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Full Length Research Paper

Patterns and its disaster shelter of urban green space: Empirical evidence from Jiaozuo city, China

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Urban green space systems play important roles in improving the ecological environment and diversity of the urban landscape. Additionally, they can also aid in disaster prevention and reduction. In the present study, the composition and patterns of the green space of Jiaozuo city and its suitability for use as disaster shelter were studied using landscape indices of ecological analysis. The results of our study revealed that large proportions of parks, productive green spaces, and small proportions of protective green spaces, attached green spaces and other green spaces, as well as high fragmentation index, low evenness index make a significant portion of the urban green space unsuitable for use as disaster shelters. The per capita green space for use as long-term shelters in Jiaozuo city increased from 5.60 m^2 in 1999 to 11.34 m^2 in 2007 far exceeding the minimum requirement for long-term shelters. The per capita green space for use as temporary shelters shows rise-decline trend to 2.80 m^2 per capita in 2007 after it increased from 1.84 m^2 per capita in 1999 to 3.55 m^2 per capita in 2005. This meets the per capita requirement for temporary shelter area for the city. Per capita green space for use as emergency shelter declined gradually from 2.61 m^2 in 1999 to 0.98 m^2 in 2007 which is below the minimum requirement for emergency shelter area per capita (1.2 m^2). Our findings indicate that increasing the area of protective and attached green space, and striving to achieve the right proportion of various types of green spaces should be considered in projects involving city reconstruction and construction of large residential areas.

Key words: Jiaozuo city, safety management, emergency shelter, urban disaster reduction, green space system.

INTRODUCTION

Natural disasters exert an enormous toll on development of society. In doing so, they pose a significant threat to prospects for achieving the ‘millennium development goals’ in particular (Shields et al., 2009). Disaster reduction has thus become a key component of the efforts of the United Nations Development Program (UNDP) to create comprehensive disaster preparedness plans and strategies, and promote disaster mitigation activities within the context of development planning and implementation (Paraskevi et al., 2007; Zarboutis and Marmaras, 2007). Cities are complex and interdependent systems, and are extremely vulnerable to threats from both natural and artificial hazards such as earthquakes, fires as well as poisonous gas leaks (Solecki et al., 2011; Wallace et al., 2007). Policy, practice and knowledge of disaster mitigation in cities have recently received widespread attention (Montoya, 2003; Chen et al., 2009; Cheng and Sheu, 1995; Zhou et al., 2006). Emergency

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shelters in cities can offer a shelter and emergency rescue for victims and the homeless when disaster occurs (Jerome et al., 1986). Public facilities such as schools, hospitals, and stadiums are generally suitable for use as emergency shelters in Western countries and in Japan (Koizumi and Katayama, 1996; Shaw, 2001), but in the case of earthquake such as the Wenchuan earthquake in China, such facilities have failed and collapsed (Liu et al., 2011).

Other facilities like urban green spaces have become more and more important due to their potential role in disaster prevention and reduction. It has characters of a large quantity and evenly distributed (Koizumi and Katayama, 1996; Hu and Tang, 2011; Wang, 2001). Ordinarily, urban green spaces serve to beautify the city environment, purify air, and provide a place for residents to relax and enjoy (Blanco et al., 2009; Geis, 2000; Li et al., 2007). When disaster occurs, the same space can be a safe venue for various kinds of emergency services such as provision of relief supplies as well as for setting up a security command center and medical aid stations (Liu, 2011). Unfortunately, studies of urban green spaces have focused on their eco-environmental functions and little attention has been given to their use for disaster mitigation. The planning and construction of disaster shelters in urban green spaces is still at the beginning stage and is rarely guided by systematic research especially in developing countries like China (Li et al., 2007). In practice, most cities still focus on the construction of a single emergency shelter and mitigation park or street. They lack an overall perspective on green space for disaster shelter and mitigation which limited the effective function of disaster shelter and mitigation on green space (Liu, 2011; Koizumi and Katayama, 1996).

The present study analyzes the use of urban green spaces as disaster shelters and tries to combine it with their known ecological roles. Strategies that ensure green spaces are built and maintained for better ecological functions and for use as disaster shelters in cities are also identified.

MATERIALS AND METHODS

Study area

Jiaozuo city (35° 08´N to 35 ° 15´ N, 113° 07´ E ~ 113° 20´ E, 100 m altitude) belongs to the northwest Henan Province of China, and is located between southern Mt. Taihang and Yellow River (Figure 1). The city covers an area of 90.0 km^2 and has an urban population of 835,000 as of 2010. It is located between the seismic belts of Fenwei and North-China plain, and is thus strongly influenced by seismic activities. For many years, it has been the key region for earthquake surveillance of China. It is rich in mineral resources and not surprisingly industries are its major economic drivers with 80.3% of the entire economic output coming from them. The major pollutants emitted by factories and mining plants in the region are SO_2, fuel dust and sewage water (Luo et al., 2006). Long-term coal mining activities have caused significant deterioration of urban ecological and geological environment in the region (Liu et al., 2005). Ground surface subsidence, deformation and wavy sinking basin appears are caused by coal mining activities. The risks of fire, gas leaks and geological disasters are significant in the region (Fu et al., 2011).

The climate in Jiaozuo city is temperate and semi-humid with a mean annual temperature of 16.5°C, an average frost-free period of 228 days, an average annual precipitation of 665 mm and an annual evaporation of 1100 mm. The quantity of green space in Jiaozuo city is pretty good after it built the National Garden City in China. In 2007, the coverage ratio of urban green space was 42.1%, and the total area of urban green space was 3,053 ha, out of which park green space was 988 ha, productive green space was 453 ha, protective green space was 529 ha, attached green space was 506 ha and other green space area was 577 ha (Figure 1c).

Green space system and its disaster shelter

A healthy, perfect urban green space system can prevent and slow the spread of natural or man-made disasters. At the same time, it can be used to provide emergency shelter because of its wide distribution and easy accessibility. It provides a safe shelter for providing emergency medical rescue as well as a shelter for the homeless and the displaced (Greene, 1992). Also, urban green space can be divided into park green space, productive green space, protective green space and attached green space according to the China National Standard for Classification of Urban Green Space (CJJ/T 85-2002) (The Ministry of Construction of China, 2002). Big parks in suburban areas are typically used as long-term disaster shelters because of their large area and location away from the city. Camps and temporary buildings are set up in such parks for providing long-term refuge to disaster victims. Medium-sized center parks and protective green spaces serve as temporary shelters or refuge. Such places can provide temporary asylum and treatment for the wounded, typically 10 and 20 min after disaster strikes. Emergency shelters mainly include small green spaces of central parks and attached green spaces close to residential districts. They can provide emergency shelter and escape immediately (3 to 7 min) after unexpected disasters strike (Figure 2).

The three types of shelters can expand their roles; for instance, an urban green space for emergency shelter can also be used for temporary and long-term shelter if needed.

Effective space for disaster shelter in green space systems

Different sizes and patterns of green space are suitable for different aspects of disaster mitigation and shelters. Urban green spaces can be divided into three regions based on information from actual disasters: disaster area, calamity buffer and safety zone (Pursals, 2009; Shendarkar, 2008; Saadatseresht, 2009). The usefulness of green spaces for disaster mitigation and shelter mainly relies on the safety zone of greenbelt patches. The dimensions of safety zones are closely related to the area and shapes of green space patches (Figure 3). Generally, the safety zone of an urban green space is calculated using formulas 1 and 2 (Zhang et al., 2005). When urban green space patches have an area less than 1.0 ha, their internal safety area is 0 ha making them invalid for use as disaster shelter (Chen et al., 2009). Such green spaces mainly consist of small accessory green spaces of streets and residential areas:

$$A_i = k_i S_i \tag{1}$$

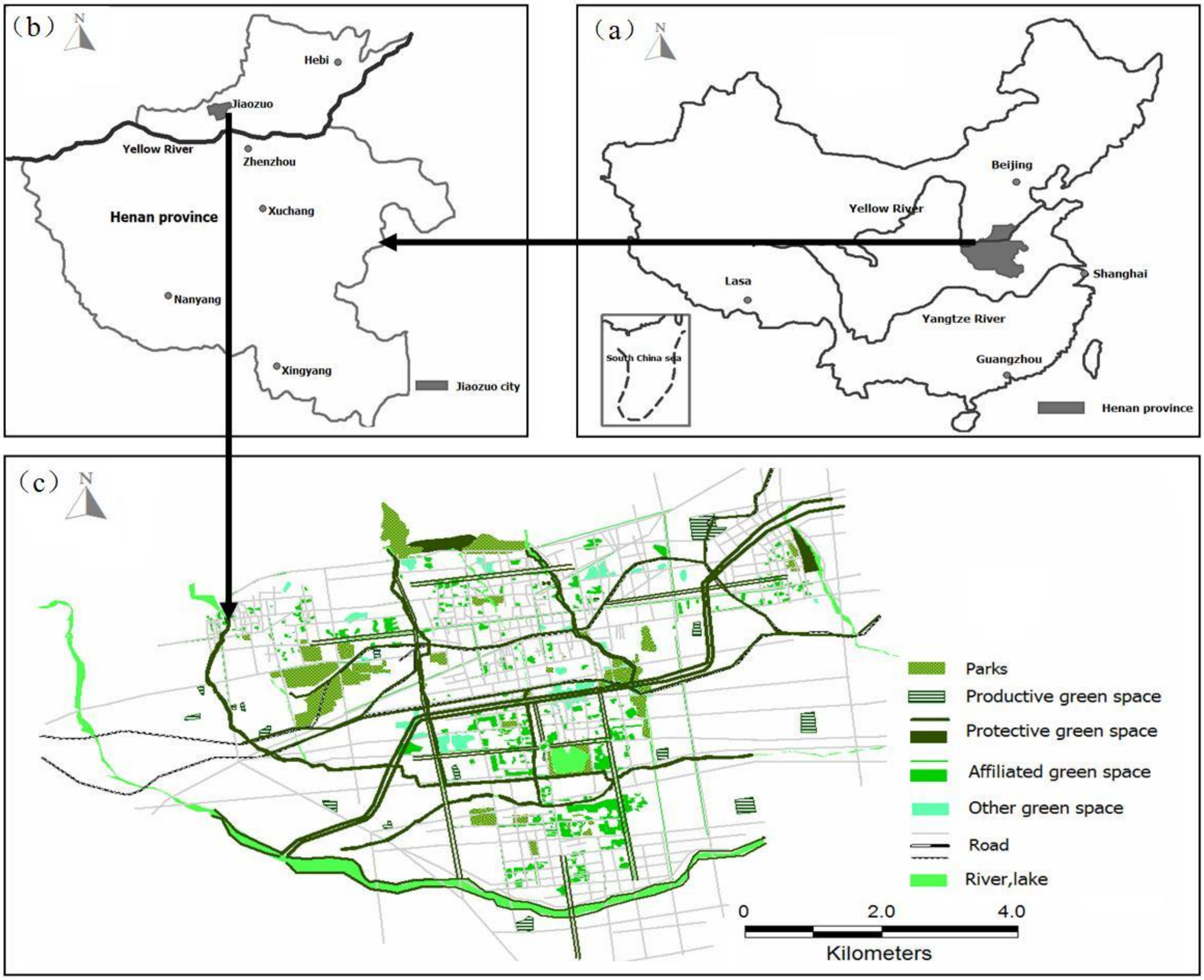

Figure 1. Location of the study region. Note: (a), (b), and (c) shows China, Henan province and distribution of the green space system in Jiaozuo city, respectively.

$$A = \sum_{i=1}^{n} A_i = \sum_{i=1}^{n} k_i S_i \qquad (2)$$

Where A is the total safety zone for disaster shelter of a city, A_i is the safety zone of i green space disaster shelter. S_i is the area of green space disaster shelter i, K_i is the safety zone coefficient of i green space disaster shelter. K_i is dependent on the shape and composition of the green space. After factoring in actual conditions like water bodies and unreachable regions of the disaster shelter, K_i is usually given a value of 0.6 (Chen et al., 2009).

Landscape pattern index and disaster reduction capability of urban green space

The landscape pattern is a set of landscape elements which are arranged from a series of different sizes and different shapes landscape elements (Feng et al., 2008; You, 2004). It results from the interaction of complex physical, biological and socio-economic activities under the effects of nature or the humanity. Therefore, in different urban environments, patch size, shape and layout of the green space will show strong differences. The performance of landscape patterns determines various ecological processes as well as the use of green spaces for disaster reduction and shelter (Table 1).

Data collection and analysis

The statistical program SPSS for Windows [version 15.0, GIS (geographic information system)] and erdas 8.4 program were used to perform data analyses. Data were collected from statistical yearbooks of Jiaozuo city (1999 to 2008), SPOT satellite images (1999, 2007) and field surveys in year 2004 to 2008.

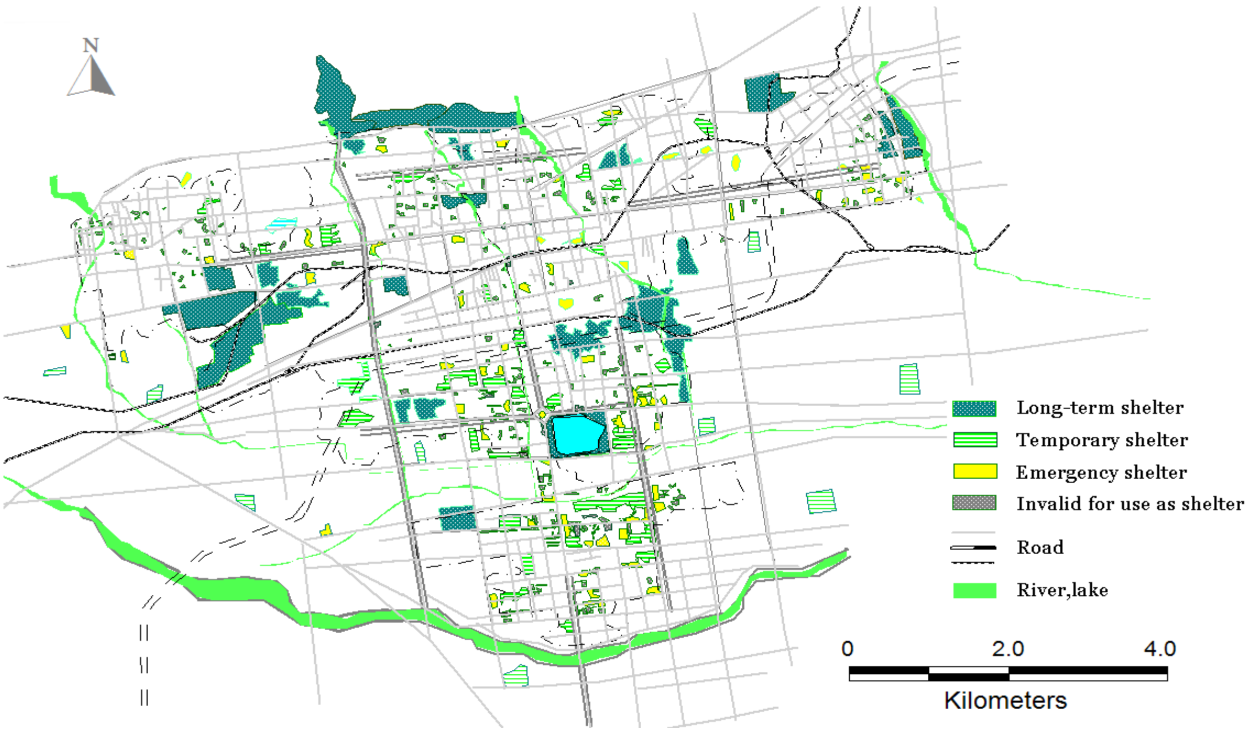

Figure 2. Green space for disaster shelter of the study region.

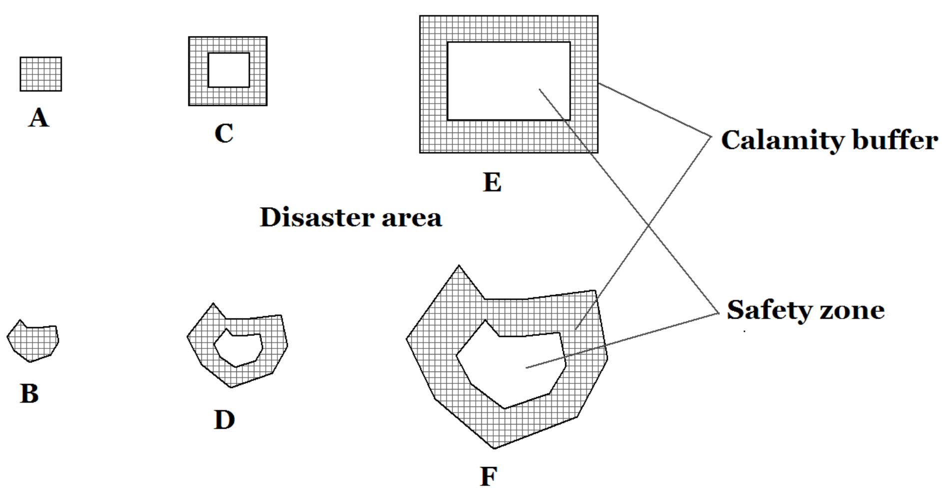

Figure 3. Disaster area, calamity buffer and safety zone of green space patches. Note: Patches A and B have no safety zone.

RESULTS AND DISCUSSION

Areas of green space for disaster shelters in Jiaozuo city

From 1999 to 2007, green space areas that could be used as long-term and temporary shelters increased from 630 and 223 ha to 1705 and 421 ha, respectively. Meanwhile, areas suitable for use as emergency shelters declined from 317 ha in 1999 to 148 ha in 2007 because of increase in the number of parks (Figure 4). The availability of safety zones suitable for long-term shelters within green spaces increased every year from 5.60 m^2 per capita in 1999 to 11.34 m^2 per capita in 2007. The availability of safety zones for temporary shelters in green spaces followed a declining trend to 2.80 m^2 per capita in

Table 1. Landscape pattern indices and disaster reduction capability of urban green space.

Structure index of green space	Formulas	Sign of the effect on disaster shelter	Sign of the effect on ecological function
Diversity index /H	$H = -\sum_{i=1}^{n} p_i \times \ln P_i$	+	+
Evenness index /E	$E = \frac{-\sum_{i=1}^{k} p_i \ln(p_i)}{\ln(i)}$	+	+
Fragmentation index/ C	$C = \frac{\sum N_i}{A}$	-	-
Dominance index/ D	$D = \log 2(i) + \sum_{i=1}^{k} p_i \ln(p_i)$	-	-
Fractal dimension index/ FD	$FD = 2\frac{\ln(l/4)}{\ln(A)}$	-	-

Note: P_i is the proportion of i type green space landscape in total; k is the total types of green space landscape; N_i is the number of green space patches in type i; N is the total number of green space patches; L is the average perimeter of green space patches and A is the average area of green space patches.

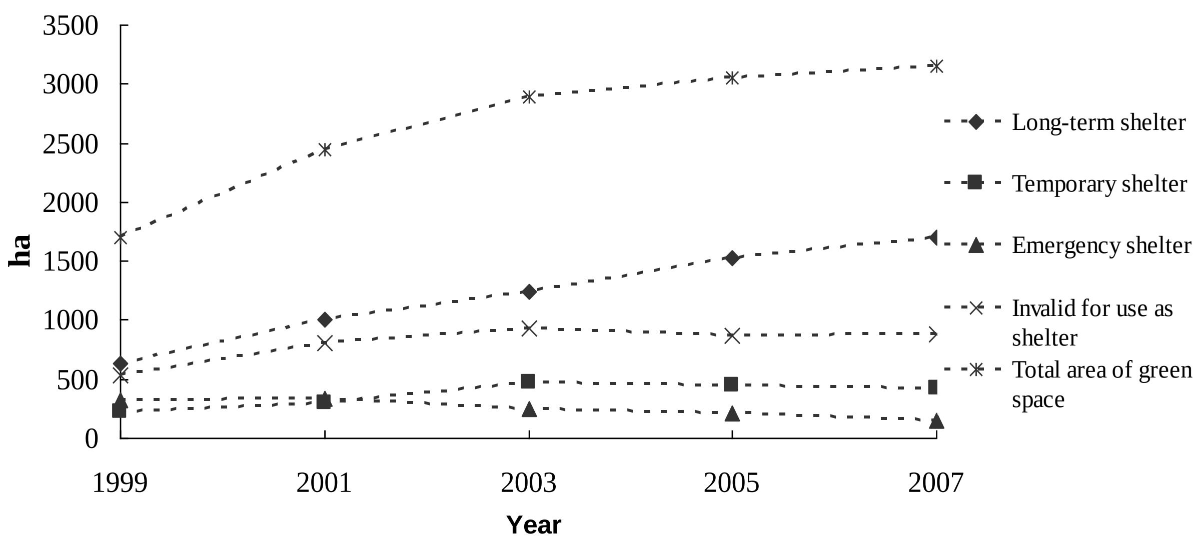

Figure 4. Disaster shelter for green space from 1999 to 2007 in Jiaozuo city.

Table 2. Minimum requirements of space for shelter (m^2/person).

Minimum requirement of space for shelter (m^2/person)	Using of space	Categories of shelters
1.2	Sit, stand and basic activities	Emergency shelter
2.5	Temporary medical aid, rest	Temporary shelter
9	Tents and transitional housing for long-term living	Long-term shelter

2007 after it increased to 3.55 m^2 per capita in 2005. The total per capita safety zone areas of green space that are suitable for long-term and temporary shelters exceeds the basic need for shelter in the city (Table 2). Per capita safety zone of green space available for emergency shelter declined gradually from 2.61 m^2 in 1999 to 0.98 m^2 in 2007 which is below 1.2 m^2, the minimum per capita requirement for emergency shelters (Figure 5, Table 2).

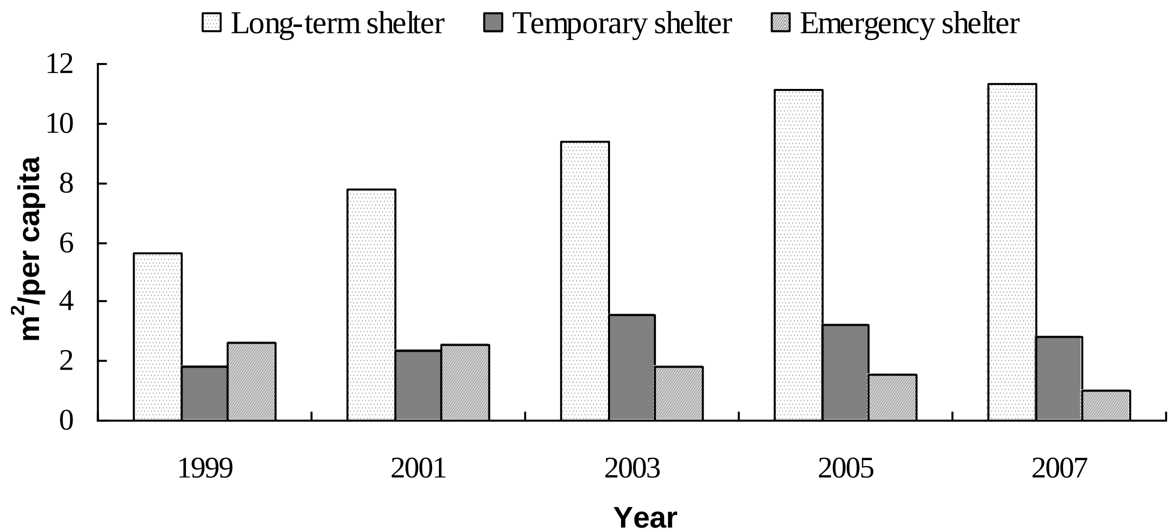

Figure 5. Per capita green space disaster shelter in Jiaozuo city.

Table 3. Area and composition of various green spaces from 1999 to 2007.

Types of green space	1999		2001		2003		2005		2007	
	A/ha	P	A/ha	P	A/ha	P	A/ha	P	A/ha	P
Park	342	0.20	571	0.24	649	0.23	813	0.27	988	32.4
Productive	158	0.09	274	0.11	313	0.11	394	0.13	453	14.8
Protective	349	0.21	418	0.18	449	0.16	556	0.19	529	17.3
Attachment	357	0.21	508	0.21	624	0.22	563	0.19	506	16.6
Other	487	0.29	624	0.26	850	0.30	656	0.22	577	18.9

Note: A and P refer to area and proportion of urban green space.

From 1999 to 2007, the total area and coverage of green space both had increasing trends. The total area of green space increased from 1706 ha in 1999 to 3,053 ha in 2007. However, the rates at which the different types of green spaces increased were different (Table 3).

The proportion of park and productive green space increased the most from 0.20 and 0.09 in 1999 to 0.32 and 0.15 in 2007. Since green space development has focused mostly on large-scale botanical gardens and ecology parks in suburban areas such as the forest park (127 ha), the Longyuanhu park (100 ha), the Fengshanzhen park (182 ha) and the People's park (28 ha), it meets the requirements of urban development, the needs of the city's inhabitants as well as the long-term and temporary shelter needs of local residents. Protective green space, the main component of temporary shelters, increased at a slow pace, while its proportion showed declining tendency from 0.20 in 1999 to 0.17 in 2007, cause of the speed of increase in protective green space is less than the total. Another reason is the changes of protective green space to lands for construction, small patches of attached green spaces and other green space along the city expansion and reconstruction of old district. Attached and other green spaces are the main components of emergency shelters. They increased from 1999 and peaked in 2003, comprising a large proportion of total green space. However, they have been heavily destroyed since 2003 because of new urban expansion and old urban reconstruction.

The areas have decreased from 624 and 850 ha in 2003 to 506 and 577 ha in 2007, respectively. These changes have thus led to a shortage of green space areas suitable for emergency shelters.

Relations between green space pattern and its disaster shelters in Jiaozuo city

The diversity index (H) and evenness (E) of green space fell from 1.79 and 0.91 in 1999 to 1.37 and 0.52 in 2007, respectively, mainly because of unbalanced development of urban green spaces. In new districts of the city, lands

Table 4. Changes in urban green system patterns between 1999 and 2007.

Year	Landscape diversity index (H)	Dominance index (D)	Evenness index (E)	Fragment index (C)	Fractal dimension index (FD)
1999	1.79	0.37	0.91	0.029	1.47
2001	1.70	0.58	0.68	0.035	1.34
2003	1.46	0.55	0.82	0.046	1.27
2005	1.48	0.64	0.61	0.065	1.21
2007	1.37	0.67	0.52	0.074	1.18

used for various other purposes have been used to build parks (Table 3). This has added relatively large areas suitable for use as long-term disaster shelters. The effects of the green space by humanity can be reflected by the fragmentation index (C) and the fractal dimension index (FD). Reconstruction of old districts and expansion of new districts have been integral parts of the expansion of Jiaozuo city in the last decade. In old districts of the city, a large number of parks were used for attached green space and other green space while some were even used for constructive land. Because the green space system of Jiaozuo city is in sustained long-term and high-intensity eco-environment pressures, its fragmentation indices show an upward trend, increasing from 0.029 in 1999 to 0.074 in 2007. In the old districts, urban green spaces that can be used for temporary shelters and emergency shelters have been declining every year. Meanwhile, in new districts of the city, most of the green spaces added in the past few years are artificial landscapes which were seriously influenced by humanity.

The shapes of the patches are simple and their fractal dimension indices have dropped from 1.47 in 1999 to 1.18 in 2007 indicating a gradual increase in the safety area per unit of green space (Table 4).

Conclusions

Urban green space areas have improved rapidly in the last decade in Jiaozuo city in China. However, they are still inadequate to meet the needs of disaster shelters especially of emergency shelters of local residents. Two major factors have contributed to this situation:

1) Green space structures have not been built at the right proportions. Large proportions of park green spaces, productive green spaces and protective green spaces and smaller proportions of attached green spaces and other green spaces make the city's green spaces inadequate for meeting the city's needs for various types of disaster shelters.
2) The distribution of the overall green space of Jiaozuo city is too uneven. Additionally, poorly designed green space patterns with high fragmentation index and low evenness index make them unsuitable and insufficient for use as green space emergency shelters in urban areas. As a result, the green spaces do not meet the needs of the city's residents for emergency shelter.

In the future, full consideration should be given to increase protective and attached green spaces, and to achieve reasonable proportions of each kind of green space while reconstructing a city and building large residential areas. Meanwhile, in Jiaozuo city, the quantity and distribution of green space has some basic conditions and functions for disaster shelter and reduction. A reliable disaster shelter system can be established by relying on existing urban green spaces. The results of our study provide a new idea for city planning and disaster management policy-makers and policy-implementers. Landscape indices can be used for analysis of green space for disaster shelter as well.

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REFERENCES

Blanco H, Alberti M, Olshansky R (2009). Shaken, shrinking, hot, impoverished and informal: Emerging research agendas in planning. Prog Plan, 72: 195-250.
Chen HG, Liang T, Zhang HW (2009). Study on the methodology for evaluating urban and regional disaster carrying capacity and its application. Safety Sci., 47(1): 50-58 [In Chin.].
Cheng FY, Sheu MS (1995). Social science approaches in disaster research: Selected research issues and findings on mitigating natural hazards in the urban environment. Urban Disaster Mitigation: The Role of Engineering and Technology, Pages 303-310. Published by Disaster Research Center, University of Delaware.
Feng XX, Xu GL, Zhang H (2008). Urban open space planning integrated with disaster prevention-a case study on Tai lake new town of Wuxi. City Plan, 6: 108-112 [In Chin.].
Fu JW, Fu XH, Hu X, Chen L, Ou JC (2011). Research into comprehensive gas extraction technology of single coal seams with low permeability in the Jiaozuo coal mining area. Mining Science and Technology (China) 21, 483–489.
Geis DE (2000). By design: The Disaster-resistant and Quality-of-life

Community. Nat Hazard Rev., 3: 151-160. http://collaborate.extension.org/mediawiki/files/1/1b/Geis-_Design-_DRC_and_quality_of_life_2.pdf. [Accessed in 16 May 2011].

Greene M (1992). Housing Recovery and Reconstruction: Lessons from Recent Urban earthquakes. In: Proceedings of the 3rd U.S./Japan Workshop on Urban Earthquakes, Oakland, CA: Earthquake Engineering Research Institute (EERI) Publication No. 93-B. http://desastres.usac.edu.gt/documentos/pdf/eng/doc3429/doc3429-contenido.pdf. [Accessed in 16 May 2011].

Hu DX, Tang J (2011). Approach to Amalgamation of Green Spaces and Emergency Shelters-Thinking after Wenchuan Earthquake. Adv. Mat. Res, 368-373:1819-1822.

Jerome K, Kathleen C, Dulcie H, Peter FD, Ellen B (1986). A Survey of Homeless Adults in Urban Emergency Shelters. Hosp Commun Psychiat., 37: 283-286. http://ps.psychiatryonline.org/cgi/content/abstract/37/3/283. [Accessed in 16 May 2011].

Koizumi T, Katayama R (1996). Urban Disaster Prevention Project-A Feasibility Study of Regional Disaster Prevention for the Government of Kobe. Congress International Society for Photogrametory and Remote Sensing XXXI, B7:.365-371. http://www.isprs.org/proceedings/XXXI/congress/part7/365_XXXI-part7.pdf. [Accessed in 16 May 2011].

Li J, Zhang L, Chen AJ, Guo H (2007). Discussion of the Ways of Combining the Urban Emergency Shelter and Urban Green Space Construdion. Chinese Landscape Archit., 23(5):83-87 [In Chin.].

Liu C (2011). Open space planning in China focusing on Urban Lifestyle -For the green system planning of Shenyang as Example. http://zibasazi.qazvin.ir/c/document_library/get_file?uuid=342e3af7-05b9-4d23-852d-648d4955eea9&groupId=44243. [Accessed in 16 May 2011].

Liu CH, Zhang HT, Wang SD, Li HJ (2005). Study on mine closure for recourses exhausting and model optimization of economic transition programming in Jiaozuo city. J. China Coal Soc., 30(3): 395-399 [In Chin.].

Liu Q, Ruan XJ, Shi P (2011). Selection of emergency shelter sites for seismic disasters in mountainous regions: Lessons from the 2008 Wenchuan Ms 8.0 Earthquake, China. J. Asian Earth Sci., 40(4): 926-934.

Luo SH, Qian JZ, Wu JF, Zhao WD, Wang KL (2006). Effect of urbanization on hydro-geochemistry and contamination of fracture-karst groundwater from Jiaozuo City, China. Geochimica et Cosmochimica Acta, 70(18): A376.

Montoya L (2003). Geo-data acquisition through mobile GIS and digital video: an urban disaster management perspective. Environ Modell & Softw., 18(10): 869-876.

Paraskevi SG, Ioannis AP, Chris TK, Nikolaos CM (2007). Modeling emergency evacuation for major hazard industrial sites. Reliab. Eng. Syst. Safety, 92(10): 1388-1402.

Pursals SC, Garzón FG (2009). Optimal building evacuation time considering evacuation routes. Eur. J. Oper. Res., 192(2):692-699.

Saadatseresht M, Mansourian A, Taleai M (2009). Evacuation planning using multiobjective evolutionary optimization approach. Eur. J. Oper. Res., 198 (1):305-314.

Shaw R (2001). Role of schools in creating earthquake-safer environment. Disaster Management and Educational Facilities, Greece. pp. 1-7.

Shendarkar A, Vasudevan K, Lee S, Son YJ (2008). Crowd simulation for emergency response using BDI agents based on immersive virtual reality. Sim Model Pract Th., 16(9): 1415-1429.

Shields TJ, Boyce KE, McConnell N (2009). The behaviors and evacuation experiences of WTC 9/11 evacuees with self-designated mobility impairments. Fire Safety J., 44(6): 881-893.

Solecki W, Leichenko R, O'Brien K (2011). Climate change adaptation strategies and disaster risk reduction in cities: connections, contentions, and synergies. Curr. Opin. Env. Sust., 3(3): 135-141.

The ministry of construction of China (2002). Standard for classification of urban green space (CJJ/T 85-2002), Beijing, China [In Chin.].

Wang X (2001). Type, quantity and layout of urban peripheral green space. J Forest Res., 12(1): 67-70.

Wallace R, Wallace D, Ahern J, Galea S (2007). A failure of resilience: Estimating response of New York City's public health ecosystem to sudden disaster. Health. Place. 13(2): 545-550.

You BJ (2004). On greenbelt system plan of city park against disaster with Taipei city as a case. City Plan Rev.,5: 28-33 [In Chin.].

Zarboutis N, Marmaras N (2007). Design of formative evacuation plans using agent-based simulation. Safety Sci., 45(9): 920-940.

Zhang LM, Xu QY, Hu ZL (2005). Study on per capita shelter index values of land use in Tianjin. City, 3:30-32 [In Chin.].

Zhou XM, Liu M, Wang Y (2006). Emergency shelter amount confirm and location optimized. J. Saf. Environ., 6(Z1):118-122 [In Chin.].