Urban Expansion Pattern Analysis and Planning Implementation Evaluation Based on using Fully Convolution Neural Network to Extract Land Range

Huanan Li[*1], Yuanhua Jia[1], Yang Zhou[2]

ABSTRACT

In recent years, due to the rapid development of China's urban, it is significant for effective implementation of urban science development and planning that grasp the process of urban development, analyze the potential of subsequent development, and evaluate the matching degree of the development status and the planning. Thereinto, an effective way we exercise today is to evaluate urban expansion pattern analysis and planning implementation. According to research results of the urban land range extraction method based on the support vector machine (SVM) and fully convolution neural network (FCN) of the depth learning method for the night light image data, this paper describes an integration of remote sensing (RS) and geographic information system (GIS) and analyzes the urban expansion pattern of Beijing based on the computed results of landscape pattern indices. The results unveil that from 1990s to 2010s, Beijing took on a circle expansion mode on the ground the spatial agglomeration degree gradually increases and the expansion potential has spatial distinctions, which basically meets the requirements of the overall planning.

Key Words: Expansion Potential, Nighttime Light Data, Urban Expansion Pattern, Fully Convolution Neural Network

DOI Number: 10.14704/nq.2018.16.5.1390 **NeuroQuantology 2018; 16(5):814-822**

Introduction

The challenge for a healthy and sustainable development in urban areas is how to achieve a scientific development pattern and rigorous planning implementation. Currently, China is walking on the way of rapid urbanization development. It is particularly important for us to timely master the history and discern the directions of future urban expansion. How to master the expansion area and speed, spatial pattern and land use information and analyze the law of urban development underlies the rational layout of urban space; a routine comparison is carried out with general and special planning in order to evaluate the effect of the planning implementation as a significant basis to ensure effective implementation of current plan and follow-up planning formulation.

The spatial expansion in urban area is originated from the foreign metrological geography revolution in the 1960s (Boyce and Clark, 1964; Lee and Sallee, 1970), but 20 years later in China than in foreign countries. An upsurge in spatial expansion in China is in the making with constantly emerging fruits in the studies. The topics mainly include the morphology and mode, model approach, mechanism, motivation and synergy (Rayner, 1993; Carlson and Arthur, 2000; Camagni *et al.* 2002; Zhou *et al.*, 2013), among which the first two are the keystones. The pattern is included in the patterns and modes. This part features the

Corresponding author: Huanan Li
Address: [1]School of Traffic and Transportation, Beijing Jiaotong University, Beijing 100044, China; [2]College of Resources Science & Technology, Beijing Normal University, Beijing 100875, China
e-mail ✉ 12114211@bjtu.edu.cn
Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.
Received: 8 April 2018; **Accepted:** 7 May 2018

quantitative approach such as landscape pattern indices, and the application of remote sensing and geographic information system (GIS) to acquire accurate information about urban spatial expansion (Sakieh *et al*., 2015; Li *et al*., 2009). The model approach focuses on the application of cellular automata and multi-agent system and other models to simulate and predict the urban spatial pattern and evolution process (White and Engelen, 2000; Ligtenberg *et al*., 2004).

Currently, the evaluation of planning implementation is studies in the terms of connotation, content, method, mechanism, theory development and practice exploration (Scherer *et al*., 1999; Oliveira and Pinho, 2010; Sun and Sang, 2012), among which the evaluation method still resorts to the establishment of evaluation indices system involving the spatial development forms of urban, gradually adopting GIS technology (Merwe, 1997; Borza, 2015; Dai *et al*., 2001), however it is still not closely associated with the urban landscape pattern. It is required to be constantly improved.

This paper assimilates the applications of urban expansion pattern analysis and planning implementation evaluation, takes the Beijing as a study case, and based on the extraction of land area, the interpretation of land use information and the calculations of landscape pattern indices, to probe into the spatial-temporal evolution morphology of urban land scope, exploit the potentiality of urban expansion, evaluate the effect of the planning implementation, and present us a clear historical trace of urban development and provide the strategic advice for urban development planning.

Methods

Object

This paper takes Beijing as the study case. Beijing, as the capital of China, lies at 115°25~117°30□ east longitude and 39°26~41°03□ north latitude, with a total area of 16,410 km2 (BMCOLGC, 2009). As a political, cultural, educational and international exchange center in China, Beijing has a strong aggregation capacity for population, economy and resources. As of the end of 2016, the permanent resident population hit upon 21.73 million, and GDP climbed up to RMB 2.49 trillion in Beijing (BMBS, 2017). Coupled with the guidance of development policies, large urban land areas, a high population density and an improved transportation infrastructure, Beijing is endowed with a strong capacity for urban expansion. It is therefore regarded as a typical city for analyzing the urban expansion pattern.

Method

(1) Extraction of urban area

Through continuous study, scholars at home and aboard think the nighttime light data is a class of data sources about the macroscale urban spatial expansion (Cao *et al*., 2009; Henderson *et al*., 2003). Therefore, this paper proposes an approach of extracting the scope of urban land by using the nighttime light data and ArcGIS. The nighttime light data includes Defense Meteorological Satellite Program-Operational Linescan System (DMSP-OLS) (NCEI, 2014) and Visible Infrared Imaging Radiometer Suite--Day/Night Band (VIIRS-DNB) (NCEI, 2016) data. The nighttime light original data with a gray value 1 ~ 63 undermines the impact of accidental noise such as cloud and flame. On the basis of research results, urban land use ranges in different years are extracted by the support vector machine (SVM) and fully convolution neural network (FCN) of the depth learning method which is the recognized research approaches.

The basic motivation of deep learning is to establish a deep neural network to simulate the leaning and analysis mechanism of the human brain (Fu *et al*., 2017). FCN, as a research method, was proposed by deepened on the basis of artificial neural network which is formed based on biology principles of brain neural network, and is an effective method for solving the problem of image segmentation (Gonçalves, 2016; Long *et al*., 2015; Kadri and Mouss, 2017; Li, 2017; Wang *et al*., 2016; Wang and Xie, 2016; Hu *et al*., 2016; Sun *et al*., 2016).

In 1990s, biologists explored that the structure of neurons in human brains is formed and transfer information by dendrites, axons, axon terminal (Figure 1). A neuron usually has multiple dendrites, which are mainly used to receive afferent information. There is only one axon, and many axons at the end of the axon can transmit information to a number of other neurons. The axon terminals connect with the dendrites of other neurons to transmit signals. The location of this connection is biologically called "synapse".

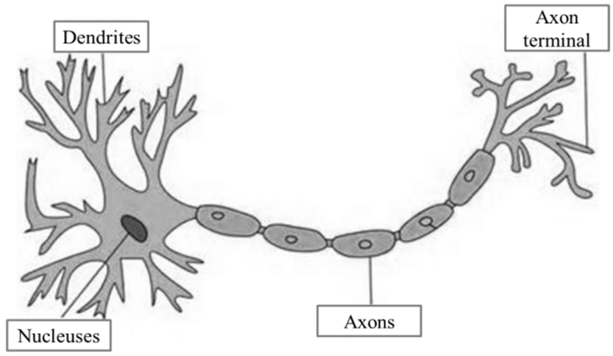

Figure 1. Neurons in the human brain

Following, according to the structure and information transfer mechanism of neurons, researchers proposed an approach of machine learning, which is formed by the input layer, the middle layer (or the hidden layer) and the output layer (Figure 2), and developed the approach systematically from neuron model to neural network. However, in fully connected neural network, researchers found that the number of weight parameters rapid expand with the increase in the number of hidden layers. Meanwhile, limited to quantum computing, the largest neural network at present is less than 1% of the number of human brain neurons.

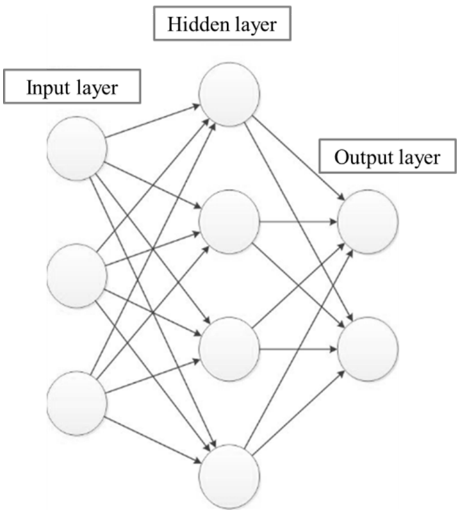

Figure 2. A neural network structure diagram

In this case, FCN takes the convolution kernel as an intermediary to replace the full connection of the hidden layers so as to effectively solve the image segmentation problem of the semantic level. Therefore, an approach based on FCN is designed to extract the scope of urban land in Figure 3. In conclusion, this paper adopts the threshold method to classify the area where the gray value in the nighttime light data exceeds the threshold as the urban area. The threshold of data in different years is defined by reference to the relevant scholars' research results (Liu *et al*., 2012; Xu *et al*., 2016; Fu *et al*., 2017; Maggiori *et al*., 2016). The urban area in 1995, 2000, 2005, 2010 and 2015 are extracted based on this threshold.

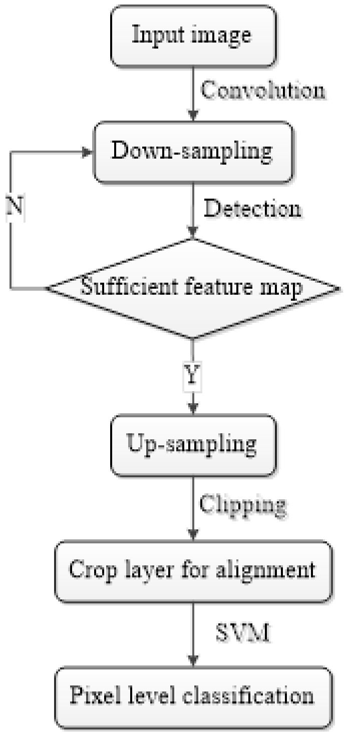

Figure 3. Process of extracting urban land use range by FCN and SVM

(2) Remote sensing image processing and land use information extraction

The multi-sources remote sensing image with a high spatial resolution in 2013 is chosen as the basic data sources, and processed by radiation correction, geometric correction, image fusion and image mosaic. The geometric correction error shall be less than 2 pixels in the mountain area, and less than 1 pixel in the plain area. The formation of remote sensing image background supports the information extraction.

The integration of automatic interpretation and manual interpretation is used to extract land use information. Automatic interpretation uses the object-oriented image analysis technology. Using eCognition software, first step is to do the image segmentation, and then creates a rule set by using spectrum, brightness, shape, texture and spatial distribution laws and other characteristic information to auto extract land use information about cultivated land, landscape ground, grasslands, water area, roads, urban construction lands, rural residential lands, other construction lands and other lands. Based on auto extractions, the manual interpretation is used to modify some contents where the extracted type is not correct and the extracted boundary precision is not high enough in order to ensure the fidelity and veracity of the extracted information by visual inspection.

(3) Spatial pattern analysis

The landscape indicator method, as the most effective method to analyze the spatial pattern, refers to a spatial pattern analysis that uses a certain number of landscape indices to describe the composition, spatial configuration and dynamic changes of landscape spatial pattern. The indices required for landscape analysis include class area *CA*, number of patches *NP*, patches density *PD*, largest patch index *LPI*, mean nearest neighbor distance *ENN_MN* and agglomeration index *AI* (Qi *et al.*, 2009), and fragstats software is used for a fast calculation.

CA (Class Area) is the area of Patch class, i.e. the total area of a patch class, *CA*> 0, unit: ha.

$$CA = \sum_{i=1}^{n} a_i / 10000 \qquad (1)$$

where, a_i is the area of the Patch *i* of a certain class and *n* is the total number of Patches of this class. $\sum_{i=1}^{n} a_i$ is the sum of the areas of all the Patches of a certain class.

NP is the number of patches, i.e. the number of a certain class of patches in the whole landscape, *NP*≥1, unit: ind.

$$NP = N \qquad (2)$$

where, *N* is the number of patches of a certain class.

PD is the patch density, *PD*> 0, unit: ind/km², which refers to the number of patches per 100 hectares, reflecting the degree of patch fragmentation. The higher value is, the higher degree of patch fragmentation is.

$$PD = \frac{N}{A} \times 10000 \times 100 \qquad (3)$$

where, *N* is the number of a class of patches, *A* is the total area of the whole landscape.

LPI is the largest patch index, 0 <*LPI*≤100, unit:%, which refers to the area of a class of the maximum patch in the landscape divided by the total area of the landscape, and is used to characterize the dominance of patch. The greater the value, the higher the degree of fragmentation.

$$LPI = \frac{\max(a_1, \ldots, a_n)}{A} \times 100 \qquad (4)$$

where, $\max(a_1, \cdots, a_n)$ is the area of the maximum patch in a type; *A* is the total area of the whole landscape.

ENN_MN is the mean nearest neighbor distance; *ENN_MN*>0, unit: m, which refers to the sum of the distance between each patch and its nearest neighbor in the landscape divided by the total number of patches with neighbors, which refers to the degree of spatial distribution intensity of the patches, the lower the value, the denser the spatial distribution.

$$ENN\_MN = \left(\sum_{i=1}^{n} \sum_{j=1}^{m} h_{ij} \right) / N' \qquad (5)$$

where, h_{ij} is the closest distance between the patches *i* and *j* of a class; *n* is the total number of patches of this class; *m* is the total number of patches of the same type as this one; *N '* is the total number of patches with the closest distance.

AI is the aggregation index, 0 <*AI*≤100, unit: %, i.e. the aggregation degree of the same class of patches, the greater the value, the higher the aggregation degree.

$$AI = \left[\sum_{i=1}^{n} \left(\frac{g_{ii}}{\max \to g_{ii}} \right) P_i \right] \times 100 \qquad (6)$$

where g_{ii} is the number of adjacent edges between the rasters of the patches *i* based on the singular method; $max \to g_{ii}$ is the maximum possible number of adjacent edges between the rasters of the patches *i* based on the singular method; *n* is the total number of patches *i*; P_i is the proportion of patches *i*.

Analysis of application result

Analysis of urban land area pattern

The results from the patch area (*CA*) index show that the urban use land in Beijing in 1995 was 908km². Over five years, it increased to 1185km² in 2000, by 392km² and 279km² every five years from 2000 to 2010, and reached 1991km² in 2015. It is observed that the growth rates in 1995~2000, 2000~2005 and 2005~2010 are

30%, 33% and 18%, but the growth rate in 2010~2015 dropped to 7%. As shown in Figure 4, the lands in urban area of Beijing in 1993~2013 show a circle expansion morphology around original center, where the expansion toward the north before 1995~2000 is highlighted. While in 2000~2005, it mainly spread to the north and east parts. Over 15 years, the expansion law takes on a typical "sharp angle", that is, the land use in one direction is increasingly expanding, e.g. in the northwest, northeast and due east, and also tends to expand to the south on this basis after 2010, presenting the phenomenon of simultaneous development of "sharp angled" expansion and "angle-to-angle" link.

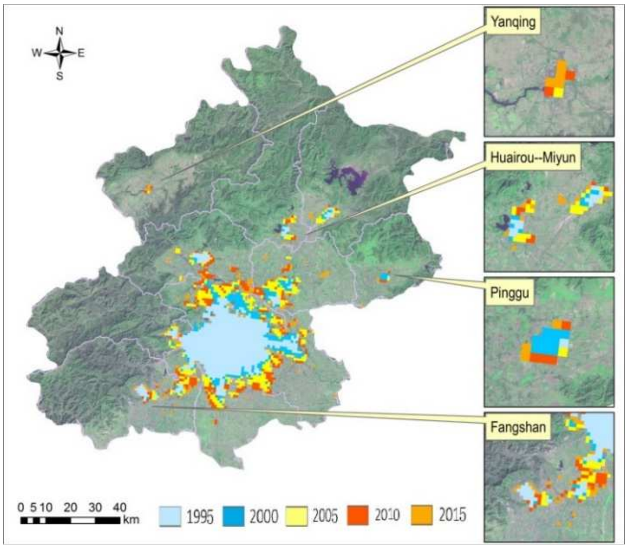

Figure 4. Expansion of urban land use

The number of patches (*NP*) and patch density (*PD*) indices show an irregular fluctuation in a small range. Over years, the urban area in Beijing keeps expanding. Some of the peripheral land plots, which are originally not adjacent to the central downtown lands are merged. While the new land plots are exploited in the farther peripheral areas, as shown in Figure 4, for example, the land patches in Shunyi, Fangshan and Changping are merged, and new land patches appear in Haidian, Tongzhou, Daxing, Fangshan and Shunyi. The fluctuation in the patch density also changes alike in patch number in urban area, that is, an increase in the patch number leads to a more fragmented urban landscape and contributes to a new development point in the city.

For *LPI, ENN_MN* and *AI*, *LPI* is on the rise, and *AI* takes the shape of U, while *ENN_MN* declines continuously. Land patches in different directions continue to close up and appear some new patches, which imply that urban development aggregations get higher and higher with obvious dominance of development in the central urban area.

As described above, the spatial pattern analysis applies the fragstats software to calculate each index with the results as shown in Table 1.

Table 1. Statistics of multi-year expansion pattern indices

Year	*CA*	*NP*	*PD*	*LPI*	*ENN_MN*	*AI*
1995	908	13	0.0008	4.91	8479.79	90.38
2000	1185	16	0.0010	6.16	6492.65	90.75
2005	1577	24	0.0015	7.70	5350.51	87.87
2010	1856	20	0.0012	9.24	4912.38	88.89
2015	1991	35	0.0021	10.84	4906.42	88.03

Analysis of interactive expansion pattern between the main and new urban areas

From the perspective of the full shot of Beijing, it mainly includes land patches of new districts in Yanqing, Huairou, Miyun, Pinggu and Fangshan. As of 2015, the urban area in Miyun and Fangshan are equivalent and largest, followed by Huairou, and the smallest is Yanqing and Pinggu, as shown in Figure 4.

From analysis of the interaction expansion pattern between the main and new urban areas, we can learn that over 20 years' development, the land patches in the Fangshan has been linked with those of the main urban areas. Before 2000, the development pattern was characterized by a co-existence of the outer spreading of lands in Fangshan and expansion of lands in the main urban areas to the "connect channel" of Fangshan. After 2000, the panel feature is that the "connect channels" evolved from year to year, eventually linked into one plot. Coupled with planning and constructions, including expressway, express bus dedicated line and rail traffic, the connection between Fangshan and the main urban areas will become closer and closer. It is estimated that the future expansion of the land area will also follow the mode that Fangshan itself continues to expand and the "connect channel" keeps filling together.

Let's look at Huairou and Miyun, there are two laws in the development of lands in Huairou, one is the trend to mutually assimilate and close up lands with Miyun, the other is the trend to mutually concentrate lands with the "sharp angle" development of Shunyi. In contrast, the first is more obvious, that is, Huairou expands the lands to the east as the major direction. Further given that forward planning of Shunyi-Huairou-Miyunrail transport construction in Beijing has a strong driving role axially in the urban pattern development (NDRC, 2015), the Huairou will continue to expand both eastward and southward in the future. Link-up with main urban areas plays an industry agglomeration effect, carrying on the economic spillover effect of Shunyi's high-tech and modern manufacturing industries. A concatenation with Miyun will produce an industry scale benefit in some aspects such as eco-tourism, economy and agriculture.

In the end, we analyze the development patterns of Yanqing and Pinggu, both of which have similar scales but differ in the development modes. In the recent 20 years, an obvious circle expansion mode has appeared in Yanqing New City, which is separated from the main city by mountains and less disturbed by other urban areas, so that the development mode is relatively independent. However, with the opportunity of hosting the Winter Olympics in Beijing and Hebei, the development mode of Yanqing is expected to be improved with the construction of Beijing-Zhangjiakou express railway (NDRC *et al.,* 2016). By constantly taping its own advantages, its ties with Beijing's central downtowns and Zhangjiakou, Hebei Province can be strengthened. It will be developed as a key link in the development of Beijing-Tianjin-Hebei region. The development model of Pinggu also diffuses to all around, with more independent development and less concatenated with the main urban areas. The "sharp angle" in Shunyi has not been extended to Pinggu. However, with the expansion eastward of the Shunyi Metro Line and the construction of Pinggu Metro Line linking Beijing Chaoyang and Tongzhou Districts, Hebei Yanjiao, Sanhe city and planning, the correlation between Pinggu and Hebei also gets more closely.

Analysis of urban land expansion potential

The urban land expansion potential is analyzed based on land use condition outside the range of urban area, whereby to make clear land cover area and spatial location distributions of cultivated land, water area and construction land and other various types of lands, and further to evaluate the subsequent expansion potential in different directions. As of 2015, with the Tiananmen, Beijing as the center point, the circle area with a radius of 20km has become a piece of urban land, with a little stretch of 20km ～ 30km area, while the peripheral area where the radius is more than 30km is used for subsequent urban expansion. The six potential expansion areas can be available from the law of urban expansion in Beijing, i.e. North and Northwest, Northeast, Southwest, East, South and Southeast, as shown in Figure 5.

North and northwest and northeast parts in Beijing belong to areas with great potential for expansion, where the plains for convenient urban expansion have a spatial scale for land use. The north and northwest parts can be expanded to an area with a radius of 50km and the northeast part

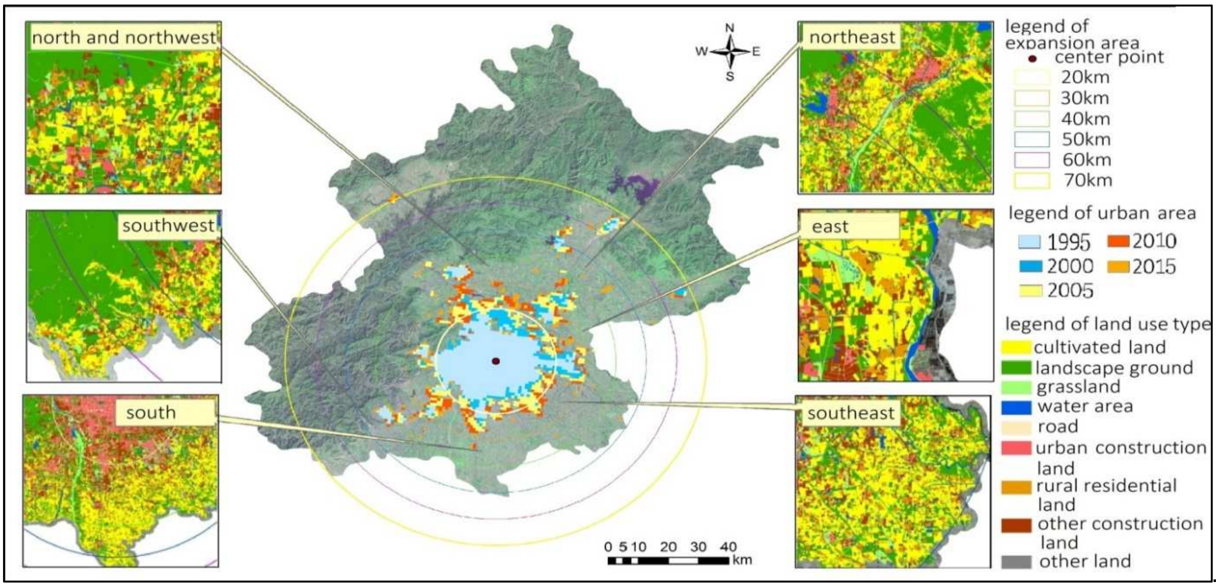

Figure 5. Spatial distribution of land use types other than urban lands

to an area with a radius of 70km; the proportion of construction land in the area is relatively high, and the distribution of cultivated land is relatively scattered, which is conducive to the urban expansion.

The southwest and east parts belong to the areas with a limited potential for urban expansion mainly due to the limited lands available for it. The southwestern part is affected by the mountains, leaving only a long and narrow channel for expansion. In the east part, due to rapid development in early stage, there is no land available for continued expansion. While to the east, it borders upon Yanjiao and Sanhe in Hebei, coupled with the ongoing integration of Beijing-Tianjin-Hebei from comprehensive transport planning to economic and industrial cooperation, where there is a greater potential for expansion. In contrast, the construction lands in the two regions are relatively high, and indeed a favorable factor for Beijing to further expand.

The south and southeast parts belong to the areas where there is a restricted potential for expansion. There is a huge expandable area, however, the cultivated land in a relatively concentrated distribution account for a higher proportion, which, as a focus of cultivated land protection, is chosen as an important area for the agricultural scale development in Beijing. In view of this important factor, combined with the status of land use with huge tracts of construction land in a radius of 30km, it is determined that there is still a certain space for expansion in the two areas beyond the radius of 30km, but required for careful implementation under the cultivated land protection policy.

Evaluation on urban development planning implementation

As prescribed in the *Beijing General Urban Planning* (2004-2020), the part of the urban spatial layout and the collaborative development of urban and rural areas, the urban spatial structure of "two axes - two belts - multiple centers" should be established in the scope of Beijing city field (BCPLRMC, 2005). The "two axes" refers to the east-west axis along Chang An Avenue and the north-south axis of the traditional central axis; the "two belts" refer to the "eastern development belt" including Tongzhou, Shunyi, Yizhuang, Huairou, Miyun and Pinggu and the "western development belt" including Daxing, Fangshan, Changping, Yanqing and Mentougou; the "Multi-center" refers to the multiple urban function centers constructed in the urban areas that serve the whole country and embrace the world, strengthening the city's core functions and comprehensive competitiveness. These include the core business zone Zhongguancun Hi-tech Park, the Olympics Center, the Central Business District (CBD), Haidian Science and Technology Innovation Center, Shunyi Modern Manufacturing Base, Tongzhou Integrated Service Center, Yizhuang High-tech Industry Development Center and Shijingshan Integrated Service Center.

As shown in Figure 6, the urban planning strategy has contributed Beijing to the formation of an obvious "two axes", that is, the east-west axis and the north-south axis. The two axes exist in the form of road trunk roads as a support for Beijing's urban development.

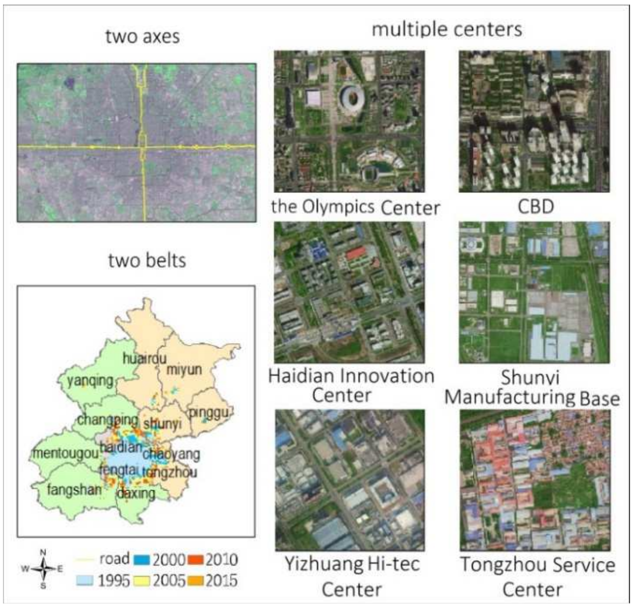

Figure 6. Urban development status

With regard to the urban planning of "two belts", the eastern development belt has taken shape owing to the development from the 1990s to 2010s, especially after 2000, Beijing has witnessed the rapid development, first in Shunyi District, followed by a junction belt between Shunyi District and Tongzhou District where the leaps and bounds have taken place. While in the Huairou, Miyun and Pinggu District, the development is in a relatively slow pace; and compared to the eastern and western parts slightly lagged behind, but in recent years have presents a trend to catch up with them. Changping District, Daxing District and Fangshan District are dominated by the expansion from

eISSN 1303-5150

2005 to 2010. The development in Mentougou has been slow in recent ten years, just like in Yanqing. To meet the requirement of balanced development of the two belts under planning, the pace of development in the western region needs to be accelerated.

In response to the planning of the "multi-center", relying on policy support, planning promotion and vigorous implementation, etc., the key areas in the past decade have witnessed rapid development, and the scales have been gradually expanded to approach to the planning goals.

Conclusions

This paper takes Beijing as the study case, incorporates the remote sensing and GIS, extracts the urban land use information based on the nighttime light data, interprets the land use information with the multi-source remote sensing images as the data sources, selects the landscape pattern indices, analyzes the urban expansion pattern, and ends in a planning implementation evaluation. The results show that from 1993 to 2013, the urban area in Beijing increased year by year, in a circle expansion mode; the gradual inter-attraction between the main urban area and the new districts. The traffic planning and construction is relied on to develop a close connection between them in the future; in combination with the terrain environment and land use status, there is a great potential for expansion in the northern and northwestern parts and northeast part of Beijing, while limited in southwestern and eastern parts, and restricted in the south and southeast parts; Compared with the urban development pattern and the development of key areas, the urban spatial structure has basically formed the "two axes - two belts - multiple centers". The analysis results have provided a scientific basis for the city's follow-up development and decision-making.

In future, we need to consider factors such as urban functions, economic benefits and travel behavior in the analysis of urban development pattern, in order to analyze whether the urban expansion mode is rational and whether new urban problems are involved in developing road. The solutions are developed for to the problems so as to make urban development greener, healthier and more sustainable.

Acknowledgments

This research is supported by the National Natural Science Foundation of China (U0970116).

References

BCPLRMC (Beijing City Planning and Land Resources Management Committee). Beijing City Master Plan (2004-2020), from http://www.bjgtw.gov.cn/web/static/catalogs/catalog_233/233.html, accessed on 1 May 2017.

BMBS (Beijing Municipal Bureau of Statistics). Statistical Bulletin of Beijing National Economic and Social Development in 2016, from http://www.bjstats.gov.cn/tjsj/tjgb/ndgb/201702/t20170227_369467.html, accessed on 1 May 2017.

BMCOLGC (Beijing Municipal Committee Office for Local Gazetteer Compilation). Beijing Local Gazetteer, from http://www.bjdfz.gov.cn/ShowNewsLevel3.jsp?NewsID=1386, accessed on 1 May 2017.

Borza S. From GIS database to spatial data warehouse. Academic Journal of Manufacturing Engineering 2015; 13(2): 136-41.

Boyce RR, Clark WAV. The concept of shape in geography, Geographical Review 1964; 54(4): 561-72.

Camagni R, Gibelli MC, Rigamonti P. Urban mobility and urban form: The social and environmental costs of different patterns of urban expansion. Ecological Economics 2002; 40(2): 199-216.

Cao X, Chen J, Imura H, Higashi O. A svm-based method to extract urban areas from dmsp-ols and spot vgt data, Remote Sensing of Environment 2009; 113(10): 2205-09.

Carlson TN, Arthur ST. The impact of land use - land cover changes due to urbanization on surface microclimate and hydrology: A satellite perspective. Global & Planetary Change 2000; 25(1): 49-65.

Dai F, Lee C, Zhang X. GIS-based geo-environmental evaluation for urban land-use planning: A case study. Engineering Geology 2001; 61(4): 257-71.

Elvidge CD, Ziskin D, Baugh KE, Tuttle BT, Ghosh T, Pack DW, Erwin EH, Zhizhin M. A fifteen-year record of global natural gas flaring derived from satellite data. Energies 2009; 2(3): 595-622.

Fu G, Liu C, Zhou R, Sun T, Zhang Q. Classification for high resolution remote sensing imagery using a fully convolutional network. Remote Sensing 2017; 9(6): 498: 1-21.

Gonçalves, CP. Quantum neural machine learning - backpropagation and dynamics. NeuroQuantology 2016; 15(1): 22-41.

Henderson M, Yeh ET, Gong P, Elvidge C, Baugh K. Validation of urban boundaries derived from global night-time satellite imagery. International Journal of Remote Sensing 2003; 24(3): 595-609.

Hu LJ, Tang L, Pan Q, Song H, Wen PG. Research and analysis of PI control strategy based on neural network in power grid. Mathematical Modelling of Engineering Problems 2016; 3(1): 25-28.

Kadri O, Mouss LH. Identification and detection of the process fault in a cement rotary kiln by extreme learning machine and ant colony optimization. Academic Journal of Manufacturing Engineering 2017; 15(2): 43-50.

Lee DR, Sallee GT. A method of measuring shape. Geographical Review 1970; 60(4): 555-63.

Li L, Chi Y, Wang Z, Wang A, Zhou H. The spatio-temporal dynamic characteristics in expansion of major cities in China in 30 years since the reform and opening-up. Journal of Natural Resources 2009; 24(11): 1933-43.

Li ZJ. Application of neural network technology in machining error recovery. Journal of Manufacturing Engineering 2017; 15(3): 6-11.

Ligtenberg A, Wachowicz M, Bregt AK, Beulens A, Kettenis DL. A design and application of a multi-agent system for simulation of multi-actor spatial planning. Journal of Environmental Management 2004; 72(1-2): 43-55.

Liu Z, He C, Zhang Q, Huang Q, Yang Y. Extracting the dynamics of urban expansion in china using DMSP-OLS nighttime light data from 1992 to 2008. Landscape and Urban Planning 2012; 106(1): 62-72.

Long J, Shelhamer E, Darrell T. Fully convolutional networks for semantic segmentation. Computer Vision and Pattern Recognition IEEE 2015: 3431-40.

Maggiori E, Tarabalka Y, Charpiat G, Alliez P. (2016). Fully convolutional neural networks for remote sensing image classification. Geoscience and Remote Sensing Symposium IEEE 2016: 5071-74.

Merwe JHVD. GIS-aided land evaluation and decision-making for regulating urban expansion: A South African case study. GeoJournal 1997; 43(2): 135-51.

NCEI (National Centers for Environmental Information) (2014). Defense Meteorological Satellite Program (DMSP), from https://ngdc.noaa.gov/eog/dmsp.html, accessed on 1 Jan. 2017.

NCEI (National Centers for Environmental Information). (2016) Visible Infrared Imaging Radiometer Suite (VIIRS), from https://ngdc.noaa.gov/eog/viirs.html, accessed on 1 Jan. 2017.

NDRC (National Development and Reform Commission), MTPRC (Ministry of Transport of the People's Republic of China), CRC (China Railway Corporation). The Mid-long Term Planning of China's Railway Network, from http://www.sdpc.gov.cn/zcfb/zcfbtz/, accessed on 1 May 2017.

NDRC (National Development and Reform Commission). Construction Planning of Beijing Urban Rail Transit (2015-2021) (second phase), from http://www.ndrc.gov.cn/zcfb/zcfbghwb/201509/t20150929_753187.html, accessed on 1 May 2017. (in Chinese)

Oliveira V, Pinho P. Evaluation in urban planning: Advances and prospects, Journal of Planning Literature 2010; 24(4): 343-61.

Qi W, Qu Y, Liu H, Li L. Selection of representative landscape pattern indexes and land use division. China Land Sciences 2009; 23(1): 33-37.

Rayner S. Global environmental change: Understanding the human dimensions. Environment Science & Policy for Sustainable Development 1993; 34(7): 25-28.

Sakieh Y, Amiri BJ, Danekar A, Feghhi J, Dezhkam S. Scenario-based evaluation of urban development sustainability: An integrative modeling approach to compromise between urbanization suitability index and landscape pattern. Environment Development & Sustainability 2015; 17(6): 1343-65.

Scherer D, Fehrenbach U, Beha HD, Parlow E. Improved concepts and methods in analysis and evaluation of the urban climate for optimizing urban planning processes. Atmospheric Environment 1999; 33(24): 4185-93.

Sun DY, Wang WH, Wang Q, Chen JQ, Niu CC, Cao C. Characteristics and prediction of frost heave of saline soil in western Jilin province. International Journal of Heat and Technology 2016; 34(4): 709-14.

Sun S, Sang J. Ideal Space. No. 54, Assessment for Urban Planning. Shanghai: Tongji University Press, 2012: 13-19.

Wang TC, Xie YZ, Yan H. Research of multi sensor information fusion technology based on extension neural network. Mathematical Modeling of Engineering Problems 2016; 3(3): 129-34.

Wang TC, Xie YZ. BP-GA data fusion algorithm studies oriented to smart home. Mathematical Modeling of Engineering Problems 2016; 3(3): 135-40.

White R, Engelen G. High-resolution integrated modeling of the spatial dynamics of urban and regional systems. Computers Environment & Urban Systems 2000; 24(5): 383-400.

Xu M, He C, Liu Z, Dou Y. How did urban land expand in china between 1992 and 2015? a multi-scale landscape analysis. Plos One 2016; 11(5): e0154839.

Zhou Y, Li H, Liu C. Study of urban expansion and driving forces based on RS and GIS, International Conference on Remote Sensing. Environment and Transportation Engineering 2013: 669-72.