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Evaluation of the Carrying Capacity of Semnan Using Urban Carrying Capacity Load Number Model

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Background: Along with rapid economic growth, many natural regions, meadows, farms, etc. have been converted into unbridled urban areas. Urban development converts natural areas into districts full of buildings leading to disrupted ecological balance of the ecosystem. The carrying capacity (CC) of urban ecosystems needs to be estimated because they require large amounts of materials and energy as well as the ability of pollutant absorption in a small location. The amount of material and energy used in cities may be more than of that provided by urban CC. High consumption rate is associated with high levels of contamination that transcends the UCC. Therefore, the CC of the urban environment and its population capacity must be evaluated for urban development planning.

Materials and Methods: In this study, UCC load number within the pressure-state-impact-response (PSIR) framework and 20 indicators were used to evaluate the CC and pressure on the urban ecosystem of Semnan.

Results: According to the results, the load number in the district 1 was equal to 180.05with a low to moderate pressure on the urban ecosystem. The load numbers in districts 2 and 3 were respectively 230.41 and 272.86 imposing a moderate to high pressure on urban ecosystem.

Conclusions: Because of the greater population density in the District 3, materials and energy consumption and waste production was higher leading to a higher pressure on the urban ecosystem.

Keywords: Critical pressure, Load number, PSIR framework, Urban carrying capacity

1. Background

Assuming that the natural environment limits human activities and various land uses (1, 2), environmentally sound and sustainable development aims to rationalize economic efficiency, social welfare and environmental protection (3). Environmental pollutions caused by widespread use of natural resources increase the cost of economic activities that lead to limitations in social welfare (4, 5). In other words, human activities exceeding a certain limit would seriously put the natural and human environment at risk (6).

Ecologists consider a city as a heterotrophic ecosystem when it depends on large amounts of materials and energy input and large capacity to

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absorb pollution and wastes (7, 8). The accumulation of materials and energy leads to major environmental changes. Transition from the ecological threshold as the result of environmental constraints will lead to unexpected nonlinear reaction of the ecosystem. Therefore, regular monitoring of human impacts on the urban ecosystem is necessary so that pressures as the result of urban development would not exceed the carrying capacity of the ecosystem (4, 9).

The concept of carrying capacity is very extensive and defined according to various ecological, social, cultural and political aspects (4, 10). Carrying capacity of an area can be defined as the maximum people or physical development which can be supported by the environment, a natural or artificial system without destruction or significant damage so that it`s capacity to support future generations would not decrease (11, 12). It points out the inherent limitations in the system beyond which leads to instability, destruction or irreversible damage (13). As human can increase the carrying capacity by eliminating competing species and consume various resources through technology, carrying capacity must not only be defined as the maximum population, but as maximum pressure which can be safely imposed on the environment without disrupting the function of the urban ecosystem (14, 15).

Urban carrying capacity is a level of human activity, population growth, land use and physical development that can be sustained by the environment without serious or irreversible damage (4, 16). This concept can be applied through determining thresholds beyond which the changes are unacceptable (17). This approach to carrying capacity can be useful when the thresholds are predefined (18).

It is critical, however very difficult, to estimate the carrying capacity to understand the concept of sustainability (19). Carrying capacity is not static, but varies based on complex relationships between priorities, use of technology, production and consumption patterns and also biotic and abiotic interactions (20). Thus, researchers use a variety of different models to estimate the carrying capacity, including ecological footprint model (21), energy analysis model (22), pressure-state-impact-response (PSIR) model (23), graphical model, uni-constraint model and IPAT (Impact= Population* Affluence* Technology) model (10).Among these models, PSIR is suggested by the environmental scholars for developing sustainability indicators (24, 25, 26, 27).

2. Objectives

Semnan as the center of Semnan province has experienced a rapid urban population growth, which grew from 75,131 in 1991 to 153,680 in 2011, an average growth of 3.64% (28). Due to close proximity to Tehran (216 km), Semnan has been proposed as an option for capital transfer. However, comprehensive studies on its environmental carrying capacity have been done. The aim of the present study is to use the pressure-state-impact-response (PSIR) framework and Urban Carrying Capacity Load Number Model (9) to monitor the urban environment and assess the urban carrying capacity of Semnan.

3. Materials and Methods

3.1. Study Area

Semnan, 35° 34 N and 53° 23 E, average elevation of 1130 m above sea level and a north-south gradient, is located in a great dry plain in the margin of Kavir-e-Namakin, the southern foothills of Alborz Mountains. It is connected to Mehdishahr from the north, Sorkheh from the west and Damghan from the east (Figure 1), and also to Tehran-Mashhad railway. Semnan city covers an area of 2370 hectares which is divided into 2 regions and 3 districts (29).

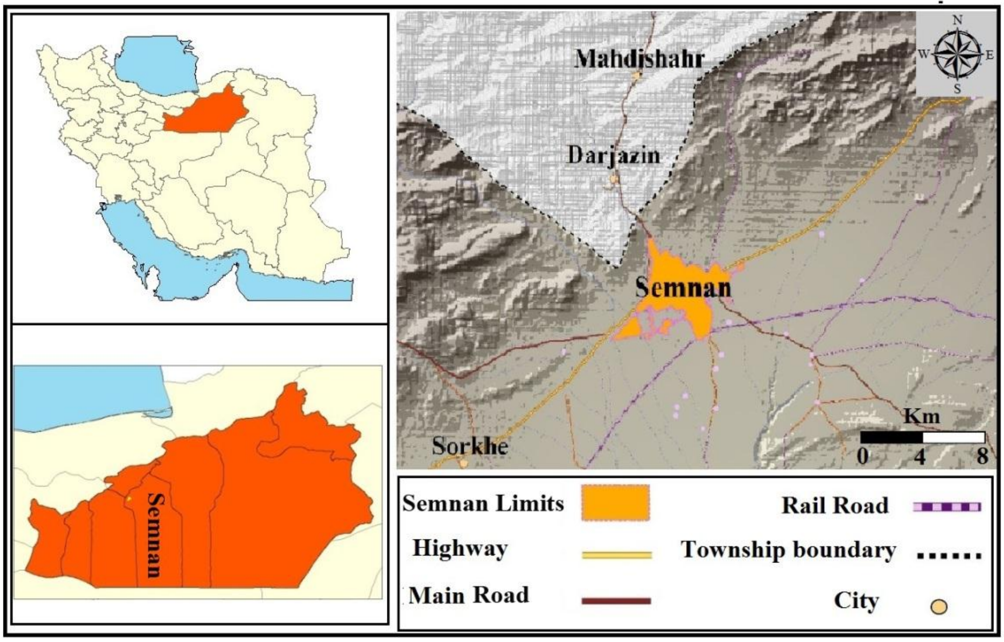

Figure 1 Geographical location of Semnan

3.2. Methods

PSIR, a generalized version of PSR was employed in this study (30). This model explicitly takes into account the effects of human activities on the natural environment. This approach can be used to determine the priority of the key environmental issues and identifying appropriate responses (31). In addition to environmental monitoring, this model has been used for monitoring and evaluating urban ecosystem sustainability and estimating the urban carrying capacity (9).

Due to the relationship between sustainability and the concept of carrying capacity, the proposed UCCLN model (23) was used to monitor and assess the ecosystem of Semnan, its distance from the sustainable situation and the desired values of carrying capacity within the pressure-state-impact-response (PSIR) framework. The urban carrying capacity load number uses carrying capacity in an indicator system that includes a minimum (optimal) load representing the value of indicator resulting in minimal changes and disturbances in the urban ecosystem. This value is extended to the maximum or allowable pressure (which is always less than the physical carrying capacity) that an urban ecosystem can tolerate before serious damage or irreversible changes in the structure or function (9).

3.3. Urban carrying capacity indicators

Indicators are key tools with multiple purposes used in monitoring the environment for better and easier understanding of the situation and problems (32). Various urban pressure indicators have been employed in different studies dealing with urban carrying capacity (4, 9, 33, 34). With regard to the PSIR framework, considering the source-sink concept and specific ecosystem of Semnan as well as restrictions on access to information, 20 indicators were selected to assess the sustainability and carrying capacity of Semnan (Table 1).

3.4. Thresholds and ranges in the urban carrying capacity model

In this model, indicators are placed in 6 categories called "Degree of Carrying Capacity

(DCC)". In the first class, the load number resulted from the indicator is estimated to be very low (zero), however since quantitative indicators are used to examine the pressure, a value of 0.1 is used in calculations instead of zero and considered as the minimum acceptable load for each indicator. In the next classes, the indicators are increased and the last class shows the critical status (Table 2) (23).

For altitude and slope, current urban standards, application of urban development ecological model (35) and considering the pressure on urban ecosystem, these indicators were classified in six categories as shown in Table 3 (9). Regarding built environment indicators and per capita urban land uses, the thresholds and standards for per capita urban use were considered (23, 36); regarding population density as one of the most important indicators, literature was reviewed on optimal and allowable urban population density (23,36) and considering limiting factors including water resources in Semnan, a minimum optimal density of 50 persons per hectare and a maximum urban population density of 110 persons per hectare were defined; the population growth rate during 2006-2011 was determined, then the desired and allowable population growth in each district was calculated separately based on the desired and allowable population density. The carrying capacity degrees of indicators were classified in 6 categories (Table 3).

In the case of indicators lacking a standard or defined threshold such as those related to material and energy consumption, it is necessary to define certain ranges indicating different levels of pressure on the urban ecosystem. To determine the ranges and classify the pressure on the area, the per capita consumption of material and energy (water, gas, electricity) was calculated, based on the data provided by the authorized organizations. With regard to the optimum population density (50 persons per hectare) and allowable population density (110 persons per hectare), the optimal and allowable consumption (maximum consumption) per unit area was achieved and summarized in the carrying capacity degree table. In the cases where the maximum available resources could be calculated, the maximum allowable resource consumption per hectare can be achieved by dividing the maximum available resources by the study area.

3.5. The importance coefficient of indicators

To determine the importance and influence of indicators imposing pressure on the urban ecosystem, the importance coefficient (IF) matrix was used. Using this matrix, the weight and importance of each pressure indicator was determined by taking advantage of AHP and fuzzy logic rules from 1 to 5 (from 0.2 to 0.5). Finally, the scores of indicators were multiplied and the geometric mean was calculated. Then, the indicator values were normalized and multiplied by 100 to achieve the importance of each indicator imposing pressure on the urban ecosystem (23). Table 1 shows the importance coefficients of indicators.

3.6. The load number of indicators

After determining the importance coefficients of indicators by the importance coefficient matrix, DCC of each indicator was multiplied by its IC. The resulting number represents the pressure on the urban ecosystem based on the concept of carrying capacity. It also indicates the priority of pressure indicators called the load number (LN) (Equation 1) (23).

$$LN= DCC \times IC \qquad (1)$$

3.7. The total carrying capacity and load number of 20 indicators

To evaluate the total carrying capacity of 20 pressure indictors, the carrying capacity table and the total pressure number of 20 indicators were used. (Table 4).

Table 1 The indicators used to evaluate sustainability and carrying capacity of Semnan based on PSIR framework

PSIR Framework		Indicator		Importance coefficient
state	Natural state	Land form	elevation	1.4
			slope	1.6
		Natural disasters	Vulnerability to earthquake	6.2
		Groundwater depth	Groundwater depth	1.7
	Built environment state	Per capita urban land use	housing	2.5
			education	2.5
			health	2.5
			Green space	2.5
			transportation	2.5
		Urban land use area	Green space/ total area	2.5
			Transportation/ total area	2.5
pressure		population	density	10
			Growth rate	10
		Energy consumption	electricity	4.6
			gas	4
			Gas consumption/ resources	4
		Material consumption	Water consumption	12.7
			Water consumption/ resources	12.7
Impact		Waste production	Waste production	6.8
response		recycling	recycling	6.8

Table 2 The ranges and degrees of carrying capacity of indictors

Range	1	2	3	4	5	6
Indicator X	Classified values of the indicator X based on the Carrying Capacity (CC)					
DCC	0.1	1	2	3	4	5
Pressure	Very low	Low	Moderate	High	Very high	Critical
The concept of LN	Optimal	CC degree 1: Between the optimal value and the physical carrying capacity. The environmental carrying capacity obtained through compromise.	CC degree 2: Between the optimal value and the physical carrying capacity. The environmental carrying capacity obtained through compromise.	CC degree 3: between the optimal value and the physical carrying capacity	CC degree 4: (Threshold of indicator). usually equal to physical carrying capacity	Critical (exceeding the threshold)
The concept of DCC	Optimal value of the indicator leading to minimal destruction and changes.	A value of the indicator leading to low pressure.	A value of the indicator leading to moderate pressure.	A value of the indicator leading to high pressure.	The maximum value of the indicator that does not lead to serious damage or irreversible pressure.	A value of the indicator leading to serious degradation or irreversible pressure.

Table 3 Grading carrying capacity of 20 indicators used in assessing the carrying capacity of Semnan

Indicator	**unit**	**Degree of Carrying capacity (DCC)**					
		0.1 (very low)	**1 (low)**	**2 (medium)**	**3 (high)**	**4 (very high)**	**5 (critical)**
Elevation	meter	400-1200	0-400	1200-1400	1400-1600	1600-1800	1800<
Slope (%)	percent	0-2	2-4	4-6	6-8	8-9	9<
Disaster's vulnerability	zone	0	1	1.5	2	2.5	3
Underground water	meter	100<	80-100	60-80	40-60	20-40	<20
Residential	Square meter/person	40<	35-40	30-35	25-30	20-25	<20
Educational	Square meter/person	5<	4-5	3-4	2-3	1-2	>1
Health/Medical	Square meter/person	1.5<	1.25-1.5	1-1.25	0.75-1	0.5-0.75	<0.5
Green space	Square meter/person	15<	12-15	7-12	5-7	3-5	<3
Transportation network	Square meter/person	25<	20-25	15-20	10-15	5-10	<5
Green space/total area	percent	15<	12-15	9-12	6-9	3-6	<3
Transportation network/total area	percent	25<	20-25	15-20	10-15	5-10	<5
Population density	Person/hectare	0-50	50-65	65-80	80-95	95-110	110<
Population growth rate	percent	*					
Electricity consumption	kwh/year/hectare	<36600	36600-47580	47580-58560	58560-69540	69540-80520	80520<
Gas consumption	Cubic meter/hectare/year	0-49008	49008-110596	110596-172183	172183-233771	233771-295359	295359<
Total gas consumption/supply	percent	0-30	30-60	60-70	70-80	80-90	90<
Water consumption	Cubic meter/hectare/year	0-3504	3504-4348	4348-5192	5192-6037	6037-6881	6881<
Total water consumption/supply	percent	0-30	30-60	60-70	70-80	80-90	90<
waste production	Tone/hectare/year	0-9100	9100-11830	11830-14560	14560-17290	17290-20020	20020<
Recycle ratio of waste	percent	80-100	65-80	50-65	35-50	20-35	<20

*Given different population growth rates, the allowable and desirable rates were calculated for each district separately

Table 4 The degrees of carrying capacity and the total load number of 20 indicators

	Degree of Carrying Capacity					
	0.1	1	2	3	4	5
Importance coefficient	100	100	100	100	100	100
Total pressure number	10	100	200	300	400	500

4. Results and Discussions

After determining the DCC and LN of 20 indicators in Semnan, the total load number of these indicators was calculated (Table 5) and the LN map was prepared (Figure 2). This map shows the distribution of pressure in different areas of Semnan and is an appropriate tool to investigate and locate critical points and to compare the overall situation in different areas.

Semnan is located on the Semnan Plain and its northern part is extended to the mountain with an average gradient of 2.3%. The slope in the northern areas (Districts 2 and 3) is slightly more than of the southern area (District 1). The LN of the slope in the District 1 is equal to 0.16 (imposing a very little pressure on the urban ecosystem). The corresponding value in the districts 2 and 3 is equal to 1.6 imposing a little pressure on the urban ecosystem. Due to faults around Semnan, all urban areas of Semnan are highly vulnerable to earthquake (vulnerability of 5 and a LN of 31).

The probability of groundwater contamination by human sewage and pollutants in the District 1 is low with an average groundwater depth of 85 meter (a DCC of 1and a LN of 1.7). The districts 2 and 3 with an average depth of 156 m and 128 m have a DCC of 0.1 and a LN of 0.17, respectively. The probability of groundwater contamination by human sewage or other wastewaters in districts 2 and 3 is zero imposing a slight pressure on the urban ecosystem.

Table 5The LNs of 20 indicators used in assessing the carrying capacity of the urban areas of Semnan

PSIR Framework		Indicator		District 1	District 2	District 3
state	Natural state	Land form	elevation	0.14	0.14	0.14
			slope	0.16	1.6	1.6
		Natural disasters	Vulnerability to earthquake	31	31	31
		Groundwater depth	Groundwater depth	1.7	0.17	0.17
	Built environment state	Per capita urban land use	housing	2.5	2.5	7.5
			education	0.25	0.25	5
			health	5	0.25	0.25
			Green space	2.5	5	5
			transportation	0.25	0.25	0.25
		Urban land use area	Green space/ total area	7.5	7.5	7.5
			Transportation/ total area	0.25	0.25	0.25
pressure		population	density	10	20	20
			Growth rate	40	30	50
		Energy consumption	electricity	4.5	9	9
			gas	4	4	4
			Gas consumption/ resources	4	0.4	0.4
		Material consumption	Water consumption	12.7	25.4	38.1
			Water consumption/ resources	12.7	38.1	38.1
response		Waste production	Waste production	6.8	20.4	20.4
		recycling	recycling	34	34	34
Total pressure number				179.95	230.21	272.66
Degree of Carrying Capacity				1-2	2-3	2-3

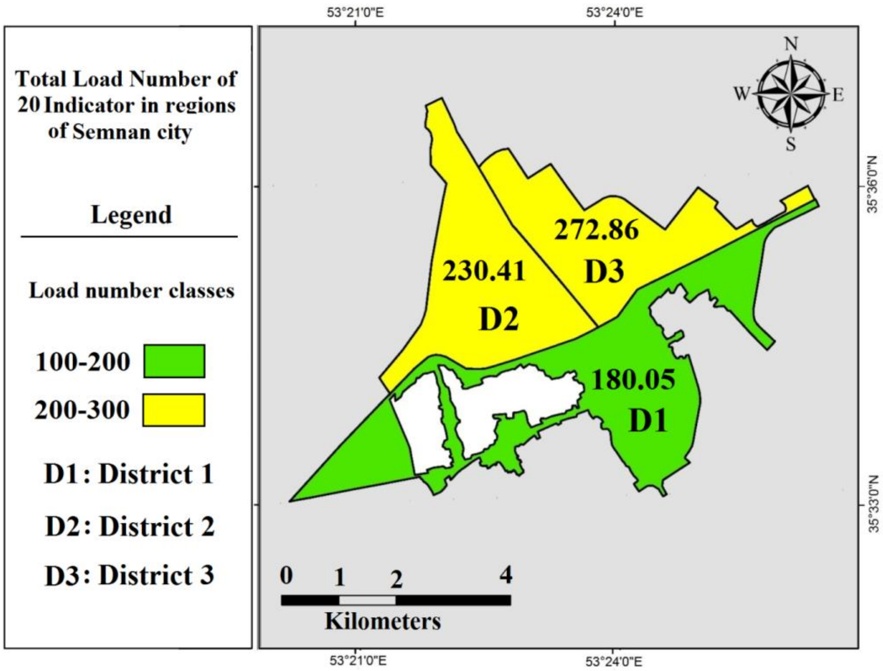

Figure 2 LN map of 20 indicators on the urban ecosystem in urban areas of Semnan

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In the case of built environment and urban land uses, important urban land uses including education, housing, health, green space and transportation were studied. The residential use in the districts 1 and 2 with a share of 36 to 37m^2 per capita showed a low carrying capacity (1) and LN (2.5), imposing a little pressure on the urban ecosystem. District 3 with a share of 29.84 m^2 per capita showed a high LN (7.5) and DCC (3) imposing a great pressure on the urban ecosystem. Given the growth rate of 7.8% in District 3, this pressure will increase in the future.

The districts 1 and 2 have a higher educational space per capita with a lower DCC of 0.1 and a LN of 0.25. Despite the modernization and the high population density in the District 3, there is no proper educational space per capita. District 3 has a higher DCC of 2with a LN of 5. In the case of health, districts 2 and 3 with per capita of *2.6* m^2 have the lowest DCC (0.1) and LN (0.25) showing good conditions of health in these two districts. With a per capita of 1.16 m^2, District 1 has the high DCC of 2 and LN of 5 imposing a moderate pressure on the urban ecosystem. Green space is one of the important urban uses. In this study, green space per capita and the ratio of green space area to the total area of each district were used. District 1 has the lower DCC of 1 and LN of 2.5 with green space per capita of 13 m^2. Districts 2 and 3 with a DCC of 2 and LN of 5 impose the highest pressure on the urban ecosystem. In the case of the ratio of green space area to the area of each district, all urban districts showed a DCC of *3* with a LN of 7.5. Accordingly, a great pressure is imposed on the urban ecosystem.

Increased population density results in more material and energy use per unit area. The material and energy consumption and waste production are a function of population density. Thus, it is essential to examine this indicator to assess urban sustainability and carrying capacity. In this study, urban density indicator was used to assess the carrying capacity and to monitor the pressure on the urban ecosystem. The lowest population density of 54.63 persons per hectare was found in District 1 with the lowest DCC of 1 and a LN of 10. In District 1, population density imposes a low pressure on the urban ecosystem. District 2 with a population density of *70.5* persons per hectare showed a DCC of 2 and a LN of 20. District 3 with a population density of 74.7 persons per hectare is the densest urban area with a DCC of 2 and a LN of 20. The urban population pressure on the urban ecosystem in Districts 2 and 3 is moderate.

Population growth rate is another important factor in planning for the management of resources (material and energy) and waste production. As shown in Table 5, the lowest population growth rate is seen in the District 2 with the lowest DCC of 3 and the LN of 30 imposing a high pressure on the urban ecosystem. District 1 with a growth rate of 3.7 shows a DCC of 4 and a LN of 40 imposing a high pressure on the urban ecosystem. District 3 shows the highest population growth rate of 7.5 with the highest DCC of 5 and the LN of 50. District 3 showed the critical population growth rate imposing a critical pressure on the urban ecosystem.

Energy consumption is another indicator imposing pressure on the urban ecosystem. In this study, gas and electricity consumption were used as pressure indicators. The ratio of energy consumption to available resources is also one of the most important criteria. The higher ratio indicates a higher pressure on the urban ecosystem. Accordingly, the ratio of gas consumption to available gas resources was used as a pressure indicator in the model. Due to the higher population density in the District 3, gas consumption is greater in terms of cubic meters per hectare. District 1showed the lowest gas consumption in terms of cubic meters per hectare due to a lower population density. According to the ranges defined for grading the carrying capacity, all three urban districts of Semnan has a DCC of 1 with a LN of 4. Thus, a low pressure is imposed on the urban ecosystem in terms of gas consumption.

In the case of power consumption, District 1 has a DCC of 1 with a LN of 4.6 due to a lower population density. Districts 2 and 3 have a greater DCC of 2 and a greater LN of 9.2 due to a greater density. There is a moderate pressure on the urban ecosystem in districts 2 and 3. Water as the most fundamental vital element has always played a crucial role in the construction of settlements and thus the rise of human civilizations. In this study, water consumption and the ratio of water consumption to the available water resources were used as two important indicators in assessing the urban carrying capacity and monitoring the pressure on the urban ecosystem. In the case of water consumption, District 3 shows the highest DCC of 3 and LN of 38.1 imposing a high pressure on the urban ecosystem in terms of water consumption. District 1 with the DCC of 1 and a LN of 12.7 imposes a little pressure on the urban ecosystem. District 2 with the DCC of 2 and a LN of 25.4 imposes a moderate pressure on the urban ecosystem. In the case of the ratio of water consumption to available water resources, District 1 has the lowest DCC of 1with a LN of 12.7 imposing a little pressure on the urban ecosystem. Due to high population density, districts 2 and 3 have a DCC of3 and a LN of 38.1imposing a high pressure on the urban ecosystem. Given that this indicator is very close to the water crisis point, it will be one of the main factors limiting the development of Semnan.

Given the pressure number obtained for the waste production in the urban areas of Semnan, the maximum pressure imposed in the districts 2 and 3 with a LN of 20.4 and a DCC of 3 impose a high pressure on the urban ecosystem. The lowest pressure is seen in the District 1 with a DCC of 1 and a LN of 6.8 imposing a little pressure on the urban ecosystem. In the case of recycling, the LN in all three districts is 34 with a DCC of 5 imposing a critical pressure on the urban ecosystem. No serious action has been made by the municipality of Semnan for recycling of wastes until 2011 and only 2 to 3% of the wastes is recycled by the purchase of wastes and recyclable materials by hawkers.

Comparing the LNs in each district with the DCC and the total load number of 20 indicators (Table 5) and using the framework for the DCC and its ranges (see Table 4), the concept of pressure and carrying capacity in the urban areas can be understood. The LN in District 1 is 180.05 with a DCC between 1 and 2 imposing a low to moderate pressure on the urban ecosystem. The LN in District 2 is 230.41with a DCC between 2 and 3 imposing a moderate to high pressure on the urban ecosystem. The LN in District 3 is 272.86 with a DCC between 2 and 3 imposing a moderate to high pressure on the urban ecosystem. Due to its greater population density, material and energy consumption and waste production, District 3puts a higher pressure on the urban ecosystem. Given a growth rate of 7.38% in District 3, this trend indicates a greater pressure on the urban ecosystem. Therefore, managers must take the necessary measures to develop the necessary infrastructures including water distribution network, electricity, gas and waste collection as well as appropriate urban land use per capita including residential, educational, health/medical, green spaces and transport uses.

5. Conclusions

To achieve urban sustainability, the urban ecosystem status should be monitored before the crisis, in order to control the pressure on the land. In many cases, delays in responding appropriately to the pressures on the ecosystem lead to irreversible damage to the urban ecosystem. UCCLN model can indicate the regions where the pressure is close to thresholds, On the other hand, compared with models determining the population or activities, it can better show the area within which the natural environment is under pressure, since the increased per capita consumption imposes a higher pressure on the carrying capacity of an ecosystem as compared with population growth. So this model is an appropriate tool for sustainable urban development planning and monitoring, and the results of this model should be considered for a balanced and sustainable urban development.

Conflicting of Interests

The authors state that there is no conflict of interest.

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Authors' Contributions

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ارزیابی ظرفیت برد شهر سمنان با استفاده از مدل عدد فشار ظرفیت برد شهری

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مقدمه: با رشد بسیار سریع اقتصادی، بسیاری از مناطق طبیعی، مراتع، مزارع و .. تبدیل به مناطق لجام گسیخته شهری شدند. توسعه شهری، مناطق طبیعی را به مناطق پر از ساختمان تبدیل نموده و تعادل بوم شناختی اکوسیستم را بر هم زده است. اکوسیستم شهری از جمله مناطقی هستند که نیازمند برآورد ظرفیت برد می‌باشند زیرا که نیازمند مصرف مقادیر بالای ماده و انرژی و قابلیت جذب آلاینده‌ها در یک مکان کوچک می‌باشند. میزان مصرف ماده و انرژی در شهرها، ممکن است بیش‌تر از آن چیزی باشد که توسط ظرفیت برد آن مکان فراهم شود. هم‌چنین این مقدار بالای مصرف مواد با مقدار بالای تولید آلودگی همراه است که نمی‌تواند توسط ظرفیت برد آن محیط جذب شود. از این‌رو در جهت برنامه‌ریزی برای توسعه شهری، بایستی ظرفیت برد محیط و توان آن محیط برای پذیرش جمعیت بررسی گردد.

مواد و روش‌ها: در این پژوهش از مدل عدد فشار ظرفیت برد شهری در چهارچوب فشار-وضعیت-اثر-پاسخ و با استفاده از ۲۰ نمایانه، به بررسی ظرفیت برد و میزان فشار وارد شده بر اکوسیستم شهری سمنان استفاده گردید.

نتایج: نتایج نشان داد، در ناحیه یک شهر سمنان عدد فشار برابر با ۱۸۰/۰۵ و میزان فشار وارده بر اکوسیستم شهری در این ناحیه کم تا متوسط می‌باشد، ناحیه دو با عدد فشار ۲۳۰/۴۱ و ناحیه ۳ با عدد فشار ۲۷۲/۸۶ دارای فشار متوسط تا زیاد بر اکوسیستم شهری می‌باشد.

جمع‌بندی: ناحیه سه به دلیل تراکم بیش‌تر، دارای مصرف بیش‌تر ماده و انرژی و تولید پسماند بیش‌تر می‌باشد و در نتیجه دارای فشار بیش‌تری بر روی اکوسیستم شهری است.

کلمات کلیدی: چهارچوب PSIR، ظرفیت برد شهری، عدد فشار، فشار بحرانی

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