

The quantification of cognitive development cultural service supply in the primary schools of Hamedan city, Iran

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ABSTRACT

Cities provide their residents and communities with specific services through urban green spaces. Cognitive development is an important service, which is the construction of thought processes such as remembering, problem-solving, and decision-making from childhood to adulthood. The present study aimed to evaluate and quantify the supply of the cognitive development services resulting from the exposure of green space for primary school students in Hamadan, Iran. In total, 179 schools were selected, and by applying a 50-m buffer, the green space within the school area was classified into five categories based on field surveys and satellite imagery processing and weighted based on expert opinions. The final index value was obtained by summing the product of each polygon value in its area for each green infrastructure class, which was classified into five groups. According to the results, gardens and parks had the highest impact on cognitive development. Only 15 schools had a proper status in terms of the green cover standard ($NDVI \geq 0.5$) affecting the cognitive development of students. Considering the per capita standard of green space (0.5 m^2) and standard area of school infrastructure (1960 m^2), only six schools met the triple standards, and four cases were added to the list by creating and expanding the green space. Since the design of schools is not focused on green spaces, its valuable capital remains a potential value. which should be recognized and activated to attain growth, academic progress, and improvement of students' learning.

Keywords: Urban ecosystem services, Green space, Cognitive development, Primary school

Introduction

The world is rapidly moving toward urbanization, and with the substantial population growth in cities, concerns about the quality of life, health, and wellbeing of humans are increasing.¹ The most important challenge in this regard is to ensure long-term quality of life and wellbeing for urban residents. On the other hand, ecosystems provide various goods and services for the survival and wellbeing of humans. Historically, many ecosystem services² have been identified and explored by

various methods. In the late 1970s, scientists examined the values of natural functions, and the services were not clearly defined. In the early 1980s, the term 'ecosystem services' was first used and became one of the most important terms in ecological discourse, with its concept widely used as a bridge between ecology and economics and a link between nature and the society. Based on one of the most important definition by daily,² ecosystem services are the conditions and processes through which natural ecosystems and the species that make them up sustain and fulfil the human life. These services are classified into four categories of provision, regulation, support, and cultural services.

Urban ecosystem services are produced in various habitats, including green

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infrastructures (GIS; e.g., agricultural lands, gardens, cemeteries, grasslands, swamps, groves, vacant lands, green roofs, street trees, orchards, urban forests) and water infrastructures (e.g., rivers, lakes, ponds, artificial pits, and stormwater storage ponds). Some of the most important GI services include water storage, social cohesion, wildlife corridors, food production, aesthetics, heritage value, learning and education, noise reduction, recreation, wood production, air purification, and cognitive development.

Similar to other complex ecosystems, cities provide specific services to the residents and community through urban green spaces. As such, the potential of urban green space as a provider of ecosystem services has been investigated, and the issue of urban green spaces has become an important research subject matter. On the other hand, cultural ecosystem services are defined as ecosystem assistance in the form of intangible interests and encompass spiritual richness, religious beliefs, cognitive development, leisure, thought, and aesthetics.

Theoretical background

The effect of GIS on cognitive development has been investigated in several experimental studies, which have indicated a significant correlation between green space in schools and education to create a sense of belonging to school in children.³ Finding desirable and effective features in the design of school green space from the students' perspective could promote learning and academic motivation.⁴ The presence of green space plays a key role in reducing stress, relieving the mental fatigue caused by school pressure in children,⁵ and increasing the concentration and attention of children.⁶

Cognitive development refers to the development of thought processes such as remembering, problem-solving, and decision-making from childhood to adulthood, which helps individuals express their understanding of the world through genetic interactions and learning from the environment. The primary areas of cognitive development include

information processing, intelligence, reasoning, and memory.⁷ With the development of urbanization, children are dominated by manmade environments, and the possible mental health consequences has a significant impact on their lives, as well as the society and their families.⁷

Practical background

According to previous studies, exposure to green space and cognitive development are positively correlated. In this regard, Dadvand *et al.* examined the correlation between exposure to green space and the level of cognitive development in 2,593 primary school students in grades 2-4 (age: 7-10 years) in 36 schools in Barcelona (Spain). The researchers assessed exposure to green space around the residence, around the school where the study was implemented, and the green space on the route from the residence to the school using a green cover index obtained from high-resolution satellite data (5×5 m). In addition, multilevel modeling was applied to determine the association between green space and cognitive development.⁸

In another study, Ward *et al.* evaluated the impact of green space exposure on the physical activity, cognitive development, wellbeing, and risk-taking ability of 108 participants aged 11-14 years in Auckland (New Zealand). According to the obtained results, exposure to green space had a positive correlation with the physical activity of the children, which could be independently associated with the other important aspects of children's development, such as cognitive development, wellbeing, and risk-taking.⁹ Furthermore, the study by Leung *et al.* indicated a significant, positive correlation ($P \leq 0.05$) between the green covers around schools and educational performance of students. The findings of the mentioned study demonstrated that exposure to green space enhanced the performance of the students, which was considered a reference for designing the green space around schools.¹⁰

Exposure to green space is associated with cognitive development,⁸⁻¹⁰ and most of the studies on cultural ecosystem services have

been performed on natural ecosystems, while cultural services (especially cognitive development) are less known. On the other hand, cognitive development services are not sufficiently measured due to the intangibility and complexity of quantitative methods, which differ from the quantification of other ecosystem services.

The present study aimed to introduce the concept of cognitive development in primary school students and quantify the cognitive development services resulting from urban green space in the urban area of Hamadan city, Iran.

Materials and Methods

Study area

Hamadan city is the center of Hamadan Province, located in the middle area of

Hamadan County covering an area of 56.27 km², which is equivalent to 2% of the total area of the county. Hamadan County is limited to Famenin and Kabudarahang counties from the north, Tuyserkhan, and Malayer from the south, Markazi province from the east, and Bahar County from the west. Fig. 1 shows the location of the study area in the country, province, and county. The target population of the study was the students of the primary schools in Hamadan (grades 1-6). According to the statistical yearbook of education of Hamadan province, the province had 179 primary schools with 49,997 students (governmental and non-governmental) in October 2019. The number of the students in grades 1-6 has been estimated at 8953, 8375, 8327, 8431, 7989, and 7922, respectively.

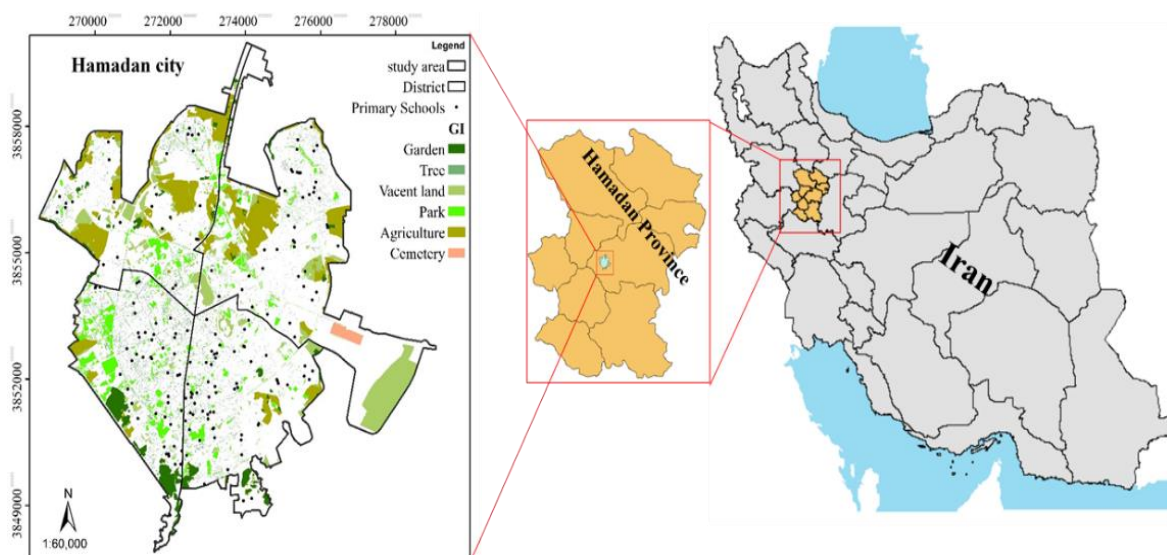


Fig. 1. Location of study area (Hamadan City)

Methodology

Initially, the map of Hamadan GI was prepared using the Terra Incognita software and images with the resolution of 5 m. As is depicted in Fig. 2, the green space in the city was divided into agricultural lands, parks, street trees, gardens, and abandoned grass fields,¹¹ each of which is considered to be a service providing unit.¹² The primary schools were located by field observations and Google Earth images, and their boundaries were digitized. Following that, a 50-m buffer was

applied to the school boundary,⁸ and the amount and type of the green space within the school boundaries and buffer range were identified and digitized as the area affecting the cognitive development of the students. Selecting the effective distance of the green cover in the learning process is highly challenging, and there are no accepted standards for the buffer size.¹³ In the present study, instead of examining the green space around the residence, the green space inside and around the school grounds was examined

as it was possible for the school principals to manage and control the green space inside and around the school¹⁴ and create green space in and around the schools with low costs, so that all the students in the school would benefit.¹⁵ Another reason was that selecting a place to study and changing it is less expensive than changing the place of residence in different urban areas.¹⁶

In order to evaluate the green space inside and outside the school border as an indicator of green cover, the density and importance of each GI class were weighted based on review studies and the expert opinions of environmentalists and psychologists. Finally, the total green coverage index of the affecting area was shown as an indicator of the available green space supply, which was classified into five categories from the maximum to the minimum value. In addition, the mean final value of the green cover index for each unit was obtained by summing the product of the value of each polygon in its area for each service providing unit (SPU) using Eq. 1, which is considered to be a statistical proxy to determine the quality of GI, with the value calculated within the range of 0-1.

$$\text{Value of Green Cover Index} = (\text{Density} * \text{Importance}) * \text{SPU Area (ha)} \quad (1)$$

Results and Discussion

Most parts of Hamadan city are covered with impenetrable infrastructures (e.g., asphalt and construction), while the remaining 25.50% is covered by GI (1,460.36 ha). The share of gardens, agricultural lands, trees, barren lands, parks, and cemeteries in proportion to the city area is 2.15, 13.67, 2.80, 1.73, 4.78, and 0.36%, respectively, with the highest share belonging to agricultural lands (782.98 ha) and the lowest share belonging to cemeteries (20.62 ha). Fig. 2 shows the urban GI categories and location of the schools, as well as the 50-m buffer around the schools.

The greatest impact of green space on cognitive development was observed within 50 m from the educational centers,⁸ and the distance was determined as the maximum area of the presence and contact of the students with

the green space and maximum distance of viewing the green space from the window. In addition, buffers with the length of 200-3,000 m were used in the evaluations that applied images with the resolution of 30 m and 250-m Landscape and MODIS images.¹⁷ Browning and Rigolon have measured the amount of green space using MODIS images with 250-m resolution over six years (spring, summer, and autumn) in three buffers of 250, 500, and 1,000 m.¹⁷ In such evaluations, large-scale images are used at the local level, which may cause errors in the area of green spaces with an area of less than 62,500 km² around schools.

There are 179 schools in the city, the range of their affected areas varies from 697.7891 to 386,861,894 m², and the total area of green polygons within them varies from zero to 1357.527 m². Seven schools (with codes 80, 99, 118, 121, 152, 166, and 172) did not have any green spaces and on the other hand, the highest area (1357/52/1952 m²) belonged to Taleghani School. The maximum number of green patches in the affecting areas was 30.

In the present study, the smallest polygon in the urban green space was 6.5 m², which was the result of high accuracy in the detection of the green space. Furthermore, the error rate in various studies may be due to different measurements of green space in one season or year, insufficient accuracy in the location of data, and low spatial resolution and low accuracy maps.¹⁷

The supply of cognitive development services is also defined as the potential of green space to provide such services based on the features of the area, number of patches, and type of the green space. The supply of these ecosystem services often reflects the capacity of green space to provide the required services by humans (especially children) in a sustainable manner regardless of whether these ecosystem services are used. Based on the results of the urban GI classification scores in cognitive development, gardens with the importance of four and density of five have the highest value. However, gardens are often located on the outskirts (as is the case with

Hamadan City), and schools are scattered in the city center and are adjacent to residential areas. Only in Abuzar School, inside 1.80 ha of buffer zone, there is only one garden patch with an area of 0.16 ha, and the green cover index for this school was estimated at 0.25 and ranked third (average vegetable index). In addition, the trees near the school and viewing of the green space from the windows are more effective in cognitive development than other

types of green space.¹⁷ In this respect, the highest rank (first) belonged to Andishmandan School. Within the scope of this school, there are eight tree patches with the total area of 2,121 m², four park patches with the total area of 4,597 m², which is in accordance with the studies by Browning and Rigolon, denoting that trees and parks have the greatest impact on cognitive development.¹⁷

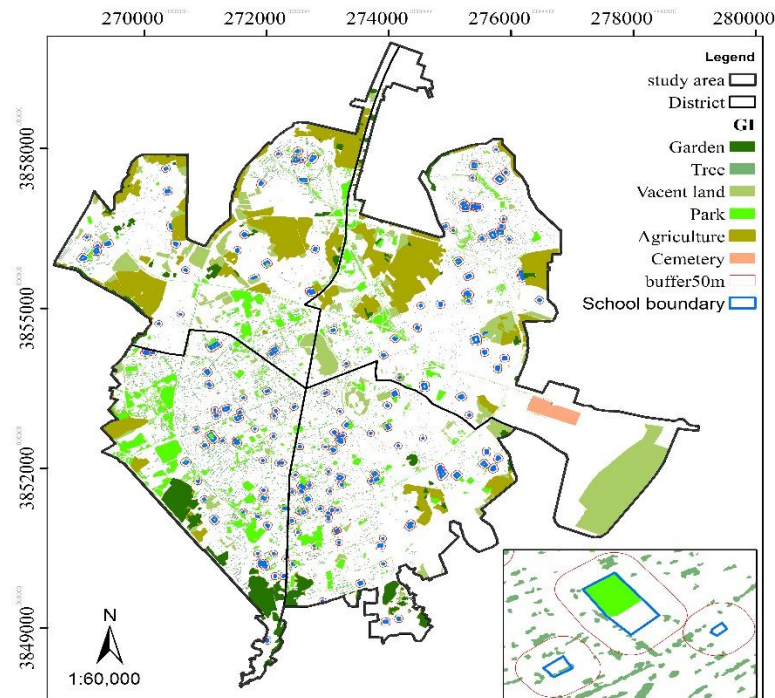


Fig. 2. GIS, school locations, and their 50-m buffer

Table 1. Results of scoring GI classes in cognitive development

Classes	Importance	Density	Value
Garden	4	5	20
Agriculture	2	2	4
Park	5	3	15
Tree	3	4	12
Vacant land	2	1	2

The importance and density of each category of the existing GI were assessed separately from 1 to 5. In the present study, the lowest density and least importance were assigned value one, and value five was considered to show the highest density and most importance. The final value of each GI category was obtained by multiplying the density score by the significance score of each

SPU (Table 1).

In the current research, the amount and value of green space in the affecting buffer of each school was calculated separately using Eq. 1. Afterwards, the values of the green cover index were normalized within the range of 1-0, so that the values close to zero would indicate the low impact of the green space (less importance and vegetation density), and the values close to one would indicate the high impact of the green space on cognitive development (more importance and vegetation density). Following that, the minimum and maximum distances from the green cover index, which had been obtained from the characterization of the GI domain, were reclassified using the Jenks algorithm (natural

breaks method) in the GIS software, which provides the optimal arrangement of values into different classes¹⁸ and results in a greater distance between the heterogeneous classes and maximum difference between the classes, so that the turning points of the data would determine the boundary between the classes. Accordingly, the total green cover index in the affecting buffer zone was ranked within the range of 1-0 as an indicator of the amount of

the green space supply. As is shown in Fig. 3, the GI was classified into five categories of extremely low, low, medium, high, and extremely high quality. Accordingly, seven schools did not have green cover, and the mean green cover index was zero. On the other hand, Andishmandan School had the highest mean green cover index (one) within the buffer range, in which the area of the green cover was 6,718 m².

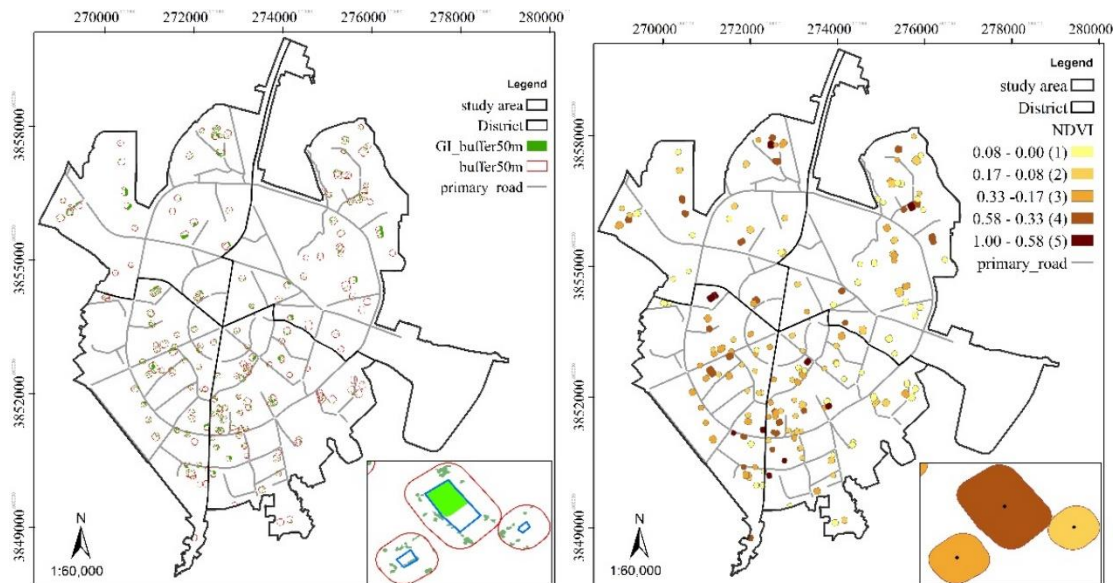


Fig. 3. Normalization of green cover index within range of 1-0 in buffer range in five classes

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When the presence or absence of green cover is used as an indicator,¹⁹ setting a threshold is necessarily a mental process. Therefore, the median number of 0.5 was

considered as the threshold of the green space. According to the information in Table 2, 15 schools with the maximum green cover were

selected based on the normalized difference vegetation index (NDVI) within the buffer range.

Table 2. Specifications of selected schools with highest value of green cover

ID	School's name	NDVI	School area (m ²)	Green space in each school (m ²)	GS standard in schools (m ²)
1	Andishmandan	1	338	15	140
2	Toohid	0.998	3894	501	
3	Kashef	0.920	2350	58	
4	Minoo	0.897	5216	330	
5	Khaje Nasir	0.827	460	59	
6	Atar	0.786	1989	5	
7	Bozorgmehr	0.711	963	128	
8	Jamaran	0.705	3724	214	
9	Esmat	0.648	6067	516	
10	Sadeqhie2	0.528	1779	147	
11	Derakhshandeh	0.566	660	10	
12	Shahid Garoosi	0.519	1942	78	
13	Mazloomian	0.521	1388	109	
14	Hedayat Andisheh	0.508	933	46	
15	Parsian	0.502	3119	606	

The area of the primary schools in Hamadan is 114-10,023 m², which is in the form of one-storey to three-storey buildings, and the average number of the students in these schools is 280. According to the principles of school design in Iran, the minimum area required to build schools for 280 students is 1,960 m², with which only 60 schools have complied. In addition, the per capita share of each student in green space is 0.5 m², and there

should be approximately 140 m² of green space on average in each school. Fig. 4 shows the position of some of the investigated schools. To select the most effective schools in cognitive development in Hamadan, three factors overlapped, including the highest NDVI index in the buffer range, standard area of the school, and standard green space within the schools.



Fig. 4. Sample images of three evaluated schools

In the classrooms where windows overlook green landscapes, reports have suggested an increase in the attention and a decrease in the stress and heart rate of students,²⁰ which in turn resulted in higher learning efficiency. Furthermore, teaching

efficiency has been reported to be higher in the classrooms held in gardens, natural environments or green spaces.²¹ According to the review studies in this regard, various green conditions include agricultural fields, grass cover, shrub cover, and tree cover.¹⁷ In the

study by Kweon *et al.*, only grass, shrubs, and tree species were considered, and other classes of green space were overlooked.²² In the present study, all green spaces are considered as different classes of green space, such as agriculture, garden, park, barren land, grass, and individual trees.

Green spaces are effective in increasing cognitive development by reducing air pollution and air temperature. In this regard, the reduction of air pollution by green spaces acts as an intermediary.⁸ Trees filter out airborne contaminants more frequently than the other classes of GIs.²³ According to the study by Derkzen *et al.*, the effectiveness of individual trees in reducing air pollution is remarkable.²⁴ Based on the scoring results, agricultural use with the significance of two and density of two, as well as grass cover and bushes with the significance of two and density of one, have the values four and two, respectively, which have the lowest impact on children's cognitive development. Agricultural fields and grasslands are far from schools, and students are not in daily contact with these classes of green space.

Conclusion

Natural capital management requires evidence to show the integration of natural capitals and ecosystem services for the decision-makings that leads to better human wellbeing outcomes. Therefore, combining ecosystem services with ecosystem management is important to reduce or even reverse the declining trend of ecosystems. Studies have shown that the combination of ecosystem service information and ecosystem characteristics could lead to the environmental decisions that prevent a wider range of adverse outcomes. Overall, few studies have assessed the impact of green space on the educational efficiency of schools as a means to cognitive development compared to other green space services. According to the literature, green space exposure and cognitive development are positively correlated in students, and the reduction of air pollution by green spaces acts as an intermediary in this respect.

Based on the principles of school design, the standards of the required land area would be determined by the number of the students attending the school. Accordingly, the minimum required area for each student is 6-8 m², while the minimum required school area has been proposed as 1,000 m² regardless of the number of students. Out of 179 schools in this study, 82 had an area of less than 1,000 m². Considering the 7-m² area (average: 6-8 m²) for each student and the average number of 280 students, the area of each school should be 1,960 m²; among the evaluated schools, 60 met this feature. Moreover, the standard of green space for each student is 0.5 m², and considering the average of 280 students in each school, 140 m² of green space should be created, of which only 23 schools out of 60 standard schools (in terms of area) had the standard green space. Considering the highest NDVI index in the buffer range, 15 schools had a higher value than 0.5 (Table 1). After combining these three parameters, only six schools had all the three features and an acceptable green space (within the affecting buffer zone) for the positive impact on cognitive development.

With the highest average green cover index (one) in the buffer range (6,718 m²), Andishmandan School had a smaller area than the standard (school area: 338 m²) and less green space than the standard inside the school (15 m²). Only Tohid, Minoo, Jamaran, Esmat, Sadeghieh, and Parsian schools had all the three input parameters and are known as the most important schools affecting cognitive development in Hamadan. Regarding the schools with a high NDVI index in the buffer range and having a standard school area (Kashef, Attar, Shahid Garossi, and Mazlumian schools), it is necessary to take action toward the planting and creating of green space inside these schools. Andishmandan, Khajeh Nasir, Bozorgmehr, Derakhshandeh, and Hedayat Andisheh schools had a high NDVI index, a smaller area than the standard, and the minimum green space inside the school.

This study had some limitations, most of

which were due to the lack of data. For instance, no documented data are available on the area and number of students per school. On the other hand, exposure to GIS encompass the green spaces inside students' residence, on the route from home to school, and inside the school; in this study, we only focused on the schools, and the two other parameters could be investigated further. In conclusion, confrontation with higher levels of green space surrounding schools could improve cognitive development. Therefore, it is essential that the Ministry of Education considers this ecological service as a valuable capital to reinforce the educational efficiency of students.

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