A study on spatial configuration change of land use in Beijing suburb from 1993 to 2004 using the centroid model

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Abstract: Beijing, the capital of China, is under high pressures from land use change and inappropriate land management in its suburban counties. The purpose of the paper is to determine the direction and degree of the land use change of different counties in the suburb, which is incurred by typical land use phenomena: expansion of the building-up land by occupying the cultivated land, agriculture-structure-adjustment and reforestation in mountainous counties. The method is to compartmentalize the suburban counties into three types , then select six typical districts (e.g. every district is a solo county in the suburb) from the above types as samples to apply a centroid model to the main land use types in the inventory database in 1993 and 2004. We can find out the obvious displacements of corresponding centroids in the types of land use of the selected samples, explicitly showing that the configurations of land use have been changed in different parts of Beijing suburb. Furthermore, according to directions of the displacements, we can explore some typical patterns, which are driven by the abstraction of Beijing downtown, topography and land use policies as well as other factors. The result will benefit the rational planning and management of suburban land use in Beijing in the future.

Key words: Land use change, spatial configuration, centroid model, displacement, direction, Beijing suburb

1 Introduction

Land use change, being one of the hot foci in global environmental change [1, 2], has been used as one of the base information for decision-making in land use planning and policy at local governments in China. Especially suburban areas of a metropolis, witnessing the fastest urbanization and industrialization process and the most complicated urban-rural land use changes, are the ideal locations for research [3]. Beijing, the capital of China, is under high pressures from land use change and inappropriate land management in its suburban counties. Among the pressures, typical land use phenomena have induced the prominent changes in land use configuration, including expansion of the building-up land by occupying the cultivated land, agriculture-structure-adjustment and reforestation in mountainous counties. According to the above phenomena, we will explore how the configuration of typical land use type changed in Beijing suburb from land use inventory database of samples.

Many works have been carried out on land use change in Beijing district. Many of them pay more attention to driving forces analysis and applying some statistics methods [4-8]. In a spatial view, Wang (2001) and Yang (2005) present a GIS method to study the speed and distribution of land use change in this area with remote sensing data [9, 10]. Additionally, Duan (2004) uses a CLUE-S model to simulate spatial change in Haidian (a county of Beijing suburb) [11]. Due to complex

driving factors in different counties of Beijing suburb, it is difficult to formulate and quantify them in a model. The obvious lack of the former works is that the study district is treated as a whole or an integrated object. Contrary to the above, this paper emphasizes to find how the special land use types change in different parts of this area, e.g. the study district more than one according to their area differentiations.

The international research on land use model has been developed available from different disciplinary backgrounds. However, land use systems are groups of interacting, interdependent parts linked together by exchanges of energy, matter, and information in social, economic, environmental and institutional dimensions. Thus, models that integrate techniques and methods developed in various disciplines would be too complex to be operational, especially for descriptive land use models that aim at simulating the functioning of the land use system and the spatially explicit simulation of near future land use patterns in heterogeneous regions [12-14]. Consequently, simplified spatially explicit models at macro level are also needed.

Thus, this paper uses the centroid model, a method of the appraisal model, to analyze the land use change at macro level. The principle of the model is as follow: there are directly relative between the spatial configuration change of land use and land use type's centroid displacement. Within a period, the general characteristic of land use change in an area is indicated by the displacement of land use type's centroid, which can be calculated by the coordinates of its centroid. [15].

2 Method

The method of the centroid model in this paper is revised lightly. The purpose of the paper is to determine the direction and degree of the changes in land use configurations of different counties in the suburb, which is incurred by typical land use phenomena: expansion of the building-up land by occupying the cultivated land, agriculture-structure-adjustment and reforestation in mountainous counties. The method is to compartmentalize the suburban counties into three types: plain counties near Beijing downtown (PN), plain counties far away from Beijing downtown (PF) and semi-mountainous and mountainous counties far away from Beijing downtown (MF). The distribution of topographical feature in Beijing suburb is obvious, ranging from the plain to semi-mountainous and mountainous with a pattern alike a star. We select six typical districts(including Haidian and Chaoyang in PN, Tongzhou in PF, and Pinggu, Mentougou, Fangshan in MF) as samples to use the centroid model of the typical land use types (e.g. cultivated land, orchard land, forest land and build-up land)in the land use inventory database from 1993 and 2004. Then we can find out the displacements of corresponding centroids of the four types of land use in the selected samples. Some key treatments of the model are as follows.

2.1 Data treatment

For land use administration in China is organized in the county level in practice, local government completely controls the conversion of rural land into build-up land and decision-making in land use planning and policy. Thus, every sample in the paper is a solo county (e.g. an independent district). In this paper, we select land use inventory database as data source. Because the selected six counties from fourteen counties have different original data, some in 1992 and others in 1993, we applied 1993 as the original year of the study and an interpolated calculation was applied to the data in 1992. The terminal year we used in the paper is 2004, when a renewal project for land use planning in Beijing district was completed.

2.2 Land classification

According to typical land use phenomena above, we select cultivated land, orchard land, forest land and build-up land, nearly corresponding to the second level of the classification system in the inventory database in China. Cultivated land refers to the actually land for food supply. Orchard land is defined as land devoted to the cultivation of fruit or nut trees. Forest land denotes the actually land for wood supply and build-up land is the land used for city, town and village as well as industrial area. In the land inventory database, we select polygonal objects of corresponding land use types. Due to the dissimilar of land classification and data type, the land data of this paper is lightly different from that of statistic in authority.

In the selected samples, polygon data has a high proportion in land use inventory (>95%). Furthermore, the centroid coordinates were calculated by a mathematical expression weighted by acreage. The result calculated by the centroid model can stand for the tendency of configuration change in the corresponding land use type.

2.3 The mathematical expressions

This modeling method can obtain the size and direction of the displacement of a land use type in a sample. Additionally, we introduce an index of yearly average changing rate of the land use type as a reference [16].

The coordinates of a centroid can be calculated as follow:

$$X_{jt} = \sum_{i=1}^{n} x_{ji} \cdot A_{ji} \Big/ \sum_{i=1}^{n} A_{ji} \qquad (1)$$

$$Y_{jt} = \sum_{i=1}^{n} y_{ji} \cdot A_{ji} \Big/ \sum_{i=1}^{n} A_{ji} \qquad (2)$$

Where, X_{jt} and Y_{jt} represent the coordinates of centroid of a land use type j in t year and X_{ji} and Y_{ji} represent the coordinates of centroid in the no. i polygon of the land use type. A_{ji} represents the area of the no. i polygon of the land use type. n is the account of polygons in the land use type j.

The displacement can be represented approximately as Euclidean distance, for the distance between the two centroids is less than 10,000 metres. Then the displacement of the land use type is given below:

$$S = \sqrt{(X_{jt2} - X_{jt1})^2 + (Y_{jt2} - Y_{jt1})^2} \qquad (3)$$

In this formula, S represents the displacement of the land use type j between t1 and t2. X_{jt1} ,X_{jt2} ,Y_{jt1} ,Y_{jt2} represent coordinates of the centroid in t1 and t2 year.

Yearly average changing rate of the land use type can be calculated with the expression below:

$$K_j = (A_{jt2} - A_{jt1}) \ / A_{jt1} / (t_2 - t_1) \times 100\% \qquad (4)$$

Obviously, the sign of K_j represents the increase or decrease of the amount in a land use type j. It is noted that this index is very common in land use change analysis and not concretely described in the following, since the focus of the paper is not the analysis of amount statistics in acreage.

2.4 Map visualization

The line between the two centroids of a land type can be visualized in GIS with an arrow showing its direction. The calculation and mapping in the paper were finished by Mapinfo7.0 GIS software.

3 Result

3.1 Yearly average changing rate of the land use type

There are obvious changes of the land use types in the study samples (or units) from 1993 to 2004. According to table 1, we can find out a general tendency: the cultivated land decreasing greatly, the orchard land, forest land and build-up land increasing rapidly. As far as the relation between absolute and relative values is concerned, the cultivated land has been badly decreased in PN and orchard land and forest land in MF greatly increased as well as the mediate degree in PF supported by the original acreage of corresponding land use type.

Table 1 Yearly average changing rate of the land use type

Suburb Partition	The selected units	Cultivated land	Orchard land	Forest land	Build-up land
PN	Chaoyang	-18.5	4.1	0.9	0.9
	Haidian	-15.4	-1.0	7.3	3.6
PF	Tongzhou	-2.9	6.0	0.9	0.9
MF	Pinggu	-8.6	5.5	2.8	2.5
	Mentougou	-35.0	5.7	0.9	0.9
	Fangshan	-6.1	3.4	2.1	2.6

3.2 Spatial configuration change

According to table 2, the centroids in all study units have obvious displacements, cultivated land by 2642.5m, orchard land by 1806.7m, forest land by 2212.9m, and built-up land by 1133.9m. It shows that the spatial configuration in Beijing suburb has changed greatly. The cultivated land with the highest displacement and the build-up land with the lowest displacement indicate that greatly cultivated land occupied have destroyed the former configuration and build-up land have developed with the strong abstraction with the former configuration. And great change variations appear in both land use types and regional partitions.

Table 2. Displacements of the land use types (unit: meters)

Suburb Partition	The selected units	Cultivated land	Orchard land	Forest land	Build-up land
PN	Chaoyang	3338.0	2904.7	2088.8	919.6
	Haidian	2163.8	436.1	1812.9	501.3
PF	Tongzhou	1815.1	1905.1	4464.3	1450.2
MF	Pinggu	3815.0	267.5	941.0	602.9
	Mentougou	3214.1	4820.1	1123.0	718.6
	Fangshan	1508.8	506.9	2847.4	2610.6
	erage displacem	2642.5	1806.7	2212.9	1133.9

Instead of the direction of each displacement, a mapping method is recommended. In the Figure 2-5, we will find out a regulation of land use change in the suburb. The shifting directions of both cultivated land and built-up area in PN were similar, backward to downtown of Beijing, which reflects land occupation during the urbanization of Beijing. However, the centroid of built-up land in another plain county in PF was moved toward to downtown of Beijing, reflecting the proportion of occupying cultivated land smaller than the above two. These results indicate that development of built-up area has occupied a large amount of cultivated land in both near and far suburb of Beijing. Adverse shift directions to orchard land, the centroids of forest land in the three MF had moved down to mountains with largely decreased cultivated land. It is indicated that poor cultivated land in these counties was reformed to forest and orchard land. One of the reasons induced these shifts might be the government new policies on agriculture-structure-adjustment and reforestation in mountainous counties. Analogously, in PN and PF, there is a tendency in the directions of forest displacements: the displacements of forest in Chaoyang and Tongzhou moved toward the Green Belt in the east of Beijing.

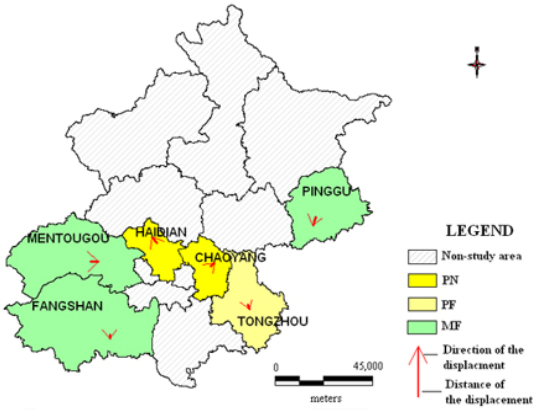

Fig. 1 Displacement of the samples in the cultivated land type from 1993 to 2004

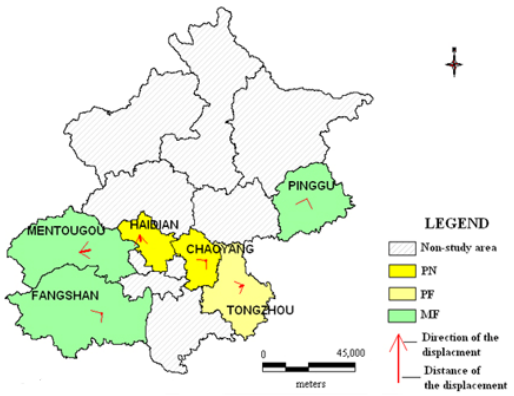

Fig. 2 Displacement of the samples in the orchard land type from 1993 to 2004

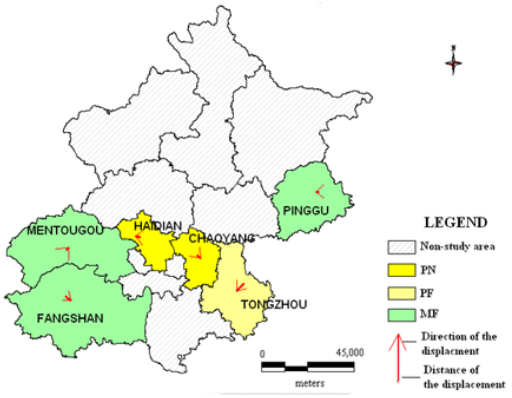

Fig. 3 Displacement of the samples in the forest land type from 1993 to 2004

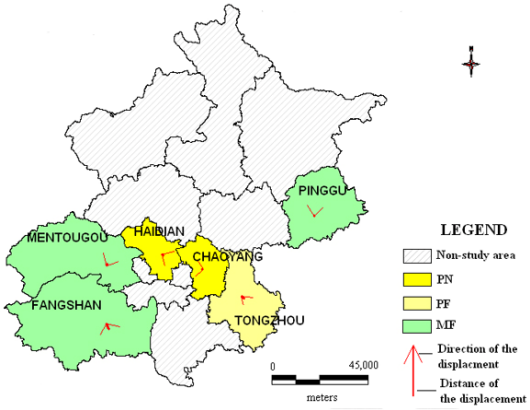

Fig. 4 Displacement of the samples in the build-up land type from 1993 to 2004

4 Discuss

In this paper, we can explicitly find out the rule in spatial configuration change in different parts of Beijing suburb. Here, we focus on the location, topography and policies factors interpreting area differentiations of spatial configuration change in the suburb.

Location factor shown in the paper is that the development of Beijing town does well to its suburb. Whether near or far from Beijing town, the part towards the town of study units, owned the convenience of the traffic and other location factors, has the prominent increase in build-up land with the rapidly decreased cultivated land of high quality mainly distributing on the plain section. The effect of location is also prominent in the semi-mountainous or mountainous region, where the plain part towards Beijing town owns mainly proportion of build-up and cultivated land. There are obvious displacements of build-up and cultivated land due to the above factor.

Topographic effect to the displacement of the land use type in a study unit is prominent in the semi-mountainous or mountainous region, which does benefit for interpreting the evident variations of displacements of the land use types. Except of the distribution of land use types, its effect can also be assumed as shape effect. Mentougou, with a thin and long shape and a largely proportion of the cultivated and build-up land enriching the plain part, has the obvious displacements of the above land use types. Pinggu, with a-semi-ring-like shape and the cultivated and build-up land enrichment in the plain part as the above, has a smaller displacement of the orchard and forest land due to their mainly distribution on the ring part. The case of Fangshan is between the Mentougou and Pinggu.

The policies factor, e.g. the agriculture-structure-adjustment, green capital project and reforest in the mountainous region, also do great effects on the changed configurations of the orchard and forest land. In the semi-mountainous and mountainous region, a great deal of the cultivated land were turned into the orchard and forest land due to agriculture-structure-adjustment and reforest policies, which also induce the destroyed configuration of the cultivated land and its obvious displacement. Simultaneously, the project of green belt in the east of Beijing abstracts the displacement of Chaoyang in PN and Tongzhou in PF.

5 Conclusion

Focusing on the prominent land use problems, a centroid model in Beijing suburb has been clearly proved that the spatial configuration of land use has been changed greatly. Furthermore, according to

directions of the displacements, we can explore some typical patterns, which are driven by the abstraction of Beijing downtown, topography and land use policies as well as other factors.

Furthermore we should take different actions to manage land use in the suburb for the future. Some policies such as agriculture-structure-adjustment and reforestation in mountainous counties and green belt in the plain should be reinforced. But other strategies such as restricting to the expansion of the build-up and preserving the cultivated land should be implemented in all Beijing suburb, especially in the plain parts.

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