Analysis of the Spatial Agglomeration Effect of Production, Living and Ecological Spatial in Duolun County, Inner Mongolia

Surigeriletu, Aruhan

Inner Mongolia Agricultural University, College of Desert Control Science and Engineering, Hohhot 010010, China.

Abstract: Optimization of the three living spaces has an important scientific guidance value for rational development of national land space and optimization of national land space pattern. Taking Duolun County of Inner Mongolia as the study area, the remote sensing images from 2000 to 2020 were selected and the distribution state of the agglomeration effect of the three living spaces was analyzed. The results show that: (1) the area of production space and ecological space are decreasing, and the area of living space is increasing; (2) the types of nuclear density zones of production space, living space and ecological space are mainly low density zones and lower density zones. (3) the production space, living space and ecological space nucleated density zones are mainly low-density zones and lower-density zones, and the area of low-density zones and lower-density zones all show an increasing trend;

Keywords: Duolun County; Three Living Spaces; Agglomeration Effect

1. Overview of the study area

Duolun County is located in Northern China, at the Southern edge of the Hunsandak sandy area in the interlocking agricultural and pastoral areas. Its topography is high around and low in the middle, with an altitude of 1039-1795 m. The landform type is dominated by low mountains, hills, river gorge valley depressions, inclined plains in front of mountains and accumulation-type sand dunes. The climate is a typical continental climate with the transition from semi-arid to semi-humid temperate zone, with rain and heat in the same season, annual average temperature of 2.8°C, annual average precipitation of 378 mm, annual average wind speed of 3.3m/s, and 49.1 days of high wind. Its soil type is mainly chestnut calcium soil, meadow soil and wind-sand soil, etc. The vegetation types include typical grassland vegetation, meadow grassland vegetation, sandy vegetation and swamp vegetation, etc.The county is rich in water resources and has the only surviving natural primitive elm forest in Asia. There are 65 administrative villages in Duolun County, and the transportation is more developed. 2020 Duolun County's county-wide gross regional product will complete 4.79 billion yuan, with a total population of 104,000.

2. Research Method

According to the trispace classification system of Du Lai [1] and the trispace assignment rules of Liu Jilai [2], the spatial distribution maps of trispace scores were obtained using remote sensing images from 2000 to 2020 (Figure 1-figure supplement 3).

2.1 Nearest neighbor index

The nearest neighbor index (NNI) judges the distribution pattern of points by the nearest neighbor distance between points, comparing the average distance of the nearest neighbor pairs of observed values with the average distance of the nearest neighbor pairs of points in the random distribution pattern. The ratio of the two is used as an indicator to determine whether the spatial point elements are clustered or dispersed in a certain area [16]. When the average distance between all the observed elements and their nearest neighbor elements is greater than the desired average distance with statistically significant differences, the elements will show a dispersed distribution characteristic, otherwise they will show a clustered distribution characteristic.

In this study, the spatial distribution pattern of production space, living space and ecological space is judged by calculating the ratio of the average distance between the center point of production space, living space and ecological space and the center point of the nearest neighboring production space, living space and ecological space and the average distance under the assumption of random distribution, which is calculated by the formula.

$$R = D/\overline{D} \quad (1)$$

$$D = \sum_{i=1}^{n} d_i/n \quad (2)$$

$$\overline{D} = 0.5/\sqrt{n/s} \quad (3)$$

The z-statistic of the nearest neighbor index is:

$$Z = n(D - \overline{D})/0.26136\sqrt{S} \quad (4)$$

In this formula: R represents the nearest neighbor index; $D, \overline{D}$ are the average distance observed and the average distance expected, respectively; d_i is the distance between the element at point i and its nearest neighbor; S is the area of the minimum outer rectangle. Z score and P value are measures of statistical significance, if Z is less than -2.58 and P value is less than 0.01, the confidence level is 99% or more, which means the analysis result is valid. When the nearest neighbor index is greater than 1, it is $\overline{D}$ discrete distribution; when the nearest neighbor index is less than 1, it is agglomerative distribution, and the smaller this value indicates more aggregation; when the nearest neighbor index is equal to 1, it is random distribution characteristic.

2.2 Thiessen Polygon Method

The Thiessen polygon consists of a set of continuous polygons consisting of perpendicular bisectors of a line connecting two neighboring points, and the area of the Thiessen polygon [48,49] varies with the distribution of the point set.

The coefficient of variation (C_v) of the area of Thiessen polygon is to be expressed as the ratio of the standard deviation of the area of Thiessen polygon to the mean, which is calculated by the formula:

$$C_v = \sqrt{\sum (S_i - \overline{S})^2/n}/\overline{S} \quad (5)$$

In this formula: C_v is the coefficient of variation; S_i is the area of the year i Thiessen polygon; n is the number of Thiessen polygons; S is the average of the area of Thiessen polygons.

When the points are randomly distributed, there is no change in Thiessen polygon area when the C_v value is between 33% and 64%; when the points are clustered, the Thiessen polygon area within the cluster is smaller and larger between clusters, and the C_v value is greater than 64%; when the point elements are uniformly distributed, the Thiessen polygon area changes little, and the C_v value is less than 33%.

2.3 Kernel density method

"Kernel density estimation" is a non-parametric test based on estimating the unknown density function, which visualizes the probability of the distribution of the study object. The kernel density value will reflect the degree of aggregation in the spatial distribution of the study area. In this study, with the help of ArcGIS10.8 kernel density analysis tool, the distribution characteristics of production space, living space, and ecological space points in Duolun County, Inner Mongolia are visualized and analyzed, and the distribution characteristics of production space, living space, and ecological space in Duolun County are formulated as follows.

$$f(s) = \sum_{i=1}^{n} k/\pi r^2 (x - x_i/r), x \in R \quad (6)$$

In this formula: $f(s)$ represents the kernel density estimates of point x at that location; n represents the number of points in the domain; r represents the search radius (bandwidth); $(x - x_i)$ represents the distance from x to x_i; and k is the kernel function of the ratio of $x - x_i$ to r.

3. Results and analysis

3.1 Analysis of the spatial and temporal changes of production space, living space and ecological space

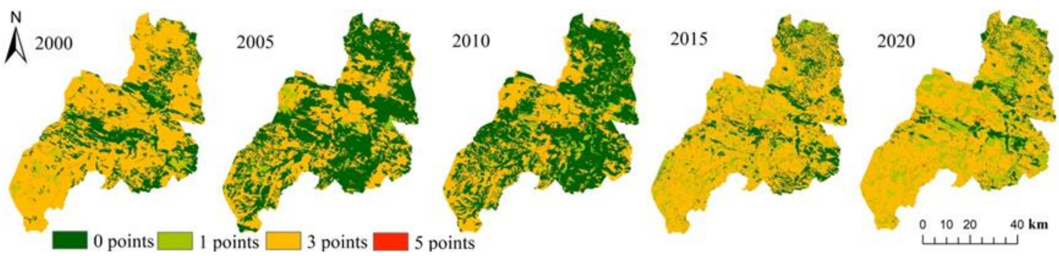

Figure 1. Spatial distribution of production functions in Dolan County between 2000 and 2020

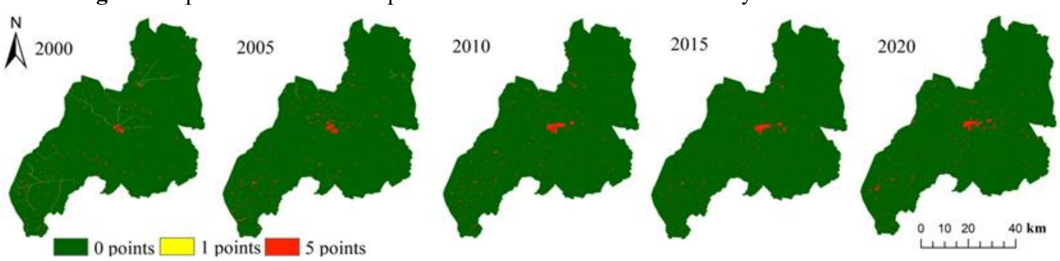

Figure 2. Distribution of living function space in Dolan County between 2000 and 2020

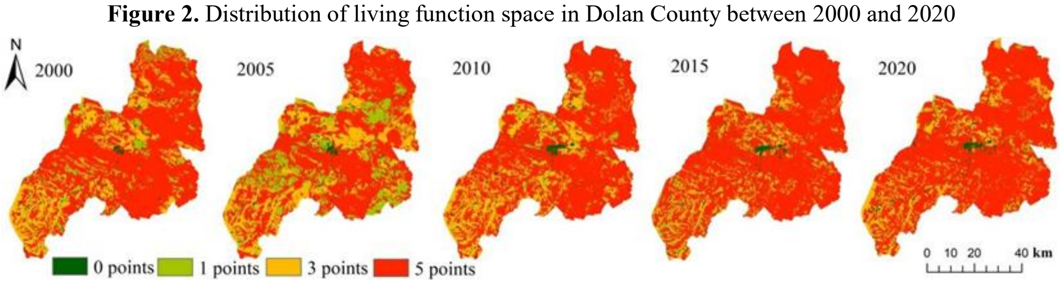

Figure 3. Distribution of ecological function space in Duolun County during 2000-2020

The area with a production function score of 0 decreased from 973.02km^2 to 512.44km^2 between 2000 and 2020, and its area accounted for 13.26% of the total land area in 2020 (Figure 1).

The area of land with production function scores of 1, 3, and 5 was on the increase, and the total area accounted for 86.74% of the total land area; the area of land with life function scores of 0 decreased from 98.17% to 98.13% between 2000 and 2020, while the area of land with life function scores of 1 and 5 increased from 1.83% to 1.87%, and its proportion of the total land area was slightly increasing. The proportion of the total land area was slightly increasing (Figure 2).

The proportion of the area with an ecological function score of 0 increased from 1.9% to 2.55% between 2000 and 2020, while the proportion of the area with ecological function scores of 1, 3, and 5 decreased from 98.1% to 97.45%, and its proportion of the total land area showed a weak trend of decrease (Figure 3).

3.2 Spatial agglomeration effect of production space, living space and ecological space

3.2.1 Analysis of the nearest neighbor index

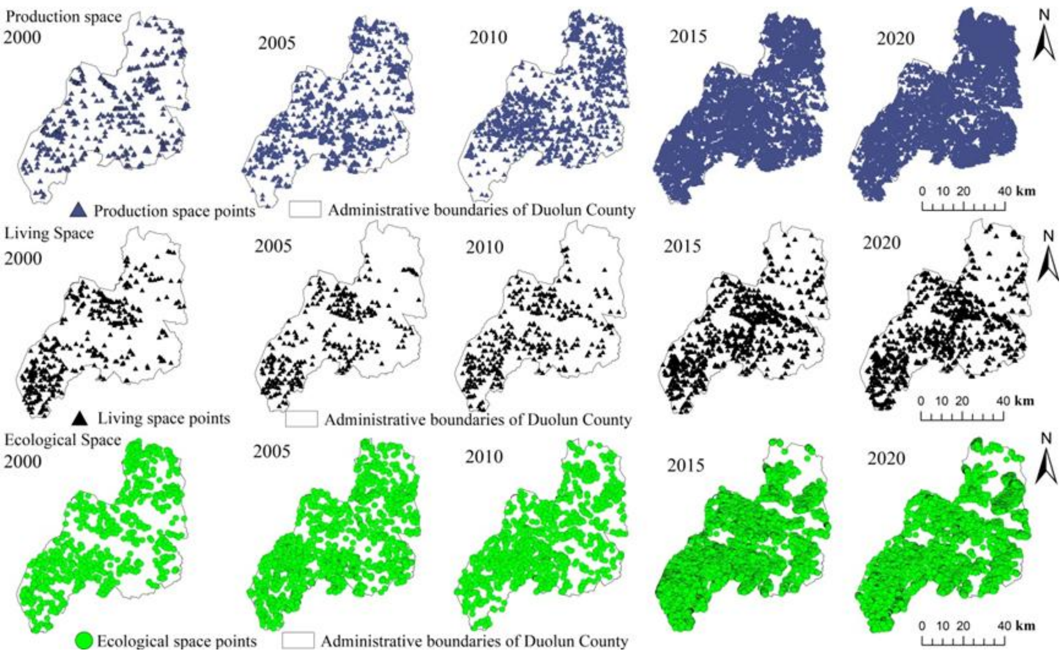

Figure 4. Spatial distribution of point elements of production space, living space and ecological space in Duolun County during 2000-2020

Any spatial point element in space has three states: clustered, dispersed or random. The average nearest neighbor distances and indices among the point elements of production space points, living space points, and ecological space were obtained by referring to the distribution map of production space, living space, and ecological space in Duolun County, Inner Mongolia (Figure 4) and the average nearest neighbor index obtained through the statistics of ArcGIS 10.8 software (Figure 5).

The Z scores of production space, living space, and ecological space in Duolun County, Inner Mongolia during 2000-2020 were very low, all negative, and showed a decreasing trend year by year, which indicates that the degree of aggregation increased year by year during this period. Meanwhile, the P values were all zero, which indicates that the spatial aggregation degree was very significant at the confidence level of 100.0%. The nearest neighbor indexes of production space, living space and ecological space in Duolun County, Inner Mongolia during 2000-2020 were all between 0 and 1 and their index size decreases year by year, indicating that the spatial clustering distribution was characterized and the degree of clustering deepens. The nearest neighbor index of living space is the smallest, and its spatial agglomeration distribution is the most obvious; the nearest neighbor indexes of production space and ecological space were not very different, and the difference of spatial agglomeration distribution was not obvious.

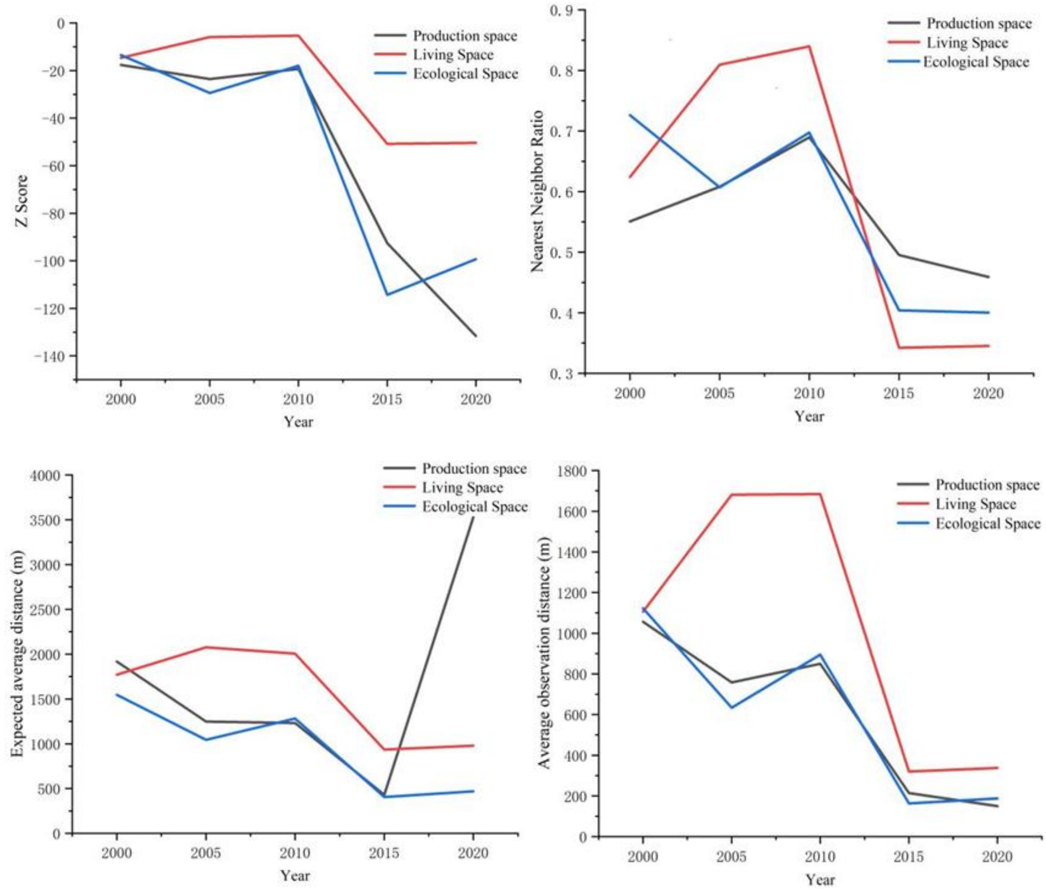

Figure 5. Change of nearest neighbor index of production space, living space and ecological space in Duolun County of Inner Mongolia

3.2.2 Thiessen polygon analysis

The Thiessen polygon tool of ArcGIS10.8 software was used to obtain the Thiessen polygon distribution maps of production, living and ecological functions generated by the differentiation of production space, living space and ecological space in Duolun County, Inner Mongolia from 2000 to 2020 (Figure 6-8) and the trend of variation coefficient C_v value of the average Thiessen polygon area of each single space in each year (Figure 9).

The mean values of production function, living function and ecological function are all greater than 64% during 2000-2020, and their mean values have increased significantly. The distribution of production functions is tight in the northeast (Figure 6), while it is looser in the southwest. The distribution of living functions was tight in the central region (Figure 7). The distribution of ecological functions is tight in the southwestern and eastern regions (Figure 8).

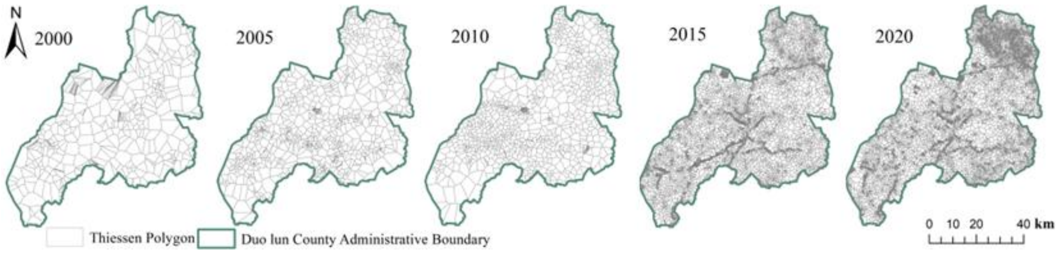

Figure 6. Thiessen polygon spatial distribution of production functions

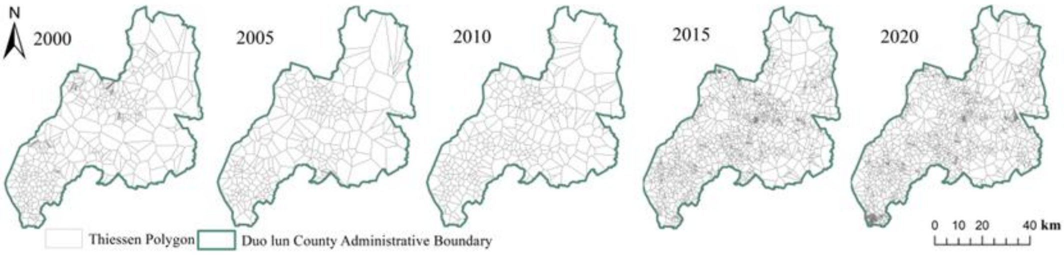

Figure 7. Thiessen polygon spatial distribution of life functions.

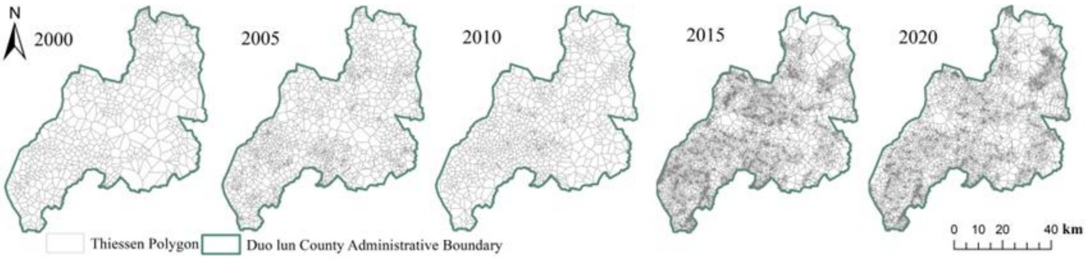

Figure 8. Thiessen polygon spatial distribution of ecological functions

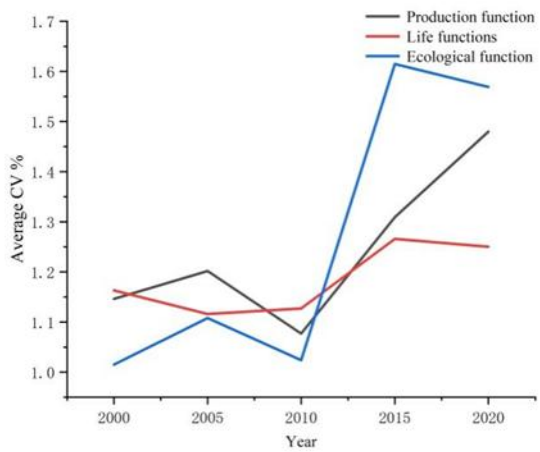

Figure 9. Trend of the average CV values of production, living and ecological functions

3.3 Nuclear density effect of production space, living space and ecological space

Using the kernel density analysis tool of ArcGIS10.8 software, the kernel density analysis was performed on the point element distribution data of production space, living space and ecological space in Duolun County, Inner Mongolia, and the kernel density distribution maps of production space, living space and ecological space in Duolun County were generated.

Then the natural breakpoint grading method was used to classify A into high density area, higher density area, medium density area, lower density area, and low density area (Figure 10-Figure 12).

The production space in Dolan County was dominated by low-density and lower-density areas during 2000-2020. The combined area shared of low-density and lower-density zones increased from 67% in 2000 to 77% in 2020, while the area share of high-density and higher-density zones did not change significantly. The area shared of medium density zones decreased from 21% in 2000 to 14% in 2020, while the spatial distribution of production kernel density in Dolan County in 2000 and 2005 showed a spatial distribution characterized by "multiple cores".

During 2010-2020, the distribution type of production space nucleation density shifted from clustering to agglomeration; during 2000-2020, the nucleation density of living space in Duolun County showed a multi-core spatial distribution. And the area proportion of low-density area, medium-density area and high-core density area had no significant changes. The area shared of higher density area decreased from 12% in 2000 to 2% in 2020.

During 2000-2020, the core density zones of ecological space in Duolun County were mainly low-density zones and lower-density zones. In 2000, the high-density and higher-density areas were mainly distributed in the northeast area and southwest area of the county, and the higher-density and higher-density areas in 2005 were mainly distributed in the southern area. In 2010, high-density and higher-density areas were mainly distributed in the central and northern areas of the county. In 2015, the high-density and higher-density areas were mainly distributed in the central part of the county. In 2020, the high-density and higher-density areas were scattered in the northeastern and southwestern areas of the county, and their area accounted for only 9% of the total area.

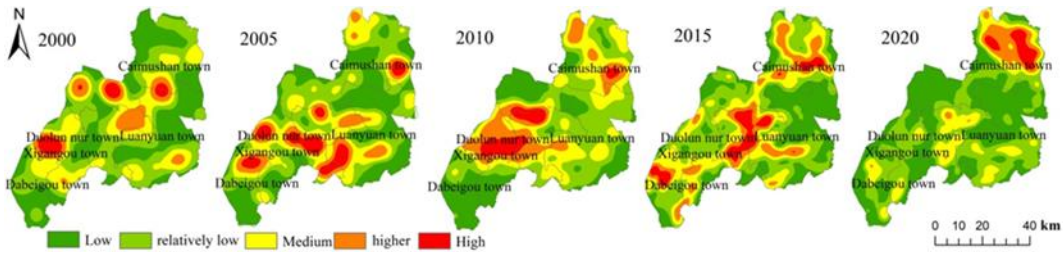

Figure 10. Distribution of kernel density space of production space

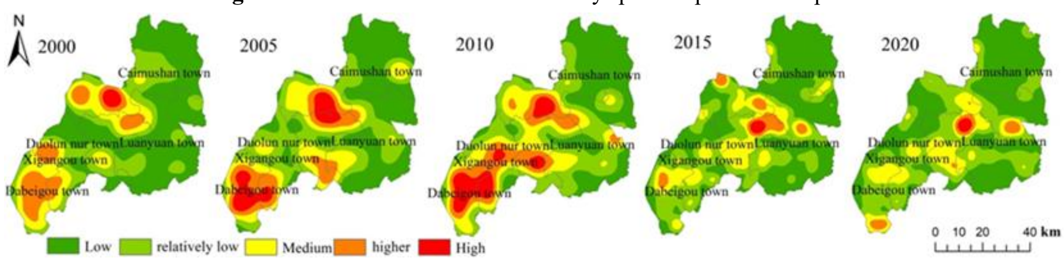

Figure 11. Distribution of the nuclear density space of living space

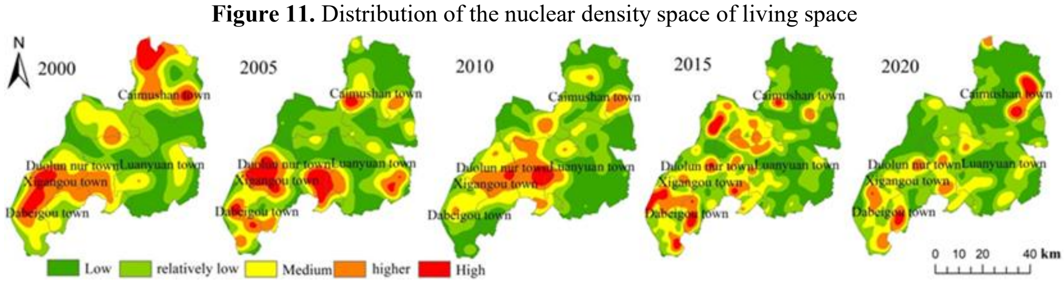

Figure 12. Distribution of nuclear density space of ecological space

4. Conclusions and discussion

The study area is located at the southern edge of the Hunsandak sandy area [3], which is a typical agro-pastoral interlacing area and an area highly prone to land desertification [4]. Due to the long-term influence of natural and anthropogenic factors [5], the continuous expansion of the land desertification area[6] has intensified the ecological environment deterioration and the continuous shinkage of natural ecological space. Since 2000, Duolun County has launched ecological projects such as the "Beijing-Tianjin Wind and Sand Source Control Project", "ecological migration", "returning farmland to forest", "no grazing The ecological projects such as "Beijing-Tianjin Wind and Sand Source Control Project", "Ecological Migration", "Returning Cultivated Land to Forest", "No Grazing", "One Million Mu of Zhangzizi Pine Afforestation" and "Hunsandak Scaled Forestry Construction" have effectively managed large areas of desertified land, reduced the area of cultivated land and grassland, and reduced the area of ecological space for grassland and forestry. The area of grassland and woodland has been expanded. At the same time, the area of productive space land was reduced and the area of ecological space, which is mainly desertified land, was significantly reduced. This is related to the growth of vegetation cover in Duolun County. Urbanization had led to an increase in the area of land used for construction and therefore the area of living space.

(1) Between 2000 and 2020. The area of production space and ecological space both showed a weak decreasing trend, and the area of living space showed a weak increasing trend.

(2) From 2000 to 2020, production space functions are closely distributed in the northeast, living functions are closely distributed in the central region, and ecological functions are closely distributed in the southwest and east

(3) During the period 2000-2020, the spatial distribution of production in Duolun County was dominated by low-density areas and lower-density areas, and the proportion of their areas was gradually increasing, while the proportion of the areas of high-density areas and higher-density areas did not change significantly. The nuclear density of living space was characterized by a multi-core distribution, with no significant change in the proportion of area occupied by each type of area. The core density of ecological space was dominated by low density areas and lower density areas, and the area share of high density and higher density areas was small.

References

[1] Du L. Research on the evolution and driving force of the functional pattern of "three livings" in Duolun County, Inner Mongolia[D].Inner Mongolia Agricultural University, 2020.

[2] Liu JL, Liu YS, Li YR. Classification evaluation and spatiotemporal pattern analysis of China's "production-living-ecological Space" [J]. Chinese Journal of Geography, 2017, 72 (7): 1290-1304.

[3] A RH.; Du L, Sheng Y, A SN, Analysis of the driving force of land desertification in Duolun County, Inner Mongolia based on Logistic regression model. Geography of Arid Regions 2019, 42(1), 137-143.

[4] Yue YJ, Geng LM, Li M, The impact of climate change on aeolian desertification: A case of the agro-pastoral ecotone in northern China. Science of The Total Environment 2022, 859(P2), 160126.

[5] Dai LW, Tang HP, Pan YL, Liang DL, Enhancing Ecosystem Services in the Agro-Pastoral Transitional Zone Based on Local Sustainable Management: Insights from Duolun County in Northern China. Land 2022,11(6), 805.

[6] Yi Y, Shi MC, Wu J, Yang N, Zhang C, Yi XD, Spatio-Temporal Patterns and Driving Forces of Desertification in Otindag Sandy Land, Inner Mongolia, China, in Recent 30 Years. Remote Sensing 2023, 15(1): 279.