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Sustainability of environmental management in Iran: An ecological footprint analysis

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ABSTRACT- Sustainability and environmental management are the most cited ideas linking the environment and development. The sustainability of natural resources depends upon our paradigm and related approaches to the relationship between society and the environment. Efficient management is a primary task due to the pressure on nature. Ecological footprint analysis has been introduced as an appropriate environmental management tool to address the environmental challenges that Iran is facing and to determine solutions. It is a resource accounting tool which could be applied in environmental planning and management focusing on natural resource consumption. Reviewing and analyzing the biocapacity (BC) and ecological footprint (EF) of Iran in the timeline of 1962-2011 was the main purpose of the study. Based on the findings, EF trend of the country has an increasing trend over time while the BC has a reverse trend. The consumption by farmers and other agricultural actors from resources has been greater than the country`s regenerative capacity regarding the BC and EF of cropland. The sustainability gap has been greater over time due to population growth and other related factors. Despite the different environmental rules and regulations, there was no improvement or progress in sustainability achievement in Iran. Returning to the condition in which EF equals BC is the least action required to decrease the pressure on nature. Effective and suitable environmental policies are needed in order to address the policy gap as well as reduce the EF level to the balance point by appropriate executive activities covering the implementation gap.

INTRODUCTION

Sustainable development was introduced as the most important subject in the late 20th century by the United Nations due to the environmental degradation and decreasing general life level. Ecologically sustainable development is defined as a development that improves the overall life quality of the people at both the present time and the future as well as protecting the required ecological processes to live. Ecologically sustainable development concerns itself with protecting land, water, plants and genetic resources, not being destructive environmentally, being appropriate technologically and justifiable economically (Rezaei-Moghaddam et al., 2005).

Sustainability and environmental management are the most cited ideas linking the environment and development. The sustainability of natural resources depends upon our paradigm, related approaches and strategies to the relationship between society and environment. Sustainable thought includes technocentrism, biocentrism and ecocentrism in the relationship between man and environment (Adams, 2009; Kortenkamp and Moore, 2001). Technocentrism is based on a managerial approach to resource and environmental protection in which the satisfaction of man is the center of all activities. It views nature as an infinite supply of physical resources for human benefit. The path for development, for example for agricultural development based on an industrial view, is basically based on technologies or strategies to increase man's ability to extract resources and production from nature. Biocenterism`s proponents believe that human beings are just one member of the earth's whole ecosystem and are not superior to other creatures. The natural ecosystem of the world is like a complex network that includes diverse interwoven elements and the function of each element relies on the others. According to biocentrism, it is not a rational viewpoint to consider a human as a premier creature on the earth, and all of the creatures have the same intrinsic value due to merit features (Taylor, 2001). Ecocentrism values nature for its own sake and judges that it deserves protection because of its intrinsic value. It is similar to biocentrism so far. But the difference is that ecocenterism is not as radical as biocentrism in attributing value to nature, and its proponents believe in paying attention to other aspects in a comprehensive manner. In this worldview, all of the dimensions of economic, social and cultural aspects are accepted as long as they are consistent with the environment and do not impose on ecosystem rights. Many governments had adopted a techno-centric approach that considered environmental problems to be the unfortunate side-effects of economic growth and development.

Sustainability goes beyond ecological efficiency to also include social sufficiency. Given the increasingly serious nature of global environmental problems, we must address these as management issues. Environmental degradation is a result of multiple major human-related factors including human intervention in natural ecosystems, current patterns of economic development, and social organization. Environmental management must balance competing forces to find a resource efficient, technically supportable, and effective management strategy (Linkov et al., 2006). This is broadly defined as the process of resource allocation to achieve optimal use of the environment while meeting the basic needs of the population with an emphasis on doing so in a sustainable manner (He et al., 2012). Indeed, environmental management is the holistic and professional process in the natural and social sciences and other more specific professions such as engineering, law or design in order to address human problems in dangerous environments based upon inter-sectoral methods and present and future perspectives (Sakr et al., 2010). Environmental management often concerns the impacts of human activities on the environment.

Sustainability of agriculture refers to the capacity of farmers to maintain the ecological services of the land. Environmental management with an emphasis on agriculture is a balance between natural resources` capacity called biocapacity (Wackernagel, 2005) and the volume and amount of agricultural activities. Given the limited capacity of natural resources, utilization of resources should be rational, reasonable and calculated in order to prevent or reduce degradation of natural resources. Paradigmatic perspective, environmental management approaches, environmental management strategies, resource accounting, environmental awareness/ concerns, sustainability, agricultural technology development scenario and natural resource degradation are the main components of environmental management in agriculture (Fatemi, 2017).

The study of environmental indicators that are able to highlight ecologically suitable options is a key factor in sustainability and environmental management. There are a number of frameworks for sustainability assessment that evaluate the performance of food companies, farms, or even the entire agricultural sector of a country (Cerutti et al., 2013). Introducing sustainability and environmental management, much research has been extended and improved to develop related indices in order to help decision makers, planners and specifically, environmentalists. This has given rise to many aggregate environmental indices, which do not always point in the same direction (Van den Bergh and Grazi, 2015).

Environmental management in Iran has become a site of discursive struggle arising out of alternative representations of the human-nature relationship and conflict about what the 'correct' relationship should be. Degradation of natural resources is caused by many factors related to humans. Some of the reasons for inefficiency of environmental management in Iran are the same as in other developing countries, but there are others that are specific to Iran. The progress of traditional environmental management has been too slow. Natural resources and environmental issues occur at the intersection of complex natural and social systems (Berkes et al., 2003). Providing a framework that integrates both social and biophysical components into one environmental management system offers great potential for more sustainable outcomes of interventions (Virapongse et al., 2016). Iran needs increased integration of social and natural sciences.

A comprehensive indicator for the measurement of natural resources consumption to resource management is the first step in addressing the challenges that Iran is facing and to determine solutions. The ecological footprint (EF) is a resource accounting tool which could have good potential to consider in environmental planning and management focusing on natural resource consumption. Possibly, the most influential effort to solve or circumvent aggregation and weighting problems has been the EF. It was proposed about two decades ago as both an approach and a method aimed at determining the degree of (un)sustainability of activities and regions/countries (Van den Bergh and Grazi, 2014). The main purpose of this study is reviewing and analyzing the total trend of biocapacity (BC) and EF of Iran in the past 60 years since land reform as well as looking at these trends individually at different points of time. Determining the gap between BC and EF indicates the sustainability situation of the nation and it is an appropriate base for policy making and implementation.

The trend of environmental management in Iran

The history of Iran showed a balance between human utilization and BC. However, the necessity of maintaining a balance between resources and development was neglected by the dominance of modernization and the expansion of industrial activities (Rezaei-Moghaddam et al., 2005). While the background of environmental legislation does not exceed more than three decades in Iran, there are many comprehensive laws and regulations in this area (Legal and Parliamentary Affairs Office, 2004). Review of environmental rules and regulations over time by Fatemi (2017) showed three distinct phases of environmental management in Iran.

First phase- Enthusiasm for modernization activities (1962-1974)

The beginning of modernization in agriculture in Iran is attributed to the land reform of 1962 and coincides with the so-called "green revolution" (Rezaei-Moghaddam et al., 2005). Based on three scenarios in agricultural technology development proposed by Shibusawa (2002): "high-input and high-output," "low-input but constant-output" and "optimized input-output", the agricultural technology development scenario in Iran in this period was based upon "high input-high output." It was the result of increased application of mechanization in order to reduce the labor force. This was a pioneering phase, where farming systems were established. In this period, most of yield increases in crops were associated with a strategy of the use of fertilizer and the application of new genetics. The prevailing belief of the dominant paradigm based on technocentrism thought in this era was that natural resources were unlimited. Indeed the authorities and farmers considered resources as unlimited sources so that humans could use the resources as much as wanted to meet their needs. Management of natural systems was based on a utilitarian and exploitative worldview that assumed limitless resources and human dominion over nature. Environmental awareness and concerns were very low among agricultural experts and farmers. Environmental management did not have any structure in this period and was applied only in isolated cases.

Second phase- Concerns about environmental issues (1974-2005)

In this period, the attention of policymakers was drawn to environmental issues attributed to some problems of modernization activities. In 1974, conservation and reform of the environment law was passed in Iran. Thus, the National Department of Environment was accorded extensive powers in terms of pollution prevention and environmental degradation by reconstruction and the assignment of nine ministers in this area (Ghasemi, 2002). The necessity of scientific and economic research in terms of environmental conservation, improvement and reform, prevention of pollution and environmental imbalance was emphasized in this law. Other regulations for protecting and preventing water, air and soil pollution due to common and industrial wastes were instituted (Shaeri and Rahmati, 2012). The laws mean that the polluter is responsible for pollution control so that prevention is the main goal, then control. They are based and focused on the strategy of end-of-pipe pollution control. According to this law, factories and different production industries shared the costs of damage compensation to the environment. The emphasis in this phase was on production. According to the agricultural evolutionary scenarios proposed by Shibusawa (2002), the agricultural technology development scenario was again based upon “high input-high output” in this period. The authorities' and farmers' perspectives about resources were changed due to environmental degradation that became apparent in those years. They noted limitations of resources and also the necessity of paying attention to resource consumption. The role of stakeholders in sustainable agricultural management and environmental conservation were passive as in the last phase (Nemat Pour and Rezaei-Moghaddam, 2014). However, the style of environmental management was top-down and command-control due to the increased negative environmental consequences. The degradation level was high and tangible in this period, but environmental awareness and concerns were again low among the agricultural experts and farmers (Rezaei-Moghaddam et al., 2005). Indeed, the activities were limited to passing rules and regulations and writing in the law books without the involvement of stakeholders. This phase can be viewed as the beginning of concerns about environmental issues in Iran, but not at the level of the general public.

Third phase- Crisis of environmental management (2005-present)

There is a great emphasis on environment conservation, land use planning and regional balance in the second part of the fourth program of economic, social and cultural development law that was released in 2005. Developing national land use planning documents in terms of a balanced distribution of population and activities on both macro and micro levels was the turning point of policies in this period. National land use planning should be the main reference in decision making and should also be updated (Tahmourian, 2007). The prevention, elimination and reduction of negative effects of human activities on the environment was the main emphasis of the rules and regulations (Shaeri and Rahmati, 2012). Study and assessment of the environmental impact is a mandatory condition for all big project plans and activities. Environmental strategic assessment was introduced and defined in the fifth program of economic, social and cultural development law as a systematic process in assessing the cumulative effects of strategies, programs and development plans at the national and regional levels and by subject. Environmental consequences of human activities of a program or project were emphasized in terms of cumulative effects and BC, and sustainability indicators were assessed due to environmental effects (Zahedi, 2012). The conflict among the conceptual paradigmatic viewpoints of different policy-makers and decision-makers in the environmental and agricultural domain on the one hand, as well as the conflict in the used environmental strategies for the policy implementing on the other hand are one of the main challenges in this area. Natural resources are exhaustible and non-renewable in the authorities’ and farmers’ perspectives, and this requires great concern. Due to irrational use of natural resources in recent decades, natural resource degradation is at a very high and critical level. Some of the macro environmental crises of Iran in this time period are the water crisis in a wide range of the country, drying of different lakes and ponds due to inappropriate water management especially in agriculture, intensification of improper land use and high pressure on the lands as well as great reduction of soil fertility (Fatemi, 2011; Shahvali and Ebrahimi, 2014). Green management is emphasized in the fifth program of Iran`s development law. Thus, there is a great emphasis on optimizing raw materials' consumption and clean and accommodated technologies.

The agricultural technology development scenario was based upon “low input-constant output” in this period. It is due to the dominance of industrial agriculture considerations. Although movements toward the third scenario of agriculture development, “optimized input-output,” were noted in policies, it was not fully implemented. Attitudes toward the role of stakeholders in agricultural management and environmental conservation are active in this phase, and it is impossible to manage and protect the resources without stakeholders' involvement. In accordance with the increase in awareness and high rate of negative environmental consequences, the emphasis is on social, bottom-up and participatory approaches in environmental management. It is described as an unsustainability intensification and environmental crisis in the agriculture sector for this period (Rezaei-Moghaddam et al., 2005). There is no specific appropriate approach and indicator in the environmental managerial system of Iran. It is based on a set of sporadic activities mostly by enacting different laws and regulations which were ineffective so far due to the environmental condition of Iran. In other words, the environmental management system does not offer a suitable indicator as a principal base for planning especially regarding the increase of natural resources use by humans in agriculture.

Ecological Footprint and Biocapacity: Background

The "Footprint" concept originates from the idea of an ecological footprint which was formally introduced to the scientific community in the 1990s (Rees, 1996; Wackernagel and Rees, 1997). Generally, for environmental issues, three important indicators are the carbon, ecological, and water footprints (CF, EF, and WF), which have recently been grouped into a "footprint family" suite of indicators (Galli et al., 2012b; Ewing et al., 2012). Each footprint indicates a particular class of impacts associated with the activities of an individual or group. Potential for global warming is indicated by the CF (Wiedmann and Barret, 2010; Wright et al., 2011), effects on water availability and quality in terms of total volume of freshwater consumed or polluted are indicated by the WF (Hoekstra, 2009), and appropriation of the regenerative capacity of the biosphere expressed in global average bioproductive hectares is indicated by the EF (Rees, 1992; Wackernagel and Rees, 1996).

In other words, the "footprint family" is a set of indicators able to track human pressures on the planet and from different angles (Galli et al., 2012b). The footprint family has a wide range of research and policy applications as it can be employed at scales ranging from a single product, a process, a sector, up to an individual, cities, nations, and the whole world. The footprint helps to monitor the environmental pillar of sustainability more comprehensively (Niccoluccia et al., 2012). The EF is built upon a tradition of seeking alternatives to the allocated carrying capacity which is related to the maximum population size that can be supported by a given set of resources (Dietz et al., 2007). Moreover, it builds on a variety of earlier analytical attempts to measure human load in order to estimate the dependence of human life on nature (Passeri et al., 2013). Currently, this has been used at the national and international level (Monfreda et al., 2004).

The EF is most commonly expressed in units of global hectares. A global hectare is a hectare that is normalized to have the world average productivity of all biologically productive land and water in a given year (Kitzes et al., 2007). It is a potential tool to jointly measure planetary boundaries and the extent to which humanity is exceeding them. It can be used to investigate issues such as the limits of resource consumption, the international distribution of the world`s natural resources, and how to address the sustainability of natural resource use across the globe. Assessing current ecological supply and demand as well as historical trends provides a basis for setting goals, identifying options, and tracking progress toward stated goals.

Basically, it consists of two measures (Borucke et al., 2013): *Ecological Footprint* that is a measure of the demand populations and activities placed on the biosphere in a given year, given the prevailing technology and resource technology and resource management of the year and *Biocapacity* which is a measure of the amount of biologically productive land and sea that are available to provide the ecosystem services that humanity consumes our ecological budget or nature`s regenerative capacity (Kitzes and Wackernagel, 2009; Bastianoni et al., 2013). While the EF shows the demand on nature, the BC tracks the supply side of the equation, and is therefore defined as the rate of resource supply and waste disposal that can be sustained in a given territory (or at the global scale) under prevailing technology and management schemes (Passeri et al., 2013). EF and BC values are used to measure one key aspect of sustainability: the human appropriation of the Earth's regenerative capacity. They analyze the human predicament from this distinct angle, under the assumption that the Earth's regenerative capacity will likely be one of the limiting factors for the human economy if human demand continues to overuse resources beyond what the biosphere can renew (Galli et al., 2012a).

The EF and BC of a country thus represent two sides of an ecological balance sheet. When a country's consumption of resources and services is greater than the capacity of its ecosystems to supply them, a situation of *Ecological Deficit* is created, which is analogous to the situation of financial deficit that occurs when spending is greater than revenue. Conversely, if a country's EF is smaller than its BC, it is living within its ecological means. This is not sufficient to determine whether the country is sustainable, but it is an essential minimum condition for sustainability (Galli and Halle, 2014). In other words, populations with an EF smaller than their available BC run an *Ecological Reserve*, the opposite of an ecological deficit. A nation's ecological reserve is not necessarily unused; however, it may be occupied by the footprints of other countries that import BC from that nation. Countries may also choose to reserve this BC for wild species or use by future generations. *Ecological Debt* is the sum of annual ecological deficits that have been accumulated over a period of time. The current global ecological debt can be expressed as the number of "planet-years" of ecological deficit the planet accrued since humanity entered into overshoot in the 1980s which could be called ecological bankruptcy. One planet-year equals the total productivity of useful biological materials by the Earth in a given year.

Wackernagel and Rees (1996) proposed the idea of EFs in relation to Vancouver, Canada, and the EF of 13 developed countries was estimated for the first time based on global databases by them (Wackernagel, 1994). So, the first systematic attempt to calculate the EF and

BC of nations began in 1997 (Wackernagel and Rees, 1997). Building on these attempts, the methodology of the EF is included in a standardization process directed by Global Footprint Network (GFN), an international think tank conducting environmental studies and releasing the annual report including EF calculations for most of the countries in the world. GFN initiated its National Footprint Accounts (NFA) program in 2003. NFA measure one main aspect of sustainability only- *how much biocapacity humans demand in comparison to how much is available*- not all aspects of sustainability, nor all environmental concerns. GFN adjusted the calculation of EF in 2008. According to the calculation of GFN in this year, the EF comprises the six main categories of farmland footprint, grazing land footprint, forest footprint, fishing grounds footprint, CF, and built-up land (Wang et al., 2012).

Rees and Wackernagel (1996) have introduced the Consumption Land Use Matrix (CLUM) in EF accounting at a more applicable level. In other words, data collecting and calculating should be done at two domains: (1) Consumption domains including food, housing, transportation, consuming goods, services and waste; and (2) Land uses including cropland, grazing land, forest land, fishing land and built-up land.

Although the original formulation of EFA (Wackernagel and Rees, 1997) focused on five different land types (cropland, grazing land, forest area, marine area and infrastructure area), several studies indicate that it can be used for investigating the contribution of direct and indirect land occupation. The first reflects the actual land required directly for the production process and the latter is the required land for production of process inputs (Wackernagel, 2005). Recent studies (Kissinger and Gottlieb, 2010; Lenzen and Murray, 2001) have investigated the importance of focusing on the "real land use" and its geographical location around the world. In the agricultural sector the real land can be: *cropland*, the actual land surface on which the farm is located and taking into account the production of animal feed not produced on-farm, *forest land*, and *built-up land*, occupied by buildings and storage facilities. The real land differs from the virtual land, used in EF calculation, which includes the forest land required to sequester all the CO_2 emissions from non-renewable energy used directly on the farm and, indirectly, for the production of farm input and machinery. This virtual land is also called "carbon land" and it is a fundamental component of almost all the used resources (Cerutti et al., 2013).

MATERIALS AND METHODS

General Concept

There are two main methods in EF calculation: the deductive method and the inductive method. The deductive method (synthetic) perspective has been extended by the pioneers of the EF model (Rees and Wackernagel, 1996). It has a centralized (top-down) method in calculating EF regarding national data. The deductive one is applicable at global and national levels (micro-scale). The inductive method, the second perspective, has a decentralized (bottom-top) way. In this one, the ecological interactions of special activities such as transportation, energy use, etc. have been calculated in a special location (Simmons and Chambers, 1998). The inductive method comprises EF assessing of the region and cities (macro-scale). Thus, an integrative methodology includes the application (inductive method feature) and precision (deductive method feature) combination (Simmons et al., 2000).

The EF accounting has six footprint components which are distinguished regarding major land use types. All of these are built on six ecosystem services for human well-being: plant-based food production, livestock-based food production, fish-based food production, timber production, living space supply, and energy-related CO_2 absorption (Galli et al., 2012a; Kitzes et al., 2009; Moore et al., 2012). Components are weighted with equivalence factors before being added up to the total. So, the EF is a land-based, composite indicator (Fang et al., 2014).

As bioproductivity differs between various land use types and countries, EF and BC values are usually expressed in units of world average bioproductive area; namely, global hectares (*gha*) (Galli et al., 2007; Monfreda et al., 2004). Global hectare is used in order to express EF results in a single measurement unit. Equivalence factors and yield factors are used to convert actual areas in hectares of different land types into their equivalent numbers of global hectares which are applied to both footprint and BC calculations. *Equivalence Factor* (EQF), translates a specific land type (i.e. cropland, pasture, forest, fishing ground) into a universal unit of biologically productive area, a global hectare and, *Yield Factor* (YF) accounts for the difference in production of a given land type across different nations (Kitzes et al., 2007; Wackernagel and Yount, 2000). These are two 'scaling factors' used to express results in terms of global hectares (Galli et al., 2014), thus allowing comparisons between various types of bioproductive land and various countries' EF and/or BC.

Methods and Techniques

The analytical trend of EF in Iran was done based on EF account calculations with special formulas as indicated below (Eq.1).

$$EF_P = \sum (P_i / Y_{N,i}) \cdot YF_{N,i} \cdot EQF_i$$

$$EF_P = \sum (P_i / Y_{w,i}) \cdot EQF_i \qquad (1)$$

Eq. 1- Main formula of ecological footprint of production

Required data were from GFN which were mainly obtained from different international databases such as United Nations datasets, FAO Resource STAT, COMTRADE, International Energy Agency (IEA), CORINE Land Cover, Global Agro-Ecological Zones (GAEZ) Model, etc. Then, the raw data were sorted, cleaned and monitored using MySQL, MATLAB and Excel. Following this data preparation, the required data were entered into the formula and the main calculation was performed for BC and EF assessment of Iran in the total trend of the study as well as different triple phases separately. GIS technique was also used in terms of comparing Iran with selected neighbor countries due to BC/EF ratio variations over time.

Here is the main formula of EF assessment. For a given nation, the EF of production, EF_P, represents primary demand for BC and is calculated as (Eq. 1):

where P is the amount of each primary product i that is harvested *(tone)* (or carbon dioxide emitted) in the nation; $Y_{N,i}$ is the annual national average yield for the production of commodity i *(t/ha)* (or its carbon uptake capacity in cases where P is CO2); $YF_{N,i}$ is the country specific yield factor for the production of each product I (tone per hectare); $Y_{w,i}$ is the average world yield for commodity i *(t/ha)*; and EQF_i is the equivalence factor for the land use type producing products I (Galli et al., 2014; Galli et al., 2015). The same equation is used for each category of cropland area, grazing land area, marine area, forest area and infrastructure area. The aggregate of these equations equals total EF or BC *(gha)* (See research method section).

A country's ecological footprint of consumption (EF_C) is derived by tracking the ecological assets demanded to absorb its waste and to generate all the commodities it produces, plus imports minus exports. It is calculated as shown in Eq. 2 (Borucke et al., 2013).

Biocapacity

Cropland Area *(ha)** Cropland YF= Cropland *(w ha)** Cropland EoF= Cropland Biocapacity *(g ha)*

Ecological Footprint

Agricultural products*(t)/* World Crop Yields= Cropland *(w ha)** Cropland EoF= Cropland Footprint *(g ha)*

$$EF_C = EF_P + EF_I - EF_E \quad (2)$$

Eq. 2- The formula of ecological footprint of consumption

where EF_P is the ecological footprint of production and EF_I and EF_E are the footprints embodied in imported and exported commodity flows, respectively (the unit of all of the EFs is gha). Since ecological footprints are calculated in global hectares, the ecological footprint of each single product i, irrespective of whether it is locally produced, imported or exported, is calculated as in Eq. 2. As previously mentioned, different human activities on the earth could be seen in five land use types as cropland, grazing land, forest area, marine area and infrastructure area. Initially, the EF and BC are calculated in different land types separately and then, the aggregate of the land types would give the total EF and BC. The main philosophy of calculations is similar for different land types as in Eq.1. For greater detail, the calculation base of cropland, which is highlighted in the current study, is provided in Eq. 3. It is calculated for different agricultural crops of Iran and then, the aggregate of all the crops will be the total EF of cropland.

As previously mentioned, the study was conducted focusing on Iran in terms of its population growth and natural resources consumption and environmental management. Iran is located in western Asia, has a population of more than 75 million, with 69.1% urban dwellers and 30.1% rural dwellers (FAO, 2013). Agriculture is the main occupation of rural people. The total land of this country is around 163 million hectares with 30% of the land dedicated to agricultural use (FAO, 2014). Agriculture is an important component of the Iranian economy, contributing to 12 percent of GDP, 21.8 percent of employment opportunities, 82 percent of food supply and 35 percent of non-oil exports. It provides considerable portion of the raw materials for industrial use. The principal cash crops are fresh and dried fruits. The main subsistence crops are wheat, barley, sugar beet, sugarcane. Mutton, lamb, fattening cattle and dairy cattle, poultry and fishery products are also important for domestic food supple (World Bank, 2012). The conventional strategies of agricultural development based on modernization in Iran are incapable of achieving sustainable development due to the many crises that exist in the agricultural area (Rezaei-Moghaddam and Fatemi, 2013).

RESULTS AND DISCUSSION

Reviewing the Ecological Footprint of Iran: An Indicator for Assessment of Environmental Management

Environmental situation of Iran has been reviewed in the timeline of 1962-2011 in terms of natural resources consumption and biocapacity. At first, the trend of EF and BC in the triple phases has been reviewed and analyzed; then, the whole trend of these two parameters in the country has been shown during the past 50 years. To provide a better comparison base, the total trend of EF consumption and BC for the whole world is presented and then, Iran is compared with some other nations in terms of natural resources consumption over time. Finally, the sustainability condition of Iran is analyzed in terms of environmental policies and implementation strategies.

Analysis of Ecological Footprint in the First Phase (1962-1974)

The first phase began in 1962, implementing land reform focused on modernization theory as a turning point in the agricultural sector of Iran. The population was totally 20 million at the beginning of this phase (Population and Housing Census, 2011). The trend of BC and EF in this period indicates a higher biocapacity of the nation compared to the people's consumption (Fig. 1). Iran had ecological reserve in this phase as the BC was greater than the Iranian EF at the beginning of this phase; these equal 1.5 and 0.9 global hectare (gha), respectively. These amounts were 1.3 and 0.96 gha at the end of the first phase suggesting that nature could regenerate natural resources due to the population of Iran in that time. But as shown in the graph, the curves approach each other; continuation of the same trend due to the use of the modernization theory will lead to crossing of the curves.

EF and BC include the aggregation of the calculations of six different land use types of which cropland is one. The trend of EF and BC in the cropland type was analyzed separately due to the emphasis of the current study on agriculture. Based on Fig. 2, the BC and EF were almost equal and around 0.3 gha in the first phase. Although the total trend of BC and EF of the nation indicates the greater rate of BC relative to the EF in the whole period of this phase, focusing on agriculture, EF was always equal or a bit greater than BC. Increasing the gap over time is shown in the graph as the amount of BC and EF which were 0.4 and 0.5 gha at the end of the first phase, respectively. The effect of new agricultural policies at that point in time could be realized regarding the trend of these two main ecological parameters.

The main objectives in agriculture were to maximize cultivation and yield growth. According to population increase, we see in this phase that more land was brought under cultivation, the use of fertilizers significantly increased along with diversification of crops and particularly cash cropping. In this period, most of yield increases in crops were associated with the use of fertilizer and the application of new genetics.

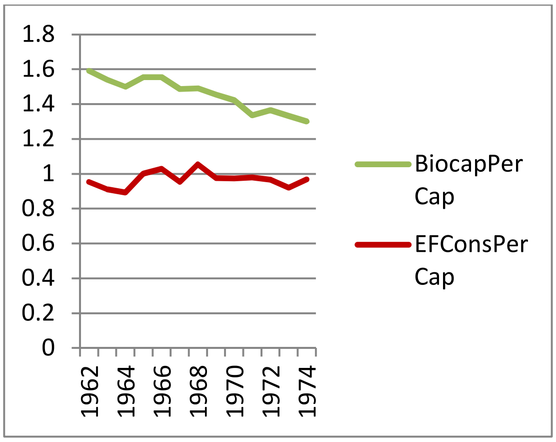

Fig. 1. Trend of EF consumption and BC of Iran in the first phase of the study (timeline of 1962-1974)

For example, between 1960 and 1980 wheat production almost doubled from 3 to 5.9 million tons (Yazdi-Samadi, 1989). Doubling of agricultural products resulted from the increased consumption of chemical fertilizers such as nitrogen (600 times) and phosphate (205 times) in the last 35 years (FAO, 2011). The soil is too poor in terms of organic matter in most parts of Iran; so, the soil texture is not appropriate for growing plants. The organic carbon of the soil is less than one percent in more than 60 percent of the cultivated lands of the country and this parameter is even less than 0.5 percent in the significant parts of Iran (Rezaei-Moghaddam and Nemat Pour, 2015).

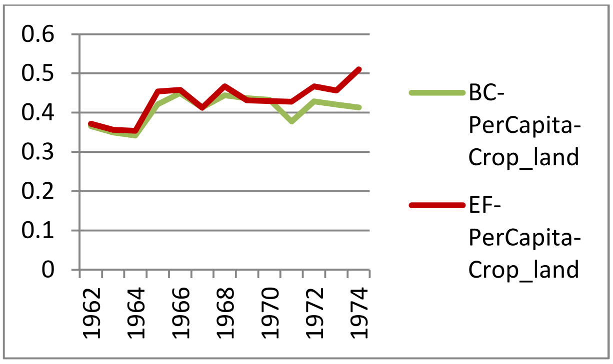

Fig. 2. Trend of EF and BC in agriculture of Iran in the first phase of the study (timeline of 1962-1974)

This phenomenon is attributed to the high consumption of chemical fertilizers to achieve high yield. Leachate refinement is another challenge in terms of waste management processes in Iran. Each ton of waste introduces 400 to 600 liters of leachate which has led to 384 cubic meters of green gas emission. There are more than 1000 hectares of land with good potential for agriculture, urbanism and industry that have been destroyed annually due to inappropriate leachate management in waste accumulation process (Karimi, 2007). In other words, encouragement of agricultural intensification, natural resource use, modern technologies and inputs application in order to maximize agricultural production can be understood by following the trend of EF and BC.

Analysis of Ecological Footprint in the Second Phase (1974-2005)

According to the trend of last phase, the second phase was named environmental concerns. It began with a jump in the EF level. At the beginning of the second phase, BC and EF were almost equal, 1.3 and 1.2 gha, respectively (Fig. 3), and the population was almost 34 million in 1974 (Population and Housing Census, 2011). The same trend continued with a little variation in the parameters until 1988, but after that, a great gap could be seen between BC and EF levels. This trend proceeded with an even deeper slope, so that the EF (1.9 gha) had become twice as much as the BC (0.9 gha) of the nation. Despite the increasing number of environmental rules and policies in this phase, the great pressure on the natural resources and incapability of nature to regenerate was observed due to increasing population and higher demand for food and agricultural products.

With an emphasis on agriculture, as shown in the graph at the end of the first phase, the EF level exceeded the BC and this trend continued for the whole of the second phase (Fig. 4). Although BC demonstrates an increasing trend in this phase due to agricultural experts' activities and modern technologies application, this growth rate was insufficient to provide for the consumption of people and the population growth of Iran.

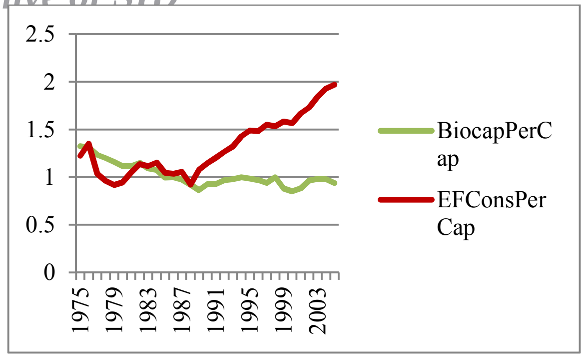

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Fig. 3. Trend of EF consumption and BC of Iran in the second phase of the study (timeline of 1975-2004)

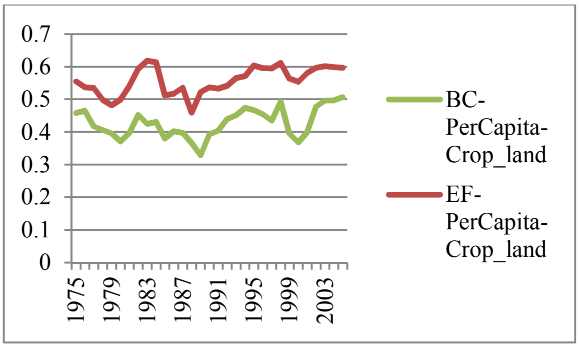

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Fig. 4. Trend of EF and BC in agriculture of Iran in the second phase of the study (timeline of 1975-2004)

The degradation level was high and tangible in this period, but environmental awareness and concerns were again low among the agricultural experts and farmers. During this period, the total use of fertilizers increased to 4,500,000 tons in 2005. This included 2,500,000, 1,200,000 and 370,000 tons in nitrogen (N), phosphate (P) and potash (K), respectively (Ministry of Agriculture Jihad, 2012). Soil erosion in Iran is estimated to be around 1,500,000,000 tons per year and 56,000,000 hectares of land are considered to have severe erosion (Yazdi-Samadi, 1989). Poor soil in terms of low organic matter is an important agricultural challenge for Iran. For instance in Fars province, which is the bread basket of the country, the organic matter is less than 1.5 percent in more than 95 percent of the lands, while the critical threshold of 2 percent is needed for soil`s organic carbon in order to maintain soil texture sustainability (Nemat Pour and Rezaei-Moghaddam, 2014). A nationwide study (Karami, 2000) indicated that the considerable percent of farming systems was unsustainable. The costs of education in this time period and urban air pollution costs to recreation centers were 0.02 and 0.04 % of GDP, respectively (World Bank, 2012). According to the environmental impact assessment of industries in terms of urban environmental management, the production of environmental pollutants has threatened human health and hygiene in some parts of Iran. The pollution of drinking water is 55 times more than COD standard, and it is 40 times more for agricultural water. Sewage arrival without any refinement has led to much environmental pollution as well as disease spread in the region (Saeidi, 2015).

Analysis of Ecological Footprint in the Third Phase (2005- 2011)

A review of policies and increasing environmental rules and regulations indicates the perception of environmental crisis and the need for difficult actions to address the crisis situation. The trend of EF and BC confirmed the intensification of unsustainability, population growth and great pressure on natural resources as well as incapability of BC in meeting the need of users. Iran`s population was around 70 million at the beginning of the third phase, it has been doubled in comparison with the previous phase (Population and Housing Census, 2011). According to Graph 5, at the end of this phase, the consumption of natural resources in Iran is 2.5 times as great as the capacity of the environment and regenerative rate of resources; these amounts are 2.10 and 0.84 gha, respectively. From a sustainability perspective, when the EF exceeds BC, the society moves toward unsustainability. In cases in which the EF exceeds productive lands, a sustainability gap or ecological deficit exists. In optimal situations, the aggregation of EFs should be lower than the whole demand of the current population of the world in order to have a sustainable ecosystem.

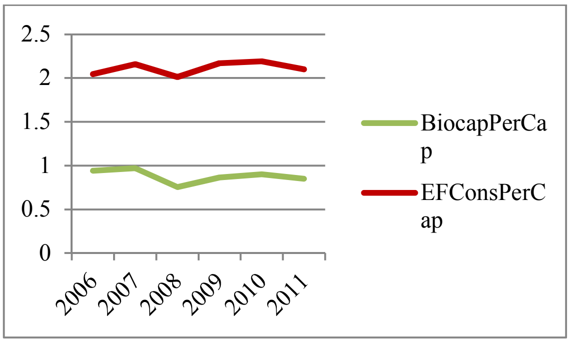

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Fig. 5. Trend of EF consumption and BC of Iran in the third phase of the study (timeline of 2005-2011)

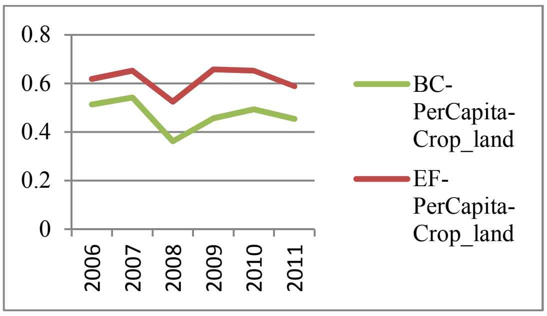

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Fig. 6. Trend of EF and BC in agriculture of Iran in the third phase of the study (timeline of 2005-2011)

The agricultural trend of EF and BC in this phase is similar to that of the last phase, so that the consumption of farmers from natural resources is higher than the regenerative capacity of nature (Fig. 6). Poverty, a large amount of smallholder farmers, populated rural households and higher demand for food due to increasing population are the main reasons for this increasing trend of EF in Iran (Rezaei-Moghaddam and Karami, 1998). The population is 75 million and 80 million in 2011 and 2015, respectively (Population and Housing Census, 2011). It shows a high rate of population growth over time as the population has become quadrupled during the study timeline and over past 50 years. Natural resource degradation is at a very high and critical level. Transfer of technology (TOT) is mostly the principal base of the agricultural extension system, so trying to increase crop production is the key agricultural policy of the country. The recent policy in terms of increasing wheat production to achieve self-sufficiency as well as other crops with high water requirement is not a wise decision due to environmental conditions and regeneration of natural resources in Iran (Rezaei-Moghaddam et al., 2005). Due to irrational use of natural resources in recent decades, the large amount of degradation and unpleasant consequences are obvious visually. Iran has the largest area equipped for irrigation at over 9 million hectares (FAO, 2014). There is a downward trend with a high slope in the variation of groundwater level during this time. The mean change in the decrease in water in 1974 was 5 times as much as that of 1962 (Bakhshoodeh and Dehghanpur, 2015). Consumption of chemical inputs was high during this period. In 2007, Iran was ranked 123rd among all countries by the World Health Organization (WHO) for health. The main reason for this is high consumption of chemical fertilizers, pesticides and herbicides (Chaychi, 2010).

According to the results of resource accounting of Iran, despite the growing concerns of policy makers and other authorities in environmental decisions, there is no progress in this area. In this regard, the inconsistency and differences among the macro policies and perspectives of the country with the needs and activities of the agricultural actors is another point. There is also deep conflict among the paradigmatic viewpoints of different policy-makers and key decision-makers of Iran. Natural resources are exhaustible and non-renewable in the authorities' and farmers` perspectives, and this requires great concern. So, a fundamental revision at a higher intellectual level similar to the paradigm shift of agricultural development policies from the basic strategies to the activities at the micro level is necessary (Rezaei-Moghaddam et al., 2005).

The Comparison of EF and BC in Iran and Other Countries

After reviewing the triple phases separately, we reviewed the entire trend of BC and EF of Iran in the timeline of the study (since land reform of 1962 to 2011) in order to provide a comprehensive perspective. The total BC and EF as well as the BC and EF of agriculture are displayed in figs. 7 and 8, respectively. Iran has an ecological reserve until 1990 for the total amount of BC and EF, and after that, it has an ecological deficit. The consumption of farmers has been greater than the nation`s BC regarding the BC and EF of agriculture (Fig. 8), and this gap has become greater since the early 1970`s.

The total trend of BC and EF of the world is the same as the trend for Iran (1962-2011). It has shown the total amount of BC and EF in gha (fig. 9). Both parameters have an increasing trend over time although the EF has increased with a steeper slope. The BC of the world (9 billion and 700 million gha) was greater than human consumption (7 billion and 700 million gha) in 1962, but this trend has reversed over time, so the human EF exceeded the BC. In other words, the BC was greater than EF between 1962 and 1970, but these became equal in 1970 and human pressure on natural resources was greater than nature`s regeneration. Indeed, the world showed ecological reserve in the 8 initial years of the study trend and ecological debt was noted after 1970 (Fig. 9).

Although man could increase the BC (Fig. 9) of the earth due to improvement of modern technologies based on the dominance of modernization theory, this increased rate has not met human needs from natural resources due to population growth.

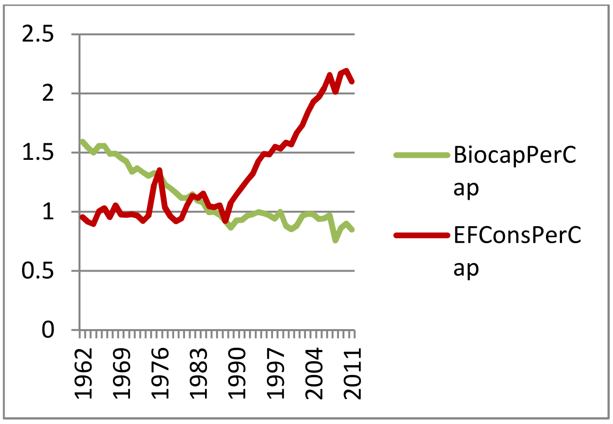

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Fig. 7. Trend of EF consumption and BC of Iran since land reform to the present time (timeline of 1962-2011

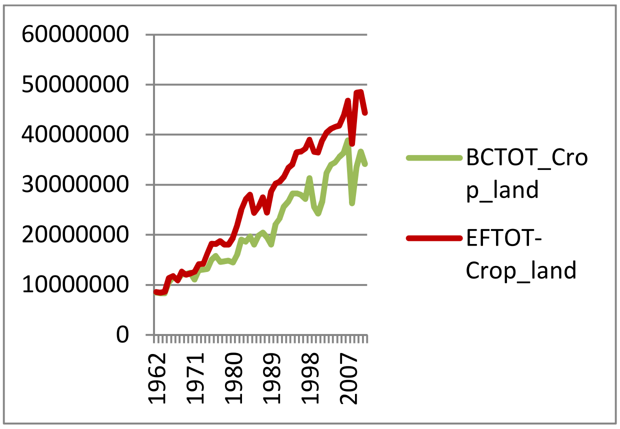

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Fig. 8. Trend of EF and BC in agriculture of Iran since land reform to the present time (timeline of 1962-2011)

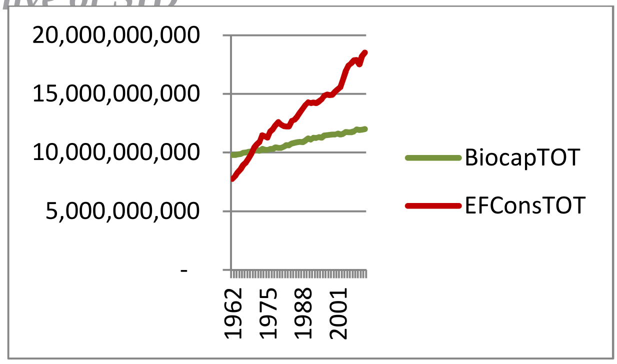

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Fig. 9. Total EF consumption and BC of the world (timeline of 1962-2011)

This is shown by reviewing the trend of BC and EF per capita considering the population growth of the world (Fig. 10). The amount of BC (3.1 gha) was greater than EF (2.5 gha) at the beginning of the trend. These two parameters became equal 2.8 gha in 1970 and afterwards, the EF became 2.6 gha (1.5 times as much as that of the earth's regeneration) with an ascending trend, resulting in a BC of 1.7 gha.

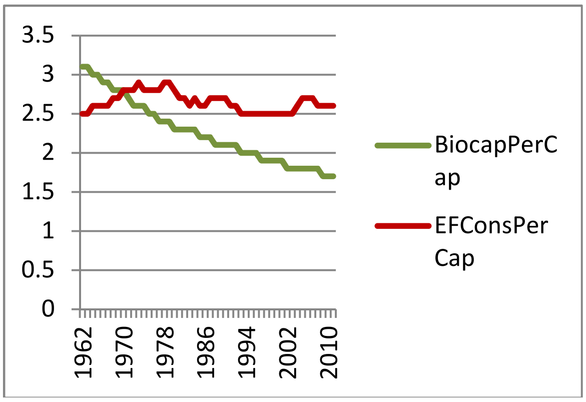

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Fig. 10. EF consumption and BC per capita of the world (timeline of 1962-2011)

Although the EF of Iran is lower than the EF of the world (Fig. 7 and 10), the slope of the EF trend in Iran (Fig. 7) is steeper than its slope for the world after 1990. Currently, Iranian consumption of natural resources equals 2.5 times as much as that of the country`s BC, while this difference is 1.5 times for the world. By comparing the EF of Iran and the BC of the world, it could be concluded that we need a globe which is 1.2 times as great as the current earth to meet the human needs if the world's population consumes natural resources like the Iranian people.

After reviewing the total trend of BC and EF of the world, we attempted to visualize the situation of the countries regarding human consumption and BC focusing on Iran and its neighbor countries on the following map (Fig. 11). Two separate figs. from the starting and the ending point of the timeline of the study (1962 and 2011) were drawn using GIS in order to provide a better understanding for comparisons over time. Based on the fig., the countries that have a BC level greater than EF (i.e., creditor countries) are shown in green and the countries with the reverse condition of a greater EF level than BC (i.e., debtor countries) are shown in red.

Conversion of a high number of countries from creditor to debtor over time is a remarkable point. It is in the line with the Fig. 9 and 10 that show the ascending trend of EF and its exceeding from BC over time. Iran was a creditor country in 1962, but currently it is a debtor country with an EF level that is 150 percent higher than BC. According to Fig. 11, Iran has a better condition than some other neighbor countries like Iraq, Saudi Arabia and United Arab Emirates (UAE) in terms of natural resource supply and demand.

Reversely, some countries including Turkey, Turkmenistan, Pakistan and Afghanistan have better situations than Iran at the present time. It is interesting to notice that countries such as Iran and Saudi Arabia have had semi-better situations in 1962 in comparison with neighbors, but their condition has worsened over time due to the lack of an appropriate environmental management system and neglect of the natural resources capacity.

The Sustainability Analysis

The EF is increasingly being evaluated or used as an indicator of organizational and corporate environmental performance, or even as an indicator of the “sustainability” of products (Wiedmann and Barret, 2010; Kissinger and Gottlieb, 2012). EF accounting does not by itself measure sustainability, but it offers information relevant to sustainability; namely, how much BC exists compared to how much people use. Knowing this information is fundamental in ensuring that the development path of societies operates within the biophysical limits of the planet. As an accounting system, it provides a snapshot of where we are today and where we have been in the past, but it does not say where we are headed; that is, footprint accounts are historical rather than predictive. For example, they do not address ecological and other factors that may result in an increase or decrease in BC, although the accounts will reflect these changes in the years in which they are reported (Goldfinger et al., 2014; Wang, 2010).

According to the triple phases of this study on the one hand and the trend of degradation on the other hand, it can be concluded that despite the different rules and regulations in terms of environment conservation, there was no improvement or progress in sustainability achievement. The schematic image of the BC and EF of Iran in triple phases of the study is shown in Fig. 12. The amount of BC (1.5 gha) was 1.6 times as much as that of the EF (0.9 gha) at the beginning of the first phase. Despite the gradual ascending trend of EF and decreasing trend of BC, the Iranian EF did not exceed the threshold of BC and this country had ecological reserve during this phase (1962-1974).

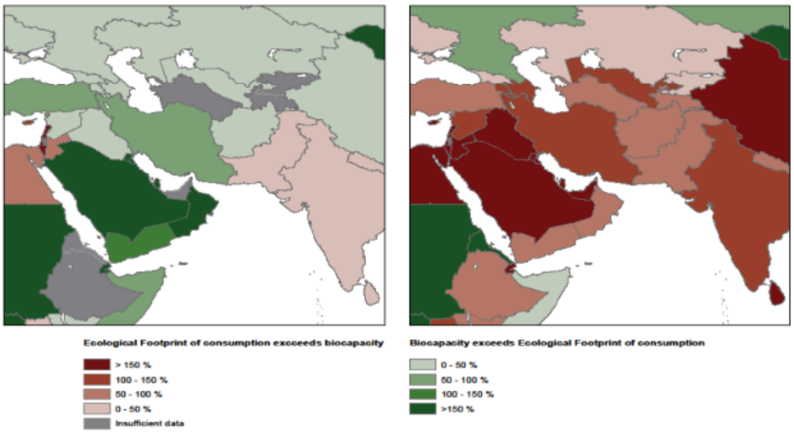

Fig. 11. Visualizing the BC and EF of the countries over time. On the left side: The ecological deficit and reserve in 1962; On the right side: The ecological deficit and reserve in 2011.

This continued in the initial years of the second phase since after the early 1980`s and the Islamic Revolution, BC and EF reached the break-even point. These two parameters were almost equal. Iranian consumption was roughly equal to the capacity of nature in regeneration of natural resources. But the EF exceeded the BC in 1988, and the ascending trend of EF and descending trend of BC occurred since the middle of the second phase. The difference between BC and EF (called sustainability gap) has been greater over time due to population growth and the increasing rate of people`s consumption from natural resources in Iran. The sustainability gap represents human exploitation of natural resources and increasing the gap places higher pressure on nature. The ascending trend of EF and the greater sustainability gap in Iran has continued in the third phase so far (Fig. 12). Iran`s population has become quadrupled during the study timeline and over past 50 years, as well. As shown in Fig. 12, if there is no action in terms of changing the EF or BC trend by policies, rules or public movement, Iran would move toward ecological bankruptcy in the near future by running out of natural resources. Currently, some scientists emphasizing on water scarcity predict that the civilization of this old country would be threatened only in 20 years.

Reducing the sustainability gap needs implementation of effective policies in this domain. Returning to the break-even point of BC and EF as a primary goal, the sustainability gap has been divided into the policy gap and implementation gap. Indeed, returning to the condition in which the consumption of natural resources (EF) equals biocapacity (BC) is the least action in order to decrease the pressure on nature.

Iran naturally would move toward this situation and the two parameters of BC and EF would be equal one day; but, this could occur with a disaster or in a desirable manner. It will be a disaster if the current trend continues without any policy changes; in this case, the BC and EF would be equal with running out of the natural resources and ecological bankruptcy. On the other hand, in the presence of systematic planning and implementation of appropriate environmental management activities, it would happen in a desirable, calculated and rational way.

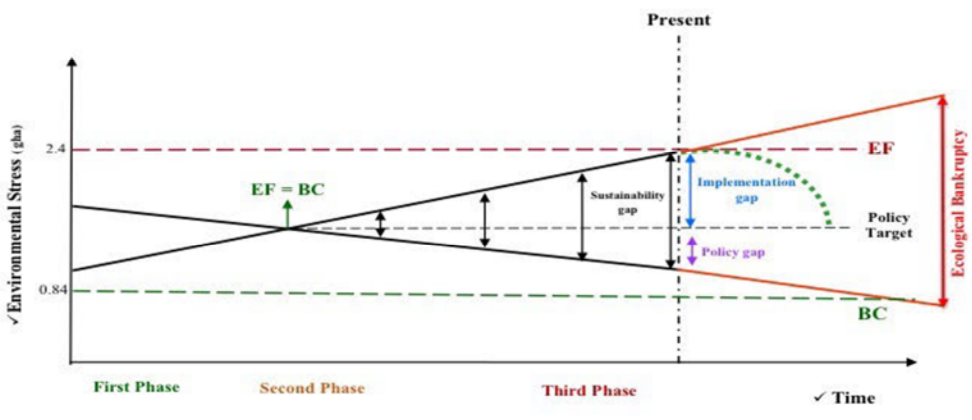

Fig. 12. Analysis of sustainability and environmental policies in terms of ecological footprint and biocapacity trend over time

According to Fig. 12, the space between the current BC and the target goal is called the policy gap. Effective and suitable environmental policies are needed in order to cover this gap. Reducing the EF level to the balance point needs appropriate executive activities which are called the implementation gap. Population growth control is one of the main solutions to reduce the implementation gap. So, policy favoring population increase, which has been mentioned by some of the politicians in Iran, is not a correct policy due to the critical condition of the environment and lack of natural resources, and implementing that policy would worsen the situation. There are some other potential solutions regarding low productivity of natural resources emphasizing water and soil in agriculture. Rational use of natural resources and regenerative resources management including the application of eco-friendly agricultural technologies, water saving techniques, soil fertility improvement methods, clean energy development and biodiversity protection are some of the main solutions that agricultural extension has good potential to promote among farmers, rural people and other stakeholders who are the natural resources users in agriculture.

CONCLUSIONS

In our current environment, environmental protection is a positive sum game that is seen as a matter of efficiency in the use of resources. Ecological and economic rationality are viewed as having their own legitimacy in development. Nowadays, environmental management needs to be considered as an important factor for sustainability. Concern for the increasing scale of resource development and resulting impacts on the physical environment and communities can no longer be ignored. Common technocentrism thoughts were found to be inadequate to deal with various environmental and social issues. Managing the environment is becoming a central issue for decision makers. The way human activities affect the environment has to be understood. The relationship between farming management and the overexploitation of natural resources is a theme of environmental management debate. Moving from technocentrism to ecocentrism is a vital action to emphasize the intrinsic rewards of environment and natural resources.

Transitioning towards sustainable human development requires better understanding and management of the relationships between nature`s thresholds, humanity's effective use of natural resources, and the economic consequences of overburdening them. The EF is perhaps the best known and most used environmental indicator worldwide. An observer might therefore interpret it as a reliable measure of environmental pressure or unsustainability. In other words, Ecological Footprint Accounting (EFA) is one of the most comprehensive ecological economic indicators for measuring the fundamental conditions for sustainability.

The EF is an effective indicator to assessment and management of appropriate use of natural resources of Iran. It is a tool for politicians and other agricultural managers to determine the effects of population growth and human activities on the environment. Using such an indicator, it would be possible to introduce natural resources consumption in different agricultural activities and estimate the greater environmental effects that they have regionally (micro levels) and comparing them with the average of national and global amounts. The EF has been recognized as an appropriate method for assessing the dependence of human on the nature.

The EF has been used for assessing the BC, final ecological capacity as well as sustainability. It is impossible to be sustainable without considering the BC of each region. Using the EF is a constructive indicator that has the potential to reduce the unsustainability of different regions, especially agricultural areas. It takes into account the interactive relations of human and environment as well as the exploitative role of man, assessing different ways of resource use and introducing managerial strategies in order to improve unsustainability. The EF is also a suitable tool to assess the sustainability of communities; the sustainability determined by this indicator means achieving a satisfactory life without exerting pressure on the BC of nature.

Currently, the EF of humans is more than the half of BC of the planet, which means it would take 19 months for the earth to regenerate human consumption. The whole trend of BC and EF of Iran since 1962 revealed that the country has ecological reserve since 1990 as the total amount of BC and EF, and after that, with a reverse trend, it has ecological deficit. The consumption of farmers and other agricultural actors has been greater than the nation`s BC regarding the BC and EF of cropland, and this gap has become greater since the early 1970`s. The increasing trend of the gap between EF and BC has been visible over time. The nation`s consumption of natural resources equals 2.5 times as much as that of the country`s BC, while this difference is 1.5 times for the world. Comparison of the EF of Iran and the BC of the world suggests that we need a globe which is 1.2 times as great as the current earth to meet human needs if the world population consumes natural resources like Iranian people. Indeed, Iran was a creditor country in 1962, but currently, it is a debtor with an EF level of 150 percent higher than BC.

Despite different rules and regulations in terms of environment conservation, there was no improvement or progress in achievement of sustainability. The amount of BC was 1.6 times as much as the EF at the beginning of the first phase and the country had ecological reserve during this phase (1962-1974). In the initial years of the second phase, BC and EF reached the break-even point. Iranian consumption was roughly equal to the capacity of nature in regeneration of natural resources. The difference between BC and EF, i.e., the sustainability gap, increased over time due to population growth and the increasing rate of people`s consumption of natural resources. The sustainability gap represents human exploitation of natural resources and the increasing gap reflects higher pressure on nature. The ascending trend of EF and the greater sustainability gap in Iran has continued in the third phase so far. It will be a disaster if the country continues the current trend without policy changes; in this case, the BC and EF would be equal, thus depleting natural resources and resulting in ecological bankruptcy. Returning to the condition in which consumption of natural resources (EF) equals BC is the least action in order to decrease pressure on nature. Effective and suitable environmental policies are needed in order to bridge this gap. Reducing the EF level to the balance point requires appropriate executive activities to bridge the implementation gap.

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پایداری مدیریت محیط زیست در ایران: تحلیل ردّپای اکولوژیک

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چکیده - پایداری و مدیریت محیط زیست به عنوان دو مقوله اصلی، مفاهیم محیط زیست و توسعه را به یکدیگر پیوند می دهند. پایداری منابع طبیعی تحت تأثیر پارادایم فکری افراد و رهیافت های مرتبط با آن بوده و بر آن اساس می توان در مورد رابطه بین انسان و محیط زیست به قضاوت پرداخت. اتخاذ نظام مدیریتی کارآمد در حوزه محیط زیست، زیربنایی ترین اقدام برای کاهش فشار بر منابع می باشد. در مطالعه حاضر تحلیل ردّپای اکولوژیک به عنوان ابزاری مناسب در مدیریت محیط زیست بکار برده شد تا چالش های زیست محیطی ایران مشخص گردیده و راهکارهای سازنده ای برای رفع آن ها معرفی شود. در واقع ردّپای اکولوژیک ابزاری برای محاسبه دقیق میزان مصرف منابع طبیعی بوده و در مدیریت و برنامه ریزی های زیست محیطی کاربردهای سودمندی دارد. هدف اصلی از این مقاله بررسی و تحلیل روند تاریخی ظرفیت زیستی و ردّپای اکولوژیک در دوره زمانی سال های ۱۳۴۱ تا۱۳۹۰ می باشد. طبق یافته های پژوهش میزان ردّپای اکولوژیک ایران در بازه زمانی مورد مطالعه روندی صعودی داشته در حالی که روند ظرفیت زیستی در حال کاهش بوده است. طبق داده های حاصل از محاسبات ظرفیت زیستی و ردّپای اکولوژیک در حوزه کشاورزی، میزان مصرف منابع طبیعی توسط زارعین و سایر کنشگران حوزه کشاورزی بسیار بیشتر از توانایی بازتولید منابع کشور بوده است. شکاف پایداری با توجه به روند افزایش جمعیت و سایر عوامل مرتبط در گذر زمان بزرگ تر شده است. علی رغم تصویب قواعد و قوانین زیست محیطی مختلف طی سال های اخیر در ایران اما پیشرفت چندانی در دستیابی به پایداری مشاهده نمی شود. کمترین اقدام در راستای کاهش فشار بر منابع طبیعی، بازگشت به نقطه سر به سر و حالتی است که میزان ردّپای اکولوژیک برابر با ظرفیت زیستی کشور باشد. در واقع ایران از یک سو به منظور کاهش شکاف سیاستگذاری ها نیازمند اتخاذ سیاست های زیست محیطی کارآمد توسط مقامات عالی کشور بوده و از سوی دیگر نیز تلاش هایی برای انجام فعالیت های اجرایی متناسب به هدف کاهش میزان ردّپای اکولوژیک و شکاف اجرایی ضروری است.