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Analysis of Ecological Footprint at Educational Institute Scale (A Case of an Iranian High School)

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Authors' contributions

This work was carried out in collaboration between all authors. Author KH designed the study, wrote the protocol and wrote the first draft of the manuscript. Author AR managed the literature searches, and introduction sections. Author HA performed empirical analyses of the data and author BS wrote the discussion and conclusion and edited the whole manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Aim: Ecological Footprint Assessment (EFA) is one of the suitable indices helping decision makers and authorities in general and environmental scientists in particular in assessing sustainable development. Schools are one of the educational institutes, where measuring this index can help in giving clear picture of the footprint of such micro-level places. We used descriptive-analysis method to assess the ecological footprint of one of the main high schools of Sanandaj City, Kurdistan, Iran. Our results indicated that the total ecological footprint of this high school is 65.6 gha, showing 0.164 gha per student (400 students) during 2011-2012 academic year. Comparing the ecological footprint of this school with the international standards showed that the maximum level of footprint belongs to food sector (35.8 gha), followed by transportation (24.4 gha). In order to reduce the footprint and its nearness to the international standard level, some measures have to be taken, for example facilitating and creating bulky transportation such as school service, changing type and composition of food materials of students, renovation or upgrading cooling and heating systems. These measures would not only result in the long-term sustainability of

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educational but also would help in environmental sustainability at neighbourhood micro-level and at the city macro-level. We suggested some alternatives, which their application may reduce the ecological footprint of Qasri High School from 65.5 gha to 59 gha, which is very close to the standard footprint rate (58.38 gha) for a high school.

Keywords: Ecological footprint; sustainability; ecological indices; high school; empirical method.

1. INTRODUCTION

During recent decades, varieties of indices and concepts have been presented to measure and assess sustainability at city level. One of these indices is ecological footprint assessment (EFA) attracted more attention at academic, political, and educational level. EFA is an index that estimates the pressure induced by population or industrial processes on ecosystem through assessing and calculating the energy and used materials in a city, region, or country [1,2]. This index shows that one can relate and assess directly the energy consumption and resource exploitation to the lands allocated to each of land uses in city, region, or country [3]. Therefore, EFA can predict the land required for producing consumables from different land uses and the land required for disposal of the wastes from these land uses with respect to the city population and per capita of citizens individual . The index could be calculated and assessed at various scales such as the earth [4,5], a country [6-8], a city or region [9,10], and an industry or a particular manufacturing process [11,12]. Many research works have been conducted on assessing ecological footprint of industrial manufacturing processes, national and international organizations and large-scale education organizations (at region scale) [13-19]. However, the scale considered significant attention in recent years is the organization scale and urban land uses in particular, which have not been studied as much as the abovementioned scales. Assessing and calculating the ecological footprint of urban land uses (especially high consuming land uses such as universities, schools, hospitals…) could be useful in two aspects: a) Calculating environmental impact assessment of these land uses through supervising their sustainability and efficiency; b) Increasing knowledge about the sustainability principles and approaches to achieve sustainability through involving citizens and individual employed in these land uses (students, hospital staffs…) in various steps including supervising, data collection, results, and implementation of operational programmes in order to reduce the ecological footprint of the abovementioned land uses [3].

Heretofore, to our best knowledge no research work has been conducted on calculating and assessing the ecological footprint at any scale in Iran. Hence, the main objective of the present work is to assess the ecological footprint of one of the main urban land uses as one of the principal and effective index in urban sustainability. For this purpose, we selected Qasri High School, Sanandaj, Kurdistan, Iran as given landuse for assessing the ecological footprint.

2. MATERIALS AND METHODS

In order to assess the ecological footprint of urban land use users, we selected Qasri high school, Sanandaj City as one of the main and important educational land uses from the area and number of student point of view. Therefore, we considered the school consumption in different sectors of energy, transportation, materials, etc. during the academic year of 2010-2011. Since only one study has been conducted on the assessing the ecological footprint at urban school scale [3], we followed the same methodology they used to calculate the ecological footprint. In contrary to other studies conducted at other scales, we tried to consider the land use users. Hence, a questionnaire was prepared and distributed among the high school students and staffs to claim their approximately annual consumption of paper, pencil by themselves. The questionnaire was consisted of 10 closed and open questions. The school population was 400; therefore, the sample size was estimated to be 196 based on the Cochran formula. We used Cronbach's alpha for determining the reliability and validity of the questionnaire. The alpha obtained was 0.93 indicating reliability and validity of the questionnaire. We calculated the water, power, and gas consumption of Qasri high school for one year in order to assess the ecological footprint of this land use. Moreover, the data about food consumption, transportation and waste generation rate was collected using

questionnaires distributed among the students and staffs. For determining annual solid waste generation, we weighted the whole solid wastes generated in the high school in different week days and considered its average as base for our work. Therefore, using ecological footprint calculations, the consumption rate of each of the above mentioned elements were converted to the hectare of the land required and at the end the summation of the hectares required was used for determining the ecological footprint of the school.

Finally, we compared the footprint calculated at different sectors of Qasri high school with the international standards in order to determine the sustainability or non-sustainability of the school during academic year of 2010-1011 and also to determine its difference with the international standards.

2.1 Case Study

Sanandaj City, capital of Kurdistan province, is one of the main cities in the province and experiences a huge wave of migration from villages toward the city. The migration issue and other problems such as increasing number of vehicles, uncontrolled urban development, and destruction of natural donations like fields and gardens around the city, village integration, wild settings development, etc. have resulted in daily non-sustainability of the city. However, it is noteworthy that this situation does not limited to the suburbs, but the inner city main land uses play crucial role in moving city towards non-sustainability for different reasons such as improper site selection, improper performance, low yield, excessive consumption, vehicle commuting, etc.; they can have determinative role in decreasing or increasing sustainability level in future. Being the oldest (40 years old) and largest (5000 m^2 area)school, Qasri high school with 400 students and staffs located in downtown of Sanandaj City was selected as the study area. The school has been surrounded by high traffic streets. Fig. 1 shows the location of Qasri high school.

3. RESULTS

3.1 Electricity (Power)

Based on the school records and documents, we found that the power consumption during the academic year 2010-2011 was about 2074 kwh. The required calculation and its conversion to the KJ energy is as follows: GFN, [5]; Gottlib et al, [3].

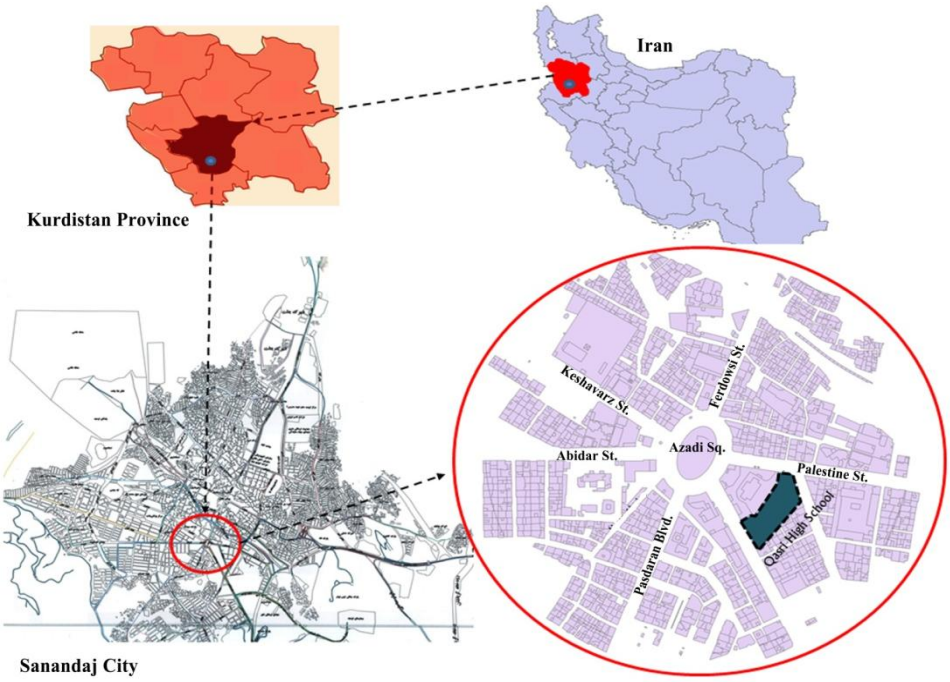

Fig. 1. Location of Qasri High School in the downtown of Sanandaj City

1watt =1 Joule/second
1000watt = 1 kw
1000 Joule =1 KJ

2074 kWh× 1 KJ/sec × 60 sec/min × 60 min/hr = 7466400 KJ

The coal used to generate the energy calculated:

7466400 KJ × 1 g/20 KJ =373320 g

Plants have about 31.4 %coal yield :

373320 ÷ 0.314 =1188917 g

As we know, 85% of coal is carbon. Therefore:

1188917 × 85 = %1010579 ÷ 1000000 =1.01 ton

1 ha land can absorb 1.8 ton carbon:

EF_{power} = 1.01 ÷ 1.8 =0.56 gha

Thus, the footprint in power sector for the high school with 400 persons equals 0.56 ha.

3.2 Water

The annual water consumption was found to be 2920 m^3 .

For having 1 million liters water, 0.8 ha land is required.

EF_{water} =2920 m^3× 0.8 =2336 ÷ 1000000 = 0.002 gha

Therefore, the footprint in water sector equals to 0.002 ha in this school.

3.3 Gas

Records available in school indicated that the annual gas consumption was 17581 m^3. Converting to KJ energy, we have:

17581 m^3× 1 KJ/sec × 60 sec/min × 60 min/hr = 63291600 KJ

The coal required to generate this energy rate equals to:

63291600 KJ× 1 g/20 KJ =3164580 g

Plants have about 31.4% coal yield :

3164580 ÷ 0.314 =10078280 g

85% of coal is carbon .Therefore:

10078280 g × 85 = 8566538% ÷ 1000000 =8.56 ton

1 ha land can absorb 1.8 ton carbon :

EF_{gas} = 8.56 ÷ 1.8 =4.8 gha

Therefore, the footprint in gas sector equals to 4.8 ha in this school.

3.4 Transportation

Access to the data on petrol or diesel consumption rate was almost impossible. Therefore, we considered the CO generated per capitain city was considered and the footprint of high school in transportation sector was calculated based on the municipality statistics for the whole city. Based on the data obtained from the Sanandaj Municipality the CO_2 per capita was 0.11 ton, which for the school would be as:

400 × 0.11 =44
$EF_{transportation}$ = 44 ÷ 1.8 =24.4gha

Therefore, the ecological footprint for the high school in the transportation sector equals to 24.2 ha.

3.5 Solid Waste

The data collected indicated that the per capita of solid waste was 90 kg (total waste =36000 kg). Since the landfill area required for 450 kg solid waste is 8 m^2, the land required for annually 36000 kg solid waste generated would be:

36000 kg × 8 m^2 = 288000 kgm^2 ÷ 450 kg =640 m^2÷ 10000 m^2 =0.064 gha

Therefore, the ecological footprint for the high school in the solid waste sector equals to 0.064 ha.

3.6 Food

Estimation of the food consumption in the school could be determined using either questionnaire or statisticall. We used both methods to find out the food consumption rate. For this purpose, we used the data of arable lands and their crops in the agricultural year of 2002-03, which are in fact the latest available data for country (www.fao.com) for determining the land required for producing one ton crops. Based on the data

obtained from the questionnaires, the consumable food stuff rate per capita per day was determined to be 50 g indicating annually 12 kg food stuff consumption. Therefore :

Food required for high school individual =High school population × food consumption per capita =12× 400 =4800 kg ÷ 1000 kg =4.8 ton

Calculating land required for supplying this food stuff:

Arable land in 2002 in Iran =15020000 ha and the agricultural crops in the same year =20129 million tons. Therefore :

Hectare land required for producing 1 ton crops = 15020000 ÷ 20129000000 =7.46 ha

The land required for food stuff of the individuals in Qasri high school equals to:

4.8 ton × 7.46 ha =35.8 gha

Therefore, the ecological footprint for the high school in the food stuff sector equals to 35.8 ha. Thus, the maximum footprint belongs to the consumption of the food stuffs. Table 1 shows the ecological footprint calculated for Qasri high school.

Table 1. Calculations for the ecological footprint factors of Qasri high school, Sanandaj City in 2010-11

Sector	EF calculated (gha)	Per capita EF (n =400)
Power	0.56	0.0014
Water	0.002	0.000005
Gas	4.8	0.012
Solid waste	0.064	0.00016
Transportation	24.4	0.061
Food stuff	35.8	0.09
Total	65.6	0.164

4. DISCUSSION

The calculations conducted showed that the ecological footprint of Qasri high school was 65.6 gha during the academic year of 2010-11. It means that the land allocated for the 400 population of this high school is almost 131 times more than its area (0.5 ha). Table 1 shows that the maximum ecological footprint belongs to food sector (35.8 gha) followed by transportation sector (24.4 gha). In a study conducted in Haifa, Israel, it was found that food (117 gha) and transportation (314 gha) allocated the maximum ecological footprint in the school studied Gottlieb et al, [3]. Klein-Banai and Theisassessed the ecological footprint of Michigan University and its impact on the climate changes. They found that maximum ecological footprint belongs to transportation and fossil fuel, which not only increased ecological footprint of the university but also had side effect on the climate changes [20]. On the other hand, in separate research works conducted by Bell et al. [19] and Svajda et al. [18] on Otego and Toronto Universities respectively, it was found that food consumption and waste generation from one side and transportation and roads from other side had the maximum footprint, which brought about bad effects on the moving this university towards non-sustainability.

Table 2 shows the comparison between ecological footprints in Qasri high school with the international standards. It is noteworthy that the international standard is based on the guidelines provided by Global Footprint Network for educational organizations and institutes having an area of 0.5-1 ha.

Table 2 indicates that Qasri high school has relatively less sustainability, which can play crucial role in reducing urban non-sustainability in Sanandaj City. Moreover, it shows that except solid waste and water sectors, the other sectors have more ecological footprint than international standards indicating the necessity to make measures to overcome this problem otherwise leads into non-sustainability of the city because of the environmental impacts on the ecological footprint. Therefore, we have proposed 4 scenarios to reduce the ecological footprint of Qasri high school.

4.1 First Scenario: Food Ecological Footprint

As the calculations conducted indicate, the maximum footprint in Qasri high school belongs to the food sector (35.8 gha, 54.5%). In order to reduce this amount and approaching the international standards (34.7 gha), the staffs and students food consumption must be under surveillance of the high school authority; this could be done by establishing buffets inside the high school. For example, the data obtained from the questionnaires revealed that biscuits and crackers are the most eaten products (35%) which not only result in waste generation

(packing) but also have little food value. While, consuming healthy sandwiches like cheese burger, egg, etc. allocated only 12% of the food consumption. Therefore, reducing items like biscuits by 20% and increasing consuming healthy sandwiches by 25% and bringing the students food intake by 25 g/day can reduce the ecological footprint of the high school to 24 gha in food sector. However, in Iran students are not allowed to leave the school to purchase fast foods such as hamburger, cheeseburger, etc. Moreover, due to the hygienic issues, the school authorities do not allow preparation such foods in schools. Therefore, biscuit, cake, crackers and such sort of foodstuffs consist the main food basket in schools.

4.2 Second Scenario: Power Ecological Footprint

As Table 2 indicates, EF_{power} has allocated about 9% of the total ecological footprint. Our study indicated that maximum power consuming is for cooling in warm months. Therefore, in order to reduce this amount and reaching it to the international standard (0.004 gha), it is suggested to exchange the old coolers with new one and renovating the rusty channels using modern tools and means. This strategy can reduce the power consumption in cooling by 70%, which in turn, can decrease the ecological footprint from 0.56 gha to 0.005 gha per year.

4.3 Third Scenario: Transportation Ecological Footprint

The ecological footprint for transportation sector was (24.4 gha, 37%). The data gathered shows that more than 79% of students and staffs were using private care or private cabs (neither public vehicle nor taxi) for commuting. It might be due to the poor public transportation system in Sanandaj City and traffic jumps or overcrowded area adjacent to the high school. In order to improve the ecological footprint in transportation sector, we suggest providing a school bus to commute the staffs and students.In addition, there is no school bus in public schools in Iran. Hence, students have to commute to schools by walk, on taxi, cab or be dropped by their parents. No bicycle is also allowed to be taken to the school environment. On the other hand, the staff and students should use the school bus instead of private car or cabs for commuting. In this case, the ecological footprint in transportation sector would reduce by 10% (from 24.4 gha to 21 gha).

4.4 Fourth Scenario: Gas Ecological Footprint

It was found that the gas ecological footprint is 7% in Qasri high school. Referring to the high school records and archives, it was found that the maximum gas consumption happens in cold season (winter, i.e. November-March). Exchanging heating system, especially radiators and reducing its number in corridors would be a useful approach in this regard. However, it must be noted that making the old and decayed radiators out of service and providing new heat package system can reduce annual gas consumption by 20%, i.e. reducing the high school ecological footprint from 4.8 gha to 2 gha per year.

The abovementioned scenarios indicate that taking simple measures can reduce the ecological footprint significantly (up to 59 gha), which is very close to the international standard value (58.38 gha) for educational organizations and institute having an area of 0.5-1 ha.

Table 2. Comparing the ecological footprints of Qasri high school with international standards

Sector	Per capita EF in Qasri High School (gha)	General EF in Qasri High School (gha)	International standard for EF (gha)	Difference between Qasri High School and international standards
Power	0.0014	0.56	0.004	0.556
Water	0.000005	0.002	0.003	-0.001
Gas	0.012	4.8	2.1	2.7
Solid waste	0.00016	0.064	0.07	-0.006
Transportation	0.061	4.24	5.21	2.9
Food	0.09	8.35	7.34	1.1
Total	0.164	6.65	38.58	25.7

5. CONCLUSION

The present study dealt with ecological footprint measurement to assess the environmental pressure from one of the metropolitan's land uses on the urban sustainability and its difference with international standards. In fact, its calculation and taking measurement to improve such land uses can play a crucial role in moving the cities towards sustainability. As one of the main land uses, we studied the ecological footprint of Qasri high school in Sanandaj City, Iran. Our results showed that the ecological footprint in this school during academic year 2011-12 was 65.6 gha, indicating 0.164 gha per capita. The maximum footprint belonged to the food and transportation sectors 35.8 and 24.4 gha respectively. Moreover, we found that except for water and solid waste sectors, the ecological footprint rate in different sectors was much more than the international standards (58.38 gha) claimed by Global Footprint Network. This difference has resulted in low level sustainability of high school, which its ignorance might result in tremendous impacts on the Sanandaj City sustainability. We suggested our alternatives in the form of four scenarios with respect to the sectors assessed. Exchanging old coolers with new ones and renovation of decayed channels using modern and new tools; emphasizing on mass public transportation system rather than private vehicles and cabs for students and staffs; providing package system and changing heating systems are some examples of alternatives suggested. In fact, applying the alternatives suggested can reduce the ecological footprint of Qasri high school from 65.5 gha to 59 gha, which is very close to the standard footprint rate (58.38 gha) for high school.

CONSENT

Not applicable.

ETHICAL APPROVAL

Not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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