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By using digitized land use maps of Beijing in 1982, 1992 and 1997 and employing GIS spatial analysis techniques, thi s paper conducts an empirical study on the spatial differentiation and spatial patterns of urban land use growth in B eijing in the period of 1982-1997. It is observed that urban land use growth in Beijing went beyond the control of ur ban planning, in terms of the extraordinary high growth rate and undesired spatial pattern. The rate of urban expansi on after 1982, which was predominated by growth of industrial land, was extraordinary high compared to its historica l period. While its growth centers have been actively shifting toward the northern part, rather than toward the south ern and eastern parts as designated by the latest General Plan (1991-2010) of Beijing, its spatial pattern of urban l and use growth in general was in distinct concentric sprawl, which seriously violated the General Plan of Beijing.

Spatial patterns of urban land use growth in Beijing LIU Shenghe1, Sylvia Prieler2, LI Xiubin1 (1. Inst. of Geographi c Sciences and Natural Resources Research, CAS, Beijing 100101, China; 2. International Institute for Applied System Analysis, A-2361 Laxenburg, Austria) Abstract: By using digitized land use maps of Beijing in 1982, 1992 and 1997 an d employing GIS spatial analysis techniques, this paper conducts an empirical study on the spatial differentiation an d spatial patterns of urban land use growth in Beijing in the period of 1982-1997. It is observed that urban land us e growth in Beijing went beyond the control of urban planning, in terms of the extraordinary high growth rate and und esired spatial pattern. The rate of urban expansion after 1982, which was predominated by growth of industrial land, was extraordinary high compared to its historical period. While its growth centers have been actively shifting towar d the northern part, rather than toward the southern and eastern parts as designated by the latest General Plan (199 1-2010) of Beijing, its spatial pattern of urban land use growth in general was in distinct concentric sprawl, which seriously violated the General Plan of Beijing. Key words: urban land use; spatial differentiation; growth pattern; G IS; Beijing CLC number: F299.2 1 Introduction Urban land use expansion is driven by population growth, social and eco nomic development. It has always been the focus of academic research as well as social and economic debates because l and use growth entails high profitability and risk in economic aspect, impacts and conflicts in social and political aspect, and huge consumption of cultivated land with serious negative externalities on environmental sustainability (Bourne, 1996; Fischel, 1982; Peiser, 1989). The spatial patterns and dynamic mechanisms of urban land use growth in the western industrialized countries have been well explored and documented in multi-disciplinary schools such as hum an ecology, spatial economics, social behavior and political economics (Liu et al., 2001). China has experienced rapi d urban growth since its economic reforms. From 1980 to 1998, the number of designed cities in China increased from 2 23 to 668 and urban population from 191 million to 379 million (NBS, 2000). Correspondingly, land area occupied by ur ban development has been expanding significantly (Shi, 2000; Yeh and Li, 1998). Considering that China is among the n ations with the lowest per capita land resources in the world, severe agricultural land loss caused by unplanned rapi d urban growth would certainly bring about significant impacts on its future sustainable development and food securit y (Hong and Li, 2000). There have been extensive discussions in and outside China regarding the potential of the coun try to feed its growing population (Brown, 1995; Heilig, 1997). The contradiction between urban land use growth and t he conservation of agricultural land is bound to become more and more intensive. In order to keep the balance and to realize sustainable development, urban land use growth has to be controlled and managed smartly. Apparently, studies on monitoring and modeling urban growth are urgently needed in the Chinese context. But due to the lack of data avail ability and the complexity of its dynamic system, the spatial patterns and dynamic mechanisms of urban growth in Chin

a are still rarely documented and understood. By using detailed land use maps of Beijing in 1982, 1992 and 1997 and e mploying GIS-based spatial analysis techniques, this paper conducts historical-morphological and spatial clustering a nalyses on urban land use changes in Beijing, aiming to explore the spatial-temporal regularities and patterns of urb an land use growth in Beijing and to make several contributions to fill this knowledge gap. The rest of the paper is organized as follows. After a brief introduction of the study area and data sources, the quantity and rate of urban l and use growth are presented. Further we conduct detailed analyses on the spatial differentiation of urban land use g rowth in the periods of 1982-1992 and 1992-1997, and then summarize the spatial patterns of urban land use growth. Co ncluding remarks form the final section. 2 Study area and data sources Beijing is the national political capital wit h a total population of more than 12 million. Between 1982 and 1997, the average annual growth rate of the total popu lation and GDP (Gross Domestic Product) for the whole Beijing Municipalized area (16,800 km2) is 1.1% and 10.7% respe ctively. In this 15-year period the per capita living floor space in Beijing increased from 5.38 m2 to 9.49 m2. Our c ase study area in Beijing municipality extends from 39o40´-40o20´N and 116o00´-117 o00´E, including the whole areas o f the Central Urban District, four suburban districts and one rural county (Shunyi County) and parts of other eight s uburban districts and counties. The case study region covers in total an area of 5752 km2, this is approximately 34% of the whole Beijing Municipalized area. It has been the main target area of urban land use growth due to its advanta geous location and plain landscape. In the period of 1982-1992, about 92% of new urban land use development of the wh ole Beijing Municipalized area was allocated in this area. Digital land use data for the Beijing case are derived fro m land use maps of Beijing for the years 1982, 1992 and 1997 with a scale of 1:100,000, produced by the Beijing Munic ipal Land Resources Management Bureau. They were respectively mapped in the first land use survey in 1982, the detail ed land use survey in 1992 and the renewed land use survey in 1997. Urban land use in this paper is defined as the to tal built-up area for urban use, excluding rural resettlements. Urban land use is subdivided into three categories: t he residential and commercial land, industrial land and other urban land. 3 Quantity and rate of urban land use growt h Tables 1 and 2 summarize urban land use statistics and their growth characteristics derived from the three digitize d land use maps for the years 1982, 1992 and 1997. First, the expansion of urban land use was extraordinary high, esp ecially in the period of 1982-1992. Over the 15-year period 1982-1997, the total urban land use more than doubled fro m 384 km2 in 1982 to 1000 km2 in 1997. The average annual growth rate was 38.35 km2 between the first 10 years and th en slowed down to 29.84 km2 for the last five-year period 1992 to 1997. In percentage terms this means an average ann ual growth rate of 8% for the first period and 3% for the second. They were extraordinary high in comparison with th e historical growth rates of urban land use in planned urban area (The planned urban area designated by the Master Ge neral Plan of Beijing, is a bit smaller than our study area. However, considering that the majority of urban developm ent was concentrated in the planned urban area before 1982, we think the annual growth rate of urban land use in the planned urban area before 1982 is still comparable with that in our study area), which was 1.43 km2 per year in the p eriod of 1949-1951, 13.62 km2 per year in the period of 1951-1959 and 6.26 km2 per year in the period of 1959-1983 (G an, 1990; Yu, 1986) (Figure 1). The urban land expansion (Liu et al., 2000) is apparently mostly driven by growth in industrial land area especially in the last five years, which is quite different from the general Western urban growt h model driven by residential expansion. Between 1982 and 1992 some 65% of the overall urban land use growth was due to expansion of industrial land compared to 22% residential and 13% other urban land. During the five years 1992 to 1 997 as much as 80% of the urban land expansion was due to growth in industrial land areas (Table 2). While the share of industrial land in total urban land was 27% in 1982, it increased steadily to 50% in 1997, becoming the most impor tant element in urban land use structure (Table 1). The rapid expansion of industrial land in Beijing is primarily dr iven by the growth of land development for TVEs (township and village enterprises), establishment of EIDZs (Economic and Industrial Development Zones) and outer-shift relocation of industrial enterprises jointly. The outer-shift reloc ation of industrial enterprises from the central urban district has been encouraged by the Beijing Municipal Governme nt since the 1980s and has been accelerated after the introduction of the paid-fee land use system. Because it is con sistent with the locational law of urban land economy and would promote the urban industrial structure transformatio n. Up to the end of 1995, there were 201 established or planned Economic Development Zones (EDZ) or Industrial Develo pment Zones (IDE). According to their development plans, a total of 213 km2 land would be occupied. However, a large portion of those EDZs or IDEs did not experience substantial development and were left idle (BLRMB, 1997). Further, T VE developments on collectively-owned land have kept expanding rapidly and are very important. According to the detai led land use investigation data conducted by the Beijing Municipal Land Management Bureau in 1992, the total area of land development for TVEs is 244 km2, accounting for 44% of the total industrial land in the whole municipal region (BLRMB, 1997). Further, it is identified that the industrial land growth did not significantly respond to the centra

l government´s growth control policies as effective as residential land development. In the first growth period of 19 82-1992, the average annual growth rate was 8.28 km2 for residential land development and 24.90 km2 for industrial la nd. Since 1993 a series of growth control and cultivated land conservation policies has been continuously issued and adopted by China´s government agencies, therefore, the average annual growth rate for residential land development de clined by 59% to 3.4 km2 per year in the second growth period of 1992-1997. However, the average annual growth rate f or industrial land development in the second growth period of 1992-1997 was 24.08 km2, showing the same growth trend as in the first period. The constant rapid expansion of industrial land demonstrates that its dynamic mechanisms are not yet properly conceptualized and managed by current growth control policies because land development on rural coll ectively-owned land was excluded. 4 Spatial differentiation and spatial patterns of urban land use growth 4.1 Measuri ng the spatial differentiation of urban growth In order to explore and understand the spatial features and trends of urban land use growth among different urban environments in multiply temporal periods, it is essential to develop som e kinds of comparable and comprehensive indicators of development (Murbandy, 2001). The most commonly-used indicator for describing the spatial differentiation of urban growth in current literatures in China is to compare the annual u rban growth area, i.e., the area of new urban development divided by the temporal units, among different orientation sectors (Fan and Cheng, 1997; Yu, 1986; Zong and Tang, 1999). This indicator is straightforward and simple but is str ictly speaking not comparable due to the unequal areas of different orientation sectors. Shi and He (2001) proposed a n indicator of intensity index, which is the average annual proportion of new urban development to the area of non-ur ban land in the initial year. However, the disadvantages of this indicator are overestimates in the suburbs where th e areas of non-urban land in the initial year are very small, and of underestimates where the areas of non-urban lan d in the initial year are rather big. The indicator we propose for our case study of Beijing is the Average Annual Gr owth Index (AAGI). It does not show any of the shortcomings mentioned above. AAGI of a spatial unit is defined as th e average annual proportion of new urban development to its total area. In fact, it is the average annual growth are a standardized by the total area of the specific spatial unit. AAGI(i, (t, t+n)) = (Ui, t+n - Ui, t)*100 / Ai / n AAG I(i, (t, t+n)), -- the average annual growth index of spatial unit i at the growth period of t to t+n year. Ui, t, U i, t+n -- the areas of urban land use at the starting year t and end year of t+n of the growth period Ai -- the tota l area of spatial unit i Using the township-level boundary polygons of Beijing as basic spatial units (155 in tota l), we calculate for each of the two growth periods, 1982-1992 and 1992-1997, the AAGIs of urban land use and its tw o main components, residential land and industrial land. Further we classify the resulting 155 AAGIs in the period 19 82-1992 into five types of spatial differentiation characteristics using the "natural breaks" classification method p rovided with a GIS. This method identifies breakpoints between classes using a statistical formula (Jenk´s optimizati on). Basically the Jenk´s method minimizes the sum of variance within each of the classes. After that, the same class ification standards for urban land use, residential land and industrial land, are respectively applied to the period 1992-1997. 4.2 Spatial pattern of urban land use growth in Beijing First we present results for urban land use growt h as a whole, thus the sum of all increases in built up land in Beijing including residential and industrial land as the most important components. Table 3 presents statistics of the AAGI calculated for the 155 townships while Figure 2 shows the respective maps. For the period 1982-1992 the overall AAGI of urban land use based on the total area of o ur Beijing case study is 0.67. The average AAGI of all the 155 townships is 0.78 and the maximum is 3.99. Compared t o the previous period AAGI decreases between 1992 and 1997, indicating that urban land use growth had become slower. The overall AAGI is now 0.52 and the average of all townships is 0.63 and the maximum is 3.85. In the period 1982-199 2 the distribution of the spatial differentiation types obviously takes a concentric pattern with the grade of spatia l differentiation decreasing from the central urban districts to the outer. Urban land use growth here is quite agglo merative and centripetal. More than half (57% or 219 km2) of the new urban development is concentrated in 44 townshi p units, occupying only 21% of the total area. Most of those strong growth centers with spatial differentiation type 1 or type 2, are situated in the suburban circle with a distance of less than 20 km to the central urban district. I n the second period 1992 to 1997, the most active urban growth centers are located in the northern suburbs. For insta nce, 8 out of the 9 township units of spatial differentiation type 1 are situated in the northern suburbs. The majori ty of the new urban development takes place in the northern triangle sector and the southern converse-triangle secto r while the eastern and western parts are mainly slower growth types. The northern triangle sector comprises 40 towns hip units located between Beijing-Changping Highway and Beijing-Huairou Highway. Its share in the new urban developme nt is as high as 45% while its share in total area is only 23%. The southern converse-triangle sector includes 25 tow nship units contributing 23% to the new urban development while occupying an area of only 12%. The remaining areas a s a whole, mainly in the eastern and western parts, contribute only 31% to the new urban development but occupy 65% o

f the area. Figure 3 illustrates urban land use in the base year of 1982, new development in the first growth period of 1982-1992, and new development in the second growth period of 1992-1997. The spatial pattern of urban land use gro wth shows the following characteristics: First, urban land use in Beijing is sprawling outward concentrically, and ha s seriously encroached the planned green belt. In the 1st General Plan of Beijing drafted in 1958, a large circular s ector with a total area of 314 km2 between the central urban mass and its surrounding satellite towns has been planne d as green belt and reserved for agricultural use. But from 1982 to 1992, the area of the planned green belt decrease d by 38% from 260 km2 to 160 km2 (Zhao, 1996). Second, the growth centers of urban land use are actively shifting tow ard the northern part. The comparative analysis on spatial differentiation in Beijing in the period of 1982-1992 (a) to that in the period of 1992-1997 (b) shows that, the spatial distribution of the most rapid growth units (Type 1) h as shifted from the concentric and symmetric pattern in the first growth period to the agglomerative pattern in the n orthern part in the second growth period. 4.3 Spatial pattern of residential land development in Beijing New resident ial development is spatially highly congregated and shows a concentric spatial pattern with the northern suburban loc ations being the most active areas while the residential land development and its growth center is gradually shiftin g to the outer. In the period 1982-1992, the growth centers of residential land development are located at Dongchen g, Chaoyang and Nanyuan townships. Their average distance to the urban center is about 7.5 km and their average AAGI is 2.08, nearly 15 times of the overall level. In the second period the growth centers remain in the northern suburb s, but have moved a bit further outward. They are situated in Datun, Laiguangying, Jiangtai and Nanmofang townships (Figure 4 and Table 4). Their average distance to urban center is about 10.8 km while its average AAGI is 0.28, almos t 24 times of the overall level in this period. This is quite similar to the static urban residential growth model (A nas, 1978). Urban development is an incremental. In each period a developed ring is added to the existing urban perip hery to accommodate population growth. 4.4 Spatial pattern of industrial land development in Beijing Industrial growt h centers tend to cluster around major highways and form several growth axes(Figure 5). This becomes especially visib le in the period 1992 to 1997. In general the growth axes are shifting toward the northern and northeastern parts of Beijing (Table 5). This means a restructuring of the cities traditional industrial land distribution. Industrial lan d development used to be allocated in the southern parts, while development in northern areas was quite slow. Before 1992 there are two growth axes situated in the south. The faster and more agglomerative one is the Gaobeidian-Tongzho u growth axis, with a length of 20 km, along the Beijing-Tongzhou highway eastwards. The AAGI there is 1.62, nearly f our times higher than the overall AAGI of 0.43. The other one is the Lugouqiao-Doudian growth axis, with a length of 33 km, down the Beijing-Shenzhen highway southwestwards. Industrial land development in this period is rather small i n the northeastern part. After 1992, the growth axes are shifting towards the northern and northeastern parts. The tw o southern growth axes from the pervious period virtually stopped extending further. They are now classified into th e low development type 4 with their AAGIs decreasing significantly. Most of the new development in the southern part s now occurs in between the former growth axes. In the northern part three distinct growth axes advanced, the Beijin g-Changping growth axis, the Beijing-Xiaotangshan growth axis and the Beijing-Huairou growth axis, all belonging to t he fast development type 2. 5 Concluding remarks (1) The rapid expansion of urban land use in Beijing was predominate d by the continuous growth of industrial land in the period of 1982-1997. The average annual growth rate of urban lan d use was 38.35 and 29.84 km2 in the first period of 1982-1992 and the second period of 1992-1997, which were extraor dinarily high compared to its historical growth rates before 1982. The contribution share of industrial land to urba n land use growth was 64.91% in the first period and increased to 80.67% in the second. Industrial land had been expa nding at the astonishing high rate of 24-25 km2 per year, and did not respond to the central government´s growth cont rol policies as effective as residential land development. (2) The spatial pattern of urban land use growth in Beijin g was in distinct concentric sprawl, and seriously violated the General Plan of Beijing. With the growth centers´ gra dual shift from the inner to outside, the new-added urban developments were increased in distinct concentric zones an d continually encroached upon the green spaces among the central mass and those "dispersed constellations". The tota l area of green spaces for isolating built-up areas in General Plan of Beijing was 314 km2 in 1958, reduced to 260 km 2 in 1983 and 160 km2 in 1993. (3) The growth centers of urban land use in Beijing are actively shifting toward the n orthern part, rather than toward the southern and eastern parts as designated by the latest General Plan (1991-2010) of Beijing. Due to their advantages in abundant development space, high accessibility of economic and transport commu nication, etc., the southern and eastern parts of Beijing, located in the North China Plain, have been selected and d esignated as the main urban development areas and directions in the future. However, our empirical analysis showed th at, the two major urban growth axes along the Beijing-Tianjin and Beijing-Shenzhen highways in the southern and easte rn parts of Beijing had stepped into their decline period during 1992-1997 and the spatial distribution of the most r

apid growth units had shifted from the concentric and symmetric pattern in the first growth period to the agglomerative pattern in the northern part in the second growth period. (4) The growth axes of industrial land are shifting from the former eastern and southern parts toward the northern and northeastern parts of Beijing and would result in restructuring of the traditional industrial spatial pattern. Industrial land development used to be planned and concentrated in the southern and eastern parts, while quite slow in the northern part. In the period of 1992 to 1997, plenty of new industrial land development, especially the new and high technological enterprises were situated in northern part and formed three visible industrial land growth axes, the Beijing-Changping growth axis.

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关键词： urban land use; spatial differentiation; growth pattern; GIS; Beijing

