Urban land expansion and arable land loss in China—a case study of Beijing–Tianjin–Hebei region

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Abstract

With significant economic development in the last decade in China, urban land has increasingly expanded and encroached upon arable land in the last decade. Although many papers have analyzed the characteristics of urban land expansion, relatively less attention has been paid to examining the different expansion features of different-tier cities at a regional level. This paper analyzes the spatio-temporal differences of urban land expansion and arable land loss among different-tier cities of the BTH (Beijing–Tianjin–Hebei) region in China in the 1990s, and identifies social, economic, political and spatial factors that led to these differences. Based on urban land change data determined by interpreting Landsat Thematic Mapper (TM) imagery, it was found that the urban land area in the BTH region expanded by 71\% between 1990 and 2000. Different-tier cites, however, had enormous differences in urban development, such as speed of urban land expansion, speed of urban land per capita growth, and so on. These differences were closely related to rapid economic development, strict household registration systems, urban development guidelines (\textit{chengshi fazhan fangzhen}), and national land use policies. Of all the new urban land, about 74\% was converted from arable land, and there was a general tendency for smaller cities to have higher percentages. One of the important reasons for this result is that urban land is highly correlated with arable land in spatial distribution.

Keywords: China; The BTH region; Urban land expansion; Arable land loss; Different-tier cities

Introduction

China is a country with vast population and scarce land per capita (Yang and Li, 2000; Albersen et al., 2002). In 2000, its population reached 1.26 billion (NBSC, 2001a), about one-fifth of the world average level. The arable land area was 128 million ha, equivalent to only 0.11 ha per capita, and less than half of the world’s average of 0.23 ha (TMLR, 1999). This limited availability of arable land has been exacerbated by population growth and by arable land losses. In the last decade, China’s population has annually increased by about 12.5 million (NBSC, 1991–2001a). Meanwhile, its arable land area has decreased dramatically. According to the monitoring data of the Ministry of Land and Resources, a total cropland area of nearly 10 million ha (0.70 million ha per year) was converted into built-up, forest/pastures and horticultural lands or destroyed by disasters in the years between 1987 and 2000. Considering the area added by land reclamation and rehabilitation of abandoned lands, it was estimated that a total net cropland area of about 4.5 million ha (0.31 million ha per year) was lost in the same period. This quick farmland loss is generally due to the combined effect of rapid economic development, population growth, urbanization, agricultural restructuring, the government-stimulated conversion of marginal croplands (to forest and pastures\textsuperscript{1}), and natural hazards and land degradation (Yang and Li, 2000; Ding, 2003). Among the factors affecting farmland decline, urban land expansion has been perceived as the crucial one, because of not

\textsuperscript{1}Because of soil erosion, desertification, flooding, and water shortages, the Chinese government launched some plans to convert arable land to forest and grassland in order to protect the natural environment (\textit{tuigeng huanlinhuancao}) in ecologically fragile regions, for instance, the Sloping Land Conversion Program.
only its resultant loss of arable land but also, maybe more important, its great impact on the farmers in highly populated urban fringes. Due to encroachment of urban land onto farmland, it was estimated that each year, 1.5 million farmers lost their farmlands in the last decade (Lu et al., 2003).

China, as a developing country on the fast track, has been experiencing a rapid urban growth over the last four decades, especially since the implementation of the reform and opening-up policy in 1978 (Longley, 2002). In 2000, the proportion of urban population in China reached 36.22% (NBSC, 2001b). It was still, however, far behind the world average of 48% (CAM and EBUUC, 2003). With China’s entry into the World Trade Organization (WTO) and the government’s promotion of urbanization, there is no doubt that synergetic effect of global and local forces will continue to transform urban China (Jiang, 2003). One of the consequences is that urban development will encroach upon more cultivated land, especially the fertile and productive croplands in the eastern part of China due to the high population density and advanced level of economic development. Thus, the conflict between decrease of arable land and population increase attracts the special attention of many scholars at home and abroad (Cai et al., 2002; Boland, 2000; Tania et al., 2001; She and Xie, 2000; Anderson and Yang, 1998).

Recently, many papers have examined the characteristics of urban land expansion and the consequent arable land loss at different scales (Shen et al., 2001; Tania, 2001; Yeh and Li, 1999; Fazal, 2000; Verburg, 1999; Verburg, 2000; Zhang, 2000; Skinner et al., 2001), but relatively less attention has been paid to the differences of urban land expansion and the resultant arable land loss around different-tier cities. China was a planned economy before 1978. Although it entered a new era of market economy after 1978, many policies still have obvious features of the planned economy. These include urban–rural migration policy, and urban development guidelines (Chengshi fazhan fazheng). The effects of these policies on urban development vary among different-tier cities, so they may exhibit diverse rates of economic development and characteristics of land expansion.

Bearing this context in mind, this paper divides all cities and towns of the study region (Beijing–Tianjin–Hebei Region) into three tiers, in terms of administrative divisions. Through this kind of city classification, it is easy to achieve the aims of the paper, which include better understanding of the conversion characteristics from arable to urban land of the BTH region, and probing some factors exerting influences on this land conversion of different-tier cities, such as land use policy and household registration. Of course, this paper also examines urban land growth and arable land loss of the region as a whole.

**Study area and database**

**Study area**

The study area is located in the northeastern coast of mainland China, which includes Beijing Municipality, Tianjin Municipality and Hebei Province (the BTH Region) (Fig. 1). Beijing and Tianjin are directly under the jurisdiction of the central government. Beijing is the capital and the second largest city of China, and the host city of the 2008 Olympic games. Tianjin is the third largest city and the second port city after Shanghai in China. This region has a long history of industrial and urban development, boasting the famous Jingjintang (Beijing Tianjin and Tangshan) Industrial Belt, and therefore the urban system of this region is more full-grown in China (Zhou, 1995).

The area of the BTH region is 214,900 km², accounting for 2.2% of the total of China. As one of the three
major industrial regions in China, the BTH region contributed 10.4% to the China’s GDP (gross domestic products) in 2000 (NBSC, 2001a). Because of rapid industrialization and urbanization, the BTH region is witnessing a dramatic land-cover change.

**Database**

The use of satellite remote sensing has been proved a good choice for detecting and monitoring land use transformation (Imhoff et al., 1997; Longley, 2002). In this study, 1:100,000 digital land-use data were obtained from the Landsat Thematic Mapper (TM) remotely sensed data in 1990, 1995 and 2000. The original map consists of 7 first class land-use types, i.e. cropland, forest, grassland, residential area and land for stand-alone industrial and mining sites, water region, and unused land, and 27 subclasses. For this study, we selected urban land and cropland. Here, the urban land is one of the subclasses, and the cropland belongs to the first class.

In this paper, the population data is from the fourth and fifth population censuses, which were conducted in China in 1990 and 2000, respectively. Non-agricultural population of a city can reflect its urban development more accurately than any other kind of urban population data in China (Zhao et al., 2002), and therefore this paper employs non-agricultural population to represent urban population. Other data come from China Statistical Yearbook (NBSC 1991–2001a), Urban Statistical Yearbook of China (NBSC 1991–2001b), Hebei Economic Statistics: 1949–2001 (HBS) and China Population Statistics Yearbook (2001) (DPSSTS).

**Methodology**

**Geographical information system**

Databases of urban land and arable land in 1990, 1995, and 2000 were developed and analyzed in ESRI’s ArcInfo™ 8.1 and ArcView™ 3.2. Area changes of urban land and arable land were obtained by comparing land-use maps in different time periods.

**Urban size classification**

Cities and towns in the BTH region were divided into three tiers in terms of administrative divisions in the BTH region (Table 1), named as large city (Zhixiaoshi), medium city (Dijishi), and small city (Xianjishi, including county cities or towns). The large city tier includes only Beijing and Tianjin (Fig. 1), whose population was 5.77 and 4.57 million, respectively in 1990. Each medium city in this regional had a population size of more than 100,000 in 1990. Most of small cities had a population of below 100,000.

**Introduction of I(i)**

Cities are generally situated in plain areas with rich water resources and suitable lands for agriculture. This situation determines that cities are usually surrounded by intensive arable farming, and thus their expansion is often associated with a loss of agricultural land. In this paper, we define an index of urban land neighboring on cultivated land \( I(i/j) \) for quantifying the spatial relationship between urban land and the arable land around it. This index is expressed as:

\[
I(i) = \left( \frac{1}{n} \sum_{j=1}^{n} L_{ij}(u) / \sum_{j=1}^{n} L_{ij}(t) \right) \times 100\% ,
\]

where \( L_{ij}(u) \) refers to the total length of borderlines between an urban land patch \( j \) of a city \( i \) and the croplands around this patch, and \( L_{ij}(t) \) is the total perimeter of the patch. The value of \( I(i) \) ranges between 0 and 100. If \( I(i) = 100 \), city \( i \) is completely encompassed by arable land. In most cases, higher \( I(i) \) means more opportunities for land conversion from arable land to urban land. An AML script was developed for calculation of the index \( I(i) \) using the ArcInfo™ 8.1.

**Elasticity of urban land expansion to urban population growth**

The elasticity of urban land expansion to urban population growth (Xiao, 1997), denoted as \( E(urb) \) in this paper, was firstly developed by the Chinese Academy of Urban Planning and Design (CAUPD) for assessing the relationship between urban land and urban population growth. It is expressed as:

\[
E(urb) = \frac{A(i)}{Pop(i)} ,
\]

where \( A(i) \) is the annual rate of urban land growth of city \( i \), and \( Pop(i) \) is annual rate of urban population growth of city \( i \).
According to the economic principle of marginal value, the growth rate of urban land areas would be expected to be less than that of urban population because the new population does not need an entirely new and independent infrastructure system but rather uses existing facilities (Shoshany and Goldshleger, 2002). The CAUPD suggested that the desirable value of $E(urb)$ had better be 1.12, to fit the urban land development in China under an assumption that urban land use can meet the need of basic construction and environment protection (Xiao, 1997).

Results

Urban land expansion

National economic growth during the last decade (1990–2000) brought immense spatial expansion of cities in the BTH region. Total urban area expanded by 71% (Table 2) and the annual increase rate reached 5.5%. However, the rate of urban land expansion was not identical among different periods. In this region, urban land sprawled out more quickly between 1990 and 1995, especially for the large and medium cities. Take Shijiazhuang city as an example. Its urban area expanded by 39.6 km$^2$ between 1990 and 1995, but only by 13.8 km$^2$ between 1995 and 2000 (Fig. 1). The rate of urban land expansion also varied among different-tier cities. The small city had the rapidest land expansion speed, with the urban area increased by 80%, followed by the large city (72%). Growth rate of the medium city was the lowest and only 48%. Noteworthy, the area of urban land was doubled from 415.7 km$^2$ in 1990 to 841.1 km$^2$ in 2000 in the peripheral areas of Beijing (Fig. 2).

Table 1
Urban tier classification in the BTH region

<table>
<thead>
<tr>
<th>City tier</th>
<th>Number of cities</th>
<th>Administrative rank</th>
<th>Representative cities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large</td>
<td>2</td>
<td>Directly under the jurisdiction of the central government</td>
<td>Beijing, Tianjin</td>
</tr>
<tr>
<td>Medium</td>
<td>11</td>
<td>Directly under the jurisdiction of the Provincial government</td>
<td>Shijiazhuang, Tangshan</td>
</tr>
<tr>
<td>Small</td>
<td>122</td>
<td>County cities or towns</td>
<td>Botou city, Naspi town</td>
</tr>
</tbody>
</table>

Table 2
Comparison of urban land use and urban population in 1990 and 2000

<table>
<thead>
<tr>
<th>City tier</th>
<th>Increase of urban land (km$^2$)</th>
<th>Urban land area in 1990 (km$^2$)</th>
<th>Urban land increase (%)</th>
<th>Urban population increase (%)</th>
<th>$E(urb)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large</td>
<td>588.4</td>
<td>812.5</td>
<td>72</td>
<td>19</td>
<td>3.27</td>
</tr>
<tr>
<td>Medium</td>
<td>288.2</td>
<td>525.2</td>
<td>48</td>
<td>34</td>
<td>1.35</td>
</tr>
<tr>
<td>Small</td>
<td>642.2</td>
<td>798.2</td>
<td>80</td>
<td>75</td>
<td>1.05</td>
</tr>
<tr>
<td>BTH region</td>
<td>1516.1</td>
<td>2135.7</td>
<td>71</td>
<td>33</td>
<td>1.89</td>
</tr>
</tbody>
</table>


Change of urban land utilization per capita

Urban land area per capita had increased by 28.7% in the BTH region despite the rapid growth of urban population in the 1990s (Fig. 3). Changes of growth speed of land area per capita varied with the city tiers in the BTH region. In the 1990s, land-use area per capita of the large city owned the rapidest growth speed and increase by 45.5%, much faster than that of the medium city (10.5%). By contrast, urban land area per capita of the small city only increased by 7.6% from 1990 to 2000, however the small city still had the highest urban land area per capita. In 2000, it reached 233.2 m$^2$, and was much more than that of the large city (114.3 m$^2$) (Fig. 3).

Variation of $E(urb)$ in different-tier cities

In the BTH region, urban land expansion rate was faster than the urban population increase rate in the last decade. The results show that the average $E(urb)$ touched 1.89, much more than the value of 1.12 suggested by the CAUPD. Although this kind of excess urban land growth relative to urban population increase is not uncommon worldwide, 1.89 is still at a very high level compared to many other countries or regions. For instance, 1.58 in America, 1.25 in South America and 1.17 in China as a whole (Shoshany and Goldshleger, 2002).

$E(urb)$ of the large city was the highest among the three types of cities, with the value of 3.27 in the 1990s (Table 2) implying that the urban land increase was unexceptionally fast compared to the urban population growth. For medium and small cities, the $E(urb)$s were 1.35 and 1.05, respectively. The low value of $E(urb)$ value for small cities indicated that rate of urban
population growth was nearly equal to that of urban land expansion.

**Substantial loss of cropland**

In the BTH region, the percentage of new urban land that was converted from arable land (denoted as $R_i$) was 74%. The $R_i$s in different-tier cities varied. The value for small cities was highest and reached 81.0%, followed by medium cities (73.9%) and large cities (65.4%). After further examining the $R_i$s of the 135 cities/towns, this paper argued that smaller cities had a higher $R_i$ value in the process of urban land development in this region.

During the 1990s, about 1128 km$^2$ of arable land was lost due to urban land expansion in this region. Within the total loss of arable land, large cities accounted for 34%, medium cities 20% and small cities 46%. During the same period, arable land per capita dropped by about 18.7% in the region (Table 3). In 2000, arable land per capita in this region was 0.113 ha, much lower than the world average. Especially in Beijing, the speed of arable land loss was the fastest in this region, and arable land per capita decreased significantly by 38.9% from 0.054 ha in 1990 to 0.033 ha in 2000. Of course, in Tianjin and Hebei, arable land per capita also dropped noticeably (Table 3).

**Discussion**

**Rapid economic growth spurs urban land expansion**

In the 1990s, the average annual growth rate of GDP (calculated at 1990 constant prices) in the BTH region was about 12.2% (NBSC, 2001a). The great economic development stimulated the urban land expansion in the study region from the following two aspects. Firstly, the economic development paved the way for the increase of living space per capita, transportation land per capita,
common green belt per capita, and so on. In the BTH region as a whole, the urban land per capita increased by 28.7% in the 1990s. Secondly, with the high rate of economic growth, the urban population percentage rapidly rose in the BTH region.

In large cities, the rapid economic growth played a noticeable role of spurring the growth of urban land per capita in the BTH region in the 1990s. For instance, the living area per capita had a strong relationship with GDP per capita from 1990 to 2000 in Beijing (Fig. 4). In China, the number of affluent people has mushroomed in some large cities like Beijing, because of the institution of economic reforms and the globalization of economy since the late 1980s (Hu and David, 2001). So some social new areas have emerged, composed of high-class suburban residential areas in some large cities, such as Beijing, Guangzhou and Shanghai (Wu, 1998; Hu and David, 2001). Moreover, the current housing reform in urban China has entirely focused on the local urban residents while the needs of the temporary population have been overlooked (Shen, 2002). So, as Wu (2002) has observed, in major Chinese cities, urban land sprawl is now often seen, but the basic purpose of massive new residential construction is for increasing living standards, rather than for accommodating population increase.

In contrast, in smaller cities, that urban land per capita increased more slowly implied that the force of urban land expansion came from the urban population increase, rather than the growth of urban land per capita. This point will be further discussed in the next section.

Demographic changes directly influence urbanization and urban change (Pacione, 2001). In the BTH region, the total urban population rapidly increased in the 1990s. However, it may be very surprising that the urban population growth rate of small cities (75%) is so much faster than that of large cities (19%). Why? We will analyze this issue from two aspects, mass population migration and the institution of strict household registration.

In China, there are some enormous driving forces of mass population migration from rural to urban areas. These forces include two main factors. First, mass population migration results from an economic gap between rural and urban areas. In the BTH region, the gap was very noticeable and was even getting wider in the last decade. For instance, in Hebei Province, the gap had been increasingly widening from 1985 to 2000 (Fig. 5). Over the last two decades, this phenomenon also existed in the whole China (Klaus and Sun, 2001). Second, cities can provide more employment opportunities compared with rural areas, considering that there are still 120–150 million unemployed labors in rural areas in China (Xu, 1995; Fang and Liu, 1997; Cai, 1995). Because of these factors, the desire of peasants to become city residents strengthened and thus resulted in mass migration from rural to urban areas and rapid increase of urban land use.

However, there was a strict household (Hukou) registration policy to constrain migration from rural areas to cities in the pre-reform era in China. In some small cities, the population mobility policies have been modified since 1984 and many rural workers have been moving to small cities, seeking job opportunities. Some of these people have settled in these small cities. Until 1997, about 400 small cities had tried to reform the institution of household registration institution (Li,

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6In China, because of the strict household (Hukou) registration policy, it is fairly difficult for the temporary population to become urban residents, so the urban population increases slowly in large cities.
After 1998, all small cities throughout China progressively canceled the limitation on rural-to-urban population flow. In contrast, although (hukou) reform policies have been extended from small cities to some medium cities, the population system is still constantly under regulation in many cities at present, especially in some large cities, such as Beijing and Shanghai. As a result, it is very difficult to become urban residents for those people who are from rural areas and seeking employment in large cities.

Moreover, the State Council of China brought forward urban development guidelines in the 1980s, which can be generalized as follows: strictly controlling the scale of big cities, rationally developing medium cities, and actively encouraging the development of small cities. Like the household registration institution, these guidelines exerted some influence on holding back migration to large cities and stimulating urban population increase in small cities.

Thus, the growth rate of urban population of small cities was much faster than that of large cities in the BTH region. The $E(urb)$ of large cities was therefore the highest because it had the slowest increase rate of urban population and a rapid speed of urban land expansion in the last decade. On the contrary, the small city had the fastest urban land expansion speed among the three tier cities, yet the population growth rate was very high. Hence, $E(urb)$ of the small city was the lowest in the BTH region in the 1990s (as shown in Table 2). Most important, this result further implied that the immense population growth, rather than increase of urban land per capita, was the most important driving force of land expansion of small cities.

**Land use policy and urban land expansion**

In the BTH region, the speed of urban land expansion in the first half of the 1990s was much faster than that in the second half. This change of rate of urban land expansion mainly resulted from land policy reform of the central government in the 1990s. In China, the change of urban land use policy is especially dramatic because the transition from a planned economy to a market-oriented institution has been involved (Ding, 2003). Since 1987, land reform that re-introduced land values in China through land leasing and charging of land use fees has created a property market and increased the rate of housing construction (Yeh and Li, 1999; Hu and David, 2001). Especially since the acceleration of land reform in 1992, foreign investment has shown a growing interest in real estate development (Wu, 2001). The rapid development of the property market intensified agricultural land loss in both urban fringe and rural areas between 1990 and 1995.

The loss of valuable agricultural land due to rapid urban growth has caught the attention of the central government. The State Council promulgated the Regulations for the Protection of Basic Agricultural Land (Jiben Nongtian Baohu Tiaoli) on July 4, 1994, and the Protection Rules of Basic Farmland (New Jiben Nongtian Baohu Tiaoli) on December 27, 1998. The two laws both focus on the protection of basic agricultural land. Moreover, because of the austere situation of arable land, the Chinese government issued the revised Land Management Act (The Land Management Act of China) to ensure sustainable socio-economic development in 1998.

Since 1994, some regulations and laws have been implemented, and they prevented excess loss of arable land and urban land expansion. In this sense, national land use policy was one of the key factors that slowed the land conversion speed between 1995 and 2000 in the BTH region.

In addition, as the rapid economic growth exerted different impacts on land expansion of different-tier cities, land use policy was more effective in holding back urban land expansion in small cities than large cities. Firstly, land expansion in small cities attracted the attention of central governments. According to the original Land Management Law enacted in 1986, local government was entitled to approve the application of construction projects (Lin and Ho, 2003; Zhang, 2000). However, the leaders of some cities, especially small ones, believe that urban land is more profitable than agricultural land, so they think that economic success is more likely to happen on urban land. This speeds up the rate of land conversion from arable to urban land (Skinner et al., 2001; Zhang and Yang, 2000; Zhang, 2000). In 1998, the National People’s Congress of China formally approved the revised Land Act. The Act reclaims powers on farmland conversion for central government (Zhang, 2000), and requires all construction projects that use cultivated land to submit land-use applications to the governments at the provincial level or higher for approval (Lin and Ho, 2003). This has held back the rate of expansion of urban land to some degree, especially in small cities. Secondly, small cities had more urban land per capita than medium or large cities, and therefore it is easier to control the increase of urban land per capita in small cities. In the BTH region, urban land...
per capita in small cities only increased by about 7.6% in the 1990s. But we still need to raise awareness of inefficiency in land expansion of the small cities, because they had the greatest speed of urban land expansion and the highest value of $R_i$ in the BTH region in the 1990s.

**Urban land highly correlated to arable land in spatial distribution**

In the BTH region, most of the new urban land was converted from arable land, and $R_i$ was over 80% in many small cities. The major reason may be that urban land and arable land have a strong relationship in spatial distribution. In order to prove this point, buffer polygons were created at a radius of 10 km around the 135 major cities or towns in the BTH region. The result suggests that most of the land around cities or towns is arable, especially in some small cities in the southern part of Hebei province (Fig. 6). After examining $I(i)$s of the 135 cities/towns, we find that most of them are over 80%, and some of them even reach 100%. Moreover, the change of $I(i)$s had similar characteristics to the change tendency of $R_i$, that is, small cities had higher values of $I(i)$. Thus, many small cities had to expand at the expense of arable land around them, resulting in high values of $R_i$s. The following formula can be employed to quantitatively express the relationship between $I(i)$ and $R_i$ of the 135 cities or towns in the BTH region:

$$\ln(R_i) = 0.53 \ln(I_i) + 2.02$$

for $i = 1, \ldots, n$, where the correlation coefficient reaches 0.63 and correlation is significant at the 0.01 level.

Formula (3) shows that high values of $I(i)$s of many cities were one of the important factors that led to the fact that most of the new urban land was converted from arable land in the BTH region in the 1990s.

In addition, because $I(i)$ can better express the spatial relationship of urban land and arable land around it, we can estimate the proportion of new urban land converted from arable land for a city by calculating the value of $I(i)$ under the assumption that the city has the same land expansion speed in all directions.

**Conclusion**

This study examined urban land expansion and the consequent arable land loss in the BTH region in the 1990s. The results show that urban land rapidly expanded in the region in the 1990s, especially in the first half of the decade. In large cities, urban population increased very slowly while urban land increased by 72%. This led to the highest value of $E(urb)$ (3.27) in the 1990s. By comparison, in small cities although the growth rate of urban land is the highest (80%) of the three tiers, urban land per capita only increased by 7.6% because of the immense urban population growth. The $E(urb)$ of the small city was therefore the lowest among three types of cities in the 1990s. Overall, urban land areas expanded at a greater rate than the urban population growth in the BTH region in the 1990s, resulting in a very high value (1.89) of the average $E(urb)$. In 2000, small cities still kept the highest urban land per capita, which approached 233.2 m$^2$ and the large city had the lowest urban land per capita (114.3 m$^2$).

At the same time, most of new urban land was converted from arable land and the average value of $R_i$ touched 74% in the study region. Moreover, there existed a tendency for small cities to have higher values of $R_i$ among the 135 cities/towns. At the same time, arable land per capita dropped by 18.7% from 0.139 ha in 1990 to 0.113 ha in 2000.

Three main reasons for these results were identified. First, high economic growth rate (the GDP growth rate touched 11.2%) was one of the main forces that led to urban land expansion and the increase of urban land per capita in the 1990s, especially in large cities. Second, in China, there are some enormous driving forces of mass population migration from rural to urban areas, but
strict household registration systems and urban development guidelines held back the population migration to the medium and large cities, especially to the latter. Therefore the rate of growth of urban population of small cities was much faster than that of large cities, and the tremendous population increase became the most important driving force of land expansion of small cities.

Third, the change of land use policies was the main factor that caused the low rate of increase of urban land expansion in the study region in the second half of the 1990s. Finally, we think that the high \( I(i) \) was one of the important factors relating to the fact that nearly three-quarters of the new urban land came from arable land, because \( R_i \) was strongly correlated with \( I(i) \) in the 135 cities and towns in the BTH region in the 1990s. Therefore we think the \( I(i) \) is not only a tool for analyzing of the spatial relationship between urban land and the arable land around it, but also is a good method for predicting the \( R_i \) of a city under the assumption that this city will expand at the same speed in every direction.

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