{k=1}^{m}\left[P_i\left(\frac{g_{ik}}{\Sigma_{k=1}^{m}g_{ik}}\right)\right]\left[ln\left(P_i\left(\frac{g_{ik}}{\Sigma_{k=1}^{m}g_{ik}}\right)\right)\right]}{2\,ln\,m}\right]\times 100$$

In the formula: g_{ik} denotes the number of grid edges adjacent to the patch type i and j.

(8) Plaque cohesion index ($COHESION$)

Ecological significance : spatial connectivity of the same type of patches in the landscape. The value range is 0 < $COHESION$ < 100. When the value approaches 0, it indicates that the core patch type in the landscape gradually decreases and is gradually divided into other types of patches. At the same time, these types of patches are not continuous in structure. If the landscape is composed of a patch type, the value is 0.

Calculation formula :

$$COHESION=\frac{\left[1-\frac{\Sigma_{j=1}^{n}p_{ij}}{\Sigma_{j=1}^{n}p_{ij}\sqrt{a_{ij}}}\right]}{\left[1-\frac{1}{\sqrt{Z}}\right]}\times 100$$

In the formula: Z represents the total number of grids.

(9) Shannon Diversity Index ($SHDI$)

Ecological significance : Shannon diversity index can reflect the number of landscape elements and the proportion of various landscape changes. The range of $SHDI \geq 0$, the greater the landscape diversity index value, indicating that the more diverse landscape types, the higher

the degree of landscape heterogeneity. When *SHDI* = 0, it indicates that the landscape is composed of single elements and the landscape is homogeneous.

Calculation formula :

$$SHDI = -\sum_{i=1}^{m} p_i \, ln(p_i)$$

In the formula : p_i represents the probability of plaque type i appearing in the landscape ; m represents m patches in the assumed landscape.

(10) Shannon evenness index (*SHEI*)

Ecological significance : Shannon evenness index can describe the distribution uniformity of different landscape elements, and its value range is 0 ≤ *SHEI* ≤ 1. Shannon evenness index value closer to 1, indicating that plaque distribution more uniform ; on the contrary, it indicates that the uniformity of plaque distribution is poor.

Calculation formula :

$$SHEI = \frac{-\sum_{i=1}^{m} p_i \, ln(p_i)}{ln \, m}$$

In the formula : p_i represents the probability of plaque type i appearing in the landscape ; m represents m patches in the assumed landscape.

3.2. GS + 7.0 Technique and Semivariance Function

GS + 7.0 technology is one of the main software used in geostatistics. In this study, GS + 7.0 technology was used, and the optimal analysis granularity of the study area was determined based on the semi-variance function.

The calculation formula of semi-variance function is :

$$\gamma(h) = \frac{\sum_{i=1}^{n(h)} \left[Z(X_i) - Z\ (X_i + h) \right]^2}{2n\ (h)}$$

In the formula: $\gamma(h)$ gammah represents the semivariance function when the spacing is h ; h Represents the spacing of sampling points; x represents the sample point in space; $Z(X_i)$ and $Z\ (X_i + h)$ represent the values of random function Z in space X and $X + h$, respectively; n (h) denotes the total number of sample pairs when the spacing is h [4-5].

Spherical model calculation formula :

$$\gamma(h) = C_0 + C_1 \left[\frac{3h}{2a} - \frac{1}{2} \left(\frac{h}{a} \right)^3 \right] \quad (0 \le \mathrm{h} \le \mathrm{a})$$

$$\gamma(h) = C_0 + C_1 \quad (\mathrm{h} \ge \mathrm{a})$$

In the formula: $\gamma(h)$ gammah represents the semivariance function when the spacing is h; C_0 represents nugget variance ; C_1 denotes structural variance; a represents the first sampling interval when the semi-variance reaches the base value ; h Represents the spacing of sampling points ; $C_0 + C_1$ represents the semi-variance base value [4 – 6].

According to the land use status and research needs of the study area, this study takes 10 m as the starting point, and the interval is 10 m. The vector data are converted into raster data (*. tif), and a total of 15 raster maps with different particle sizes are obtained. By comparing the changes of each landscape pattern index under different particle size benefits, the inflection point appeared when the particle size was 30 m, and the loss of landscape area in the study area was relatively least. Therefore, 30m was selected as the best analysis granularity.

On the basis of 30m analysis granularity, the window radius is 60m, 120m, 180m... 1200m grid. Through the Spatial Analyst module in GIS, the grid values of the spread index (*CONTAG*) and Shannon evenness index (*SHEI*) were extracted by points, and the change trend of block-to-

base ratio under different moving window radius was counted and analyzed by using the geostatistical software GS + 7.0. The optimal analysis range of this study area was 360 m.

4. Results and analysis

4.1. Landscape space fragmentation in Tai ' an County

Landscape pattern index is a high concentration of landscape pattern information, which can quantitatively reflect the characteristics of landscape pattern. Fragstats (landscape pattern analysis software) technology is an integrated analysis environment for landscape index, which can calculate a variety of landscape pattern indexes. Landscape pattern index usually includes three levels, namely

Landscape spatial fragmentation can be described and analyzed by patch number (*NP*), patch density (*PD*) and landscape shape index (*LSI*). In general, the larger the number of patches, patch density and landscape shape index, the higher the degree of fragmentation of landscape space in the study area.

The analysis shows that the number of patches (*NP*) in the study area is 1-33, the patch density (*PD*) is 5.64-186.12 / 100hm^2, and the landscape shape index (*LSI*) is 1.17-4.24.

The red region indicates a higher degree of fragmentation, and the blue region indicates a lower degree of fragmentation, that is, the high value area and the low value area. It can be seen from the figure that the high-value area is more concentrated in the southern region than in other regions, and at the same time, it is also more distributed in linear woodland, rivers and roads. The low value area is distributed throughout the study area, and the parts are more uniform. In terms of the fragmentation degree of the whole space, the high-value area and the low-value division are relatively uniform.

According to the classification of landscape types in the study area, the landscape types in the areas with high fragmentation degree are mainly woodland, transportation land, water area and water conservancy facilities. The landscape types in regions with low fragmentation degree are mainly cultivated land. The fragmentation degree of garden land, grassland, urban and industrial and mining land and other land is between high value area and low value area, which belongs to the transition from high value area to low value area.

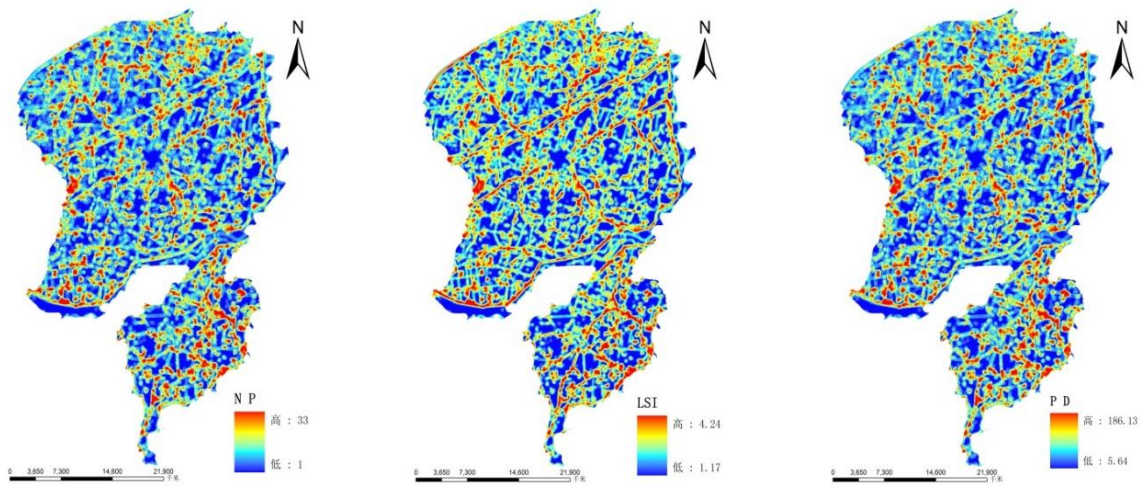

Figure 1 Grid map of landscape fragmentation

4.2. Analysis on Inlay Degree of Landscape Space in Taian County

The landscape spatial mosaic can be described and analyzed by the spread index (*CONTAG*) and the patch cohesion index (*COHESION*). Generally, the values of spread index and patch cohesion index have a certain negative correlation with landscape spatial mosaic. The higher

the index value is, the better the connectivity between patches is, but the worse the spatial mosaic is.

The analysis shows that the spread index (*CONTAG*) of the study area ranges from 8.74 to 100, and the patch cohesion index ranges from 70.88 to 100.

In the figure, the red region indicates that the mosaic degree is poor, and the blue region indicates that the mosaic degree is good, namely, the low value region and the high value region. It can be clearly seen from the map that the high value area of the study area is evenly distributed. The regional landscape types are mainly forest land, transportation land, water area and water conservancy facilities, and the distribution is mostly banded. The low-value areas are mostly concentrated in cultivated land and urban and industrial and mining land landscape, and the distribution is relatively uniform. In the grid map of the spread index, the high value area is concentrated in the north of the study area, but the distribution is relatively uniform in the whole study area. In the grid diagram of plaque aggregation index, the high value area is mainly banded, and the northern part is more concentrated than other areas.

According to the classification of landscape types in the study area, the landscape types in the high-value area are mainly forest land, transportation land, water area and water conservancy facilities land, which are distributed in strips. The landscape types in the low-value area are mainly cultivated land landscape and urban and industrial land landscape. The mosaic degree of landscape space of garden, grassland and other land is between high and low values.

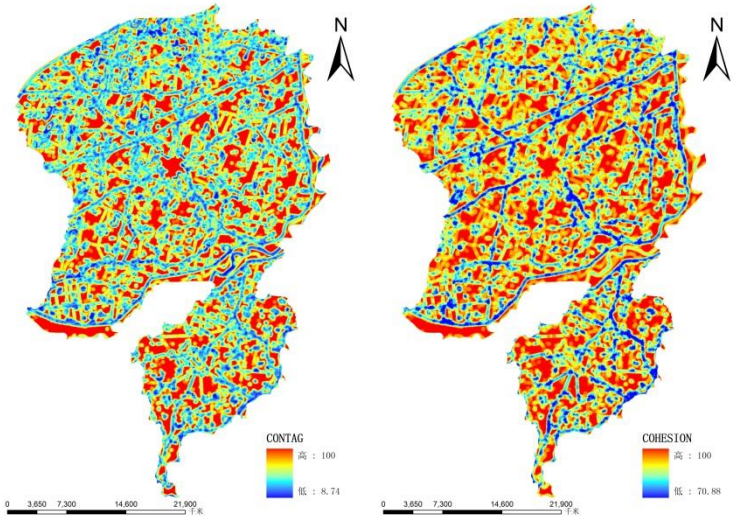

Fig 2 Landscape spatial mosaic grid map

4.3. Analysis of Landscape Spatial Diversity in Taian County

The landscape spatial mosaic can be described and analyzed by the spread index (*CONTAG*) and the patch cohesion index (*COHESION*). Generally, the values of spread index and patch cohesion index have a certain negative correlation with landscape spatial mosaic. The higher the index value

The analysis shows that the value range of Shannon diversity index is 0 – 1.78, and the value range of Shannon evenness index is 0 – 0.99.

In the figure, the red region indicates a high degree of landscape diversity, while the blue region indicates a low degree of landscape diversity, namely, high-value region and low-value region. It can be seen from the figure that the high-value areas in the study area, that is, the areas with high diversity are mainly distributed in the north, and the high-value areas of other areas are mainly distributed in woodland, transportation land, water area and water conservancy facilities land landscape. The areas with low degree of diversity in the study area are mainly

distributed in cultivated land, urban and industrial land landscape, and the distribution is relatively uniform.

According to the classification of landscape types in the study area, the landscapes in the areas with high diversity are mainly forest land, transportation land, water area and water conservancy facilities. The landscapes in the areas with low diversity are mainly cultivated land, urban and industrial land. Garden, grassland and other land landscape diversity between high and low value.

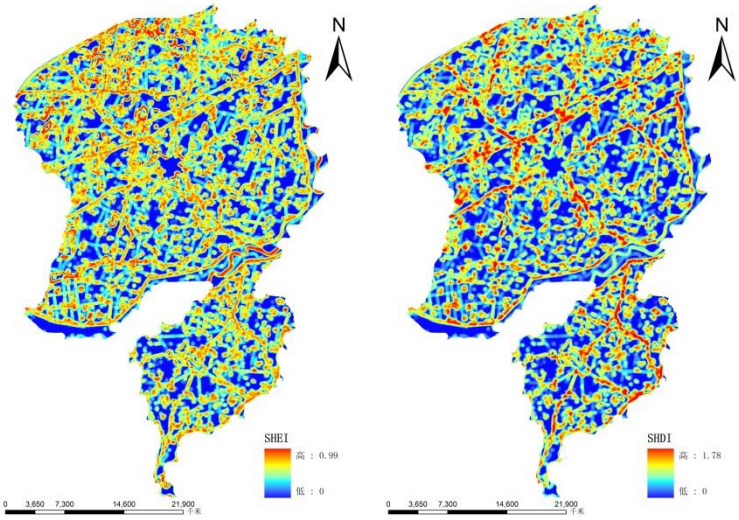

Figure 3 Grid map of landscape spatial diversity

5. Conclusion

(1) The high degree of fragmentation of landscape space in the study area is mainly distributed in forest land, transportation land and water and water conservancy facilities landscape, mainly because the distribution of the three landscape types is mostly banded. The patch number (*NP*) and patch density (*PD*) have a good positive correlation with the degree of landscape spatial fragmentation. At the same time, according to the landscape index value, it also shows that the degree of landscape spatial fragmentation of woodland, transportation land, water area and water conservancy facilities is high. The matrix landscape of the study area is the cultivated land landscape, and the figure also clearly shows that the area where the cultivated land landscape exists belongs to the area with low fragmentation degree, mainly because the study area is dominated by agricultural production, and the cultivated land area occupies the highest proportion and is distributed in contiguous areas. In terms of the fragmentation degree of the overall landscape space in the study area, the high-value area and low-value area of landscape fragmentation degree are relatively evenly distributed. Generally speaking, there is a positive correlation between the degree of fragmentation of landscape space and the heterogeneity of landscape space. Regions with higher degree of fragmentation usually have higher heterogeneity. Therefore, the heterogeneity of forest land, transportation land, water area and water conservancy facilities land landscape distribution in the study area is higher than that in other regions, and the region with the lowest heterogeneity belongs to the cultivated land landscape distribution region.

(2) The areas with high degree of landscape spatial mosaic in the study area are mainly distributed in woodland, transportation land, water area and water conservancy facilities land landscape, mainly because the three landscape types are mostly distributed in ribbons and run through the whole study area. The low degree of landscape spatial mosaic in the study area is mainly distributed in the cultivated land and urban and industrial and mining land landscape, mainly because the cultivated land landscape is the matrix landscape of the study area, and the

degree of plaque spatial connection is good, and the distribution area is wide. In terms of the mosaic degree of the overall landscape space in the study area, the distribution of areas with better mosaic degree and areas with poor mosaic degree is relatively uniform.

(3) The high value area of landscape spatial diversity in the study area is mainly distributed in the northern region, and there are high value areas in the landscape area with strip distribution. The landscape types of the high value area are mainly forest land, transportation land, water area and water conservancy facilities. Combined with the landscape index value, it also shows that the landscape diversity of the region is high. There is a certain correlation among landscape spatial diversity, mosaic and fragmentation. According to the landscape spatial raster map and landscape index value, it can be seen that in regions with high diversity, the fragmentation degree of landscape space is relatively high, and the mosaic degree of landscape space is relatively good. The distribution of high and low value areas of overall landscape diversity in the study area is relatively uniform.

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