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Strategic spatial analysis of urban greenbelt plans in Mashhad city, Iran

Neda Kardani-Yazd¹, Nadia Kardani-Yazd² and Mohammad Reza Mansouri Daneshvar^{3*}

Abstract

Background: Greenbelt, known as the most restrictive form of urban containment policy, is a geographical boundary around a city or urban region to prevent urban sprawl. In the present study, the urban greenbelt plans were investigated with spatial, temporal, and statistical attitudes in Mashhad city, Iran. Spatial and temporal data analyses were carried out in ENVI, and GIS programs based on satellite imageries in addition to the expert analyzes of SWOT (strengths, weaknesses, opportunities, and threats) and QSPM (quantitative strategic planning matrix) matrixes to achieve the key strategies concerning the revitalization of a new greenbelt plan.

Results: Four temporal sequences of Landsat imageries were extracted for 1988, 1998, 2008, and 2018 to classify the expansion of real estates and urban sprawl. The results showed that the legal greenbelt plan failed after 10 years because the status of greenbelt in 2018 revealed nearly of occupation by sprawl expansion over than 20%. Then a new greenbelt plan was proposed around the city. Based on the lowest value of the environmental change index (ΔY_i), with an average of 0.14, the proposed greenbelt plan will demonstrate an optimum efficiency in the future time intervals (2030–2050).

Conclusions: Therefore, expert analyzes of SWOT and QSPM matrixes were shown that the essential weakness of greenbelt planning in the Mashhad city depends on the lack of a legal mechanism to conserve the greenbelt boundaries. Therefore, the total sum score of external factor's matrix with the value of 2.65 demonstrated that the opportunities for greenbelt planning in the study area are more effective than threats in the study area. Ultimately, six key strategies in greenbelt planning were presented to achieve a general equilibrium through future urban development.

Keywords: Greenbelt planning, Urban sprawl, Satellite imageries, Geographic information system (GIS), Mashhad City

Introduction

Rapid urban expansion has led to several unsustainable problems such as sprawl, reconstruction, pollution, etc. (Girardet 1999). The sustainable development declaration, derived at the Earth Summit in Rio de Janeiro in 1992, has deliberated to curb urban growth (Burchell et al. 1998). In this regard, greenbelt planning exerted around urban regions (Chaulya et al. 2001, Rao et al. 2004), was considered as one of an aggressive approach to curb urban expansion (Johnson 2001) by urban planners and policy-makers (Pham et al. 2011).

A greenbelt refers to a physical area of open space, e.g., farmland, forest or other green space that surrounds a city or metropolitan area to curb the urban expansion (Han et al. 2017) and to gain the more arrangement of sustainable land uses (Aguado et al. 2013). Among the kinds of restrained urban policies, greenbelt, known as the most restrictive form of urban containment policy (Bengston and Youn 2006), is a geographical boundary around a city or urban region to prevent urban sprawl. Currently, greenbelt policies have been adopted by many cities around the world (Yokohari et al. 2000; Kuhn 2003; Fung and Conway 2007). Recently, Kim et al. (2019) have noted that the effectiveness of the greenbelt plan may also depend on the stage of urban development. Indeed, the greenbelt affects the shape of cities by surrounding urban patches with a belt of agricultural or open areas,

*Correspondence: mrm_daneshvar2012@yahoo.com

³ Department of Geography and Natural Hazards, Research Institute of Shakhes Pajouh, Isfahan, Iran

Full list of author information is available at the end of the article

enforcing on land development from the city edges to remote suburb areas (Wang et al. 2002).

The greenbelt concept constitutes against urban sprawl (Cadieux et al. 2013). Urban sprawl is a concept dealing with the dynamic expansion of the cities (Yuan et al. 2005), which form the suburban growth, scattered leapfrog development, segregation of land uses (Pichler-Milanović 2007), and environmental land degradation (Arsanjani et al. 2013). Hence, there are some crucial factors in urban greenbelt planning and its environmental attributions against the sprawl. Amati (2008) has revealed that the greenbelt is worldwide planning to control sprawl and land degradation. According to local studies, the growth of informal settlements and suburb inhabitations depend on the sprawl expansion and land degradation in Iran (Rabbani et al. 2017). Hence, urban management in Iran is obliged to control the sprawl expansion by environmental and spatial solutions such as greenbelt planning. For instance, Madanian and Smaniotto Costa (2017) exercised the spatial characteristics for greenbelt planning to evaluate the land potential for implementing greenbelt.

On this basis, this paper aims to analyze urban greenbelt plans in Mashhad city, as a second greatest city of Iran, with spatial, temporal, and statistical attitudes. Spatial and temporal data analyses are carried out in ENVI and GIS programs based on a remote sensing procedure. Therefore, expert analysis of strengths, weaknesses, opportunities, and threats (SWOT) in addition to a quantitative strategic planning matrix (QSPM) are used to achieve the key strategies concerning the revitalization of a new greenbelt plan in future. The main innovation of the proposed method in this study is the aggregation attitude of spatial, temporal, statistical, and strategic analysis concerning urban greenbelt, which is a frontier effort in Iran. Furthermore, the major advantage of the proposed method is the application of remote sensing analyses to evaluate the past, present and future spatial urban expansion in order to estimate the efficiency of greenbelt plans and their local sensitivity.

Data and methods

Study area

In this paper, the study area is the Mashhad city located in northeastern Iran, with nearby 3,000,000 populations (SCI 2016). This location situates between northern latitudes from 36°37' to 36°58' and eastern longitudes from 59°26' to 59°44' (Fig. 1a). One of the most historical-cultural points of the city is the holy shrine of Imam Reza attracting many pilgrims and tourists in every time (Ali-zadeh 2011). From a natural viewpoint, the city has a sensitive semi-arid climate that experiences mean annual temperature of 14 °C and annual precipitation of 260 mm

based on a long-term time-period of 1966–2016 (IMO 2017). GIS-based spatial analysis of urban topography indicates that the mean elevation values vary between 900 and 1400 m above sea level in the north (close to Kashafrud River) and the south (over the Binaloud elevation heights), respectively. As the second largest city in Iran, Mashhad has experienced rapid growth in spatial extension and population in the last decades because of its economic, social, and religious attractions (Rafiee et al. 2009). The surface area of the city depends on historical urban expansion from the city core to the environment, especially to the western parts.

After some decades of uncertain attempts to govern the city growth, Mashhad is still deficient of suitable solutions for its sprawl expansion. Despite the latest development action plan of Mashhad metropolitan (Farnahad

2008), the historical problem of the accelerated urban sprawl remains largely unresolved. In the mentioned time (2008), the surface of the city had been estimated equal to 250 km². Hence, the legal development plan of the city attempted to point out an efficient procedure to control the urban growth towards a compact city pattern by definition of a legal greenbelt plan with a 300-m width and area of 28 km² around the whole of the city (Fig. 1b). This legal plan of greenbelt attempted to protect all private or public green spaces (with a total area of 30 km²) interior the belt boundary, while it has adopted an ambiguous policy on the natural or agricultural regions exterior the greenbelt boundary. This lack of legal policies caused to leapfrog sprawl, which has dilapidated these spaces with illegal and informal settlements within 2008–2018. In the status quo (2018), the surface area of the city comprised real estate and built-up areas are approximately 340 km².

Methodological framework

The legislation of legal greenbelt in Mashhad turns back to the latest development action plan of Mashhad metropolitan (Farnahad 2008). The measurement of the greenbelt efficiency needs to obtain data covering the periods before and after its approval. For this purpose, remote sensing analysis is carried out to investigate the spatial and temporal dynamics of urban expansion in the first step. In the second step, the future development of urban expansion is predicted at the confidence level of 75% and 50% of probabilities. In the third step, the efficiency of greenbelt plans and their local sensitivity are estimated toward the future settlement extension. Finally, SWOT and QSPM analysis carry out to identify the strategies concerning greenbelt planning. Fieldwork observations are used to examine internal and external factors, which is used in SWOT and QSPM analyzes.

Remote sensing data

Geo-statistical techniques of remote sensing and GIS are used repetitively in urban growth research to determine dynamic quantification of the sprawl (Jat et al. 2006; Wei et al. 2006; Yu and Ng 2007; Schneider and Woodcock 2008; Singh 2014). In this study, Landsat sensors, including TM, ETM+, and OLI at equal intervals were considered to achieve four imageries during periods of 1988, 1998, 2008, and 2018. Satellite imageries were collected from the Landsat archive of satellite remote sensing data hosted by the United States Geological Survey (USGS 2018) via web-based Earth-Explorer program with the corrected format of geometric and radiometric errors. All images were chosen in the driest month of the study area (August), to remove the error caused by cloudiness. The information and specifications of the aforementioned satellite imageries are shown in Table 1. ENVI software

Table 1 Information and specification of Landsat imageries

Date	Satellite	Sensor
1988	Landsat 4	TM
1998	Landsat 5	TM
2008	Landsat 7	ETM+
2018	Landsat 8	OLI-TIRS

was carried out to prepare the images, and GIS software was used to present the layout maps. Before to classify, the maximum likelihood classifier was applied for the land use/cover classification according to ten pixel-group samples. Accuracy assessment was conducted by using a visualized comparison method proposed by Cohen et al. (1998). For each land use class, 100 pixels were randomly selected from both the original and classified images and were compared.

Forecasting settlement extension data

Prediction of development urban sprawl in probabilistic future is important to plan a reliable boundary of greenbelt beside of the investigation urban sprawl growing in the past times. In this study, forecasting settlement extension data were collected from global Human Built-up and Settlement Extent (HBASE) hosted by socioeconomic data and applications center of the National Aeronautic and Space Administration (NASA 2018). HBASE dataset is derived from the global land survey of Landsat dataset for the target year 2010 and consists of a probabilistic classification of built-up and settlement extension (between 0 and 100%) in future (Wang et al. 2017). In the present study, two levels of settlement extensions are used at a confidence level of 75% and 50% of probabilities to forecast the possible sprawl effect on the greenbelt plans in the future time windows.

Environmental change index

Environmental change index can be determined as local environmental sensitivity (Burdon et al. 2016). According to Burdon et al. (2016), the change index can be applied to assess sensitivity and environmental changes in response to an anthropogenic disturbance as below equation (Baharvand and Mansouri Daneshvar 2019):

$$\Delta Y_i = \frac{Y_i}{X} \times \Delta X \quad (1)$$

where Y_i is a current status measurement of a variable at the temporal or spatial sequence of i , X is a current status of disturbance, and ΔY_i is an environmental change index depending on the modification of disturbance ΔX . In this study, modification of disturbance ΔX is estimated based

on an occupation rate of urban expansion into the greenbelt zone by settlement extension at a confidence level of 75% (future). Y_i is the contribution rate of greenbelt area to whole urban real estate areas in 2018 (present). Therefore, X is an occupation rate of urban expansion into the greenbelt boundary dividable between 2008 (past) and 2018 (present). The minimum value of ΔY_i (close to zero) relates to the high efficiency of greenbelt plan and its lesser changes affected by sprawl expansion, while the maximum value of ΔY_i (close to one or greater than one) reveals the low efficiency of greenbelt plan and its higher changes toward the future settlement extension.

SWOT and QSPM analysis

A SWOT analysis, comprised of strengths, weaknesses, opportunities, and threats, is a matrix, which is used to identify the priorities of the strategies in the case of an objective (Buta 2007). A SWOT analysis includes two internal and external factors' matrixes to examine the strength/weakness and opportunity/threat factors, respectively (Harfst et al. 2010). In both matrixes, normalized importance values are given for factors called as weighting values between 0 and 1. Therefore, the status quo is measured for each factor.

Using a range from 1 to 4, depending on essential weakness to massive strength. By multiplying weighting values in the status quo, the factor score is obtained. By summing all factor scores, a total score is obtained in which can be less than or over than 2.5, revealing the ascendancy of weaknesses (threats) or strengths (opportunities) in the status quo, respectively (Bohari et al. 2013). By considering the interactions between strength, weakness, opportunity, and threat factors, four types of strategies can be explained as aggressive (SO), defensive (WT), competitive (ST), and conservative (WO) strategies (Ghorbani et al. 2015). In the next step, all strategies are evaluated based on internal and external factors and their weighting values in a qualitative strategic planning matrix (QSPM). The attractiveness score is determined based on the improvement of each factor in the light of an objective. The attractiveness score (AS) is ranged between 1 and 4, revealing low to high attractiveness. By multiplying the AS in weighing values, a total of attractiveness score (TAS) is produced for each strategy, and by summing the TAS values (STAS), all strategies can be prioritized in the light study's objective (Ommani 2011).

Results and discussion

Sprawl story based on the satellite imageries

Remote sensing (RS) procedure has widely been used in environmental change detection studies at different spectral and spatial resolutions (El Asmar and Hereher 2011). In this study, four temporal sequences of satellite

imageries were extracted for 1988, 1998, 2008, and 2018 from Landsat 4, 5, 7, and 8 imageries. The results of the accuracy assessment were obtained with a mean overall accuracy of 78% and Kappa coefficient 75%, representing the normal ranges for urban land cover classification. Overall accuracy as a measure of the sample pixels depended on corrected classification results and Kappa coefficient as a random-based measure depended on the expected classification results. The satellite imageries were classified in ENVI to discriminate real estate and built-up expansion, as shown in Fig. 2, representing true natural color (RGB). The statistical results of this figure were shown in Table 2, revealing rapid urban expansion from 133.51 km² (1988) to 337.49 km² (2018) with mean alteration pace of 36% and growth rate of 1.56. Investigation of population growth of the city in synchronized time intervals showed increasing population from 1,467,209 (1988) to 3,001,184 (2018) with mean alteration pace of 27% and growth rate of 1.20 (Table 3). This fact revealed a faster growth of physical land development against that the urban population in Mashhad city, which is well corresponded on the research of Tewolde and Cabral (2011) noting the physical development of urban regions is faster than its growing population.

A dominant tendency of sprawl development within 30 years period of 1998–2018 was observed in the northern and the western parts due to their capacity of leap-frog expansion of the new settlements. The pattern of the new settlement in these parts is contributed to suburb real estates and occupied brown fields, which absorbed increasing urban sprawl. Contrarily, the elevation heights in the southern city and large agricultural ownerships in the eastern city have relatively controlled the sprawl extension during the last three decades. Hence, the essential need for a greenbelt plan is observed in the northern and western parts of Mashhad.

Re-thinking on the greenbelt plans

As mentioned in the section of the study area, the initial plan of the legal greenbelt in 2008 attempted to point out an efficient procedure to control the urban growth by definition of a 300-m width and area of 28 km² around the city. By spatial overlapping, the legal greenbelt plan upon the urban expansion it can be observed that the legal greenbelt plan failed because the status of greenbelt in 2018 revealed nearly of occupation rate by sprawl expansion over than 20% (Table 4). Hence, the present study proposed a new greenbelt plan based on remnant agricultural and pasture land with a maximized aspect of surrounding the urban sprawl in 2018. In this regard, the proposed greenbelt plan, to define a new equilibrium concerning the spatial expansion of the city, had only less than 1% overlapping with the status of urban expansion

Table 2 Urban expansion in the study area based on the satellite imagery

Date	Expansion (km ²)	Alteration (%)	Growth rate
1988	133.51	—	—
1998	192.19	44	1.84
2008	249.94	30	1.32
2018	337.49	35	1.51
Mean	228.28	36	1.56

Table 3 Urban population in the study area based the SCI (2016)

Date	Population	Alteration (%)	Growth rate
1988	1,467,209	—	—
1998	1,887,405	29	1.27
2008	2,410,800	28	1.23
2018	3,001,184	24	1.10
Mean	2,191,650	27	1.20

(Fig. 3a). The proposed greenbelt plan with averagely 1200-m width and area of 162 km² around the whole of the city aimed to protect all intact or natural spaces

inside the belt zone against sprawl effects by including the most part of legal greenbelt (22.43 km²) and a part of urban green spaces (8.22 km²) (Fig. 3b). GIS-based

Table 4 Occupation rate of sprawl expansion inside of greenbelt plans based on past and present status of urban development

Time	Greenbelt plans			
	Legal		Proposed	
	km ²	%	km ²	%
2008	2.25	8.05	0.15	0.09
2018	5.85	20.94	1.46	0.90
Mean	4.05	14.50	0.81	0.50

spatial overlaying the urban expansion on the legal and proposed greenbelt plans within time intervals of 2008 and 2018 were shown in Fig. 4. This figure assisted the results of Table 4, revealing the occupation rates of

sprawl expansion inside of greenbelt plans based on past and present status of urban development.

Analyze of greenbelt plans by sprawl probabilities in the future

In this section, the probabilistic classification of built-up and settlement extension in the future was used, according to Wang et al. (2017). In this regard, two levels of settlement extension at a confidence level of 75% and 50% probabilities were used to forecast the possible sprawl effect on the greenbelt plans in the future time windows. The spatial expansion of the city based on both probabilities was calculated in GIS equal to 459 and 651 km², respectively. After the mean alteration pace and growing rate of urban expansion during the past decades (see Table 2), the probabilistic classification of built-up and settlement extension can be adapted for time intervals of 2030 and 2050 in the future. Accordingly, GIS-based spatial overlaying the settlement extension on the legal and proposed greenbelt plans within time intervals of 2030 and 2050 were carried out in Fig. 5. Therefore, the occupation rates of settlement extension inside of greenbelt plans based on two future time intervals were estimated in Table 5. The results showed that the legal greenbelt would be possessed by settlement extension nearly 69% and 99% up to 2030 and 2050, respectively. Hence, the legal greenbelt plan will explain 1–31% efficiency in the future. Contrarily, the proposed greenbelt plan would be occupied approximately 45% and 88% up to 2030 and 2050, respectively. Hence, the proposed greenbelt plan will explain the better result of 12–55% efficiency in the future.

Characterization of the index of the environmental change was carried out to reveal the local sensitivity of legal and proposed greenbelt plans in the future. For this purpose, the estimation of environmental change index (ΔY_i) and its components for legal and proposed greenbelt plans was computed in Tables 6 and 7, respectively. Based on Table 6, a very weak modification ratio (ΔX) was estimated equal to 0.69 and 0.99, with an average of 0.84 in the future periods. Consequently, a broad environmental change index (ΔY_i) was estimated between 3.19 and 4.58, with an average of 3.89 for future time intervals (2030–2050). In vice versa, a moderate modification ratio (ΔX) was estimated equal to 0.45 and 0.80, with an average of 0.63 for the proposed greenbelt plan in the future periods (Table 7). Consequently, a low value of ΔY_i (close to zero) relates to the high efficiency of the proposed greenbelt plan was estimated between 0.10 and 0.17, with an average of 0.14 for the future time intervals. This result indicates that the proposed greenbelt plan will demonstrate an optimum efficiency in the future concerning the legal plan.

At the time of legal greenbelt established, the urban boundary generally lied well within the inner side of the

belt. As a city extended in the recent decade, the effectiveness of the legal greenbelt became uncertain in light of the urban sprawl. On this basis, the present study proposed a new greenbelt plan to define a new equilibrium concerning the spatial expansion of the study area. As Anas and Rhee (2006) have noted, the planners should set new greenbelts to achieve general equilibrium through new urban development.

Developing key strategies for greenbelt planning in Mashhad

In this study, a set of 3 strengths and 3 weaknesses was surveyed as internal factors concerning the proposed greenbelt plan (Table 8). The total weighting values for

strength and weakness factors were estimated equal to 0.55 and 0.45, respectively. Subsequently, the total scores for strength and weakness factors were estimated equal to 0.95 and 0.90, respectively. A total sum score of internal factor's matrix was calculated as 1.85, which is less than 2.5, demonstrating the strengths of greenbelt planning were less effective than weaknesses in the study area. This problem dominantly depends on the lack of a legal mechanism to conserve the greenbelt boundaries in the Mashhad city.

Furthermore, a set of 3 opportunities and 3 threats was surveyed as external factors (Table 9). The total weighting values for opportunity and threat factors were estimated equal to 0.70 and 0.30, respectively. Subsequently, the

Table 5 Occupation rate of settlement extension inside of greenbelt plans based on two development probabilities in future

Time	Greenbelt plans			
	Legal		Proposed	
	km ²	%	km ²	%
2030	19.16	68.58	72.87	44.88
2050	27.56	98.64	130.25	80.21
Mean	23.36	83.61	101.56	62.55

total scores for opportunity and threat factors were estimated equal to 1.90 and 0.75, respectively. A total sum score of external factor's matrix was calculated as 2.65,

Table 6 Estimation of environmental change index (ΔY_i) and its components for legal greenbelt plan based on two development probabilities in future

Time	Y_i	X	ΔX	ΔY_i
2030	12.08	2.60	0.69	3.19
2050	12.08	2.60	0.99	4.58
Mean	12.08	2.60	0.84	3.89

which is more than 2.5, demonstrating that the opportunities of greenbelt planning were more effective than threats in the study area. This good potential can be related to the proper pattern of the proposed greenbelt plan to covers around the city against all sprawl expansions.

Table 7 Estimation of environmental change index (ΔY_i) and its components for proposed greenbelt plan based on two development probabilities in future

Time	Y_i	X	ΔX	ΔY_i
2030	2.08	9.73	0.45	0.10
2050	2.08	9.73	0.80	0.17
Mean	2.08	9.73	0.63	0.14

In the next step, six key strategies were developed by SWOT analysis in Table 10. In this regard, two aggressive strategies were proposed including (SO_1) developing an ecological greenbelt based on carbon sequestration and saving energy, and (SO_2) developing a horticultural action in brown fields to create an agricultural greenbelt. With accordant to a paper (Madanian and Smaniotto Costa 2017), the transition from greenbelt concept to agricultural or natural buffer can be considered in Iran because the most cities in Iran are located in arid

and semiarid regions, faced with the lack of green spaces around their selves. Similarly, Madanian and Smaniotto Costa (2019) have noted that transferring the horticultural spaces into greenbelt domains can be an effective strategy for improving environmental liveability.

A conservative strategy was proposed as (WO_1) training of decision-makers to enhance the legal mechanism of protection and conservation. Two competitive strategies were identified including (ST_1) encouraging the agricultural entrepreneurship to absorb the investment of greenbelt planning, and (ST_2) preparing a link between recreation and elevation heights to improve the greenbelt action plan. After that, a defensive strategy was proposed as (WT_1) preparing a program to conserve the greenbelt zone for prevention the leapfrog sprawl. Findings of a research (Gupta et al. 2008), correspond to our results, revealed the major role of greenbelt regarding to the attenuation of industrial air pollution and carbon sequestration.

Table 8 Internal factor's matrix for strengths and weaknesses

No.	Internal factors	Weight	Status quo value	Score
Strengths				
1	S_1 . Combination of suburb brown fields into public green spaces	0.10	2.0	0.20
2	S_2 . Protecting all ecological pasture lands in the elevation heights	0.30	1.0	0.30
3	S_3 . Having a suitable connection with the fertilized soil types and land covers	0.15	3.0	0.45
	Sum	0.55		0.95
Weaknesses				
2	W_1 . Lack of an action plan to reduce the segregation of agricultural lands	0.20	1.0	0.20
3	W_2 . Lack of a legal mechanism to conserve the greenbelt boundaries	0.15	4.0	0.60
4	W_3 . Reduction of greenbelt efficiency due to its large surface area	0.10	1.0	0.10
	Sum	0.45		0.90
	Total sum	1.00		1.85

Table 9 External factor's matrix for opportunities and threats

No.	External factors	Weight	Status quo value	Score
Opportunities				
1	O_1 . Potential of proper horticulture to support food and fruit plantation	0.10	1.0	0.10
2	O_2 . Having a proper pattern to covers around the city against sprawl expansion	0.30	3.0	0.90
3	O_3 . Potential of a great zone of carbon sequestration zone to reduce CO_2 emissions	0.30	3.0	0.90
	Sum	0.70		1.90
Threats				
1	T_1 . Possible environmental impacts of recreational and tourism activities	0.05	1.0	0.05
2	T_2 . Extreme effect on financial investments due to its large area	0.10	4.0	0.40
3	T_3 . Extreme effect on shifting leapfrog sprawl expansion outward the city	0.15	2.0	0.30
	Sum	0.30		0.75
	Total sum	1.00		2.65

Table 10 Developing key strategies for greenbelt planning by SWOT analysis

External factors	Internal factors	
	Strengths (S)	Weaknesses (W)
Opportunities (O)	Aggressive SO strategies SO ₁ . Developing an ecological greenbelt based on carbon sequestration and saving energy	Conservative WO strategies WO ₁ . Training of decision-makers to enhance the legal mechanism of protection and conservation
Threats (T)	SO ₂ . Developing a horticultural action in brown fields to create an agricultural greenbelt Competitive ST strategies ST ₁ . Encouraging the agricultural entrepreneurship to absorb the investment of greenbelt planning ST ₂ . Preparing a link between recreation and elevation heights to improve the greenbelt act plan	Defensive WT strategies WT ₁ . Preparing a program to conserve the greenbelt zone for prevention the leapfrog sprawl

Table 11 QSPM analysis of key strategies

Factor	Weighting value	SO ₁		SO ₂		WO ₁		ST ₁		ST ₂		WT ₁	
		AS	TAS	AS	TAS	AS	TAS	AS	TAS	AS	TAS	AS	TAS
S ₁	0.10	2	0.2	2	0.2	2	0.2	2	0.2	3	0.3	1	0.1
S ₂	0.30	3	0.9	2	0.6	3	0.9	1	0.3	4	1.2	1	0.3
S ₃	0.15	3	0.45	4	0.6	2	0.3	1	0.15	2	0.3	2	0.3
W ₁	0.20	1	0.2	3	0.6	4	0.8	2	0.4	2	0.4	3	0.6
W ₂	0.15	1	0.1	1	0.1	4	0.4	2	0.2	1	0.1	4	0.4
W ₃	0.10	2	0.3	1	0.15	2	0.3	3	0.45	1	0.15	2	0.3
O ₁	0.10	3	0.3	4	0.4	2	0.2	3	0.3	1	0.1	1	0.1
O ₂	0.30	2	0.6	2	0.6	1	0.3	1	0.3	1	0.3	3	0.9
O ₃	0.30	4	1.2	2	0.6	1	0.3	2	0.6	1	0.3	2	0.6
T ₁	0.05	2	0.1	1	0.05	3	0.15	4	0.2	4	0.2	1	0.05
T ₂	0.10	1	0.1	1	0.1	2	0.2	4	0.4	1	0.1	1	0.1
T ₃	0.15	2	0.3	2	0.3	3	0.45	1	0.15	2	0.3	4	0.6
STAS			4.7		4.3		4.6		3.6		3.75		4.45
Priority			1		4		2		6		5		3

Finally, the QSPM analysis was performed in Table 11 to prioritize the aforementioned key strategies. On this basis, the sum of total attractiveness scores (STAS) for six key strategies was calculated as 4.7, 4.6, 4.45, 4.3, 3.75, and 3.6 for strategies of SO₁, WO₁, WT₁, SO₂, ST₂, and ST₁, respectively. The essential key strategies were chosen as (SO₁) developing an ecological greenbelt based on carbon sequestration, and (WO₁) training of decision-makers to enhance the legal mechanism of protection and conservation.

These strategies will make up the significant impacts on the prospect of greenbelt. Kim et al. (2019) have mentioned that the effectiveness of a greenbelt strategy is controversial due to its different effects. Some

researchers have claimed that the proper strategies in greenbelt planning can result in sprawl restriction (Amati and Yokohari 2006; Woo and Guldmann 2011), while other researchers have noted that the unsuitable greenbelt strategies can encourage leapfrog development (Jun and Hur 2001; Dawkins and Nelson 2002; Bae and Jun 2003; Ogura 2010). In any way, the present study attempted to propose suitable strategies to define an optimal plan of greenbelt based on the past changes and the future probabilities. Several studies link sustainability to the urban planning proposed by a greenbelt concept (Yokohari et al. 2000; Lindsey 2003; Brown et al. 2004; Yang and Jinxing 2007). With accordant to the aforementioned studies, the present paper has operated the

urban greenbelt approach to restrict the physical expansion of urban sprawl, preserving green space and preventing environmental degradation. The findings allow urban planners and policy-makers for making and taking efficient decisions regarding greenbelt plans in other urbanized regions. The proposed method and its environmental index can be considered as an environmental tool for rapid evaluation of greenbelt potentials through other urbanized regions in the Iran and neighbor countries, which have same-sized population or environment, such as Isfahan (Iran), Tabriz (Iran), Baku (Azerbaijan), Kabul (Afghanistan), Dubai (UAE), and Kuwait (Kuwait) (WUP 2018).

Conclusion

The present study aimed to analyze urban greenbelt plans in Mashhad city, as the second greatest city of Iran, with spatial, temporal, and statistical attitudes. After some decades of uncertain attempts to govern the city growth, Mashhad is still deficient of suitable solutions for its sprawl expansion. Hence, remote sensing analysis was carried out to investigate the spatial and temporal dynamics of urban expansion based on satellite images and future urban development at the confidence level of 75% and 50% of probabilities. The statistical results revealed a rapid urban expansion in the last three decades with mean alteration pace of 36% and a growth rate of 1.56. This growing fact indicated that physical land development was faster than the urban population growth (with mean alteration pace of 27% and a growth rate of 1.20). Hence, the legal greenbelt plan, initially suggested by local development action plan around the Mashhad city in 2008, failed regarding limit urban sprawl after 10 years, because the status of greenbelt in 2018 revealed nearly of occupation by sprawl expansion over than 20%. A large environmental change and weak efficiency of the legal greenbelt plan was obtained based on the estimation of change index ΔY_i (with an average of 3.89). A low environmental change index (ΔY_i) for proposed greenbelt was obtained averagely as 0.14 in the future time intervals (2030–2050). This result indicated that the proposed greenbelt plan would have optimum efficiency in the future.

Ultimately, the following six key strategies were produced in greenbelt planning, briefly including (SO₁) developing an ecological carbon sequestration, (SO₂) developing a horticultural action, (WO₁) training the legal mechanism of protection, (ST₁) encouraging the agricultural entrepreneurship, (ST₂) preparing a link between recreation and elevation heights, and (WT₁) preparing a program to conserve the greenbelt zone. These strategies firstly revealed the essential ecological role of the proposed greenbelt plan in the future and

secondly bolded the lack of legal mechanism of protection and conservation the agricultural and natural spaces against the increasing urban sprawl.

Abbreviations

GIS: geographic information system; HBASE: Human Built-up and Settlement Extent; QSPM: quantitative strategic planning matrix; RS: remote sensing; SWOT: strengths, weaknesses, opportunities, and threats; TAS: total of attractiveness score.

Acknowledgements

We thank anonymous reviewers for technical suggestions on data interpretations.

Authors' contributions

All authors were equally involved in analyzing and editing the paper. All authors read and approved the final manuscript.

Funding

This study was not funded by any grant.

Availability of data and materials

The data that support the findings of this study are available from the corresponding author upon request.

Ethics approval and consent to participate

This article does not contain any studies with participants performed by any of the authors.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Informed consent

Informed consent was obtained from individual participant included in the study.

Author details

¹ Department of Urban Planning and Design, Mashhad Branch, Islamic Azad University, Mashhad, Iran. ² Department of Art and Architecture, Mashhad Branch, Islamic Azad University, Mashhad, Iran. ³ Department of Geography and Natural Hazards, Research Institute of Shakhsh Pajouh, Isfahan, Iran.

Received: 16 August 2019 Accepted: 29 September 2019

Published online: 08 October 2019

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