LAND POTENTIAL EVALUATION FOR LARGE-SCALE GREENBELT

DEVELOPMENT AT URBAN-RURAL TRANSITION ZONE
A CASE STUDY OF BEIJING, CHINA

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ABSTRACT:

There has been a public recognition among urban planners that greenbelt hold enormous potential for limiting city expansion and improving city ecological conditions. As one mega city all over the world, Beijing faces the uncontrolled urban sprawl recent years. Many urban problems are caused by this disordered development pattern. A concept about planning one large-scale greenbelt surrounding the central city is proposed by the local government, which is expected to both control urban sprawl and improve environments. The objective of this research is to analyze the existing land use/cover pattern within the proposed greenbelt zone, and evaluate the land potential for greenbelt development. The results show that the current landscape pattern provides considerable potential for greenbelt development. Totally, all the undeveloped land resources occupied more than 60%, while the developed built-up areas occupied less than 40%. All these undeveloped land resources might be available for green space development if with strict control for transforming into built-ups in the future. In addition, the major transportation routes passing the greenbelt are found as the important factor for large built-ups increase. These transportation routes are suggested as the major axes to formulate a wedge-based greenbelt pattern design, which might efficiently regulate and control the rapid large-scale built-ups development. However, various existing built-up lands developed without regular pattern, and go against the greenbelt requirement. How to regulate existing land uses, increase land use efficiency, freeze built-ups development, and release some developed lands would be the key for successful greenbelt development.

1. INTRODUCTION

1.1 Overview Greenbelt Development of The World

Since the industrialization resolution, the global urbanization speed increases rapidly. Although urbanization improves human life quality and benefit the all world development, the uncontrolled urban sprawls cause many problems, such as environmental degradation, social and economic crisis (Yang 2003). It has reached the public awareness that urban expansion need be restricted within suitable scale. Urban-rural transition zone was recognized to be the sensitive zone to the whole urban system. It plays important roles to link the central city and far suburb, transform urban functions, and monitor urban growth (Wang et al. 2002). How to plan, manage and develop the "sensitive" transitional zone is critical for urban sustainable development.

"Greenbelt" is defined as the large greenways, usually located at urban suburb, filled with various vegetations. The concept of "greenbelt" was firstly proposed by Howard (1898) in his famous book, Garden of Tomorrow. The main functions of greenbelt were to limit urban sprawl, evacuate centralized urban population and improve ecological environment. Since 1950s, many big cities in the world developed large-scale greenbelts, such as Ottawa, London, Paris, Moscow, Tokyo, Seoul, and Bangkok. The major goals of these greenbelts are similar, although their structure and pattern are different (Taylor et al. 1995; Yokohari et al; 2000; Jun and Hur 2001; Cho 2002).

Based on these worldwide experiences, the major functions of greenbelt could be summarized: (1) to control urban sprawl and optimize urban landscape pattern (Yokohari et al. 2000). (2) to improve urban ecological conditions, such as purifying atmospheric environment, regulating local microclimate, protecting water resource, restoring degenerate ecosystem, and increasing urban biodiversity (Binford and Buchenau 1993; Bolund and Hunhammar 1999). (3) to provide recreational functions (Little 1990; LaCour 1991). (4) to provide educational services. Through recognizing the multi-functionality of greenbelt, people have more chances to know the importance to harmonize human development with nature (Robert 1995).

1.2 The Necessity Analysis for Beijing Greenbelt Development

Beijing, the Capital of China, one of the largest cities of the world, covering 16,800 km2 and living about 13 million people, originated from 3000 years ago, and develops very fast since 1949, after the foundation of the Republic of China. In recent ten years, the fast transportation routes development and extension from the inner city, clearly indicates the fast sprawl pattern. In 1949, the urbanized inner city was only 84 Km2. Then after the following four decades, the inner city expanded to 400 Km2 until 1990 (Lu 2001). Especially within the recent decade, fast urban sprawl made the inner city size, over urbanized areas, extended into more than 700 Km2. The city expansion pattern is the typical concentric model, accompanying with closed ring roads development. The

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compact and densely developed built-ups outspread into all directions from the inner city (He et al. 2002). Since as the Capital and mega city, Beijing takes important positions on the national and international economic, political, and cultural development, there are more impetuses to drive the city development (Peng 2000). However, over fast urban sprawl brought many serious environmental and social problems (Report by Environmental Bureau 2002). Considering the development situation, a big "greenbelt" plan was put forward by local government (Ou and Wang 2002). This greenbelt is expected to position at urban-rural zone, mainly between the fifty and sixth ring roads. Besides the important function to limit urban sprawl, this large-scale greenbelt could fulfil several other important functions. (1) to limit the heavy industry developed at the urban fringe. (1) to evacuate dense urban population of the inner city. (3) to defend or reduce the intension of sandstorm. (4) to improve the ecological conditions of riparian area. (5) to provide recreational services. (6) to develop modern agriculture and provide food resource.

2. METHOD AND RESULTS

2.1 Introduction on the Proposed Greenbelt Design

The greenbelt is proposed to be a closed belt between the fifth and sixth ring road, the average width of which is about 10 km. In northwest part, this greenbelt would be extended out the sixth ring road and connect with the mountainous areas in order to strengthen ecosystem functions (Ou and Wang 2002).

According to the goals to be achieved, seven major landscape elements are desired to be within the greenbelt: (1) Forest: forest, nursery and orchard. (2) Water body and wetland: river, lake, reservoir, and fishpond. (3) Grassland: lawn, grass and shrub mixture. (4) Built-ups: satellite town, high-technology gardens, and modern residential communities. (5) Transportation routes: railway, road, and highway. (7) Agriculture.

Ecological and urban planning theories are applied as the main theories to support the greenbelt design. The greenbelt would be designed by scientifically integrating various landscape elements to efficiently achieve the planning goals. Within the proposed greenbelt, more than 60% lands need be reserved for "green" cover, and the total built-up areas need be controlled less than 40%. The basic planning rules are suggested to instruct greenbelt design: (1) to set up forest as the matrix of greenbelt. Because forest can fulfil many ecological functions, forest would be the main component of the greenbelt. At lease 70% of the total "green" elements are expected to be forests. (2) to build green corridors and develop "green" network to link the inside and outside greenbelt: The green network could be developed mainly by greening road network and riversides. In addition, new corridors are necessary to be developed to link separate nodes or corridors. (3) to mosaic greenbelt with other landscape elements. Except for forest matrix and green corridors, diverse other landscape elements are proposed to be included within this greenbelt. It is quite important to position different landscape elements at the suitable sites, which must be beneficial to achieve the planning goals. For "green" elements, the suitable sites should be identified mainly according to the requirements of greenbelt goals. Try to keep the "green" as it is now as possible is the important rule to save financial budget. For urban "built-up" dominant elements, much more attention and efforts are required. To strictly control new urban extension and maximally optimize the distribution pattern of the existing built-ups is primary basic rules for planning built-up dominant land use within greenbelt.

The basic planning rules above are mainly based on city's major requirements. However, whether the plan or design could be put into real implementation would depend on how much land potential left and how to take efficient measures to minimize the conflicts between greenbelt and urban development. In the following sections, it will focus on land potential evaluation for greenbelt development.

2.2 Land Cover Characteristics within the Proposed Greenbelt Zone

The ETM image (May, 2002) was selected to extract the update land cover/use information (Urban Planning of Beijing 1992). The existing land cover extraction process was completed mainly under the support of ERDAS software. For land potential analysis, it needs to accurately identify the distribution of non-built-ups dominant and "built-ups" dominant land cover/use (see Table 1). The combination of ETM band 3, 4, 5 are efficient for distinguishing the urban dominant and non-urban dominant land cover/use. Through large ground truth survey, the characteristics of different land cover/use corresponding to the image were well investigated. Representative training samples for all kinds of land cover/use were selected and tested during the field investigated. GPS was applied for recording the geological positions of all sample sites. The positioned error was limited within one pixel in order to guarantee the accuracy of classification. Some valid sample sites were collected for testing image classification.

Land Cover	Land use
Water body	River, lake, reservoir, fishing pond, lotus
Built-up	Residential sites, public facility sites, industry sites, and transportation place
Bare space	Bare space without and cover
Agriculture	Corn, rice, vegetable
Forest	Tree nursery, orchard

Table 1. Land cover classification system

Following this land cover classification system, Maximum likelihood supervised classification method was used for land cover classification. At the first stage, more classes were classified with more training samples. At the second stage, similar classes are merged together to get the final land cover classification (see Fig 1).
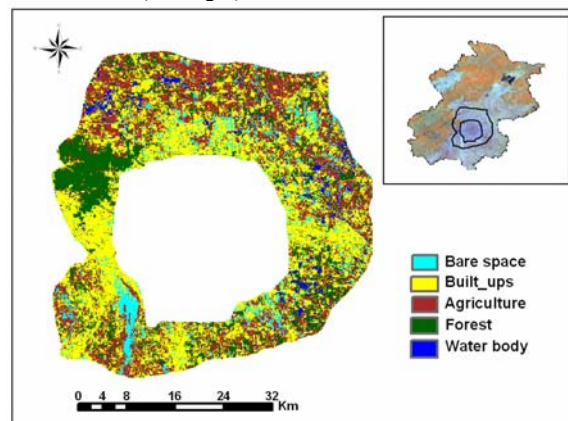

Figure 1. Land cover/use characteristics

2.3 Land Cover Structure and Distributed Pattern Analysis

Seven important landscape indexes are selected to analyze the

characteristics of existing landscape pattern. Fragstat software was applied for these calculations (see Table 2).

Land Cover	Patch Area (Ha.)	Number of Patches (NP)	Patch Density (PD)	Largest Patch Index (LPI)	Landscape Shape Index (LSI)	Clumsiness Index (CLUMPY)	Patch Cohesion Index (COHESION)
Forest	30212.6	13436	4.7441	2.9937	113.1907	0.7828	96.5401
Built-ups	64324.5	18945	6.6893	4.8976	189.1603	0.7117	99.4676
Agriculture	46200.5	20376	7.1946	0.9084	174.0209	0.711	97.1436
Bare space	13603.6	14416	5.0901	0.6765	130.8625	0.648	91.9362
Water body	5529.6	3786	1.3368	0.1232	70.0706	0.7145	90.6123

Table 2. The landscape characteristics

The results showed that about 40% of the whole areas were occupied by built-ups. Except for urban built-ups, all kinds of agriculture occupied 28%. Natural forest, tree nursery, and orchard occupied 19%. Most the natural forest locates in the northwest part. Most tree nursery and orchard are recently developed to ornament the environments and provide scenic sites for people's visit.

Considering the patch number and density of different land cover/use, the number of agriculture patches was 20376 and the patch density was 7.1946. These two indexes are the highest among all the land cover/use types, which shows that urban sprawl had great impacts on agriculture so that more and more cultivated areas were separated or replaced by urban uses. Agriculture developed without well plan and management. The number of urban built-ups dominant patches was 18945 and the patch density was 6.6893. It found although the total patch area of urban built-ups was higher than that of agriculture, the number of urban built-up patches and the patch density were relatively less than these of agriculture. The difference can be explained that fast urban extension make large-scale built-up patches increase and smaller separate built-up areas being merged together. The Largest Patch Index (LPI) of urban built-ups, 4.8976, was much higher than that of other land covers. This pointed out that the size scale of the urban built-up patches had exceeded that of other land covers and fast urbanization tendency within the transitional zone was very clear.

Through analysing the Clumsiness Index (CLUMPY), it showed that the CLUMPY of built-ups was lower than that of forest and almost similar with that of agriculture. It means that built-ups developed arbitrarily without regular plans. However, the Patch Cohesion Index（COHESION）of built-ups were quite high, 99.4676. This index result supports two points. First, diverse separated built-up patches were highly connected by all kinds of transportation routes. Second, some different separately developed built-ups had merged together, and some others showed clearly tendency to be merged further.

In summary, the landscape characteristics within the proposed greenbelt could be concluded: (1) urban built-ups and agriculture are the dominant land cover/uses, not only considering their patch number, but also their areas. (2) Undeveloped land cover/use, such as bare space, water body, and forest, occupy less land resources. (3) Both the built-ups and agriculture are highly fragmented distributed.

2.4 Land Potential Evaluation for Greenbelt Development

Through integrating the existing landscape characteristics and urban development pattern, we evaluate the land potential for greenbelt development from three aspects: land amount, structure, and distributed pattern potential.

2.4.1 The radioactively developed transportation routes provide basic "axes" for formulating "Wedge" based greenbelt design

Several major transportation routes pass through the proposed greenbelt zone from different directions. Among them, eight railways and several important highways are the main traffic arteries connecting the inner city with other places of the whole country. No matter with short-term plan or long-term plan, these major traffic lines would be very important for fulfilling many transport functions (Urban Planning of Beijing 1992). Moreover, these traffic arteries are the main factors to promote the development of their surrounding environments. Almost all large-scale urban built-ups sprouted near the traffic arteries. These traffic lines provide the potential "axes" for "wedge" based greenbelt pattern development. The whole greenbelt could be designed as the components of different "wedge" units, and the traffic arteries would be set as the axe for different wedges (see Fig 2). For each wedge unit, "greenbelt" could be planned to specify on some functions aiming at fulfilling both the master goals and local goals, based on its special natural, social and economic conditions.
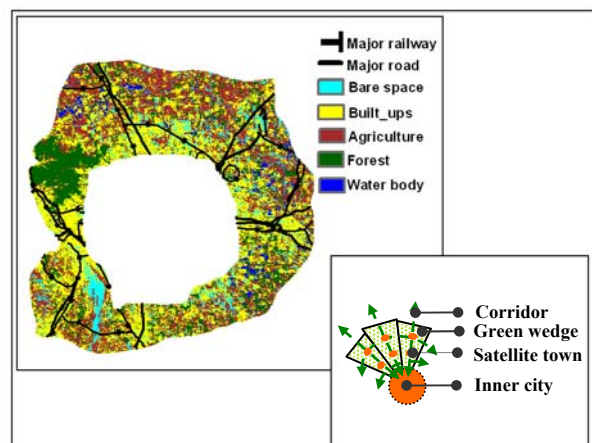
Fig 2: Landscape distribution characteristics and land pattern potential for wedge-shape greenbelt development

2.4.2 The amount of various undeveloped land cover/use provide direct potential for greenbelt development

The amount of various undeveloped land cover occupy more than 50% of the proposed greenbelt zone. In principle, these lands could be directly reserved for green space development. However, the spatial distributed pattern of these lands is disordered, unplanned, and poor managed. Scientific methods are necessary to instruct the planning of these undeveloped areas.

Furthermore, the existing transportation network provides great potential trails for developing green corridors. Although fast transportation system developed within this area greatly drive the urbanization process, no adequate protective forest system along keeps up with these traffic routes. It is estimated that the potential amount of protective forest network might be 100~200 km2, which could support to set up the basic green corridor network.

2.4.3 Urban extension trend is very obvious within urban-rural transition zone

The total number of various built-up patches together has increased to more than 2000, from the size less than 10000 M2 to more than 100 Km2. Among all of them, many large patches, the size of which exceed 5 Km2, directly extended from the inner city. These large built-up patches take the import positions for driving urban extension, such as large heavy industry garden, high technology garden, centralized modern residential communities, and international airport occupy large built-up areas. These high dense built-up patches grow such fast with radioactive extension patterns that they themselves or other smaller built-up patches become closer to each other. Therefore, to adjust and control the land use pattern within large built-up patches is the primary hard work for greenbelt plan and development.
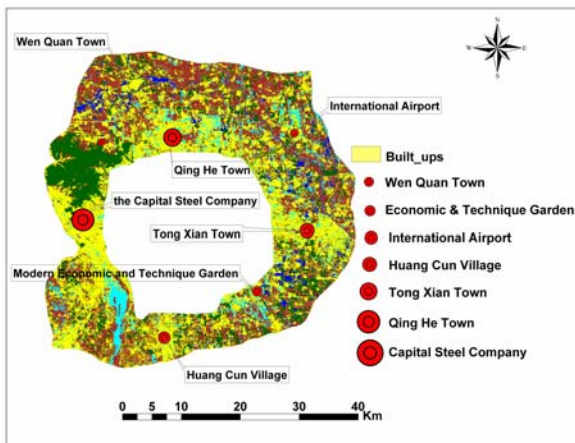

Fig 3: Large built-up area distribution pattern within proposed greenbelt zone

3. CONCLUSION

Urban-rural transition area is the sensitive zone for urban development and has important functions. Therefore, how to plan and develop this zone is important for sustainable urban development. As a mega city, Beijing develops very fast and caused many problems without regular control. The large-scale greenbelt is proposed to both efficiently control urban sprawl and improve urban ecological conditions. Based on the land potential analysis, it shows that the greenbelt planning concept is an efficient measure for controlling urban expansion. The result indicate that between the fifth and sixth ring roads, there are totally around 60% undeveloped land resources left, which might directly provide potential for green space development. Moreover, various developed urban built-up areas (40%) have considerable potential to release some open spaces for greenbelt development. The major radioactive transportation routes provide structure potential for forming "wedge-based" greenbelt pattern.

However, the study found how to control and re-adjust the existing land development pattern is the difficult task for successful greenbelt planning and implementation. Overall, under the analysis on land potential evaluation, some issues are considered as the primary key contents and deserve to pay more attention on. First, the basic green "wedges" should be further delineated due to careful consideration on the land use development pattern with different sections. Secondly, strict measures to control urban dominant land use development need to be established and really put into practice. Thirdly, large existing built-up patches should be frozen in order to control their further extension, be re-planed in order to release some urban lands into open space as much as possible, and separate merged built-up patches. It is expected that the separate "centralized-functional-group" pattern could be re-activated and a healthful urban ecosystem composed of the inner city, greenbelt buffer, and far suburb would be developed.

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