



Assessment of Land Use Ecological Footprint in an Iranian Small City

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ABSTRACT: The ecological footprint as an indicator estimates the effect of population and industrial products process on ecosystem by evaluating and calculating the used energy and materials in a city, region or country. Dehgolan County is located in Kurdistan province between Hamadan and Sanandaj cities. Dehgolan is one of the important and effective counties of Kurdistan in agriculture. However, with the population growth in the county and especially in Dehgolan town, productive and fertile lands have been invaded incrementally due to constructions in recent years. This is the main cause of severe reduction in the biological resources of the county. The main goal in this research is to evaluate and assess the rate of ecological footprint indicator of different land uses in Dehgolan County and its change during 2005 -2011, and moreover try to find difference of ecological footprint and biological capacity in this county. A criteria-based method is used to calculate the footprint of land uses in this paper. Based on Rees and Wackernagel perspectives, major land uses include forest, pasture, cropland, fisheries and built-up land. Results show that the most increase in rate of ecological footprint belongs to pasture (270%) and forest (94.7%) in 2005 -2011. Also the most decrease in biological capacity related to cropland (-9.6%). Difference between footprint and biological capacity has constantly increased and reached its maximum universal level (1.133 hectares) in 2011.

Keywords: Ecological Footprint, Biological Capacity, Land use, Dehgolan County.

INTRODUCTION

The publication of the Brundtland Commission's report entitled 'Our Common Future' in 1987 provided the most commonly used definition of sustainable development, as development which 'meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED, 1987, p. 54). In recent years, many researchers have used prediction indicators, such as sustainable socio-ecological indicator (Christian, 1996), index of sustainable economic welfare (ISEW), genuine progress indicator (GPI) (Anielski & Rowe, 1999) and genuine savings rates (Dharieshwar et al., 2000) to estimate the degree of sustainable development. But these methods have some limitations in measuring the degree of sustainable development (Zhongmin et al., 2000). Ecological footprint is regarded

as a method in measuring the sustainable development. At first it was proposed and developed by Rees and Wackernagel in 1992 (Wackernagel & Rees, 1997; Wackernagel & Onisto, 1999). An ecological footprint is a measurement of the land area required to sustain a population in every size. Under prevailing technology, it measures the amount of arable land and aquatic resources that must be used to continuously sustain a population, based on its consumption levels at a given point in time. To the fullest extent possible, this measurement incorporates water and energy use, uses of land for infrastructure and different forms of agriculture, forests, and the other forms of energy and material "inputs" that people require in their daily life. It also accounts for the land area as a main requirement in waste disposal. The University of British Columbia's School of Community and Regional Planning developed the ecological footprint in the early 1990s. The concept was popularized by Wackernagel and Rees (1996) in the publication entitled *Our Ecological Footprint—Reducing Human Impact on the Earth*. Wackernagel et al (1999) acknowledge

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Vitousek et al (1986) study on the human appropriation of photosynthesis products as the intellectual predecessor to the footprint concept. However, its antecedents can be traced back in a near future further.

In the recent years the ecological footprint has experienced a great development and extensive application due to its scientific theory and simple indicator in the world (Muñiz & Galindo, 2005; Haberl et al., 2001; Stoglehner, 2001; Kathryn, 1998; Hanley et al., 1999; Zhiqiang et al., 2001). Ecological Footprints become established as important environmental indicators, following the pioneering work of Wackernagel and Rees (1996). Footprint accounts have been calculated for various scales: the entire planet (e.g., Wackernagel et al., 2002; GFN, 2011), specific nations (e.g., Kitzes et al., 2007; Wackernagel et al., 1999; Haberl et al., 2001; Monfreda et al., 2004; Moran et al., 2008), cities and regions (e.g., Warren-Rhodes & Koenig, 2001; Barrett et al., 2002; Wood & Lenzen, 2003; Aall & Norland, 2005; Collins et al., 2006; Wackernagel et al., 2006; Kissinger & Haim, 2008; Scotti et al., 2009). There has not been any research work based on the assessment of ecological footprint in Iran. So far only, some researchers have carried out an introduction of this indicator as an effective tool for evaluating stability scales in cities. Sarai and Farshad (2009) attempt to introduce it and to show how to calculate it without presenting any case study for assessing the environmental effects. Rezvani et al (2010) present the ecological footprint scale as a new approach for measuring stability of cities and they also described how to calculate by just reviewing the global experiences instead of giving an example in Iran. Shakor et al. (2010) analysed tourism ecological footprint in Boan Mamasani and studied the tourism sustainability in this area. Hossinzase Dalir and sasanpor (2010), by means of ecological footprint indicator, studied the sustainability of Tehran, and found that sustainability in Tehran city is very low mainly because of irregular migration and irregular increase of cars in this mega city. This paper attempts to calculate the ecological footprint and the biological capacity of land use in Dehgolan Town, Iran from 2005 to 2011.

The main goal of this study is to measure the degree of sustainable development in Dehgolan; and to evaluate

the land use environmental impact of Dehgolan.

MATERIAL AND METHODS

The analytical methods in calculating the ecological footprint are based on two types: compound and criteria-based methods. This research applies the criteria-based method. The criteria-based approach sums the ecological footprint of all relevant criteria of a population's resource consumption and waste production. The content of research is divided into two parts: the ecological supply (or bio productive areas) and the demand on nature (ecological footprint). The bio productive areas can be divided into five distinct types—cropland, forest, pastures, fisheries and built-up land—that provide economically useful concentrations of renewable resources. And the ecological footprint expresses the use of built-up areas, and the consumption of energy and renewable resources. It can be divided into six types—cropland, forest, pasture, fisheries, built-up land and fossil energy land. Process of calculation is as follows:

First step is to calculate the ecological footprint of each consumption item. The computational formula can be defined as:

$$A_i = C_i / Y_i = (P_i + I_i - E_i) / (Y_i \times N)$$

where i is the item type of consumption, Y_i is annual average yield item (kg/hm^2), C_i is the per capita consumption item (kg/capita), A_i is the per capita ecological footprint item ($\text{hm}^2/\text{capita}$), P_i is annual yield of the item (kg), I_i is annual importation of the item (kg), E_i is annual export of the item (kg), and N is the population of research region. The ecological footprint of energy consumption can be calculated through the constant conversion factor. For instance, the constant conversion factor of coal is $55\text{GJ}/\text{hm}^2\text{a}$, and the constant conversion factors of oil and gas are $71\text{GJ}/\text{hm}^2\text{a}$ and $93\text{GJ}/\text{hm}^2\text{a}$ (Wackernagel & Rees, 1997).

Second step is to calculate the ecological footprint of research region. The following formula can be used.

$$ef = \sum r_j A_i = \sum r_j (P_i + I_i - E_i) / (Y_i \times N) \quad (j=1,2,\dots,6)$$

Where ef is the per capita ecological footprint ($\text{hm}^2/\text{capita}$). J is bio productive area; it can be divided

into six types: cropland, forest, pasture, fisheries, built-up land and fossil energy land. The meanings of i , A_i , Y_i ,



Pi, Ii, Ei and N are same to that in the first step. And the r_j are equivalence factors. Equivalence factors represent the world's average potential productivity of a given bio productive area relative to the world average potential productivity of all bio productive areas (Monfreda et al., 2004). Cropland, for example, is more productive than pasture, and so has a larger equivalence factor than pasture. The equivalence factors of each bio productive area are listed as follows: cropland is 2.9, forest is 1.1, pasture is 0.6, fisheries are 0.2, built-up land is 2.9 and fossil energy Land is 1.1.

The total ecological footprint of research region can be defined as:

$$EC = N \times (ec)$$

Where EF is the total ecological footprint (hm^2) and N is the research area population. Third step is to calculate the biological capacity of research region. Bio capacity is the ecological footprint counterpart. A region's total Bio capacity is the sum of its bio productive areas. The computational forms of per capita Bio capacity can be presented as:

$$ec = a_j \times r_j \times y_j \quad (j=1,2,\dots,6)$$

Where ec is the per capita Biocapacity ($hm^2/capita$), a_j is the per capita bio productive area, r_j is equivalent factors, y_j is the yield factors. The Yield factors describe the extent to a productive area biologically in a given country or region, which is more (or less) productive than the global average of the same bio productive area. Each area has its own set of yield factors (Monfreda et al., 2004). The yield factors of each bio productive area in Dehgolan are listed as follows: cropland is 1.82, forest is 0.61, pasture is 0.98, fisheries are 1.0, and built-up land is 1.82.

The total Bio capacity of research region can be defined as:

$$EC = N \times (ec)$$

Where EC is the total Bio capacity of research region (hm^2), N is the research region population.

The fourth step is to calculate ecological deficit. A comparison between the footprint and bio capacity reveals whether existing natural capital is sufficient to support consumption. An ecological deficit means that a region whose footprint exceeds its bio capacity. The computational forms of ecological deficit can be presented as:

$$\text{Ecological deficit (} hm^2 \text{)} = \text{Footprint (} hm^2 \text{)} - \text{Biocapacity (} hm^2 \text{)}$$

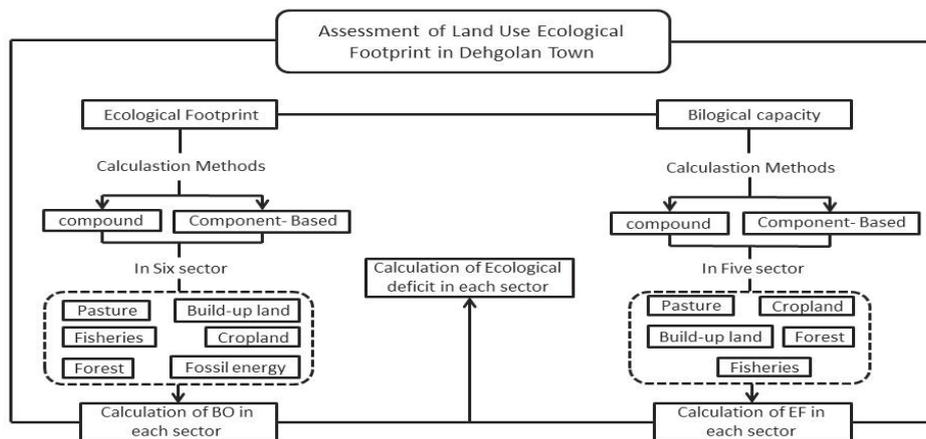


Fig. 1. Methodology Flowchart.



CASE STUDY

Dehgolan is one of the Kurdistan provincial town located in the southeast of Kurdistan between Hamedan and Sanandaj. Dehgolan’s population in 2011 was 63189, consisting of 20602 urban and 42587 rural population. It converse an area of 582.56 acre (Table 2).Dehgolan’s

economy depends mostly on agriculture, so the migration rate of population into the urban areas is low (Table 1). Dehgolan is well known due to prolific plains in Iran and because being located in the route of underground water sources. Dehgolan is poor in terms of industry. It hasjust 5 factories located in Dehgolan Industrial Complex.

Table1. The Change of Population Rate (in 1000) in Dehgolan from 2005 to 2011.

Years	2005	2006	2007	2008	2009	2010	2011
Total Population	60.114	61.749	61.890	62.130	62.432	62.976	63.189
Urban Population	15.950	17.894	18.234	18.879	19.231	19.897	20.602
Rural Population	44.164	43.855	43.656	43.251	43.201	43.079	42.587

Table 2. The Change of Various Land Area (Thousand Hectares) in Dehgolan from 2005 to 2011.

Years	2005	2006	2007	2008	2009	2010	2011
Cropland	351.92	346.78	334.96	328.94	326.47	324.40	324.11
Garden land	28.91	23.35	26.1	27.19	28.63	29.48	29.41
Forest	7.17	12.6	28.42	34.53	36.71	38.55	38.73
Pasture	64.04	64.05	64.04	64.01	63.99	63.94	63.94
Fisheries	6.73	6.83	6.93	7.03	7.13	7.23	7.23
Build-up land	70.12	72.15	74.2	76.09	77.11	77.95	78.78
Unused land	119.81	47.12	43.10	42.19	41.08	40.59	40.36



Fig. 2. Location of Dehgolan in Kurdistan Province

RESULTS AND DISCUSSION

Land Use Ecological Footprint Calculation in Dehgolan Town

Our finding indicated that the ecological footprint of Dehgolan's land use has an increasing trend (Table 3). From 2005 to 2011, the per capita footprint of Dehgolan's land use has increased by 40.2%. The footprint of fossil energy has increased by 74.7%, the footprint of cropland has reduced by 3.7%, and the footprint of pasture has increased by 270%, the footprint of forest has increased by 94.7%, the footprint of build-up land has increased by 62.5%, but the footprint of fisheries has remained unchanged in this period (2005-2011). The main reason is that the demand structure of resident in Dehgolan had an obvious change from 2005 to 2011. As the demands of residents to population for, traffic, merchandise, service and animal product have obvious increase, so do the footprints of pasture, forest, build-up and fisheries have a great increase.

Table 3. The Per Capita Ecological Footprint (Hm²/Capita) of Land Use in Dehgolan from 2005 to 2011.

Years	2005	2006	2007	2008	2009	2010	2011	EF changes(percent)
Fossil energy	0.701	0.692	0.708	0.820	1.088	1.082	1.225	74.7
Cropland	0.644	0.684	0.649	0.661	0.666	0.668	0.620	-3.7
Forest	0.038	0.042	0.053	0.063	0.059	0.067	0.074	94.7
Pasture	0.010	0.012	0.013	0.017	0.020	0.025	0.037	270
Fisheries	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0
Build-up land	0.008	0.009	0.009	0.010	0.010	0.011	0.013	62.5
Total	1.41	1.448	1.437	1.58	1.852	1.862	1.978	40.2

In composing the ecological footprint in Dehgolan, the footprint of fossil energy land possesses the most proportion, which has achieved 53.9% on average. The footprint of cropland is the second, which has achieved 40.4%. But the footprint of pasture, forest, fisheries land and build-up land is very small on proportion. So the footprint changes of fossil energy land and cropland have great effect on the total footprint in Dehgolan.

Bio Capacity Calculation in Dehgolan Town

We found that the Bio capacity of Dehgolan has a decreasing trend (Table 4). From 2005 to 2011, the Bio capacity per capita of Dehgolan has reduced by 3.4%. The cropland bio capacity has reduced by 9.6%, but the pasture bio capacity and fisheries have remained unchanged, the forest bio capacity has increased by 15.5%, and the build-up bio capacity has increased by 15.09%. The main reason is that there is a rapid growth of urbanization in Dehgolan from 2005 to 2011 (Table 1). More and more



residents start to live in the urban areas, so that the build-up area has a great increase.

Table 4. The Bio Capacity Per Capita (hm²/capita) of land use in Dehgolan from 2005 to 2011.

Years	2005	2006	2007	2008	2009	2010	2011	BO changes(percent)
Cropland	0.497	0.481	0.465	0.460	0.460	0.455	0.449	-9.6
Forest	0.058	0.060	0.064	0.066	0.067	0.067	0.067	15.5
Pasture	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0
Fisheries	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0
Build-up land	0.106	0.106	0.111	0.117	0.117	0.122	0.122	15.09
Total	0.668	0.654	0.647	0.65	0.651	0.651	0.645	-3.4

Change of Land Use Ecological Deficit in Dehgolan Town

Table 5 shows that the ecological deficit of Dehgolan has an increasing trend from 2005 to 2006 and 2007 to

2011, but the trend is decreasing from 2006 to 2007. The increasing is attributed to the influence of rapid growth of urbanization (Table 1), and the decreasing is contributed to the reform of environment which diminished the ecological footprint in Dehgolan.

Table 5. The Ecological Deficit per Capita (Hm²/Capita) Of Land Use in Dehgolan from 2005 to 2011.

Years	2005	2006	2007	2008	2009	2010	2011
Total Ecological Footprint	1.41	1.448	1.437	1.58	1.852	1.862	1.978
Total bio capacity	0.668	0.654	0.647	0.65	0.651	0.651	0.645
ecological deficit	0.742	0.794	0.79	0.93	1.201	1.211	1.333

The ecological deficit per capita of Dehgolan was 1.333 hm² in 2011. This is very high biological capacity. The main reasons for this include:

Firstly, in composing of Dehgolan ecological footprint, the fossil energy land footprint possesses the most proportion, on average 53.9% (Table 3). The fossil energy footprint reflects the condition of energy consumption, so there is great energy consumption rate in Dehgolan, and the ecological deficit is great for the high energy consumption.

Secondly Dehgolan is a known plain of Iran because of its suitability in agriculture.

In addition, environmental pollution is a crucial problem too. Though, the condition of environmental pollution has a reform trend, it has an important effect on the ecological deficit in Dehgolan. The waste item footprint shares a bigger proportion in all consumption

items; it has reduced from 45.7% in 2005 to 24.5% in 2011. Therefore the environment pollution has improved the Dehgolan ecological deficit.

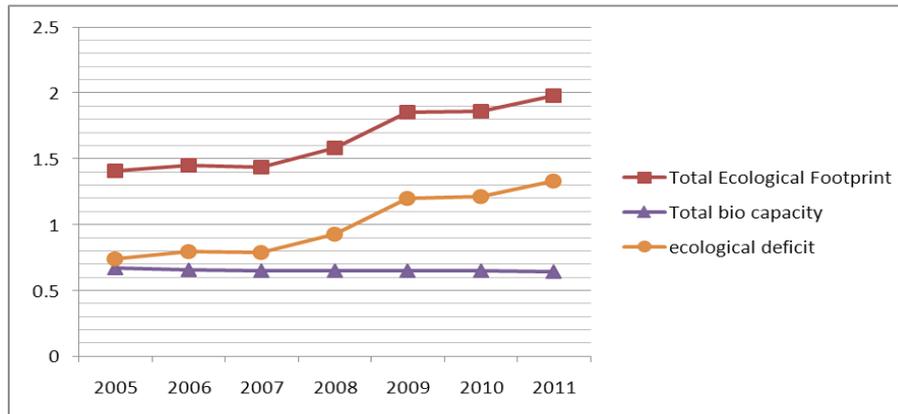


Fig. 1. The Change of Ecological Footprint, Biological Capacity and Ecological Deficit in Dehgolan from 2005 to 2011.

During 2005-2011, the rate of ecological deficit has increased constantly, and this rate was 0.742 in 2005 reaching to 1.333 in 2011. If this trend continues, Dehgolan town, in near future, will move toward unsustainability. In order to avoid this trend, the footprint and biological capacity, as a positive point from 2005 till 2011, should be directed in a manner that, in future, it will move towards zero and reach the negative point in its best state. Regarding to the fact that every area biological capacity is nearly constant and unchangeable (for example Iran biological capacity per capita is 0.8) so, we should act in a manner that Dehgolan ecological footprint reduce considerably. Table 6 shows the prediction of ecological footprint rate in Dehgolan as long as this situation continues. Ecological footprint rate exploited by the authors based on place-oriented approach (in recent years this method introduced by Gottelib et al, Kissenger and Gottelib,2010 and Guzman,2013 say that the ecological footprint researchers can introduce some useful methods and formulas) predict for near future.

$$EF_N = EF_{N-1} (P_N) / P_{N-1} (ED_{N-1})$$

In this formula EF_n is the ecological footprint in year of n. P_n is the population in year of n and ED_n is the ecological deficit in year of n.

Table 6. Predicting the Ecological Footprint for Future Years.

Year	2012	2013	2014	2015
Population ¹	66348	69665	73148	76805
Ecological deficit ²	0.913	1.146	0.996	1.084
Ecological footprint	1.558	1.791	1.641	1.729

CONCLUSION

Sustainable development concept has made a great progress in the research by creating the indicators to assess this concept, in order to help planners and decision makers generally, and ecologists specifically. One of the indicators attracted more attention in academics, politics and didactic communities, is ecological footprints assessment (EFA). This indicator shows area sustainability by calculating the effects on the environment and comparing the performance of its bio-capacity for each of the functions. In this paper we tried to assess understanding of the sustainability by using ecological footprints. Therefore, at first stages, the ecological footprints were calculated by methodology presented by Wackernagel & Rees, and then biological capacity was calculated for each land use. The results show that the most increase in percent of ecological footprint belongs to forests and pasture and the most decrease in percent of biological capacity is related to cropland in the period between (2005-2011). In the last years because of rapid population growth in Dehgolan County and especially in Dehgolan town, this process resulted in more housing needs which was built on vast productive and fertile land. Hence, this caused an



intensive decrease in the biological capacity of productive lands in 2005-2011 periods. In recent years trend is to create a large garden and plant trees that have taken place on the one hand, and the funds are allocated for reviving pastures by the government which cause the meadows and forests greatly increasing ecological footprint over 2005 to 2011. However, the dominant view is that more arboriculture or more attention to grasslands can improve the environmental condition, but overusing the fertilizers and non-planned arboriculture in grasslands caused day by day soil erosion and negative environmental impact and more intensive increase in the ecological footprint. Finally, by comparing the two last steps we found that Dehgolan has experienced unstable development in this period. To direct Dehgolan town toward sustainability, irregular population growth should be reduced. For this, construction in fertile lands should be stopped. So, it is suggested that construction should be directed to east side of town in the low fertile agricultural lands and water resources. The eastern part of Dehgolan town finished in Hossini village, because of low fertile agricultural land and low construction level is considered to be more suitable than south, west and north parts of Dehgolan town. Hence, in reaching the main aim, means civic sustainability and directing Dehgolan town development toward east part of this town, the following policies are recommended:

- Using the unutilized spaces of the town in construction.
- providing the plan for the urban fabric textures to avoid the residents immigration to the sub-urban parts.
- Controlling construction on fertile lands and sub urban (especially in west and south parts).
- Preparing a comprehensive plan for the city to avoid irregular development (Dehgolan town has been considered from 2006 as a city, yet there has been no comprehensive plan for this city. Till now the urban guide plan is regarded as the standard one which is very old and unreliable).



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ENDNOTE

1- Based on 1995 and 2005 census growth population rate in Dehgolan is equal 5 Percent.

2- Ecological deficit for future year considered to be 0.645.

3- Biological Capacity for future year Considered 0.645.