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Application of DPSIR Framework for Integrated Environmental Assessment of Urban Areas: A Case Study of Tehran

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ABSTRACT: Investigating urban environmental conditions, informs us about the unsustainability and excessive degradation of ecological context, which result in rising environmental concerns among the society. Classified information about the status and trends of environmental components is needed as a rational tool to help urban sustainable planning and SOER reports can help provide such information. Preparing the state of environment report (SOER) for cities around the world has become a pervasive action and fortunately Tehran is among pioneer cities in this aspect. This research is based on the results of Tehran's second state of environment report, in which different aspects of environmental problems are investigated in city of Tehran. The results show an increase in environmental loads, which is evident from the rate of land cover change, water consumption and waste production. Degradation of ecological environment in Tehran is severe for soil pollution, biodiversity loss and climate change which can be the result of other environmental factors degradation such as air and water. In the end, according to components of DPSIR causal chain, different responses are proposed that can serve as a framework to develop strategies and action plans for a more efficient environmental planning of city of Tehran. We conclude that DPSIR model can link different aspects and depict the interaction and interconnectedness of different components of environmental issues in urban areas.

Key words:DPSIR framework, Environmental factors, Urban planning, Tehran

INTRODUCTION

The ecology of the entire planet is being reshaped by human population expansion and development, especially in urban areas (Alberti, *et al.*, 2003; McPhearson, *et al.*, 2013). There is a global trend that ecosystems have become increasingly domesticated through urbanization, and 50% of the global population is now living in urban areas (Wu, 2014). Urban systems consist of several interconnected components including social, economic, and environmental subsystems and that influence one and other at different structural and functional levels (Kang and Xu, 2010). Cities are characterized by dynamic interactions between socio-economic and biophysical factors (Kattel, *et al.*, 2013) in which manmade and natural environment should be in a harmony so that local and regional urban ecosystems provide important functions that beneût urban residents including habitat for biodiversity, primary productivity, storm water retention, air pollution removal and heat mitigation (Bolund and Hunhammar, 1999).

Investigating environmental situation in urban areas informs us about the unsustainability and excessive degradation of their ecological context, which results in rising environmental concerns among the society. Therefore urban planners and decision makers eagerly want to address these problems in an effective manner. In order to do so, classified information about the status and trends of environmental conditions is needed as a tool to help urban sustainable planning.

A State of Environment Report (SOER) covers the condition of environmental parameters in a pre-defined geographical area and in a certain period of time (Wells, 2003). Prior to the 1960s, State of environment reports did not exist. The United States and Japan pioneered preparation of SOERs in the early 1970s, variously referred to as Quality of the

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Environment reports. Since the Earth Summit in Rio in 1992, countries of the world committed themselves to prepare regular state of environment reports. Preparing the state of environment report (SOER) for cities around the world has become a pervasive action and many cities (such as London, Sydney, New Delhi, Johannesburg, etc…) have undergone preparing such reports. Fortunately Tehran is among pioneer cities in this aspect. This research is based on the results of Tehran's second state of environment report, in which Tehran's different aspects of environmental problems are investigated.

Urban environmental problems are complicated by several interconnected factors playing role in creating them and therefore require holistic approaches to address. The second SOER of Tehran, which this paper depicts a part of its results, is prepared using an integrated and holistic cause-effect model named Driving force- Pressure- State- Impact- Response (DPSIR) which is a tool for integrating economic, social and natural system into a systemic approach in order to provide a basis for a more detailed analysis (Bidone and Lacerda, 2004). This model is a framework for functional analysis and structuring the cause-effect interactions of environmental problems (Ness, *et al.,* 2010). It is a decision support tool (Gregory *et al.,* 2013) that involves a great deal of information gathering to formulate indicators that can reflect the causal relationships between human activities, environmental consequences and responses to environmental changes (Jago-on *et al.,* 2009). This framework was firstly introduced by the Organization for Economic Cooperation and Development (OECD) as Pressure-State-Response (PSR) framework and was later adopted and expanded by the European Environmental Agency (Gari *et al.,* 2015). As this model can depict the relationships between social, economic and environmental systems, it has been widely adopted to analyze the interacting processes of human-environmental systems (Pinto *et al.,* 2013; Hou *et al.,* 2014).

In this paper the main driving forces causing environmental problems in Tehran and resulting pressures are investigated. The status of major environmental factors i.e. air, water, soil, biodiversity and climate are presented and the impacts and consequences resulting from changes in states are shown. After that for each part of the causal framework, related responses are suggested as a guide to follow for further strategies and action plans.

MATERIALS & METHODS

Tehran is capital of Iran and located between 35° 34´ – 35° 50´ N and 51° 02´ – 51° 36´ E. The area of the city is about 570km^2 (Ashrafi, 2012). Geographically, city of Tehran, is Located at the southern slopes of the Alborz Mountains, which gives it relatively rich resources of water and mild climate. The local topography of Tehran with mountains surrounding the city forms frequent stagnant air masses, causing a natural reason for concentration of air pollutants in this mega city (Saadatabadi, *et al.,* 2012). Excessive pressure on the resources of the city and whose environmental limitations are violated is another cause of Tehran's environmental poor condition.

In this research, Integrated Environmental Assessment (IEA) is carried out for environmental problems and their causes and consequences in city of Tehran. Analyzing the trends of the environmental indicators is the basis of IEA. This involves identifying priority environmental state issues, and analyzing changes retrospectively in spatio-temporal scale, which is performed by DPSIR model.

In order to find out what is happening to the environment and why, an analysis of state variables must be accompanied by an understanding and appreciation of the Driving forces and pressures that affect state variables individually and collectively. Drivers (including demographic changes, economic and societal processes) lead to more specific pressures on the environment (including land use change, resource extraction, emissions of pollutants and waste). These pressures lead to changes of the state of the environment (e.g., climate change, changes in biodiversity and pollution or degradation of air water and soils), which are in addition to those that result from natural processes (Jago-on *et al.,* 2009).

Ecosystem components have fundamental role in maintaining sustainablity in urban areas. In this research driving forces, pressures, states, impacts and responses related to these components, including air, water, soil, and biodiversity in city of Tehran are investigated. The spatial scope of this study is the 22 municipal district of tehran and the temporal scale is from 2000 to 2010. For some indicators such as climate and land cover, because changes can only be observed in a long time, broader time scale is considered. Fig. (1) shows different parts of DPSIR model used in this research.

RESULTS & DISCUSSIONS

Population density in city of Tehran and its vicinity, has always been the main reason for environmental problems. Tehran has always been a magnet for population due to uneven distribution of facilities and job opportunities in the rest of the

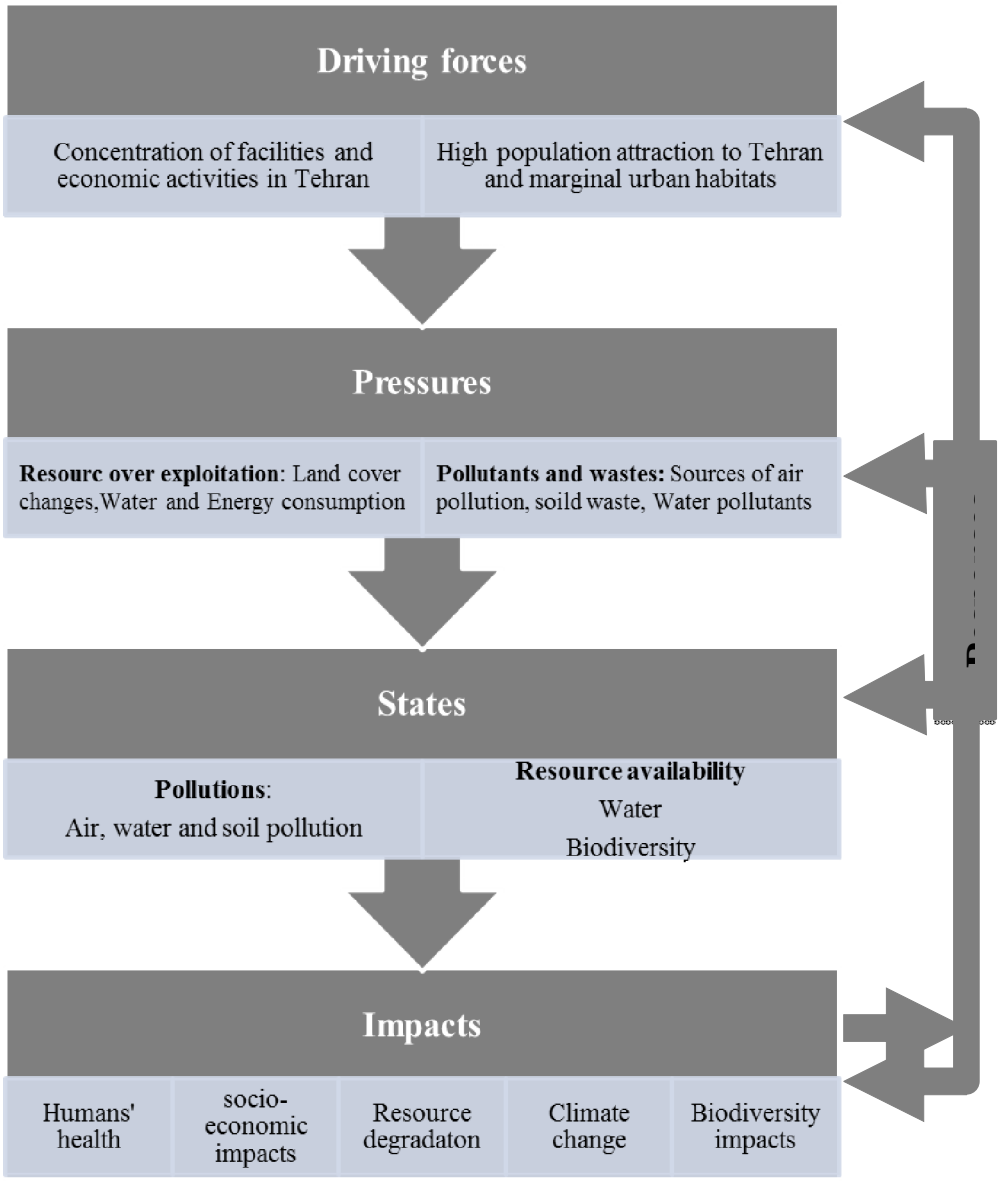

Fig. 1. Ecosystem components alaysis by DPSIR framework in present study

country. However it is mentionable that the population average annual growth rate during the 2006 to 2011 is the most uncommon growth rate during the history of the city of Tehran, and it is even less than the country's natural growth. This can be due to expansion of marginal urban settelments near Tehran like Parand (Fig. 2).

Tehran is also the center for economic activities in the country and considering the political centralization and better economic infrastructures, it is without any doubt the most important economic focal point in the country. Tehran is making more than 30% of the national gross domestic production (GDP) and the largest share of the added value is related to service sector and this part accounts for 70% of the gross production (Tehran Municipality, 2012).

As it was stated before, environmental pressures in urban areas can be categorized to land cover change, resource exploitation, and emissions of pollutants and waste, which are analyzed separately in this part of the research.

Fig. 3 shows the land coverage in three classes including green, open and built in the year 1988, 2002

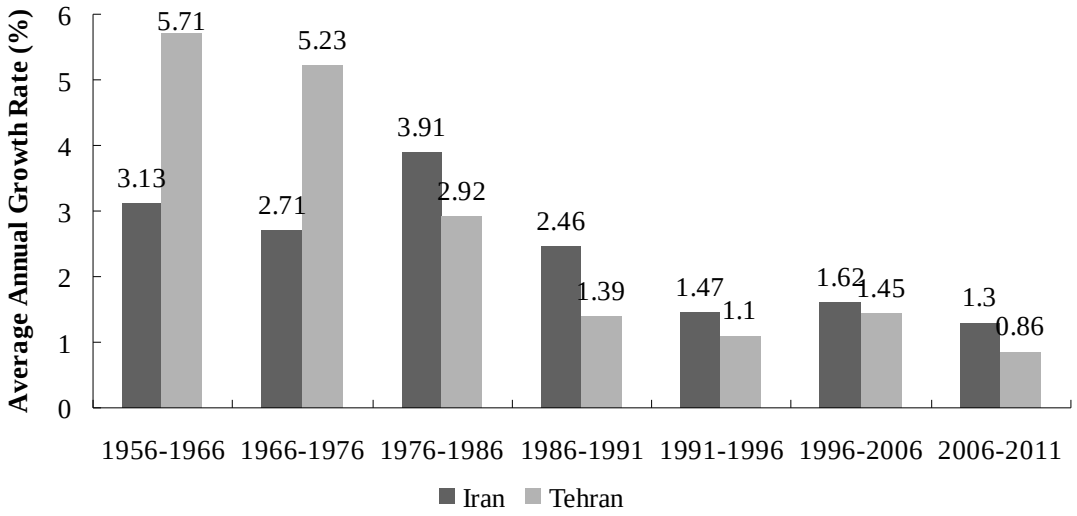

Fig.2.Comparison of the annual population growth in Tehran, in the census years

(Statistical Centre of Iran, 2011)

and 2010, based on the interpretation of landsat images taken from the city in the three mentioned years. According to this statistics, the green area and open spaces have been constantly and gradually decreased and the area has been taken by construction of buildings. In the year 1988, only 37% of the present area of Tehran was built and constructed while in the year 2010, this area was increased to 61%.

Resource over exploitation has always been a problem of both population concentration and individual behavior or life style, which causes pressures on resources and ends in production of waste and pollution in city of Tehran. Water and energy are among main resources which can be discussed in this section.

The trend and associated changes in the total water consumption in the city of Tehran from the year 2000 to 2010 has been upward and increasing from 886 to 1033 million cubic meters (Fig. 4). Accordingly, the rate of water consumption increase in Tehran is almost 17% from year 2000 to 2010.

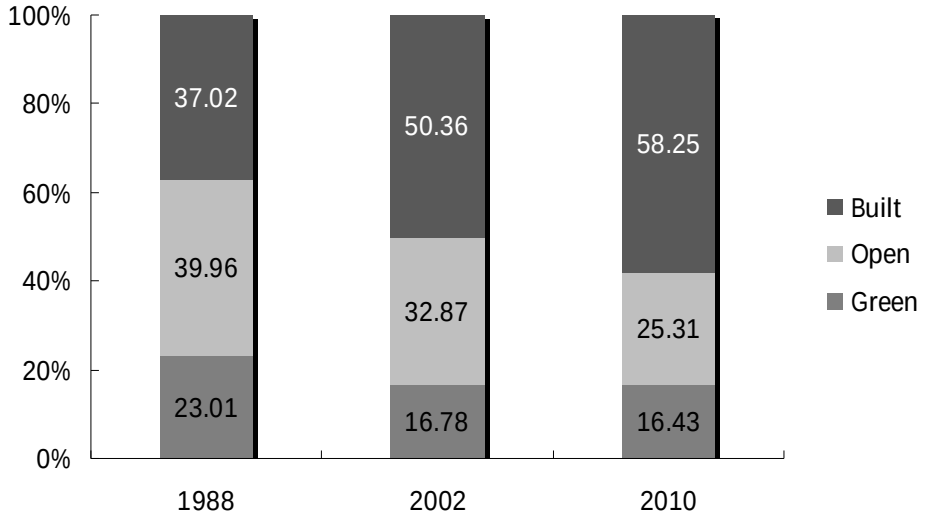

Fig. 3. Percentage of green, open space and built land cover types in the year 1988, 2002 and 2010 in city of Tehran based on satellite images interpretation

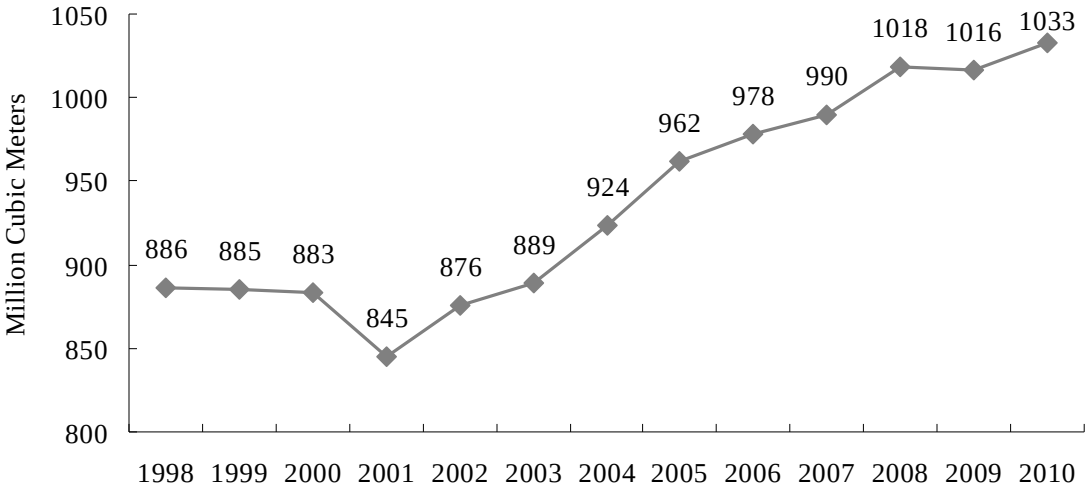

Fig. 4. The total volume of water consumption in the city of Tehran from 2000 to 2010
(Salvitabar et al., 2006; Tehran Urban Planning and Research Center, 2011)

Iran is in a constant battle to use its energy resources more effectively in the face of subsidization and the need for technological advances in energy exploration and production. The energy consumption in the country is extraordinarily higher than international standards. In City of Tehran, consumption of fossil fuels is remarkably high. In year 2010, 3570 million liter of gas was consumed which is about 16 percent of the total consumption in the country.

In Fig. 5, the trend of changes in consumption of the gas and gasoline from 2004 till 2011 has been presented. Based on this figure, the rate of fuel consumption has had a constant trend. In addition the consumption of diesel fuel from 2004 till 2010 has had some fluctuations but the general trend has been decreasing. Gas rationing since the year 2007 can be mentioned as the main reason for stabilization and reduction in consumption in Tehran and also the rest of the country.

In this part of the research, pollutants emitted to air and solid waste and waste water production in city of Tehran are investigated.

The high volumes of road traffic and also areal transportation in Tehran metropolitan in period of investigation have been the major source of air

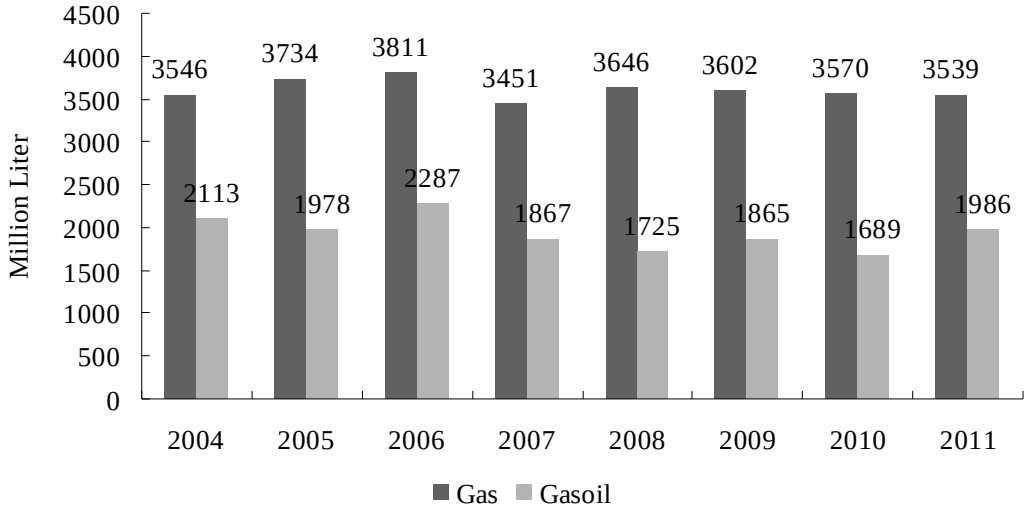

Fig. 5. Consumption of the gas and gas oil from 2004 till 2011 of motor vehicles in the city of Tehran (National Iranian Oil Refining and Distribution Company, 2011)

pollutions. Therefore, the major cause of air pollution is the mobile sources. In Fig. 6, the air pollution share from the mobile sources in the study period is shown. Accordingly, the percent share of mobile source of pollution has increased from 90 % in 2000 to 92.73% in 2010.

The rate of total solid waste produced in the city of Tehran from the year 2000 to the year 2010 has been growing constantly from 2241 to 2973 thousand tons (Fig. 7). Based on this figure the growth rate of solid waste production in Tehran is 24.63% from 2000 to 2010 which is equal to 2.46% annual average growth rate.

In this part of the research, states of ecological factors of Tehran environment, i.e.: air, water, soil, climate and biodiversity are investigated.

Air pollution is one of the major problems in the city of Tehran. Several factors are involved in the city's air pollution, including climate, land form, pollutants and emission characteristics (Shafipour Motlagh, 2008). In Fig. 8, the state of air condition in city of Tehran is illustrated from 2000 to 2010. According to this chart, there have been fluctuations in Tehran air condition and from 2000 to 2002, which can be partly due to lack of data. Establishing more air pollution monitoring stations can help to perform more detailed investigation about state of air in Tehran.

In order to control the surface waters and also provide fresh water supply for the urban and agricultural consumption, several dams have been constructed on the flowing rivers in the province. These include; Karaj (Amir Kabir dam), Lar Dam, Latyain, and Taleghan Dams. In Fig. 9, the information related to the water resources existing in the reservoirs behind these dams have been presented.

Not considering the newly built Mamloo dam, the sum of water amount existing in Karaj, Lar and Latian dams was the highest in years 2003 and 2009 and the lowest amount belongs to the years 2000 and 2001.

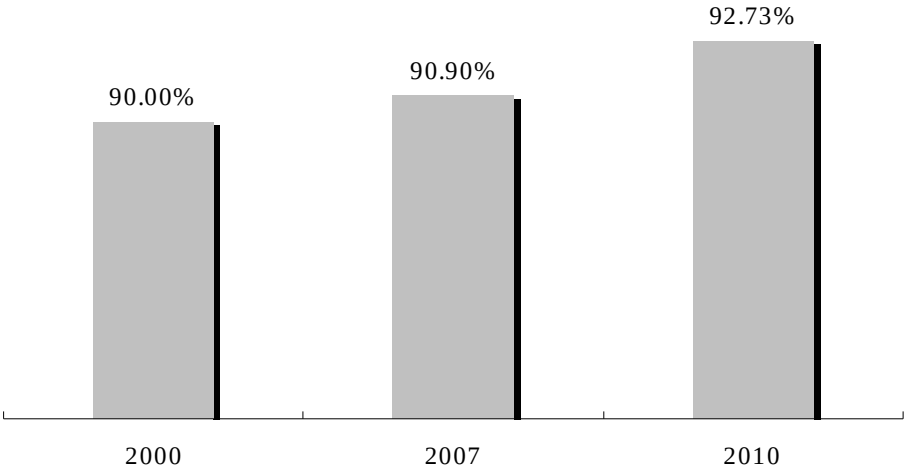

Fig. 6. Share of mobile sources in pollution emission from 2000 to 2010 in the city of Tehran

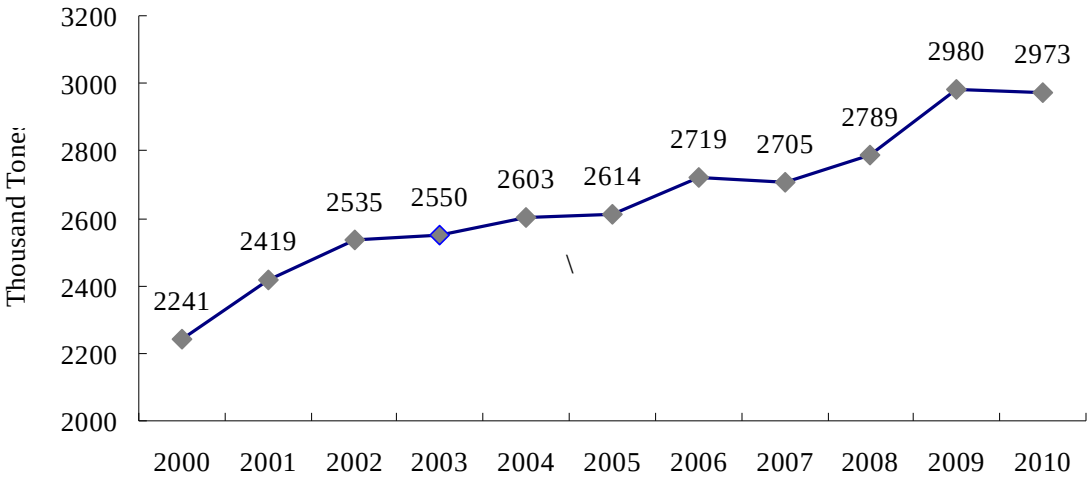

Fig. 7. The amount of wastes received in the landfill center in Aradkuh, except for the construction wastes from 2000 to 2010 (Tehran Urban Planning and Research Center, 2011)

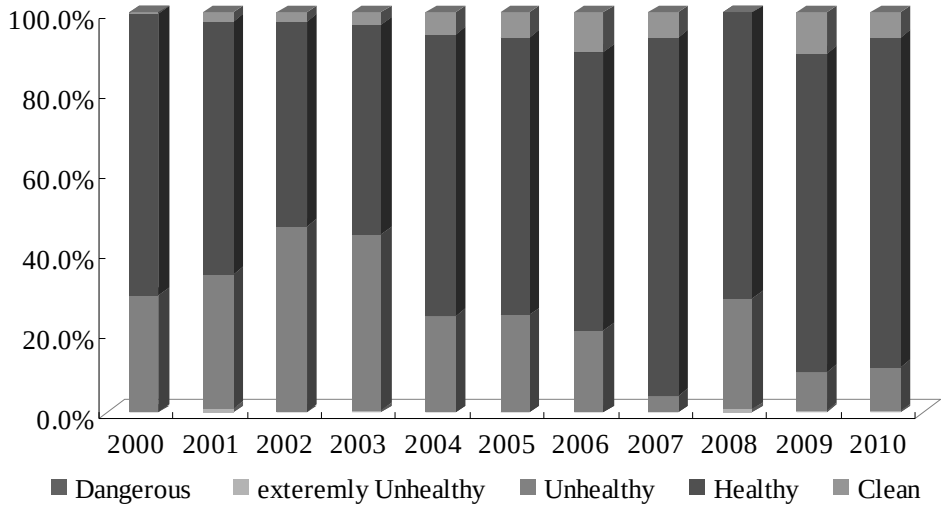

Fig. 8.The state of air condition in city of Tehran from 2000 to 2010

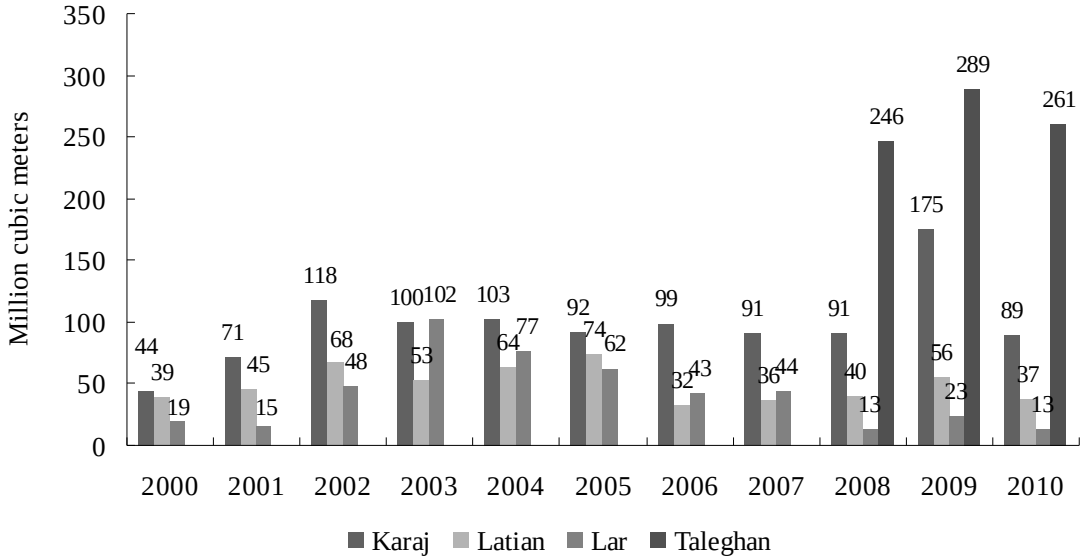

Fig. 9. The total volume of water in the reservoirs of the Karaj, Lar, Latyain, and Taleghan dams in March 2000-2010

Building Mamloo dam, with a bigger reservoir, shows the increasing need for drinking water in the city of Tehran and its marginal human settlements.

The ground water aquifers are considered as strategic resources in the arid regions. The drop in annual average water level in the entire Tehran plain is about 18 centimeters every year. In addition, the drop in water level in Kan's River plain is about 1 meter which is registered for an 11 year period in a highly used section of the river. Also it is predicted that the completion of the waste water collection network system will decrease the rate of water injection into the aquifer and the conditions for the Tehran ground water aquifer will be much more critical than before. The depth at which the water in encountered in the northern Karaj is about 80 meters and at the end of Karaj is about 40 meters (Mohammad, 2006).

One of the most severe and dangerous soil pollutants considered to be heavy metals. Since the overall slope is from north to south, in south of the city, lands are subject to pollution from runoff. In one study which was carried out in southern part of the city in 2010, the concentrations of the heavy metals in 8 regions in the southern part of the city were subjected to soil sampling and the locations of these points are shown in Fig.10. There is no approved standard for soil pollution in the country. However, if we take the Pb (lead) standard for Germany which is 50 milligram per kilogram, then it appears that the southern part of Tehran is polluted with respect to Pb.

Table 1. The average concentrations of heavy metals in soil samples taken in southern parts of the city of Tehran (mg/kg) (Mardani *et al.*, 2010)

Chemical compound	Point-1	Point-2	Point-3	Point-4	Poin-5	Point-6	Point-7	Point-8
Pb	58.7	62.8	110.2	74	58.8	74	57	55
Zn	113.4	120.8	155	299	51	70.2	61.2	64.4
Cd	1.7	1.8	3	6	2.5	1.3	1.2	0.7
Ni	3.3	3.8	41	96	86	18	8.5	4.4
Cu	34	68	83	94	87	8.8	4.6	3

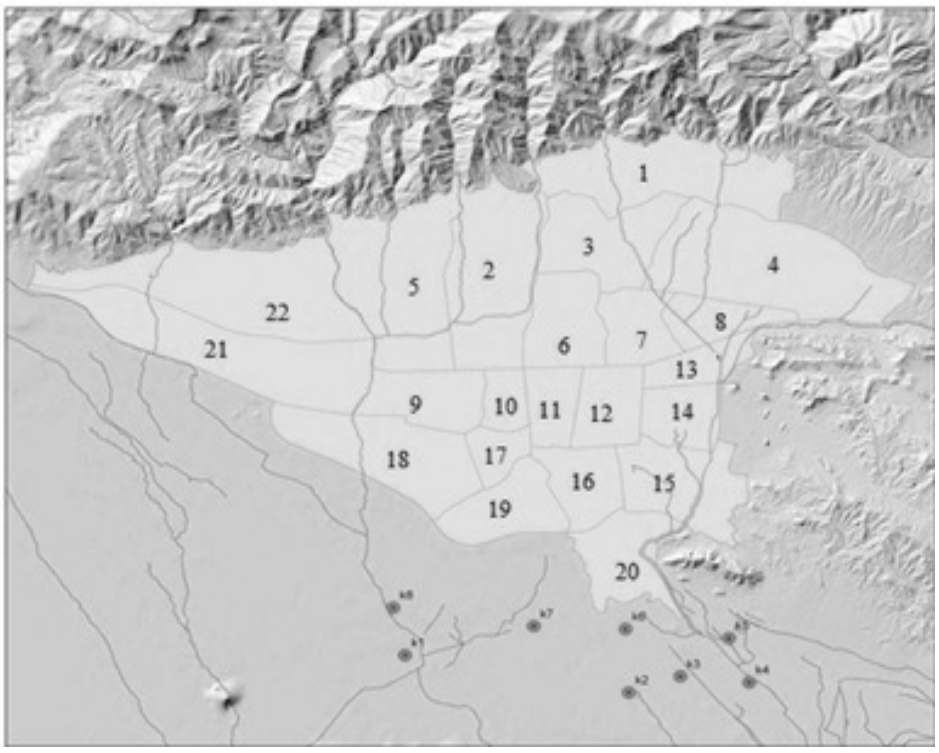

Fig. 10. Location of sampling points for soil pollution detection (Mardani *et al.*, 2010)

Urban development is one of the major factors that create negative impacts on biodiversity (Andersson and Colding, 2014). Although urban green spaces are not considered as natural ecosystems, they provide suitable ecologic services to the urban environment. (La Rosa, 2014). Therefore, in this research, presence of urban green spaces is considered as an indicator of biodiversity. In Fig. (11), the spatial distribution of urban green space in the city of Tehran has been presented. As it is clear, GSs don't have an even distribution in city of Tehran and are mainly concentrated in northern and west part of the city. According to interpretation of satellite images, more than 16 percent of Tehran area can be considered as GSs.

The high rate of changes in the land coverage from green and open spaces to constructed lands in the city of Tehran can created thermal islands and increase the temperature in the urban area and the studies are attesting and confirming such changes. The trend of changes in average temperature of Tehran in Mehrabad synoptic station is presented in Fig. 12. As it is clear, the average temperature in Tehran from 1951 to 2010 has a meaningful increase with Correlation Coefficient of 0.76 and it can be concluded that Tehran climate has become warmer in comparison to the past.

Degradation in ecological factors in Tehran causes serious impacts on both human health and ecological services. In following part, main impacts of Tehran environmental degradation are presented.

Lung and heart diseases are the most important causes of death in the city of Tehran which are directly affected by air pollution to the point that in 2010, about 45.4% of total deaths was due such diseases. Also polluted soil and water transfer different disease to people. In places close to the landfill sites, huge

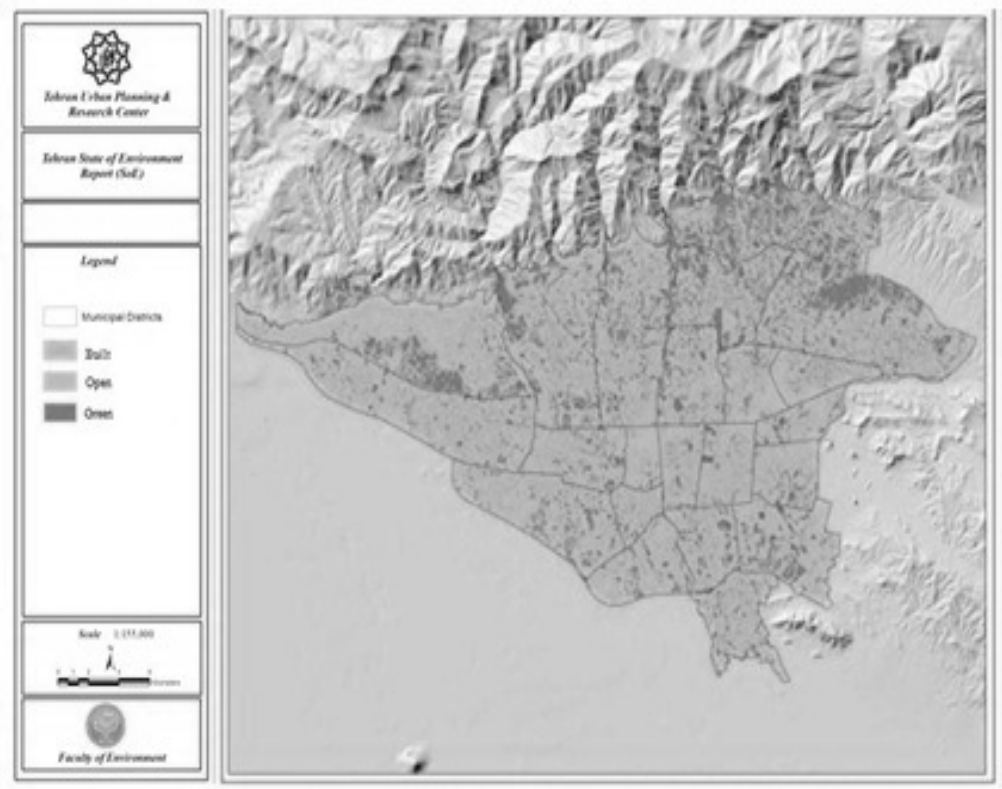

Fig. 11. Built, open and green land covers in city of Tehran in 2010

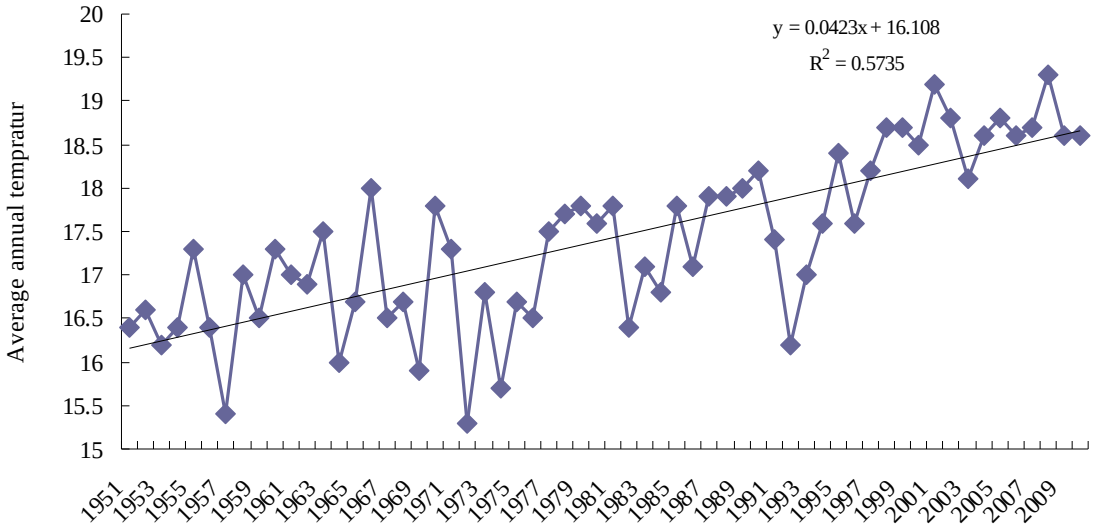

Fig. 12. changes in average temperature in Mehrabad station from 1951 to 2010

deposits of wastes are responsible for transferring different types of illnesses and disease to human.

Air pollution causes lots of socio- economic costs in the city of Tehran that are not considered in policy making, such as health problems, damages to buildings and facilities. In this part of the research, external cost of environmental degradation due to consumption of fossil for air pollutants such as NOx, SO_2, CO, CH_4, and SPM is calculated and presented in Fig. 13. It is clear that the social costs of pollutants are relatively high. Therefore, in case, if the air pollutants are controlled, the cost imposed on the society for health care and economic management will also be reduced.

Providing enough drinking water for high concentration of population in Tehran has always been

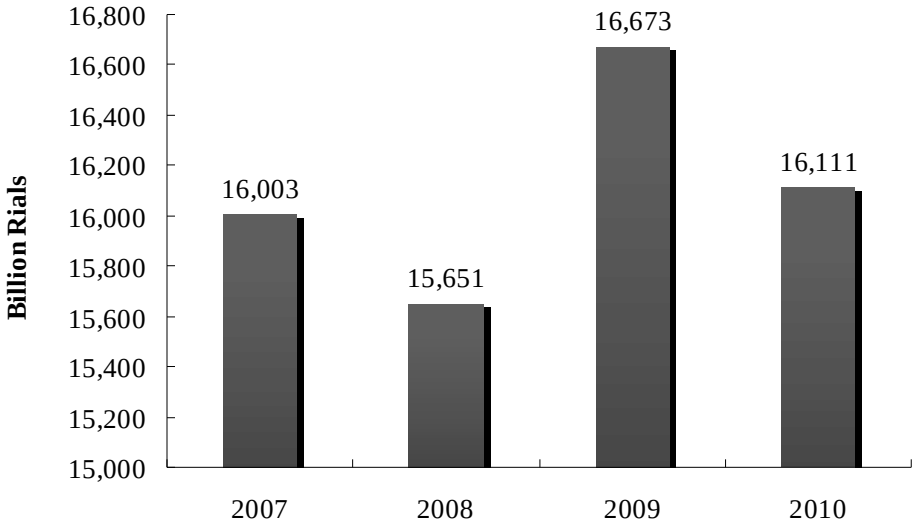

Fig.13.Social costs of air pollution in the years 2007 to 2010

Table 2. four types of responses and some proposed measures for improving the state of environment in city of Tehran

Type of Response	Some proposed measures
Responses to Driving forces	• Even and fair distribution of facilities and economic activities in the whole country • population displacement from Tehran through persuasive measures
Responses to Pressures	• Controlling and stopping the conversation of green and open lands to constructed areas and further expansion of the city both horizontally and vertically through powerful regulations • Reduction of water and energy consumption through education and preventive actions. • Reducing the number of vehicles usage in the city and increasing public transportation • Use of cleaner fuels for vehicles, industrial and domestic uses. • Reduction in solid waste production and emphasizing on separation of wastes from the origin • Reduction in water pollutants such as managing municipal waste water and runoff.
Responses to States	• More detailed monitoring of air pollution • Monitoring drinking water quality • Improving the green spaces using endemic plant species with appropriate water needs. • Spatial planning of ecological network with emphasis on river valleys and proper zoning of green and open spaces in order to facilitate air movements in Tehran.
Responses to Impacts	• Monitoring of diseases related to environmental pollutions • Educating and giving information to people to avoid pollution • Displacement of population and spatial planning for places adjacent to landfills and areas with high risk of environmental pollutions. • Monitoring the impacts of air pollution on historical building and valuable sites • Determining environmental flow for dams that supply drinking water for greater Tehran • Monitoring the status of exotic and pest species and applying effective methods for combating them.

a strategic challenge and therefore lots of dams have been constructed over rivers in nearby basins causing degradation of riparian, wetlands and groundwater resources.

The over-exploitation of ground water resources and aquifer has resulted in acute drop of the ground water level in Tehran. In addition, mixing of ground water with waste water due to the lack of extensive sewage network system and presence of waste water wells in the city are among other factors disturbing the ground water aquifers. Furthermore, dedicating a major portion of water in reservoirs of the Dams to domestic usages and consumption has resulted in an increase in illegal operation and water withdrawal from a number of water wells for agricultural and industrial purposes.

The structural disturbances of the landscape in Tehran are mainly due to the destruction of natural ecosystems and their modification to constructed areas. This included the elimination of valuable ecosystems or the reduction of their size and growth and expansion of built disturbing surfaces.

Rise of tall buildings with no particular planning, especially in the elevated areas of the city of Tehran have resulted in disturbance of the natural air flow from the mountainous areas to the flat plain in the south. Such interruption has caused the stagnation in air flow and also increase in concentrations of pollutants in the air.

Pollution and unsuitability of the environmental conditions in the habitats result in elimination of native species that are highly dependent on their habitats and secondly result in expansion of non-indigenous animals (without dependent on habitats) with high ability in reproduction. These organisms also transfer disease are called “nuisance”. This can be observed as elimination of vocal birds and increase in population of rats.

As it was shown in Fig.1, in the DPSIR framework, responses, are the political and societal and answers to problems that exist in different part of the causal framework. It is obvious that responses to the beginning of the DPSIR chain are more effective and will prevent the further consequences, but they are timely and need high political determination to be successful. Also responses given to the end of the chain, or impacts, are least effective and will not solve the problem and main symptom and can only be reactive and short time solutions. In this part of the research, responses to different components of DPSIR framework for the city of Tehran are presented in form of broad strategies. Table 2 shows the four types of responses and some of the proposed measures for each of them.

CONCLUSION

Investigating the trend of changes in environmental parameters shows increase in environmental loads in Tehran. As it was discussed, the percentage of area under construction has increased from 37% in 1988 to 58% in 2010 which not only means instability in ecosystem due to producing heat islands, runoff etc., but also much environmental pressure due to population associated with the built areas. It’s mentionable that the vertical growth in Tehran’s built environment needs to be considered in further studies.

The growth of water consumption in period of this study is an important pressure which shows 17 percent growth or an average annual growth rate of 1.7% in the period of study. This is extremely an alarming situation due to water scarcity in Iran semi-arid regions like Tehran. Constructing new dams with larger reservoir happened in this period of time which absolutely indicates the need for providing drinking water for people living in Tehran. Increase in solid waste production is also admonitory which 32.66% in the period of study is. All these show overwhelming pressure on environmental assets such as water, soil and air. Existence of pollutants in the environment will finally lead way to food and respiratory system of humans and will bring about serious health problems apart from damages to ecosystem components. Therefore in this study, we concluded that pressure over the environment in city of Tehran is constantly increasing that threatens the quality and quantity of environmental resources and will cause both socio-economic and ecological consequences that people feel in everyday life and worry the planners and decision makers for the future of such unleashed human settlement development.

In this research, we showed that DPSIR model can link different aspects and can show the interaction and interconnectedness of different components that form environmental issues in urban areas. In the end, different responses for components of DPSIR causal chain are proposed. These overall responses can be observed as a framework that related strategies and action plans for environmental planning of city of Tehran can be developed according to them.

Although, city of Tehran consists of 22 municipal districts and has the population of 8154000, it’s so much under the pressures of adjacent marginal settlements with inhabitants who work or educate in Tehran. Unfortunately difference between populations of Tehran in day and night time is not considered in planning and daily lots of automobiles and people enter this city and leave in the evening time. Although public

transportation development in Tehran has been successful, still a vast population load and the need for transportation remain increasing. So we suggest that for future SOER of Tehran, the total area and settlements that affect and are affected by Tehran should be considered and the outcome of this report be used for a sort of strategic planning for the total area.

In order to keep on preparing SOER for Tehran, surveying and monitoring the status of ecological parameters specially soil and biodiversity in which less information is available can be very helpful. Also increasing the spatial scale of investigation form city of Tehran, to the whole area under its influence can depict the environmental drivers, pressures and also impacts in a more realistic manner.

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