Article

Evaluation of the sustainable urban development in the Mashhad Metropolis using Ecological Footprint Method

Q. Haghparast, **Ahmadizadeh**, **Javad Dawoudian**
University of Birjand, Birjand, Iran
E-mail: ghasemhaghparast@gmail.com, ssahhmadizadeh@yahoo.com, jav_1367@yahoo.com

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Abstract
The footprint analysis approach is based on the idea that a certain amount of land will be required in one or more environmental domains for the consumption of any commodity or energy in order to ensure the flow of the resources consumed and the disposal of the resulting fossil fuels. So, there are several methods to calculate the sustainability and ecological effects of urban areas. Meanwhile, the method of ecological footprint is a new approach that offers clear and measurable results in urban management. The purpose of this research is to assess the sustainability of Mashhad's metropolis development with ecological footprint indicators in different sectors of consumption, such as housing, transportation, food, goods and services. In this research, all services and goods which are consumed by inhabitants of Mashhad, used throughout their lives, included in six types of land use including land energy, agriculture, pasture, fishery, forest and land, and the per capita footprint of any types of land use. The results of this research show that per capita ecological footprint of every person in Mashhad is 1.27 average of world hectare. Considering the bio capacity in the study area (0.66 hectares), facing ecological deficit and meeting the needs of its inhabitants, according to the population of 3.135.618, an area equivalent to 3,982,235 hectares is needed to respond their habitants. That is almost twice the living capacity of the region. It indicates the Mashhad Metropolitan dependence on supporting areas to meet the needs of its inhabitants.

Keywords ecological footprints; urban development sustainability; Mashhad Metropolis.

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1 Introduction

Over the last century, cities have attracted a large percentage of the world's population (Zhang, 2008; Neumann, 2015). For the first time in history, the number of people living in cities is equivalent to those who live outside the city. Predictions United Nations estimates that by 2030 more than 60 percent of the world's population will live in urban areas. Although cities occupy only about 2 percent of the Earth's surface, they hold more than half of the world's population, which is increasing at around 55 million tons per year. They consume about a quarter of the world's resources and are the main producers of waste in the world (Nejat et al.,

2015). Cities due to parasitic energy requirements and feed on large structures have become depleted and degenerative world, consumers no mercy, no compassion and ardent infected participants (Agir, 2005). Today, most of the issues in the world, such as traffic and land congestion, abandoned buildings, waste problems, land use change, noise pollution, water pollution and many other environmental issues raise the subject of urban sustainability. Therefore, considering the problems and problems that cities have to address the dimensions and principles of sustainable human development, sustainable cities and urban sustainability should consider the characteristics that a healthy city needs. Also, urban planners and managers, with proper and healthy management, can create a healthy environment for people (Maleki, 2003). Continuous growth of the economy and population has caused human needs twice the productive capacity. It leads to reduction in ecological capacity, the erosion of ecological and large-scale capital, and increase in the collapse of ecosystems (Waknagel and Riz, 1996). Currently, ecological footprints are used as indicators for measuring the supply and demand of renewable sources (Luke, 2011). In the ecological footprint, the question arises as to how much space is available locally or globally to humans and thereby identifies ecological constraints that are able to trace human beings in the long term in nature (Waknagel, 2010, Zhang et al., 2017).

1.1 Sustainable Urban Development

Our understanding of cities, in both theory and practice, is at a turning point. Urban areas across the world face complex and rapidly evolving challenges. The classic definition of sustainability comes from the Brundtland report of 1987: "Sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs." But the term has become like a rubber band that can be stretched in all directions. Whatever the interpretation, it is clear that sustainable development is not enough anymore. This is because "the ability of future generations to meet their own needs" is already compromised (The guardian, 2017). The development of a comprehensive process of economic, social, cultural and political activism is aimed at continuous improvement of life, and the activities of freedom, proper participation and equitable distribution of benefits are among its key pillars (Atfild and Mickens, 1992; Mosco, 2014). Sustainable development is one of the most comprehensive concepts in recent decades (Bolis et al., 2014). In the broad sense of the word, this term means the proper and efficient operation and administration of financial, human and … resourcesto achieve the desired consumption pattern by utilizing the technical facilities, structure and organization appropriate to meet the needs of today's and future generations. Satisfactory is possible. Sustainable development will not only improve the current generation but also has considered the improvements of future generations (Ziari, 2008; Rezaei et al., 2014). The goal of the sustainable urban development process is to achieve the "sustainability" of urban communities. It is a process that aims to create or strengthen the characteristics of sustainability in the city's economical, social, cultural and environmental life. The topic of sustainable urban development in recent years has been considered as an important scientific issue in all societies and has a large part of the literature of urban development. In this regard, various dimensions of sustainable urban development have been studied, analyzed and evaluated in different perspectives, and various ways have been considered in the frame of various visions. In order to, some definitions of sustainable urban development can be listed in Table 1.

Table 1 Some main definitions of sustainable urban development **(**Source: Authors, 2017**).**

Author & year	**Definition**
Hawken (1993)	Sustainability as an economic state where the demands placed upon the environment by people and commerce can be met without reducing the capacity of the environment to provide for future generations.

Meadows (1998)	Sustainable development is a social construct, referring to the long-term evolution of a hugely complex system—the human population and economy embedded with in theocons stems and bio geochemical flows of the planet
Kennedy et al (2007)	A sustainable city can only be one for which the inflow of material and energy resources, and the disposal of wastes, do not exceed the capacity of the city's surrounding environment. In other words, for achieving environmental sustainability urban consumption must match or be below what the natural environment — such as forests, soil and oceans — can provide, and the resulting pollutants must not overwhelm the environment's ability to provide resources to humans and other members of the ecosystem.
Sharifi (2016)	It is an application of sustainability and resilient principles to the design, planning, and administration/operation of cities. There are a range of organizations promoting and researching sustainable urbanism practices including governmental agencies, non-governmental organizations, professional associations, and professional enterprises around the world.
Camagni (2017)	The concept of sustainable development is steadily approaching recognition, if not full disciplinary autonomy, becoming the focus of new theoretical and normative reflection. However, the same cannot be said of a more specific field of application of the concept – the urban environment. In our opinion, this has been hindered until recently by some unresolved problems of definition, methodology and epistemology – intrinsic in the more general concept, and also by some specificities of the urban case which have not been sufficiently borne in mind

Today, the sustainability of human life is threatened by Multiple factors. Technology development, economic dynamism, population growth and environmental damage are one of these factors (Sepahand et al., 2013). In order to have sustainable development, the first step is to know about the stability of the region so that, if unstable, planning for its sustainable development is carried out and implemented. There are several quantitative and qualitative methods for measuring the level of stability. One of these methods is the ecological footprint method (Juma Pour et al., 2012).

1.2 Ecological Footprint

The first academic publication about ecological footprints was by William Rees in 1992. The ecological footprint concept and calculation method were developed as the PhD dissertation of Mathis Wackernagel, under Rees' supervision at the University of British Columbia in Vancouver, Canada, from 1990–1994 (Rees, 1996; Wackernagel, 1994). Originally, Wackernagel and Rees called the concept "appropriated carrying capacity". To make the idea more accessible, Rees came up with the term "ecological footprint", inspired by a computer technician who praised his new computer's "small footprint on the desk". In early 1996, Wackernagel and Rees published the book Our Ecological Footprint: Reducing Human effects on the Earth with illustrations by Phil Teste male (Zavadskas et al., 2007). In 2013, the Global Footprint Network estimated the global ecological footprint as 1.6 planet Earths. This means that, according to their calculations, the planet services were being used 1.6 times faster than they were being renewed (Rees, 1996). The ecological footprint measures human demand on nature, i.e., the quantity of nature it takes to support people or an economy. It tracks this demand through an ecological accounting system. The accounts contrast the biologically productive area people use for their consumption to the biologically productive area available within a region or the world

(bio capacity). In short, it is a measure of human effects on Earth ecosystem and reveals the dependence of the human economy on natural capital (Lenzen and Murray, 2003; Nitzbon, 2017).

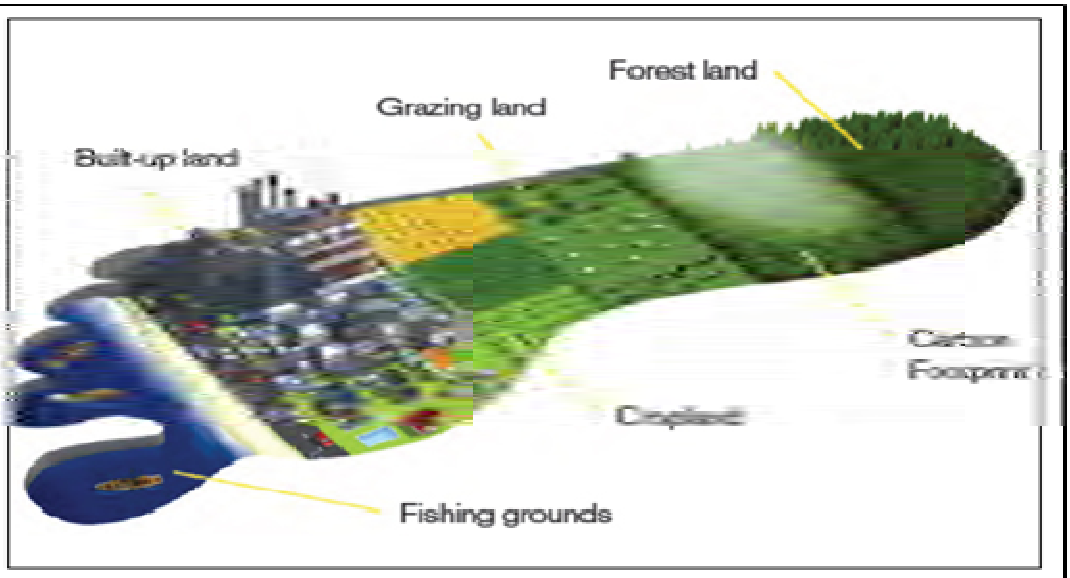

Fig. 1 City area and ecological footprint (http://www.overshootday.org, 2017)

The ecological footprint is defined as the biologically productive area needed to provide for the people consumption: fruits and vegetables, fish, wood, fibers, absorption of carbon dioxide from fossil fuel use, and space for buildings and roads (Zhang, 2007; Zhang et al., 2007; Zhang and Zhang, 2007). Bio capacity is the productive area that can regenerate what people demand from nature (Zhang et al., 2006; Moffatt et al., 2012). Footprint and bio capacity can be compared at the individual, regional, national or global scale. Both footprint and bio capacity have been changed every year with the growing number of people, per person consumption, efficiency of production, and productivity of ecosystems. At a global scale, footprint assessments show how big human demand is compared to what planet Earth can renew. Global Footprint Network calculates the ecological footprint from UN and other data for the world as a whole and for over 200 nations (Martinez, et.al, 2018).

1.3 Background

Gharlakhlo et al. (2013) evaluated the sustainability of urban development using ecological footprint method for Kermanshah. The results of this study showed that the ecological footprints of Kermanshah city in food consumption groups, transportation, natural gas heating, water, electricity and land required for waste disposal of 1.82 hectares. Comparison with its supporting spaces indicates that the city of Kermanshah relies on a region beyond the province of Kermanshah to meet its biological needs and sustainability. Samadpur and Farayedi have studied the ecological footprints in Tehran's Elahi neighborhood in 2007. In this study, comparing the trend of increasing green lands and changes in the use of the divine neighborhood has showed that between 2004 and 2005, the land was built up and green lands decreased. Then, by using the ecological trail method, it was determined that the amount of land consumed to meet the needs of the inhabitants of the Divine area was 1.6 times the total area of Tehran.

- In 2006, Sasanpour assessed the stability of Tehran metropolis with a high ecological footprint in his doctoral dissertation. The results of this study indicated that the consequences of instability of metropolitan ecology such as Tehran have reduced the ecological capacity of the supported region,

thus, the ecological space of Tehran metropolis cannot meet the basic needs of its population. The ecological trace of every the people in Tehran is about 2.46 hectares, its distribution in food groups, housing and transportation is 0.91, 0.34 and 0.38, respectively. Considering the population numbers and the Tehran area, it means that if human needs in Tehran continue to do this way of production and consumption, they will need more than 25 times the space of the current Tehran metropolis.

- Zahmatkesh and Parastar (2013) presented new conceptual ecological footprints in sustainable development. In this paper, the method of calculation, the advantages and disadvantages of it were studied and proposed solutions to reduce the use of natural ecosystems.
- Juma Pour et al. (2012) examined the status of sustainable development in Rasht city using this method. The results show that the ecological footprints in Rasht city is 1.97 hectares per person, and also the biological capacity is 0.414 hectares per person, which indicates the instability situation in this city.
- Moore et al. (2013) evaluated the ecological footprint and urban metabolism in Vancouver of Canada. The results show that the footprint of Vancouver's per capita in 2006 was close to 4.74, which was nearly three times the per capita contribution of environmental capacity. The components of the trail were: food, 2.13 hectares, world average, transportation 1.10, construction 0.84, waste 0.68 and water 0.002. The city ecological space should be 36 times larger than Vancouver to meet the needs of the present and future populations.
- In 2005, in a study by Medwood, he examined the sustainability of the country in Slovenia. For the first time, Slovene ecological footprint was calculated in this study. The results show that the ecological footprint of Slovenia was3.85 hectares worldwide, its more fertile area (2.55 hectares worldwide) and is much higher (1.8 hectares) to the Earth planet. This indicates that Slovenia, whether on a global scale or on a local scale, was experiencing a problem of instability and should be placed in the group of unstable countries.
- Yang and et al in 2009 have examined the sustainable development of the ecological footprint in the period of 1988-2006. The results show that the ecological footprint per capita of 1,854 hectares in 1988 reached 2.11 hectares in 2008. As a result of increasing in ecological deficit, rapid population growth and consumption levels have occurred. In order to achieve sustainable development in Yunnan, consumption and production rates need to be adjusted.
- The World Wildlife Fund in its "Live Planet Report" in 2012 measured the ecological footprint for all countries with a population of over one million. According to the report, Qatar has 11.68, followed by Kuwait with 9.72 hectares, the world largest and the Palestine with 46.6 and Afghanistan with 0.54 hectares of the world smallest ecological footprint among all countries.

2 Material and Methods

2.1 Study area

The city is located at 36.20º North latitude and 59.35º East longitude, in the valley of the Kashafrud River near Turkmenistan, between the two mountain ranges of Binalood and Hezar Masjed Mountains (Asadi et al., 2017). Also, Mashhad is the capital of Khorasan Razavi Province in Iran. It is one of the most important cities due to its religious, historical and economic values that attract a large number of people from all of the world as pilgrim each year. In 1986, its population was 668,000, however its current population is about 2.8 million. Since 1987, built-up areas in the city have expanded significantly (Rafiee, 2009); the city has witnessed a rapid growth in construction which it has caused destruction of green spaces areas. This trend in the urban park is in sharp contrast with the rules governing improvement and establishment of new urban parks within the current boundary and the projected future of the city. In addition, the provinces of Iran are all under extensive land use

evaluation and planning, the results of which will be available in near future. The land use is mostly environmentally oriented giving high value to public urban parks and aims to upgrade the per capita green areas in the newly built regions. However, there are other players in the filed including major private stakeholders who have influenced in deciding the physical and biological properties of built-up area development plans (Iranian Statistical Center, 2014). The Natural Step Framework is a methodology for successful organizational planning. It is based on systems thinking, recognizing that what happens in one part of a system affects every other part. The vast majority of people in Mashhad city are ethnic Persian, who forms over 95% of the city population. Other ethnic groups include Kurdish and Turkmen people. The people of Mashhad who look like Asians are of Turkmen or Hazara descent. Among the non-Iranians, there are some population of Afghanistan, Iraq and Pakistan. The Afghan immigrants have several neighborhoods around the city. One of the districts inhabited by Afghan immigrants is Golshahr. There are also over 20 million pilgrims who visit the city every year (Mashhad Municipality, 2015).

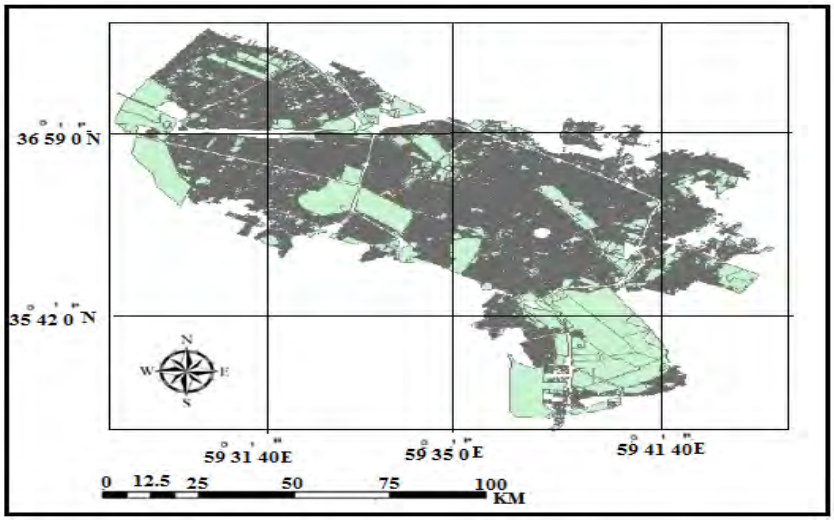

Fig. 2 A view of Study Area.(Heydari et al., 2017).

2.2 Method

Since measuring the amount of land needed is not very feasible, preparing, storing and disposing of waste, dozens of commodities are limited only to calculate the main consumables and individual goods. The estimation of a specific population ecological footprint is a multi-stage process. The main structure of the approach is this. At the same time, the description of this process is related to the use of resources, and the same logic is also true for many waste and absorption of produced resources (Sasan Pour, 2011). The ecological footprint is measured with the unit level. The unit level is about 0.3 hectares of land, compared to the global average, the productivity of the same unit is about 0.6 hectares of the average forested land or 2.7 hectares of the average pasture land or 16.3 hectares of the sea (coast); Therefore, a completely fertile ground of hectare represents a greater amount of unit area than the same not so fertile amount. The unit method estimates the full scale of the ecological footprints of different regions and countries based on the types of land use, built land, biological capacity, and ecological deficiencies. Based on the general methodology developed by Wackernagel and Reez (1996), the calculation of the ecological index is comprised of the following steps:

- Estimates of land allocated to each person for each item by dividing the average annual consumption of each item by the average annual production, or return on the land;
- Estimated per capita annual consumption of primary consumables based on total regional data and total consumption divided by population;
- Calculates the average total number of ecological footprints of each person by aggregating all allocated areas for all parts that have been consumed by a person in one year;
- Calculating the ecological footprint to the population of a special area (Wackernagel and Reez, 1996).

The ecological trace in its original form is computed from the relation

$$EF = \frac{D_{ANNUAL}}{Y_{ANNUAL}}$$

D: Annual product demand and Y: Annual yield of the same product

The unit of measurement is the ecological footprint of the global hectare. Global hectare is evaluated by two factors:

- The coefficient of efficiency compares the average national yield per hectare of land with the average global yield of the same land type.
- The equilibrium coefficient shows the relative productivity of the different types of ground and water zones; hence the ecological footprint will be in the form of equation

$$EF = \frac{P}{Y_N} \times YF \times EQF$$

P: The amount of finished product or waste produced (equal to); $Y_N$is the average national return for P; YF and EQF: respectively, the coefficient of return and equilibrium for the country and the type of land in the subject under discussion.

After calculating the ecological footprint, biological capacity is calculated to determine stability or instability and compared with the ecological footprint. The biological capacity of an area for each type of earth is calculated in accordance with equation

$$BC = \mathrm{A} \times YF \times EQF$$

BC: Biodiversity; A: Areas available for a given land use type; YF and EQF: respectively, coefficient of return and equilibrium coefficient for different types of earth zones. The returns coefficient is the ratio of the average national return to the global average. The equilibrium coefficient shows the existing or demanded areas of a particular type of land (such as the average global agricultural land, pastures, etc.) within the average units of the global productivity zone in terms of land use and year. To calculate the ecological displacement of the Mashhad metropolis, a small and fast-moving pattern (1996) is used from the land-use matrix**.**

3 Results and Discussion

3.1 Ecological footprint of energy (earth energy)

At first, the energy consumption (electricity, gas and fossil fuels) was extracted from the Statistical Yearbook of Khorasan Razavi Province (2013) in the sectors (transport, housing and food). Then, based on the energy conversion factor, its units converted to a single unit, i.e., mega joules. In order to obtain the amount of land energy, according to Waknagar, CO_2 emissions from the use of 100 gigawatts of fossil fuels require a hectare of earthly belief like forest. Therefore, all consumed quantities were converted into a global average hectare. In order to estimate the energy footprint in the consumer goods and services sector, information on household expenses (family size 3.45) was used and converted to the equivalent of crude oil barrels to obtain the required

amount of energy in this sector and for the total ha of land allocated Each citizen of Mashhad was estimated for all sectors of energy consumption (housing, transportation, food, services and consumer goods).

Table 2 Energy consumption in consumable sector (in Giga Jules) (Authors, 2017.)

Consumption Sector	Consumption Rate
Housing	33.5
Transportation	23.4
Food	3
Services and consumables	16.95
Total	76.85

If for every 100 gigajoules we need a hectare of fertile land, then the per capita energy trail (energy needed) for each citizen of Mashhad is estimated to be 0.76 hectares.

3.2 Agricultural ecological footprint

To calculate the agricultural land, food is divided into two groups of vegetable and animal food, and then the land allocated to each section is estimated according to the following diagrams. The data requirements of this section were generalized based on the per capita consumption of foodstuffs in Mashhad and Mashhad population due to the lack of separation of per capita consumption in Mashhad.

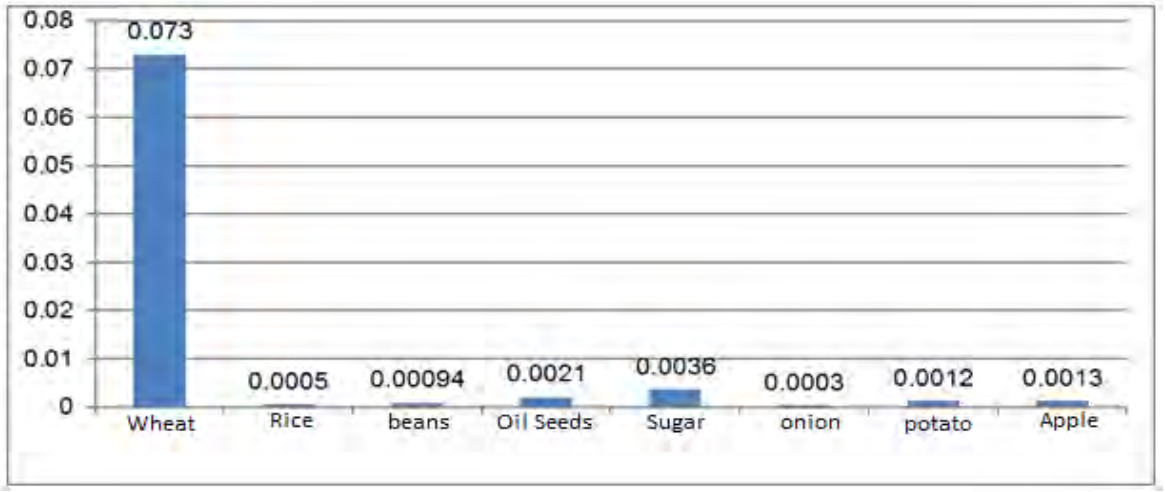

Fig. 3 Per capita footprint of ecological agricultural crops (Authors, 2017).

The needed land for services and consumer goods in the agricultural sector was based on field studies only on cotton consumption in Mashhad, and based on the per capita consumption rate of cotton in the country, 4.6 kg, and according to the yield of this product, the amount of cotton cultivated land Estimated. In total, the per capita footprint of agricultural land ecology was estimated to be 0.32 hectares per citizen of Mashhad. If we multiply this footprint in the population of 3135618 people in the city of Mashhad, we need a figure of 1003398 hectares of agricultural land so that we can supply the food needed for this sector.

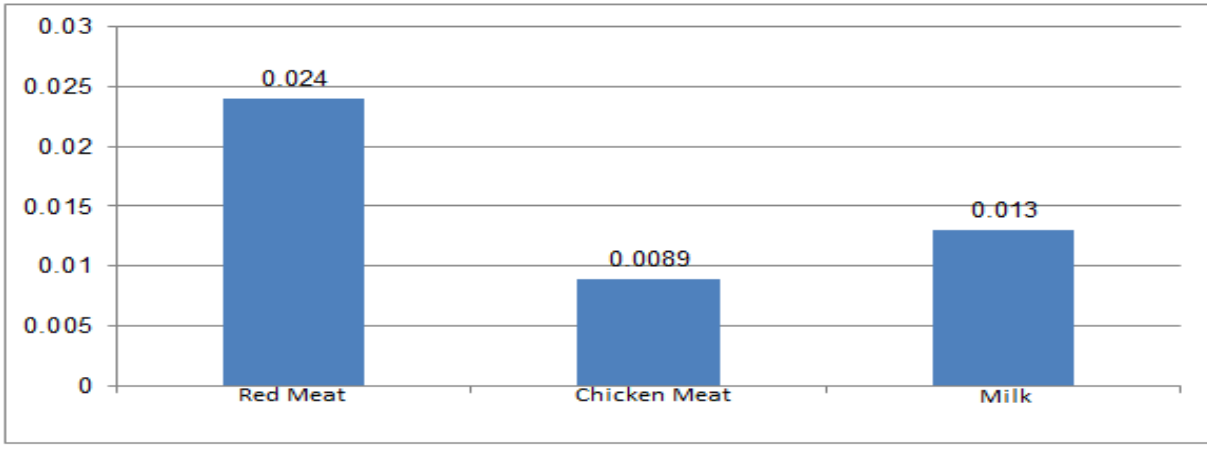

Fig. 4 Per capita footprint ecological tract of animal food related to agricultural land (Authors, 2017).

3.3 Ecological footprints in fisheries

Per capita consumption of fish was taken from Agricultural Jihad Department of Mashhad city and according to the performance rate of fish farming per capita, the ecological footprints of the land plot were estimated 0.002 hectares per citizen of Mashhad.

3.4 Built land ecological footprints

Land use map of Mashhad was used to calculate the Built Land. In this section, the land made or assigned to four parts of transportation, housing, services and goods was extracted from the land use map and the statistics of the transportation section were extracted from the statistics of Mashhad.

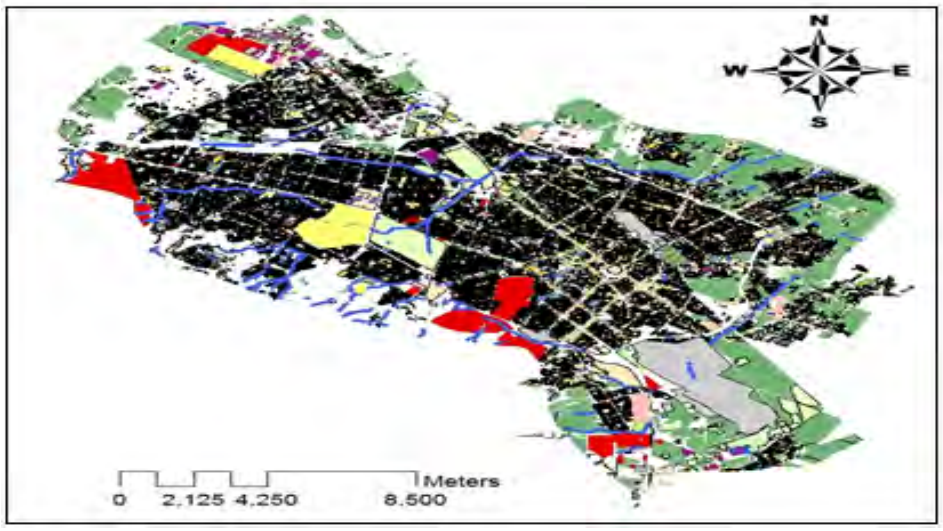

Fig. 5 Land use map of Mashhad Metropolis (Authors, 2017).

Table 3 Area allocated to the consumption areas of each use (ha) (Authors, 2017).

Total (he)	Sub-basement (hectare)	Land Use	Consumption district
5278.58	5278.58	residential	Settlement
	1064.54	Military	
	438.93	Trading	
	181.93	administrate	
	159.07	education	
	52.27	Urban services	
	74.21	water	Goods and Services
	332.77	industry	
3420.51	16.07	facilities	
	85.15	healthily	
	639	Tourism, Recreation and Sports	
	310.79	Green Space	
	64.92	Resident	
	0.86	Etc.	
	1239.84	Transportation and warehousing	Transportation
5078.76	3838.92	Total Roads	
131.32	131.32	Agriculture	Food

According to Fig. 4 and Table 3, the per capita ecological footprint of the built land was estimated to be 0.011 hectare. According to the calculations, the ecological footprint per capita of Mashhad is 1.273 hectares.

Table 4 Comparison of ecological footprints of Mashhad with biological capacity and estimation of ecological deficit of this city (Rahnama and EbadiNia, 2014.)

Total	Built land	Land Fishier	Land Forest	Land Grassland	Land-energy	Agri-land	
1.27	0.011	0.002	0.05	0.13	0.76	0.32	Ecological footprint
0.66	0.06	0.23	0.009	0.07	-	0.30	Biodiversity capacity
-0.62	0.04	0.22	-0.04	-0.06	-0.76	-0.02	Ecological deficit

According to Table 4, the results can be obtained as in Fig. 5.

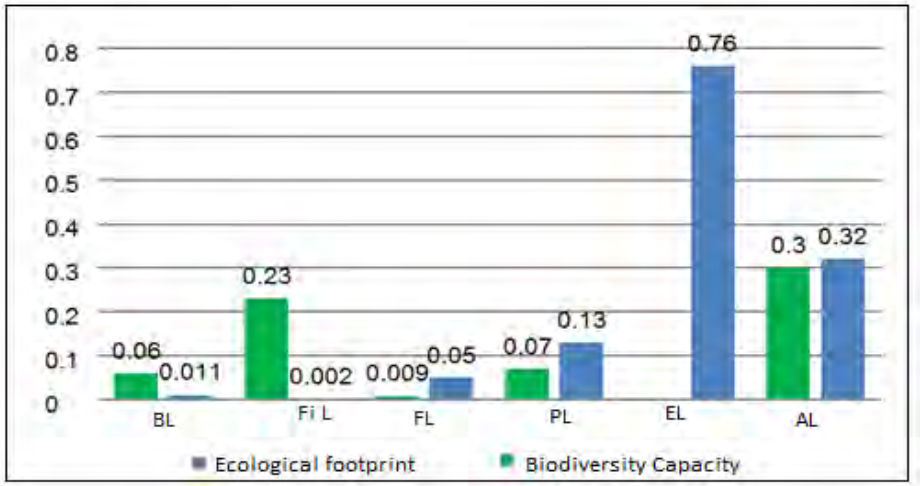

Fig. 5 Comparison of Biological Capacity with ecological footprints (Authors, 2017).

4 Conclusion

Today, many of the world most important issues, such as traffic and land congestion, abandoned buildings, waste problems, land use change, noise pollution, water pollution and many other environmental issues raise the subject of urban sustainability. Therefore, considering the problems and problems that cities have to address the dimensions and principles of sustainable human development, cities and urban sustainability should consider the characteristics that a healthy city needs. Also, on the one hand, planners, urban planners and urban managers, with proper and healthy management, can create a healthy environment for people. The first academic publication about ecological footprints was done by William Rees in 1992. The ecological footprint concept and calculation method was developed as the PhD dissertation of Math is Wackernagel, under Rees' supervision at the University of British Columbia in Vancouver, Canada, from 1990–1994. Since measuring the amount of land needed is not very feasible, preparing, storing and disposing of waste, dozens of commodities are limited only to calculate the main consumables and individual goods. The estimation of a specific population ecological footprint is a multi-stage process. The main structure of the approach is this. At the same time, the description of this process is related to the use of resources, and the same logic is also true for many waste and absorption of produced resources. At first, the energy consumption (electricity, gas and fossil fuels) was extracted from the Statistical Yearbook of Khorasan Razavi Province (2013) in the sectors (transport, housing and food). Then, based on the energy conversion factor, its units converted to a single unit, i.e., mega joules. In order to obtain the amount of land energy, according to Waknagar, CO_2 emissions from the use of 100 gigawatts of fossil fuels require a hectare of earthly belief like forest. Therefore, all consumed quantities were converted into a global average hectare. The needed land for services and consumer goods in the agricultural sector was based on field studies only on cotton consumption in Mashhad, and based on the per capita consumption rate of cotton in the country, 4.6 kg, and according to the yield of this product, the amount of cotton cultivated land Estimated. In total, the per capita footprint of agricultural land ecology was estimated to be 0.32 hectares per citizen of Mashhad. According to Fig. 4 and Table 3, the per capita ecological footprint of the built land was estimated to be 0.011 hectare. According to the calculations, the ecological footprint per capita of Mashhad is 1.273 hectares.

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