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Analysis of Urbanization Based on Center-of-gravity Movement and Characteristics in Songhua River Basin of China and its Southern Source Sub-basin between 1990 and 2010

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Abstract: Urbanization in modern times led to a series of development strategies that brought new opportunities in China. Rapid urbanization caused severe stress to the ecosystems and the environment. Using the center-of-gravity (COG) method and parameters such as population, economy, and land, we studied the urbanization pattern in Songhua River Basin and its southern source sub-basin from 1990 to 2010. Urbanization was analyzed based on the COG position, eccentric distance, movement direction of COG, and distance of COG movement. Various characteristics of urbanization in the southern source sub-basin of the Songhua River were explained in relation to the whole Songhua River Basin. Urbanization in the southern source sub-basin of the Songhua River is balanced, relatively advanced, and stable compared to the whole Songhua River Basin. The average eccentric distance between the urbanization COGs in the Songhua River′s south source basin indicated rapid expansion of land urbanization during the span of this study. A basic pattern of urbanization COG in the whole Songhua Basin was observed, but there existed differences among the three aspects of urbanization process. Land urbanization is still in its active stage, so future studies should focus on analysis of such urbanization trends.

Keywords: urbanization; Songhua River Basin; southern source sub-basin of Songhua River; center of gravity method; eccentric distance

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1 Introduction

With the growth of industrialization, China has been experiencing rapid urbanization since the 1980s. From 1978 to 2013, the urban population increased from 1.7×10^8 to 7.3×10^8 and the urbanization rate increased from 17.9% to 53.7%, with an average increase of 1.02% per year. During this time span, the number of cities in China increased from 193 to 658 and the number of towns increased from 2173 to 20 113 (The State Council, 2014). Urbanization in China has led to other critical impacts such as large population, relative shortage of resources, fragile ecological environment, and unbalanced development between urban and rural areas. China will continue to experience a rapid increase in the urbanization rate of approximately 30% to 70% in the near future. However, this extensive urbanization comes with risks, such as slow industrial growth, resource and environmental deterioration, and increasing social impacts (The State Council, 2014).

There are significant regional differences in societal, economic, and cultural development across China because of the diversity in natural endowments and the influences of policy. There is an increasingly expanding

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volume of literature on agent-based models and simulations in the context of geographic and urban studies (Valbuena *et al*., 2010; Bandini *et al*., 2011). The center-of-gravity (COG) method can clearly and accurately reveal regional differences in development in both time and space; present the direction and balance of national or regional development; and evaluate the effects of policies on regional development (Zhang *et al.*, 2012). The COG method was introduced to China in the early 1980s. This method was combined with geography in social spatial analysis to study China′s population COG and its path of movement from 1912 to 1978 (Li, 1983a) and from 1953 to 1982 (Li, 1983b). The COG method has also been used in economic spatial analysis (Hu, 1987), to discuss the regional migration of China′s economic COG. This method was first applied to industrial spatial analysis, to conduct an in-depth study of the southward COG migration of China′s silk-weaving industry (Li, 1989). The COG method was used in agricultural analysis, and the movement of the grain COG in China was discussed (Guo, 1992); while Lao (1992) analyzed relevant fields from the perspective of industrial COG. However, because of the lack of advanced spatial analysis technology, these studies put particular emphasis on individual and macroscopic aspects.

As computer technology and geographic information systems are widely used these days, the scope of these studies has been expanded to analyze changes in latitude and longitude (Huang and Feng, 2005), migration direction and distance (Yan and Wang, 2010), as well as the angle of migration based on analysis of the COG path (Tian *et al.*, 2013). These results suggests that the COG path research field is expanding, while the depth is being extended from the national level (Lian, 2007) to the provincial (Xu and Yu, 2009) and city levels (Huang and Zhang, 2012). Previous studies have discussed the spatial relationships among population, economy, and industry with regional COG analysis approaches. However, at present, there are only a few studies on social or economic COG in drainage basins. In particular, urbanization-oriented studies utilizing COG methods have rarely been reported. This paper reports the COG movement paths of population, economy and land urbanization in the southern source sub-basin of the Songhua River. By doing this, we can represent the pattern of spatial equilibrium relations and variations in the development of basin urbanization, as well as the change characteristics in the Songhua River Basin. In this study, statistical socio-economic data and remote sensing monitoring data were combined with the powerful spatial analysis software ArcGIS to calculate the indicators of COG.

The Songhua River Basin was one of the earliest urbanized centers in China since the 1950s. However, since the early 1980s, several factors, including the entrenchments under the ′Reform and Opening up Policy′, are responsible for the emerging institutional and structural contradictions among the old industrial bases.

In 2006, the Chinese central government put forth a policy, ′revitalization of the Northeast′s old industrial base′, and carried out a plan for industrial and economic revival in Northeast China. In November 2013, a policy of ′adherence to the new path of urbanization with Chinese characteristics′ was introduced at the third plenary session of the 18th National Congress of the Communist Party of China.

This series of developmental strategies brought in new opportunities for the Songhua River Basin and promoted rapid expansion of towns. However, urbanization adversely affected the surrounding ecosystems and environment. Urban sprawl and the scale and direction of development have received extensive attention from academicians and policymakers. This paper analyzes urbanization of the southern source sub-basin of the Songhua River between 1990 and 2010, based on three aspects: population, economy, and land. The reasons behind the changes in these aspects are discussed in this paper. So these three aspects were also taken into consideration for the whole Songhua River Basin.

2 Materials and Methods

2.1 Site description

The Songhua River Basin (41°42′–51°38′N, 119°52′–132°31′E) is 20 km wide from east to west, and 1070 km long from north to south. The total area of the basin is about 561 200 km^2, accounting for about 60% of the total area of the northeastern China (The Ministry of Water Resources of the People′s Republic of China, 2013). The Changbai Mountains are located in the southeast.

The Songhua River Basin is an important source of commodity grain and cash crops in China (Guan *et al.*, 1995). There are various forest resources and products

and abundant mineral reserves in the basin, which is the largest forested region in China. The Songhua River Basin has a long history of industrial development and is an example of the metropolis-centered development pattern (Lu and Ju, 2007). With the rise in economic globalization and strengthening of regional economic cooperation based on geographical relationships, the Songhua River Basin is going to play an important role in the economic development of Northeast Asia and in economic exchange in Northeast China.

As one of the sub-basins of the Songhua River Basin, the southern source sub-basin accounts for 14.33% of the total drainage area of the Songhua River Basin and supplies 39% of the water for the Songhua River. The southern source originates from Tianchi (Lake of Heaven) near the main peak of Changbai Mountains and flows northwestward through 14 counties and cities. Its annual average runoff and precipitation are 81.9 m^3/s and 800–1000 mm, respectively. It is an important river in the Jilin Province.

This paper describes the urbanization of the whole Songhua River Basin and its southern source sub-basin (Fig. 1), based on the above-mentioned regional natural conditions and socio-economic development background, over a period of 20 years. In this study, county-level administrative regions were regarded as the minimum research units, and Jilin Province, Heilongjiang Province and eastern Inner Mongolia were included. The statistical data used in this study focused on five particular years (1990, 1995, 2000, 2005, and 2010) as reported in *Statistical Yearbook of Jilin*, *Statistical Yearbook of Heilongjiang*, and *Statistical Yearbook of Inner Mongolia* (Jilin Province Statistics Bureau, 1990, 1995, 2000, 2005 and 2010; Heilongjiang Province Statistics Bureau, 1990, 1995, 2000, 2005 and 2010; Inner Mongolia Autonomous Region Statistics Bureau, 1990, 1995, 2000, 2005 and 2010).

2.2 Research method

2.2.1 Indicators of urbanization

To understand the evolution of COG paths in the urbanization of the Songhua River Basin, we employed simple indicators to represent different aspects of urbanization development, instead of modeling a complex system. This study defines the characteristics of urbanization based on three aspects: population, economy, and land; and utilizes different understandings of the connotation of urbanization (Chen, 2008). Of these, population urbanization is the main aspect because it shows the process of population transfer in economic activities.

In this study, the proportion of non-agricultural population to the total population represents population urbanization. Urbanization increased economic performance across the entire socio-economic spectrum in the urban areas. The increased output reflects an increase in the economic aggregate and in the non-agricultural economic sector. The contribution of output from secondary and tertiary industries to the GDP

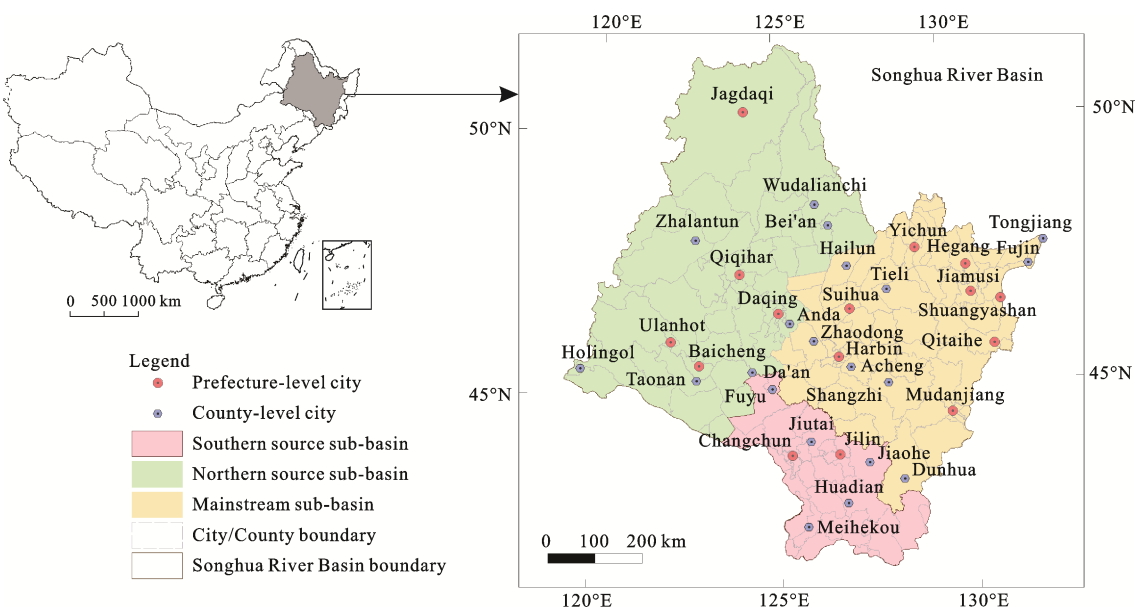

Fig. 1 Geographical location of Songhua River Basin and its sub-basins

represents economy urbanization. Land urbanization shows an increase in urban lands, represented by the proportion of urban land area to the total area. These indicators were calculated as follows:

$$p_1 = \frac{P^*}{P} \tag{1}$$

$$p_2 = \frac{V_2 + V_3}{GDP} \tag{2}$$

$$p_3 = \frac{A^*}{A} \tag{3}$$

where urbanization attributes for each administrative unit are defined for p_1 (population urbanization), p_2 (economy urbanization), and p_3 (land urbanization); P is total population and P^* is non-agricultural population; V_2 and V_3 are secondary and tertiary industrial output, respectively; A is the total area and A^* is urban area.

2.2.2 COG path

The concept of COG originated from mechanics. It refers to the point of action at which a resultant force is generated from gravity borne by all parts of the object. This point of action is called the geometric COG when applied in spatial mathematical statistics (or the geometric center in a regular polygon). When the average of a spatial phenomenon is significantly different from the geometric COG, it indicates a non-equilibrium spatial distribution of that phenomenon.

In a region with several subordinate administrative districts, the COG calculations for a property are usually expressed by the characteristics and geographical coordinates of its subordinate administrative districts. Given that a region consists of n subordinate regions (or mass points), where the coordinates of the geometric COG of the ith subordinate region are (x_i, y_i), and P_i is the value (or mass) of any property in the subordinate region, then the geographical coordinates of the property′s COG are as follows:

$$\bar{x} = \frac{\sum_{i=1}^{n} p_i x_i}{\sum_{i=1}^{n} p_i}, \bar{y} = \frac{\sum_{i=1}^{n} p_i y_i}{\sum_{i=1}^{n} p_i} \tag{4}$$

With respect to calculation methods, only two factors determine the position of the COG: the geographic position and the value of the property for all districts. In our study, based on the assumption that the geographic position of the geometric COG of all subordinate administrative districts remained unchanged, the change of COG reflected the change of the property that it represents. Because there are regional and inter-annual differences in the speed and level of population, economy, and land urbanization, the change in urbanization of any county would affect the position of the urbanization COG. In other words, the COGs for population, economy, and land urbanization (as properties) are dynamic processes, and a movement path of the COG would be formed during a time period (Feng and Huang, 2005).

In this study, ArcGIS 10.2 and the Geographic Coordinate System CGCS_2000 were used. The following data were integrated to form the COG paths for population, economy and land urbanization in the various basins: extracted coordinates for geometric COG for all minimum research units; the rate of population, economy, and land urbanization in all counties of the Songhua River Basin from statistical data; and the geographic information. This was performed for the northern source sub-basin of the Songhua River, the southern source sub-basin of the Songhua River, the main stream sub-basin, and the entire Songhua River Basin. The COG paths were analyzed with respect to the following four aspects (Wang, 2009).

2.2.2.1 COG position

COG position refers to the spatial position of the scatter distribution area of the urbanization COG in the basin relative to the geometric COG. It can provide a preliminary estimate of the overall development level of urbanization in all regions of the basin.

2.2.2.2 Eccentric distance

Eccentric distance refers to the linear distance between the COG position for all representative urbanized properties, and the geometric COG. It reflects the equilibrium level of urbanization and the differences between regional urbanization levels. In addition, it can be used to predict changes in the differences of urbanization levels among all regions in the basin.

2.2.2.3 Movement direction of COG

Movement direction of COG refers to the angle between the line connecting urbanization COGs in two particular adjacent years and the True North (The angle takes True North as the reference direction. Clockwise rotation is regarded as positive and counterclockwise rotation as negative). This variable can determine the location of major spatial distributions that cause changes in urbanization equilibrium, and can infer the centripetal or cen-

trifugal tendency of overall COG movement based on the average movement direction.

2.2.2.4 Movement distance of COG

Movement distance of COG refers to the linear distance between the urbanization COGs in two adjacent years. It reflects the degree of variance in regional urbanization, and can be used to analyze whether regional urbanization is in a stable or an active stage.

3 Results

3.1 Analysis of movement trajectory of urbanization COGs in river basin

3.1.1 Movement trajectory of urbanization COGs throughout Songhua River Basin from 1990 to 2010

The urbanization COGs for population, economy, and land throughout the Songhua River Basin were all distributed close to Harbin (Fig. 2). Eccentric distance increased successively, indicating the high level of urbanization development in the Songhua River Basin, while simultaneously highlighting the regional urbanization gap in the basin: population urbanization < economy urbanization < land urbanization.

Since 1990, the COG of population urbanization in the Songhua River Basin has moved steadily to the northeast. The rate of movement has fluctuated, peaking at 10.41 km from 2000 to 2005. Overall, the population urbanization COG has been relatively active.

From 1990 to 2010, the COG of economy urbanization has moved generally to the southwest. The minimum movement was 0.43 km from 1990 to 1995. This indicates that the level of development of economy urbanization did not change significantly in those years. The distance moved in the three 5-year stages afterward exhibited high levels, indicating that highly centralized industry is developing rapidly in the basin, and there is greater energy in the economic development of the basin as a whole.

The COG of land urbanization moved generally west-northwest from 1990 to 2010, changing direction several times. The movement distance was greater in the earlier part of the study period. The absolute value of movement distance for land urbanization is higher than that for population and economy, indicating that the land urbanization process is active throughout the basin. Cities in the western part of the basin are undergoing more gradual urbanization than are cities in the eastern part of the basin.

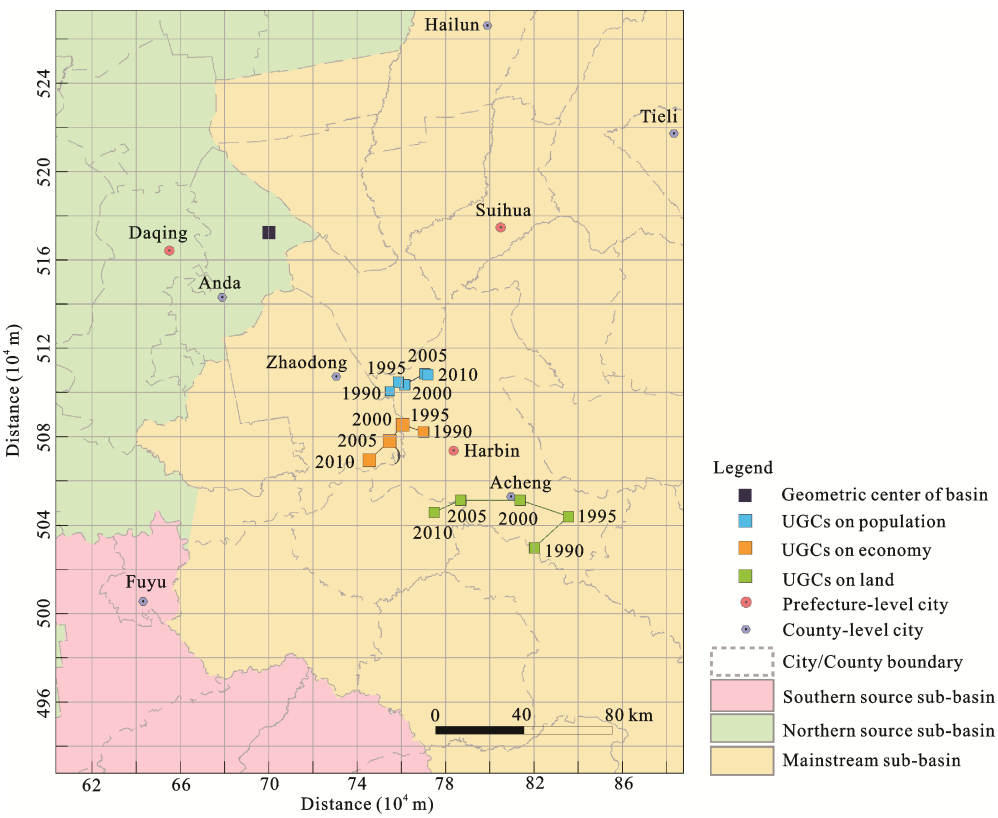

Fig. 2 Movements of urbanization COGs in Songhua River Basin

Eccentric distances for the COGs of population and economy urbanization throughout the Songhua River Basin were generally stable, with only slight fluctuations from 1995 to 2000 (Fig. 3). This indicates that the overall development levels for population and economy urbanization in the Songhua River Basin were stable, with no significant differences. The eccentric distance for the COG of land urbanization significantly decreased during the time span of this study, indicating that differences in the development level of land urbanization are becoming narrower. The COGs for population and economy urbanization showed no obvious centripetal or centrifugal movement during the study period; these centers moved around the geometric COG. However, the COG for land urbanization exhibited large centripetal movement, showing changes in the urbanization and development pattern in the basin, and decreasing differences between the northwestern and southeastern areas.

3.1.2 Movement trajectory of COGs of urbanization in basin of southern source sub-basin from 1990 to 2010

Figure 4 shows that the COGs for population and economy urbanization were distributed southeast of the geometric COG in the southern source sub-basin, indicating that the level of population and economy urbanization was higher in the southeast than in the northwest. The eccentric distance of the population COG was greater than that of the economic COG (Fig. 5), indicating that in the southern source sub-basin of the Songhua River, the difference in population urbanization was greater than that of economy urbanization. The COG for land urbanization was located northwest of the geometric COG, and the eccentric distance for this COG was greater than that for population or economic COGs, indicating that land urbanization (construction and development) was concentrated in the northwest region of the southern source sub-basin of the Songhua River.

The COG for population urbanization in the southern source sub-basin of the Songhua River showed a general northwestward movement. From 2000 to 2010, the movement distance has significantly decreased. The movement distance was only 0.84 km from 2005 to 2010, indicating that the regional population urbanization level is close to stabilization.

The COG for economy urbanization also continued to move to the northwest during the study period. The movement distance showed an overall decrease, indicating a dynamic economic process. COGs for population and economy urbanization generally moved toward the geometric COG, indicating that the differences in population and economy urbanization levels were shrinking in all directions. From 1990 to 2000, the COG for land urbanization moved northwest by nearly 50 km, and from 2000 to 2010 it moved slowly to the southwest. The apparent centrifugal movement reflected the active expansion of land urbanization in the northwest. As movement directions of the COGs for population, economy, and land urbanization are all to the northwest, the northwestern part of the southern source sub-basin of the Songhua River seems to be a key area to the development of urbanization in the last 20 years.

The eccentric distances for urbanization changed over time in the southern source sub-basin of the Songhua River (Fig. 5), showing that the population and economy urbanization COG eccentric distances have generally

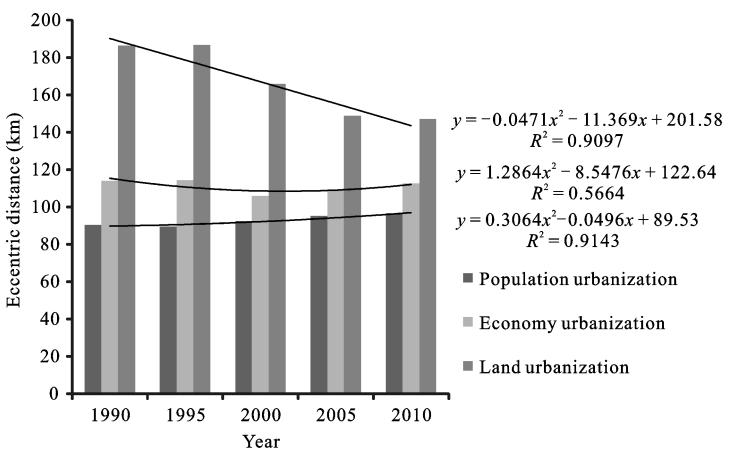

Fig. 3 Eccentric distances of urbanization COGs in Songhua River Basin

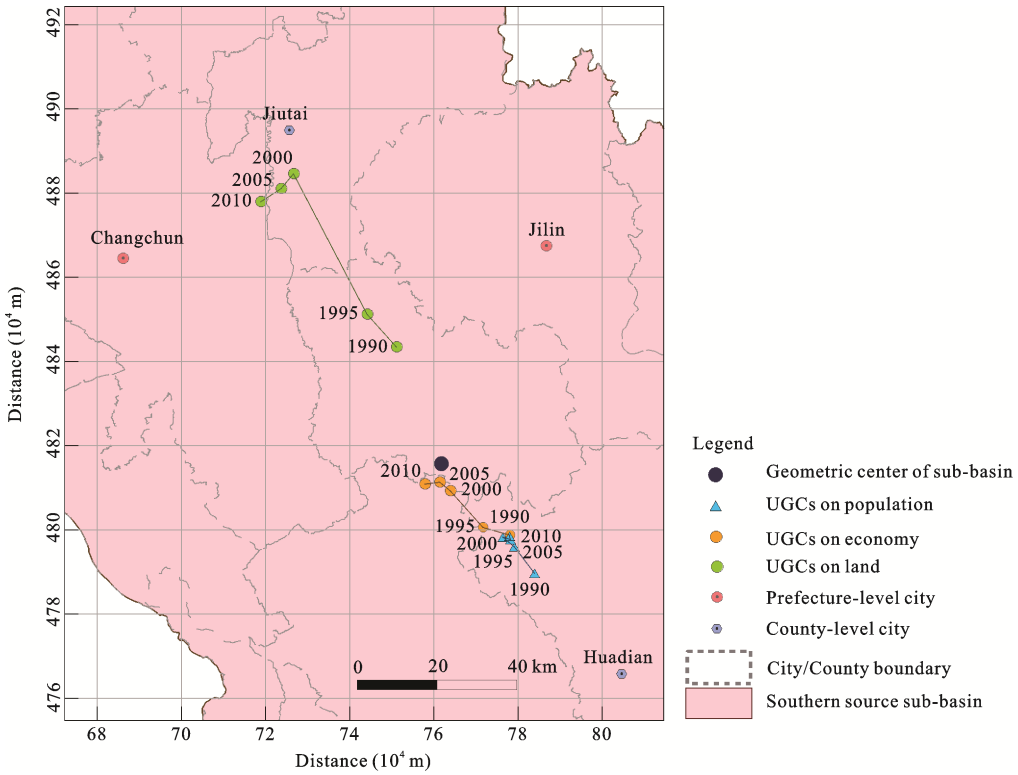

Fig. 4 Movements of urbanization COGs in southern source sub-basin of Songhua River

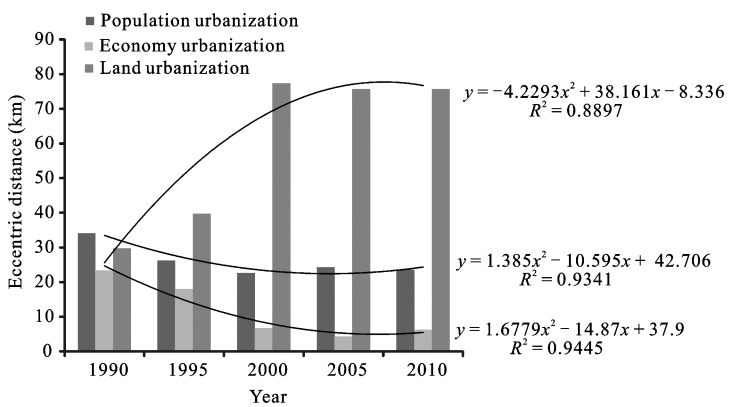

Fig. 5 Eccentric distances of urbanization COGs in southern source sub-basin of Songhua River

decreased since 1990, and population urbanization has a pronounced decreasing trend. The values of the eccentric distances for urbanization indicate that the level of economy urbanization in every region has reached its equilibrium. The eccentric distance for the land urbanization COG increased during the study period, especially in 1995 to 2000. Recent land urbanization levels have shown remarkable regional differences in the southern source sub-basin. The change in eccentric distance of urbanization COGs was found to be stable from 2000 to 2010, suggesting that changes in regional differences of urbanization in the southern source sub-basin had eased.

3.2 Evolution of southern source sub-basin urbanization COG trajectories relative to evolution paths of whole basin

The urbanization COG movement trajectories of the southern source sub-basin of the Songhua River and their effects on the distribution and change of population, economy, and land urbanization COG trajectories of the Songhua River Basin as a whole are analyzed in the following sections.

3.2.1 COG position

The population, economy, and land urbanization COGs in the Songhua River Basin were all located in southeast

of the geometric COG, indicating that urbanization levels to the east and south of the geometric COG were higher than those in the northwest, and that urbanization levels to the east and south of the geometric COG had strong impacts on the entire basin. The southern source sub-basin of the Songhua River is located in the southeastern Songhua River Basin, suggesting that this area played an important role in the development of urbanization for the whole Songhua River Basin.

The population urbanization COG of the southern source sub-basin was located in southeast of the geometric COG of this sub-basin; whereas the economy urbanization COG was located in south of its geometric COG. The land urbanization center was located in northwest of its geometric COG.

3.2.2 Eccentric distance

Figure 6 shows a comparison of the average eccentric distances of urbanization COGs in the southern source sub-basin of the Songhua River to those of the whole Songhua River Basin. The average eccentric distances of the urbanization COGs in the southern source sub-basin were found to be far smaller than those in the entire basin, indicating that differences in the level of urbanization between the sub-basins of the Songhua River Basin were quite large. This might have led to a high level of imbalance in development of urbanization throughout the whole basin, although development of urbanization in the southern source sub-basin of the Songhua River was relatively balanced.

The average eccentric distances for the population and economy urbanization COGs were similar in the southern source sub-basin of the Songhua River and the whole basin, and both were smaller than the average eccentric distance of land urbanization COGs. This indicates rapid land urbanization expansion in both the basins during the period of this study. Compared with the whole basin, the development of economy and population urbanization in the southern source sub-basin was more balanced.

3.2.3 Movement direction of COG

As shown in Fig. 7, for the whole Songhua River Basin the average direction of movement for the economy COG was southwest, for the land COG was northwest, and for the population COG was northeast. In contrast, the average movement directions in the southern source sub-basin of the Songhua River were all towards the northwest. It is evident that although the average movement directions of land urbanization COGs were similar in the southern source sub-basin of the Songhua River and the entire basin, the average movement directions of the economic and population urbanization COGs were different.

3.2.4 Distance of COG

As shown in Fig. 8, the cumulative movement distances for population, economy, and land urbanization COGs in the southern source sub-basin of the Songhua River were small, indicating that urbanization development in this basin was relatively stable, influencing the primary pattern of urbanization COGs for the whole basin. The cumulative movement distances of the three aspects of urbanization in the southern source sub-basin, and in the whole Songhua River Basin, were characterized by: population urbanization < economy urbanization < land urbanization, showing that population urbanization has reached a relatively stable stage, economy urbanization ranks second, and land urbanization is still in the active stage. Expansion of regional land urbanization was quite extensive.

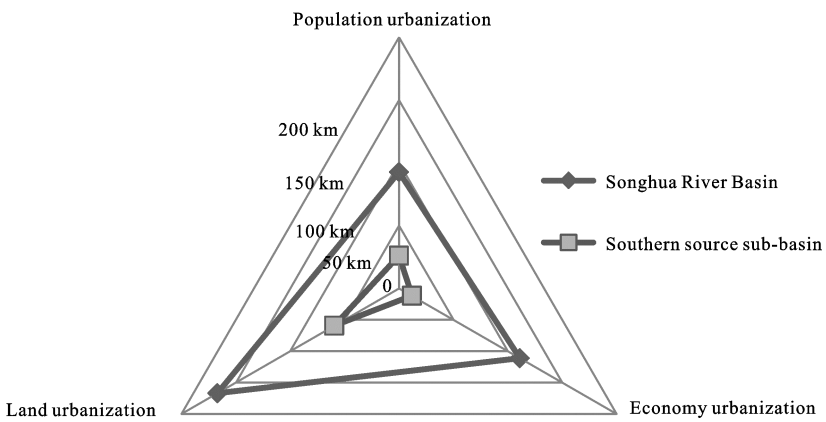

Fig. 6 Average eccentric distances of urbanization COGs

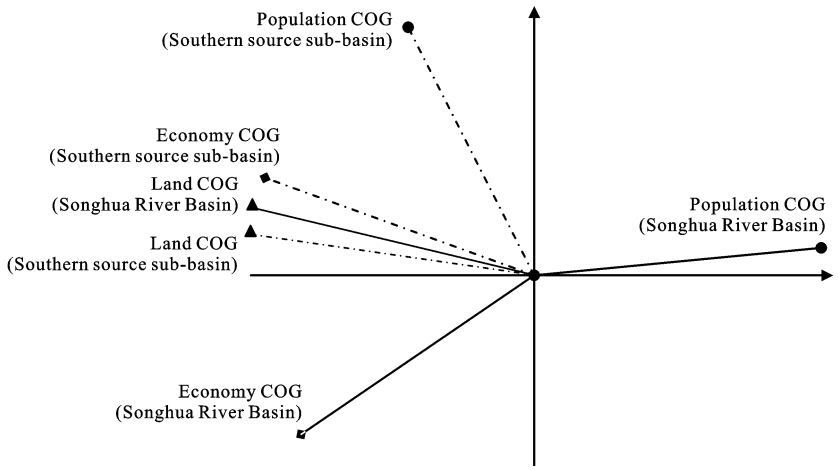

Fig. 7 Average directions of urbanization COG movements in southern source sub-basin of Songhua River and in whole river basin

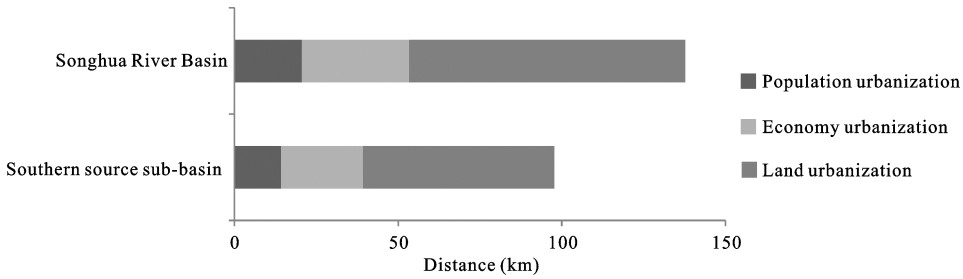

Fig. 8 Cumulative movement distances of urbanization COGs in southern source sub-basinr and whole river basin

4 Discussion

4.1 Pattern of urbanization in Songhua River Basin and southern source sub-basin

In 1933, German geographer Walter Christaller proposed the Central Place Theory (Wang, 2009). Wang explained the theory in terms of: 1) the geometric COG, which is the equilibrium point of a region; 2) the core city, which is the area with the highest function and is responsible for regional values; and 3) the group focus area, which is the optimum point for centrality of all secondary urban areas and for regional equilibrium.

Following the principle of urban first-degree evaluation (Lei and Kang, 2010), the non-agricultural population, the outputs of secondary and tertiary industries, and the urbanized areas were analyzed in the whole Songhua River Basin. Changchun was identified as the core for the southern source sub-basin, and Harbin was identified as the core for the whole basin. These results have been verified in Feng′s (2010) study of the northeast region.

Figure 9 shows the basin urbanization pattern classification based on the above analysis of urbanization COG movement trajectories and on an understanding of the connotation of the core, core cities in the basin, and the calculated COGs of urbanization for the area. The core city was referred to as ′Core′ and the urbanization COG was referred to as ′Center′.

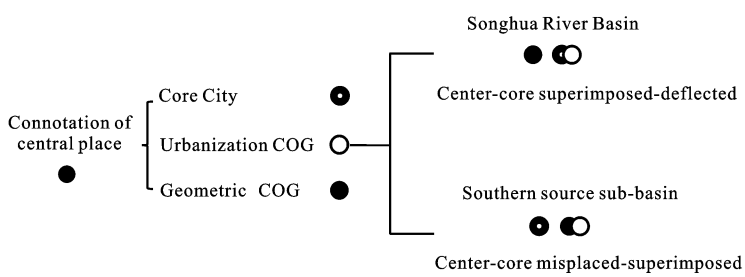

Fig. 9 Classification of urbanization patterns based on Central Place Theory

(1) The urbanization pattern of the southern source sub-basin of the Songhua River shows that the core city of Changchun and the COG of urbanization are offset, as it is shown on Fig. 4. The COG of urbanization is superimposed on the geometric COG, which shows that urbanization in this basin is balanced to a high degree and the core city′s control of the COG of urbanization is not obvious.

(2) The urbanization pattern of the whole Songhua River Basin shows that the COG for urbanization in the Songhua River Basin is superimposed on Harbin, which is the core city of the whole river basin. These two points deviate from the geometric COG. This indicates that the core city strongly controls the urbanization pattern of the whole basin. This is in acceptance with the spatial development pattern expressed by the Central Place model.

4.2 Development model of the Songhua River Basin and southern source sub-basin

In urbanization, the three aspects of population, economy, and land are relatively independent, although there is interaction between the three. Following the improved three-dimensional equivalence model built by Bian *et al.* (2013), urbanization development patterns were classified based on the relative magnitude of the three urbanization aspects (Table 1). The relationships of the relative levels of the three urbanization dimensions in a research area can be expressed by an equilateral triangle in two dimensions. The closer a point is to its corresponding side, the higher the degree of urbanization.

Table 2 shows the ratios of various urbanization rates for the southern source sub-basin of the Songhua River to those of the whole river basin, and indicates the relative relationships of the three aspects of urbanization in which the speed of urbanization is reflected.

Table 1 Urbanization development patterns based on three-dimensional equivalence model

Classification	State
Ⅰ	Population urbanization > Economy urbanization > Land urbanization
Ⅱ	Population urbanization > Land urbanization > Economy urbanization
Ⅲ	Economy urbanization > Population urbanization > Land urbanization
Ⅳ	Economy urbanization > Land urbanization > Population urbanization
Ⅴ	Land urbanization > Population urbanization > Economy urbanization
Ⅵ	Land urbanization > Economy urbanization > Population urbanization

Table 2 Ratios of urbanization rates for southern source sub-basinr to whole river basin

Year	Population urbanization	Economy urbanization	Land urbanization
1990	1.010	1.008	1.641
1995	1.014	1.054	1.569
2000	1.043	1.016	1.629
2005	1.030	1.038	1.755
2010	1.048	1.051	2.018

From 1990 to 2010, the urbanization development pattern of the southern source sub-basin alternated between types Ⅴ and Ⅵ, indicating that land urbanization was the forerunner of the urbanization process in this basin. Development areas, new districts, and industrial parks were representative activities. Economic and population structure adjustments were driven by land urbanization investments (Fan and Zhao, 2012).

5 Conclusions

(1) The COG evolution characteristics reveal the development process and characteristics of urbanization in the southern source sub-basin of the Songhua River, based on the three aspects of population, economy, and land.

(2) Population, economic, and overall urbanization in the southern source sub-basin of the Songhua River is advanced. This has had a strong impact on the COGs of urbanization throughout the Songhua River Basin. Urbanization has reached a balance for each of the three aspects (population, economy, and land) in the southern source sub-basin of the Songhua River.

(3) Land expansion of cities in the northwestern Second Songhua River Basin is quite active, and this is the key area of urbanization in this basin. Urbanization of land is becoming more pronounced in the southeastern part of the southern source sub-basin of the Songhua River. The northwestern cities such as Jilin and Changchun, with their large flat terrain advantage and urban development history, are gaining higher background values of urbanization. In addition, from 1990 to 2010, Jilin Province promoted major administrative changes, summarized by slogans such as ′from county to city′ and ′from custody to governing directly′ to promote the

transformation to urban land development in the northwestern region.

(4) Urbanization in the southern source sub-basin of the Songhua River is more stable than whole Songhua River Basin, and has influenced the basic pattern of urbanization COG for the entire Songhua River Basin. However, there are differences among the three aspects of the urbanization process. Population urbanization is most stable, economy urbanization ranks second, and land urbanization is still in an active stage.

(5) Urbanization of the whole Songhua River Basin is unbalanced because of significant differences in urbanization levels between the sub-basins, although it shows steady development. The directions of movement of the COGs for population, economy, and land urbanization are different, because there is a lag in the movement of the centers owing to the different rates of development.

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