

**Case Report**

# Assessment of Metropolitan Environment Sustainability with Use of Ecological Footprint Index (Case Study: Tehran Metropolis)

**Mohammad Javad Amiri<sup>1</sup>, Shahrzad Bouzari<sup>2\*</sup>, Sepideh Karimi<sup>2</sup>**<sup>1</sup>Faculty of Environment, University of Tehran, Tehran, Iran<sup>2</sup>Environmental Planning, Faculty of Environment, University of Tehran, Tehran, Iran**Email address:**

Sh.bouzari@ut.ac.ir (S. Bouzari)

\*Correspondence author

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**Abstract:** Sustainable development is an environmental reaction to traditional development patterns emphasis on coordinating development in the economic, social and environmental dimensions simultaneously. It specially takes two fundamental principles of natural resources preservation and observance of people's rights in future satisfaction of the natural resources into consideration. Both qualitative and quantitative indicators for measuring sustainable development for many communities have been provided that one of the most efficient of them is ecological footprint index. This index is an introduction to environmental planning which is one of the crucial pillars to reach the maintainable environmental growth. Ecological footprint is applied to measure the progress of societies in to the sustainability. So far, the value of the ecological footprint in different levels global, national and regional have been estimated. The article outlines the "Evaluation on the Sustainability of Metropolitan Environment by Ecological Footprint Index". Due to the growth of environmental problems, rapid development of urban area without planning, population grow of the city, changing in consumption patterns and unstable ecosystem, this study mainly focuses on Tehran metropolis. By considering the scale of the present study, six elements have been considered to estimate ecological footprint. These factors include: electricity, Warming natural gas, water, transportation, garbage and food. The rate of the land consumption for the population's requirements of Tehran metropolis during 2006 and 2011 has been estimated by use of ecological footprint index. The results have shown that during these five years, the population of Tehran metropolis has raised five percent. Meanwhile, the amount of the ecological footprint index has also increased 22%. The trend illustrates that ecological footprint is not influenced by only the impact of population but also the amount of the wealth, consumption pattern, technology used along with unstable urban development are the main reasons of increasing Tehran metropolis ecological footprint.

**Keywords:** Evaluation, Urban Environment, Ecological Footprint, Sustainable Development

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## 1. Introduction

Today, one of the most important global issues faced by human societies in developed or developing countries, is the issue of damages leading to the degradation and deterioration of the environment mostly caused by human actions (Fotros et al., 2011). The necessity for considering the urban issues for urban planners and those who are involved, has become an

inevitable issue due to excessive growth of urbanization and increasing urban population in different countries after World War II (Hesam, et al., 2013). The global urban population has quadrupled over the past century, and global resource consumption and waste emissions have grown to the extent that human beings today have gone farther than the ability of the earth to rehabilitate itself. (WWF, 2010) Global changes of environment is so high that the earth's ecosystem is

excessively exploited (Haberl, 2006). Countries around the world have experienced economic growth, poverty reduction and social welfare increase over the past four decades (UNDP 2006 and UNEP 2007). The important issue to the contemporary world today is not the concept of development or economic development, but sustainable development. Sustainable development takes into account all technical, economic, social, cultural and environmental aspects and dimensions as an integrated entity (Asayesh, 2002). Application of sustainable development was first introduced in the mid-1970s by "Barbara Ward". In order to effectively manage environmental resources in line with the role of human welfare, this general concept was widely discussed along with the global protection strategy (Motiee Langroodi, 2003). Ecological sustainable development is considered as the best and most ideal type of development, a development that improves the overall quality of life now and in the future, in order to protect necessary ecological processes to lead life. Such sustainable development preserves land, water, plants and the genetic resources, it is not environmentally destructive, it is appropriate in technology terms, and is economically justifiable (Goudarzi, 2000). Numerous qualitative and quantitative indicators are presented to measure the sustainable development of the societies, and ecological footprint indicator is one of the most efficient ones which is a proper tool to measure the progress of societies towards sustainability.

Estimation of ecological footprint in order to reveal the lifestyle relationship, is the consumption patterns of a population with natural capital consumption (Niccolucci *et al.*, 2012). Tehran is selected as a sample for case study. Tehran is a metropolis facing with serious environmental problems. These problems include rapid and unplanned growth of urban areas, disproportionate growth of urban population, change in consumption patterns and consumption services of urbanites, low quality of energy supply and poor quality of public transport.

Quality loss of urban environment in recent decades has made this metropolis to be listed among 10 poor quality cities of the world, based on the ranking of the world cities in livability index for life in 2014 (economist, 2014).

Tehran as a metropolis, and an outstanding city in economic, political, and social terms, is facing with the increasing population and area. On the other hand, like many other metropolises, due to the unidirectional dependence to input flows of material and energy and output flows of pollutants and waste produced which is a feature of modernist cities, such metropolis will be damaged more than sustainable cities that feature less input flows of material and energy and less flows of pollutants and waste (Turner, 2002). One of the issues and challenges in the twenty-first century is urban instability (Sarraf, 2000). In this regard, this study seeks to measure and evaluate sustainability in Tehran using ecological footprint analysis method so that by getting informed of the sustainability status of the city, we can determine the necessity to apply policies and executive plans in line with the environmental improvement and realization of sustainable

development. Ecological footprint doesn't include social and economic development, but the use of this concept is a new method in measuring regional sustainable development by a comparison of natural capital consumption of people with available requirements (Huang *et al.* 2007). Calculating the ecological footprint showed that today, on the one hand, human beings utilize natural capital at the expense of reducing the earth's capacity to support future generations, and on the other hand, human consumption and waste production is beyond the capacity of new resources creation and waste absorption by the earth. As a result of such excessive utilization, human economy leads to the loss of natural capital of the earth (Wackernagel *et al.*, 2002).

In the field of ecological footprint index, a few studies have been carried out in Iran, which are as follow: Sarayee and Zareei Farshad in a study in 2011, investigated the ecological sustainability using ecological footprint index, from Islamic Revolution to year 2001 in Iran. Studies and statistics indicated that the ecological resources are unstably utilized in Iran. Shakoore *et al.* in 2011 evaluated and measured tourism sustainability, in the lost paradise of Bavan Mamasani using ecological footprint model. In this study we investigated five factors of ecological footprint including electricity, water, transport, garbage and food. Finally the ecological footprint calculated for each tourist was estimated 0.877 hectares. In a study in 2010, Sheikh Azami, and Divsalar conducted a comparative study of the ecological footprint effectiveness in Muslim countries of Southwest Asia and Western industrialized countries and the comparison showed that due to remarkable industrial progresses, industrialized countries have a high carbon footprint and meet their ecological deterioration by enlarging their carbon footprint through the countries with a lower carbon footprint. The thesis for Master's degree conducted by Samadpour in 2008, entitled as determining the ecological footprint in high density urban areas (Case Study: Elahieh District, Tehran) who adapted EF calculation method in accordance with the circumstances of Iran in neighborhood scale for the first time. He finally calculated ecological footprint in Elahieh neighborhood scale. The results show that the ecological footprint of Elahieh is 6.33 hectares per person (Samadpour and Faryadi, 2008).

## 2. Materials and Methods

This research is descriptive-analytical in terms of nature, and the data required for this research have been collected using library studies and investigating the documents and statistics of related organizations and departments. Its ecological footprint calculation method is based on inductive or detailed approach which is more appropriate in order to calculate the ecological footprint of regions and cities. In this approach calculating the ecological footprint of a specific location is estimated with respect to certain activities such as food consumption, the amount of CO resulting from transportation, natural gas heating, water consumption, electricity and the amount of garbage produced. The above statistical data is taken from the global FAO reports, Tehran

Municipality waste management organization, National gas Company, water and wastewater Company, Great Tehran Electrical Distribution Company, and the electronic data bases of Census Bureau. In this study, the ecological footprint of the above activities has been calculated for the years 2006 and 2011 in Tehran. The method for calculating each of the activities is in compliance with the procedures specified in the Colorado College, which was first adapted and extended by Samadpour and Faryadi in Iran. These calculations consist of the following main steps according to the general method invented by Rees and Wackernagel:

Estimating the per capita of annual consumption of consumables based on the total regional data (dividing total consumption by population).

Estimating the land allocated to each individual for each consumable item (dividing the average annual consumption per item on average annual production or land yield)

Calculating the average of total ecological footprint per person by adding all the ecosystem areas which is allocated to each person.

Obtaining ecological footprint (EFp) for the population of the study area (n), by calculating the average multiplication of footprint per person by the population size ( $EFp = n * EF$ ).

### 2.1. Location of the Study Area

With a population of over 8 million, Tehran metropolis is the twenty-fifth most populous city in the world and the central part of Tehran. Measuring 730 square kilometers, it is one of the largest cities in West Asia and the world's twenty-seventh largest city. Population density in Tehran is estimated between 10700 to 11000 people per square kilometers. Tehran in the north of Iran is located at the Southern foothills of the Alborz Mountain ranges between longitude 51 degrees and 2 minutes East to 51 degrees and 36 minutes and latitude 35 degrees and 34 minutes North to 35 degrees and 50 minutes North. This altitude of the city at the highest portion of the north is about 2,000 meters and at the most Southern portion is about 1,000 meters above sea level in the southern portion. On North it leads to the mountainous and on South it leads to desert areas, as a result in the south and north it has a different climate.

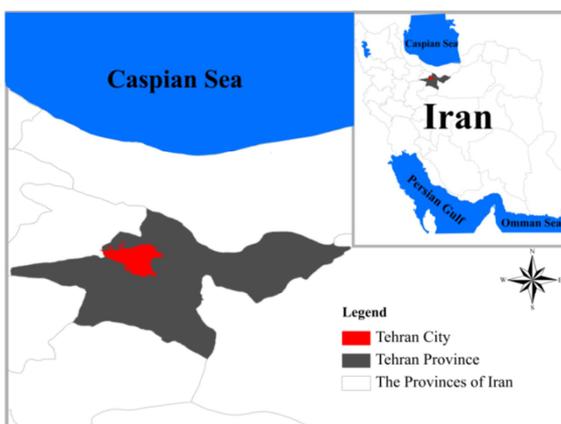


Fig. 1. The geographical location of Tehran.

### 2.2. Data and Methodology

A sustainable city is the one which is able to survive using economic optimum use of resources, avoid excessive production of waste, recycle wastes to the extent possible and accepts useful long-term policies, (Hosseinzadeh Dalir and Sasanpour, 2008). The ecological footprint analysis is one of the most sophisticated tools for measuring the sustainability of certain places or lifestyles. (Gharakhlou et al., 2013). This index was first introduced in 1996 by Mathis Wackernagel and William Rees at the University of British Columbia in Canada and was accepted as an indicator of sustainable development. Ecological footprint is a type of accounting tool which is used for population or economy to estimate and measure resource consumption and pollutant absorption and is calculated by converting them into fertile lands (Wackernagel and Rees, 1996).

This method is indeed an introduction to planning and one of the efficient and important tools that contributes to the realization of sustainability. The basis for studying the ecological footprint is associated with the concept of carrying capacity and initially it was raised as the exclusive carrying capacity (Wackernagel and Yount, 2000). Carrying capacity is the number of species that a specified region can give shelter, yet maintain their production, compatibility and renewing capacity (Manning, 2002). Ecological footprint index investigates the amount of land required to support a specific population. Contrary to carrying capacity, ecological footprint calculates all impacts generated by a population regardless of where they have happened (Monfreda, 2004). This index, which has turned into the subject of comparing stability among the countries, compares the effects and consequences of the societies, different regions, countries and individuals on the environment by transforming them into the land required to produce basic needs and absorption of pollutants. In other words, ecological footprint links life style of human beings with environmental consequences. Of course, these calculations depend on the level of information and their accuracy, the conversion index, the area of agricultural land, the surface of forest lands and other natural resources.

Conceptual simplicity is the most important strength of the ecological footprint analysis. Ecological footprint addresses this issue that to what extent should people reduce their consumption, improve their technology, or change their behavior to achieve sustainability. In case the study is time-series, the ecological footprint can contribute to reduce the sustainability gap by introducing new technologies and changes in consumer behavior. Also, in simulation studies footprint analysis can be used to test the effect of alternative technologies or settlement patterns on the ecological footprint of the amount of population. It's noteworthy that the ecological footprint analysis is not a perspective to the future (Wackernagel, 1996).

## 3. Discussion

The consumption amount of six factors: electricity, natural

gas heating, water, transportation, garbage and food waste was separately calculated in year 2006 and 2011 in terms of hectares to estimate the ecological footprint of Tehran. Summing up the per capita of the six factors considered, the amount of ecological footprint in Tehran in 2006 and 2011, was calculated, 6.57 and 8.039 hectares respectively per each citizen. Considering the 1.16 hectares of ecological footprint per capita in the country (Makhdoom 1384), ecological footprint in 2006 is 5.6 times and almost 7 times of the country's ecological footprint per capita in 2011 which is allocated to meet consumable goods and services of citizens in Tehran. The growth rate of ecological footprint in Tehran has been 22% during the past five years based on the figures obtained and population of Tehran has seen a growth of 5 percent which shows that increase in the ecological footprint of the Tehran population is not only due to population increase and is change in the consumption patterns and lifestyle of the Tehran citizens is the main factor for the growth of ecological footprint. Tehran province is ranked thirty-first in terms of ecological footprint and the impact of individuals on the nature which means that in meeting the ecological needs of its residents, Tehran has the highest trend of environment destruction and that if this trend of changing consumption patterns and lifestyle continue, then it can increasingly reduce the ecological sustainability of this metropolis.

**Table 1.** The consumption amount of factors considered in the years 2006 and 2011.

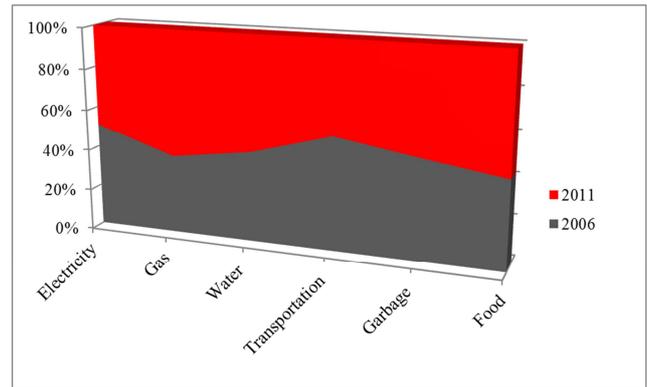
The index for measuring EF	2006	2011
Electricity (Million kw hours)	17267000	16631000
Gas (million Sq. m)	7900	13000
Water (Thousand Sq. m)	1051850000	1339140000
Transportation (Thousand Sq. m)	1053500	860000
Garbage (Tons)	2283000	2410000
Food (Kg)	6156327000	8195290000

**Table 2.** Ecological footprint in Tehran separated by consumption factors in 2006.

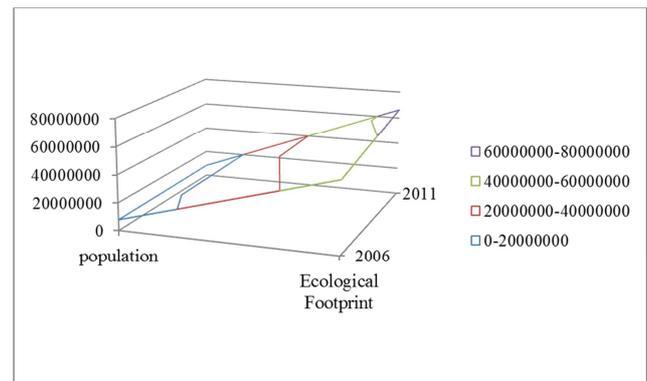
EF consumption factors	Obtained EF (hectares)	EF Per capita n = 7803883
Electricity	4674260	0.59
Natural gas heating	37800	0.0048
Water	84000	0.0107
Transportation	585000	0.074
Garbage	51	0.0000065
Food	45926000	5.88
Total	51308000	6.57

**Table 3.** Ecological footprint in Tehran separated by consumption factors in 2011.

EF consumption factors	Obtained EF (hectares)	EF Per capita N = 8244759
Electricity	4502000	0.54
Natural gas heating	60985	0.0073
Water	107000	0.012
Transportation	476400	0.057
Garbage	53.5	0.0000064
Food	61136900	7.415
Total	66283422	8.03



**Fig. 2.** The percentage of changes of consumption factors in years 2006 and 2011.



**Fig. 3.** Comparison of population growth trend and ecological footprint in years 2006 and 2011.

### 4. Conclusion

In this study, we have evaluated the environmental sustainability of Tehran using the ecological footprint index. The quantitative index of ecological footprint is provided to measure the sustainable development of the societies which is one of the most efficient appropriate tools to measure the progress of societies and communities toward sustainability. In order to calculate the ecological footprint of Tehran, the amount of land needed to meet goods and services to citizens in the years 2006 and 2011 per citizen is estimated 6.57 and 8.04 hectares respectively. According to the report of ecological footprint Atlas in 2010 that has estimated the ecological footprint per person in the world as 2.70 hectares, in Asia 1.78 hectares and 2.68 hectares in Iran, the per capita calculated in Tehran is far more than its fair share. In fact, in 2006 and 2011, Tehran has consumed 2.45 times and 3 times of its fair share of global resources, respectively. Significant changes in ecological footprint will depend on a number of factors, including the location of the city, the quality of used goods and services, consumed resources and wastes generated to provide these goods and services (WWF, 2012). Due to the 5 percent growth of the population in Tehran and 22% increase in ecological footprint index of this metropolis, it can be concluded that this index is not only affected by population and wealth, otherwise it is affected by the extent of wealth, consumption patterns and technologies used and in fact the

life style of citizens is the main factor for the increase in ecological footprint of Tehran metropolis. Therefore, we can consider urban development as one of the critical factors for increase in the size of the ecological footprint. Today, more than 50% of the world's population live in cities. Urbanization is usually made by an increase in income growth, which leads to the ecological footprint growth, especially due to the increase in the carbon footprint (Poumanyong and Kaneko, 2010). Considering the direct effect of urbanization in increasing ecological footprint and increasing development of Tehran as the capital and largest metropolitan center in Iran, urban instable development can be regarded as a contributing factor in the excessive increase of ecological footprint and environmental instability in Tehran. As a result, some strategies are suggested as following in order to promote environmental sustainability of Tehran metropolis and other major cities, in accordance with the theoretical foundations of the sustainability concept: reducing pollution, preserving natural resources, reducing the volume of urban waste, increasing recycling, reducing energy consumption, excessive increasing of useful organisms in urban and rural areas by creating a community forest and urban trees and green areas, urban decentralization and reducing dispersions, increasing the average density in the suburbs and towns, reducing communication distances, creating local jobs, divers development of housing in employment centers, development of small towns to reduce reliance on big cities, balanced social structure, public transportation and reducing road traffic, managing unrecyclable waste and distribution of resources and providing sustainable local food. In this way, adoption of proper use policy and protection of the land is enhanced through the replacement of resources and modernization of them, and urban sustainable development will be achieved with respect to urban planning and space organization.

Scientific management that could guarantee the achievement of sustainable urban amenities, especially in urban settlements is one of the major factors in reducing the ecological footprint, and through which urban life will become sustainable. In accordance with this view, it should eventually be said that attention to the environment and natural ecosystems in planning and decision-making requires more knowledge about the ecological footprint, and adoption of environmental protection policies in order to control and reduce the ecological footprint. To this aim, it seems necessary to raise awareness in order to reduce the excessive use of ecosystem and reduction of waste and garbage and their recycling, and the use of efficient technologies to reduce the use of natural ecosystems, and controlling industrial pollution of modern technologies. To this end, strategies for reducing ecological footprint is proposed as follow: First in the energy sector, using natural sunlight instead of electric lights if possible, using electronic devices only when necessary, wearing warm clothes instead of heating devices, using green energy such as solar and wind power, using public transportation, cycling or walking instead of private cars. In the food sector, using organic and local foods, following diets with less meat, and finally in goods and services sector, buying recyclable products from local shops and supermarkets, using

personal bags for shopping instead of plastic or paper bags.

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