Land use structure of typical county with conversion of farmland to forests in loess areas of Northern Shaanxi

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Abstract. Loess Plateau is the key construction area of ecological environment restoration in China. Since implementing the project of converting farmland to forests, the land use structure and existing problems in the loess area of northern Shaanxi have received extensive attention. Land use structure is the area and proportion of all kinds of land within a certain area, which determines the play of regional functions and land use benefits. This work took Wuqi County, Loess District, Northern Shaanxi, the demonstration county of national project of converting farmland to forests. Based on the land use data of Wuqi County in Loess District of north Shaanxi Province in 2009, this work carried out the quantitative analysis and discussion of land use quantitative structure in this area by means of quantitative geographical model and GIS spatial analysis and by using indexes such as diversification, centralization and combination coefficient of ground class. The results show that the quantity and structure of land use in Wuqi County are diversified, the concentration is low, and the complete degree of land use type is high. Additionally, the land combination type is mainly forestland-grassland, and the overall function needs to be improved. This study can provide reference for the quantitative analysis of land use structure in similar areas and counties.

1. Introduction

The Loess Plateau is a typical fragile ecological environment area in China. Due to the unreasonable land use activities such as deforestation, over-grazing and estrepement as well as the rapid population growth, the spatial pattern of land use in this area has changed dramatically, the vegetation is sparse, the soil erosion is serious, and the contradiction between people and land is prominent [1]. Wuqi County is an "advanced county for converting farmland to forests". Since 1998, Wuqi County has responded positively to the call of the Party Central Committee and actively carried out the afforestation work in the whole county. It is one of the counties with the earliest seal, the fastest retreat, the largest area, the most remarkable effect and the most substantial benefits for the masses [2]. As the global climate change has become a hot topic in international academic research in the 1990s, the study of land use structure began to pay attention to the process of land use change, and the study of land use and land cover change began to become the core content of global change research, which has also become the research hotspot and frontier topic in the academic circles of various countries nowadays [3].
In recent years, RS, GIS and other space technologies have been used more and more widely in land use, which has greatly improved the information accuracy of land use research and enriched the depth and breadth of land use research. Current domestic research on land use focuses on land use change processes, driving mechanisms and models, scenario prediction and structural optimization, but there are few researches on quantitative analysis and exploration of land use structure characteristics. The current research on land use structure and its spatiotemporal variation has become the focus of land science research [4]. Many scholars use landscape pattern method, land use conversion matrix, land use degree analysis method, linear programming analysis, fractal geometry, neural network method to analyze the land use structure. The landscape pattern method uses ArcGIS and landscape pattern analysis software Fragstats to analyze land use pattern at patch level and landscape level [5]. In recent year, the metrological geographical model has been applied to the analysis of land use structure characteristics. For example, Yang et al. used diversification index and Lorenz curve to analyze the land use structure of Hebei Province, and concluded that the land use structure of Hebei Province is highly diversified and the land use function is limited [6]. Based on the detailed land survey and change survey data of Gansu Province from 1998 to 2003, Pan et al. analyzed the land use status of Gansu Province by using the metrological geographical model, and drew the conclusion that the current land resources of Gansu Province have obvious regional differences [7]. The study of land-use structure in China mainly focuses on the western China, the southeast coastal hilly region, agro-pastoral transition zone and multiple typical regions, focusing on the provincial large and medium regional scale. There are few studies on counties. County unit is the ones closest to the actual scale in land use monitoring and management. Therefore, it is of certain significance to carry out the analysis of land use structure at the county level based on the metrological geographical model to reasonably guide the land use planning at the county level.

As a result, this work selected Wuqi County in loess region of northern Shaanxi as the study area, and tried to explore the use of land use comprehensive degree, local regional significance and other indices to characterize the structural characteristics of county scale land use based on the method of combining metrological geographical model and GIS spatial analysis technology. It expects to quantitatively analyze and reflect the characteristics of land use structure under the policy of converting farmland to forests, reveal the law and trend of land use structure change, and provide the basis for land use planning and land sustainable development strategy in this county.

2. Materials and methods

2.1. Overview of the study area
Wuqi County is located in the northwest of Yan'an City, Shaanxi Province, and it is located at 107°38′57″-108°32′49″ east longitude, 36°33′33″-37°24′27″ north latitude, area of 3791.5 km², and sea level of 1233-1809m above. It belongs to the hilly-shaped gully region of Loess Plateau. The topography is dominated by hills and gullies, and has serious soil erosion, which was once one of the most serious areas of soil erosion in the upper and middle reaches of the Yellow River. The climate is temperate continental arid monsoon climate. The annual mean temperature is 7.8℃, the extreme maximum temperature is 37.1℃, the extreme minimum temperature is -25.1℃, and the daily difference is 62.2℃. Annual precipitation is relatively small, with an average annual rainfall of 478.3mm. The precipitation is relatively concentrated from July to September, accounting for 62.4% of the annual rainfall. Wuqi county has rich soil types and great difference between north and south. The vegetation type is characterized vegetation transition from middle temperate forest shrub to steppe vegetation in forest scrub, and the composition of plant is dominated by the flora of north China.

2.2. Data sources and processing
The research data of Wuqi County includes the SPOT remote sensing image (ground resolution 10 m) in 2009, the digital topographic map of Wuqi County at 1:50000, the administrative division map of Wuqi County and the related image and text data. Remote sensing image processing software ERDAS
and GIS software ArcGIS are mainly used for image correction, pixel resampling, image mosaic, image clipping, and image enhancement.

Land use classification: in order to distinguish the constituent units of land use spatial regions, land use types need to be divided. According to the land use classification scheme of the National Committee of Agricultural Zoning in 1984 (Qin Ming Zhou, 1997) and the National Standard of the People's Republic of China - Classification of Land Use Status (GB/T 21010-2007), the land use types of Wuqi County are classified into five primary categories: woodland, grassland, cultivated land, construction land and water area.

2.3. Research methods

2.3.1. Quantity structure. The quantitative structure of land use can be understood as the relationship between various land use types and their area proportion in the region. The analysis of land use diversity analysis, land use centralization analysis and land category combination type analysis can overcome the defects that the single method can not completely reflect the characteristics of land use quantitative structure. The diversification of land use structure uses Gibbs-Martin diversification index to evaluate the completeness and diversification of various land resources in the county. The expression is as follows:

\[ GM = 1 - \frac{\sum f_i}{\sum (f_i)^2} \]  

(1)

GM is diversification index, and its theoretical maximum value is (n -1)/n; fi is the area or percentage of type i land use. The smaller the diversification index, the larger the area of each land use type in the area, the less the land use type and the lower the degree of completeness. GM value range is 0 to 1, if there is only one land class in a certain area, the diversification index is 0; if the land is evenly distributed in various land classes, the diversification index is 1. Centralization index I is an index that quantitatively describes the degree of centralization of regional land use types. The expression is as follows:

\[ I_i = \frac{(A_i - R)}{(M - R)} \]  

(2)

ii is the land concentration index of the i region, Ai is the sum of the cumulative percentage of the area of various land types in the i region, and the cumulative percentage of the area of the ground class is obtained by adding the number of the ground class successively; M is the sum of the cumulative percentage of land-type areas in the distribution of land concentration, R is the sum of the accumulated percentage of land-type areas in the higher-level region (Wuqi County is selected as the higher-level region in this study), and R is used as a benchmark for measuring the degree of centralization. The greater the concentration index, the higher the degree of concentration. When R = 455.243 and M = 600, the land use centralization index of each township in Wuqi County is calculated according to formula (2).

2.3.2. Land type combination. In order to determine the main types and characteristics of land use structure accurately and reasonably, the Weaver-Thomas combination coefficient method is used to analyze the combination types of land use space structure. Its basic principle is to use the land hypothesis distribution (assuming relative area percentage) to compare gradually with the actual distribution (actual relative area percentage), so as to obtain a uniform distribution closest to the actual distribution, then the combination type of this distribution is the combination of the land use types.

The specific steps are as follows: first, arrange the various land types from large to small in proportion to their area; second, assume that land is allocated to only one type, and the assumption distribution for this type is 100%, while the assumption distribution for other types is 0. If only the first two types are assigned, then its assumption distribution is 50%, while the assumption distribution for other types is 0; if the land is evenly distributed among the 5 types, the distribution is assumed to be 20%; third, calculate and compare the sum of squares of the difference between each hypothetical distribution and the actual distribution (that is the combination coefficient); fourth, choose the hypothetical
combination type with the smallest sum of squares of the difference between the hypothetical distribution and the actual distribution, then the portfolio is considered as the type of land portfolio in the region. The combination type of land use reflects the overall function of regional land. The land use diversification index, centralization index and combination type number of Wuqi County obtained by the above methods are analyzed by using the K clustering method in SPSS software, and the spatial distribution of various indexes is obtained.

3. Result and analysis

3.1. Land use diversification analysis

The results of the land use diversification index show that the diversification index of Wangwazi township is the smallest 0.49, and the diversification index of Great Wall township is the largest 0.62; the diversification index of other townships is between 0.5-0.62. On the whole, the diversification characteristics of land use types in Wuqi County are obvious, and the degree of diversification of each township is not different. By calculation, the average diversification index of 12 townships in Wuqi County (the sum of diversification index / number of townships) is 0.58, which has a certain gap with the theoretical maximum value of 0.857 [19], indicating that the degree of diversification of land use types in Wuqi County is in the middle degree. If the diversification level is divided into three levels, less than 0.5 is low level, 0.5-0.57 is middle level, and greater than 0.57 is high level, then the diversification level of Wangwazi township is low level by K cluster analysis. The degree of diversification is moderate, including Wugu Town and Country, Tiebian City and Town and Wucangbao Township; Baibao Town, Zhouwan Town, Miaogou Township, Zhang Guanmiao Township, Wuqi Town, Xinzhai Township, Xue Cha Township and Chang Cheng Township are at high diversification level. From a spatial perspective (Figure 1), the highly diversified areas are mainly concentrated in the northeast and south of Wuqi County, while the northwest of Wuqi County is less diversified. The degree of land use diversification the degree of land use diversification is closely related to the climatic conditions in the area. From south to north, due to the decreasing distribution of precipitation, the more arid the climate, the less land use available, so the less diversity there is. In the northwest of Wuqi County, Wangwazi Township has the most arid climate, so the degree of diversification is the lowest, while the Chang Cheng Township and Zhouwan Town in the northeast area belong to the landform of wind and sand area, and the natural geographical conditions are different from the loess hilly and gully area, and the two villages and towns have developed agriculture and concentrated population, so the degree of diversification is higher.

![Figure 1. The distribution characteristics of diversification index](image-url)
3.2. Centralization of land use structure
The lowest concentration index is -0.16 in Wuqi County, while the highest concentration index is 0.3 in Wangwazi Township. The concentration index of other townships is between -0.08 to 0.19, which indicates that the degree of land use centralization in the whole county is relatively low. This is mainly because the region is located in hilly and gully region of the Loess Plateau, and the landscape fragmentation seriously affects the concentration of land use. The concentration level is divided into three levels, so the concentration is less than or equal to 0 as low level, 0 to 0.20 as middle level, and more than 0.20 as high level, then the concentration degree of Wangwazi Township is high level by K cluster analysis, and the diversification degree is middle level of Wugu Town and Country, Tiebian City and Town and Wucangbao Township; Baibao Town, Zhouwan Town, Miaogou Township, Zhang Guanniao Township, Wuqi Town, Xinzhai Township, Xue Cha Township and Chang Cheng Township are at low concentration level. From a spatial perspective (Figure 2), the concentration index shows a trend of decreasing degree of concentration from north to south. At the same time, it can also be seen intuitively from the spatial analysis map that the township with low diversification index has a higher concentration index, such as the lowest diversification index in Wangwazi Township, and it also has the highest concentration index, which is also due to the most arid local climate and the single land use mode; the township in the southern region has a low degree of concentration because of the good water conditions, the variety of land use types and the better economic development.

![Figure 2. Centralized index distribution](image1)

![Figure 3. Distribution characteristics of combination types](image2)

3.3. Combination type
The number of land use combination types in each township of Wuqi County is uniform, and the overall distribution law is consistent with the geomorphologic type; among them, the maximum number of land use combination types in Changcheng Township and Zhouwan Town is 3, that is, forest land, grassland and cultivated land, and the land use type homogeneity is the highest. From the spatial point of view (Fig. 3), the land use types of the two towns in the northeast of Wuqi County, Changcheng Township and Zhouwan Town, are forestland-grassland-cultivated land combination, and the rest areas are mainly forestland-grassland. This is because since the project of converting farmland to forests and grassland was launched in 1998, policies and measures such as artificial afforestation, mountain closure and grazing prohibition, and grass planting have been implemented. Almost all the
sloping farmland in Wuqi County has been converted into farmland, and forest land and grassland have increased significantly. The Changcheng Township and Zhouwan Town belong to the wind and sand area, so the terrain is relatively flat, and it is the key area of basic farmland construction, therefore, the combination type is forest and grass land-cultivated land combination; while the other villages and towns belong to the loess hilly and gully area, the terrain is relatively broken, and the cultivated land is not concentrated, so it is all forest land-grassland type.

4. Discussion and conclusions

4.1. Discussion

Topographic features, climatic conditions and human activities are the main factors affecting the land use structure of Wuqi County. The large proportion of hills and gullies and the complex topography determine the wide distribution of unused land in Wuqi County and the slow construction of towns. From south to north, due to the increasingly dry climate, water conditions gradually become poor, and land use mode is also gradually reduced. Because of the development of petroleum industry, the construction land in the central region has obvious significance. This study uses the econometric geographical model to analyze the land use structure of Wuqi county in 2009. The diversification index, centralization index and land type combination type play the role of mutual test, so that the results are scientific and have certain applicability to the analysis of the structural characteristics of county land use. The results show that the current land use structure of Wuqi County is reasonable, so it is necessary to continue to reduce the area of unused land, control the area of cultivated land, and promote the construction of ecological restoration and economic development through ecological measures such as converting farmland to forest and grassland and afforestation.

This study only analyzes the land use structure in a certain period of time in the study area, but lacks the change characteristics of the land use structure in multiple periods and the discussion of the spatial and temporal distribution law, which is the problem that should be solved in the future further research.

4.2. Conclusions

Through analyzing the quantitative structure and spatial structure of land use in Wuqi County, the following summary can be drawn:

(1) The quantitative structure analysis of land use shows that the level of diversification in Wuqi County is generally on the middle side, and the level of centralization is low, which indicates that the land use types in Wuqi County are complete and the intensity of human intervention is large.

(2) There is a negative correlation between the concentration index and the diversification index, and the higher the diversification, the lower the degree of land concentration, and the two indexes can be tested against each other.

(3) There are few types of land assemblage in Wuqi County, mainly forestland-grassland, which is the result of the policy of returning farmland to forest and grassland. Of course, the combination type of land use dominated by other types of land, such as agricultural land and construction land, remains to be further explored. It is necessary to strengthen the rational development and utilization of forest land and construction land, and adjust and optimize the structure of land use.

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