Application of Driving force- Pressure- State- Impact- Response (DPSIR) framework for integrated environmental assessment of the climate change in city of Tehran

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ABSTRACT: Climate change is a complicated issue with many factors playing role in its formation and distribution. Considering this complication, a comprehensive and holistic approach is needed for a better understanding and management of those factors. The causal frameworks are among systemic and integrated methods for addressing the causes of environmental problems and the relationships that exist between the environmental systems in order to propose proper solutions. The DPSIR model is a functional analysis framework that depicts the cause-effect relationships that exist in creating environmental problems. Tehran is one of the major megacities in the Middle East that faces environmental consequences of overpopulation and unplanned urban sprawl, and being located in an arid region, makes it vulnerable to rise of temperature and reduction of precipitation. In this research, by using the DPSIR framework, different aspects of climate condition of Tehran are analyzed and later with the help of this conceptual framework, strategies for controlling climate change are presented.

Keywords: climate change, integrated environmental assessment, DPSIR framework, Tehran

INTRODUCTION

Climate change has become such a challenging issue all around the world that urban planning couldn't address its consequent uncertainties properly (Hamin and Gurran, 2009; Larsen *et al*., 2013). To tackle those uncertainties and giving effective planning responses, acknowledging the impacts of this phenomenon will be very advantageous. Urban responses to climate change can take multiple forms and different scales, yet, less attention has been given to experiments through which effective responses could be organized and pursued (Bulkeley *et al*., 2014)

Urban areas have characteristics that cause their inhabitants vulnerability to the climate change. Many of the large cities are located near coastal areas, riverbanks, or mountain hills that make them susceptible to the risks of climate change (Gasper *et al*., 2011). In Iran urban areas are mainly located in arid region; therefore the rise in temperature and a reduction in precipitation can have many negative consequences on the environment and the lives of people.

Changes of climatic parameters are a complicated issue that many factors play different roles in its formation and distribution. Considering this complication, a more comprehensive and holistic approach is needed for a better understanding and performing an integrated environmental assessment. The causal frameworks are among systemic and integrated methods for

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addressing the causes of environmental problems and the relationships that exist between the environmental systems for proposing proper solutions.

The DPSIR model is a functional analysis framework to depict the cause-effect relationships that exist in creating environmental problems (Ness *et al.*, 2010). It is a tool for integrating socioeconomic and natural environment into a framework to provide a basis for detailed analysis (Bidone & Lacerda, 2004;Ness *et al.*, 2010). The scheme makes it possible to identify important relations as well as to develop an overview and understanding of a problem (Ness *et al.*, 2010), by presenting information in an organized and purposeful manner.

The unplanned development of metropolitan areas greatly increases environmental problems such as air pollution and increasing the temperature (Sodoudi *et al.*, 2014).Tehran is one of the major megacities in the Middle East that face changes in climatic parameters due to the environmental consequences of over population growth. Factors such as urban development, the need for transportation and other socio- economic factors related to population density cause environmental pressures that affect the climate of Tehran, which has shown its consequences on human welfare, the existence of water resources and reduction of biodiversity. In this research, by using the DPSIR framework, different aspects of climate condition of Tehran are analyzed and later with the help of this conceptual framework, strategies for controlling climate change are presented.

MATERIALS AND METHODS
This study is performed in City of Tehran, which is Geographically Located on the southern slopes of the Alborz Mountains, which gives it relatively rich resources of water and mild climate. A glance at the geography of Iran and the spatial distribution of population and settlement patterns, it clearly shows this excellent position. Today Tehran faces various bio-environmental problems such as pollutions, that is not because of its poor location, but because there is excessive pressure on the resources of the city and whose environmental limitations are violated.

In this research, the DPSIR model is applied for analytical investigation over factors that affect and are affected by climate change in Tehran. The roots of the DPSIR framework can be traced back to the Stress–Response framework developed by Statistic Canada in 1970s (Svarstad *et al.*, 2008). This idea was later evolved to Pressure–State–Response (P–S–R) launched by the Organization for Economic Cooperation and Development in the 1980s and the United Nations Commission on Sustainable (Tscherning *et al.*, 2012).The purpose of the DPSIR framework is stated as overcoming the communication gap between scientists, political systems and the public by means of classified indicators (Tscherning *et al.*, 2012). Recently, DPSIR has been applied in fields like indicator developments, model building and structuring of policy researches (Svarstad *et al.*, 2008).

This model can be applied to delineate processes and relationships that exist in human-environmental systems (Shu-dong, *et al.*, 2013). This framework is a causal chain presented whereby a distinction is made between (1) forces that act on the environment, (2) changes that, as a consequence, take place in the environment and (3) the societal reaction to those changes (Niemeijer and de Groot, 2008). It is made of 5 elements that form a causal chain. The driving forces are mainly human related factors that cause an environmental problem. These factors are usually related to socio-economic developments which need to use environmental resources. Exploitation of natural resources and production of wastes cause pressure on the environment and as a result, the status of environmental parameters will change. These changes will bring about

unfavorable consequences on humans' welfare and ecosystem and will cause society to response for solving them (Svarstad, *et al.*, 2008; Koornneef, *et al.*, 2011).

Responses can address and feedback to Drivers, Pressures, States or Impacts (Weterings, 1999; Tscherning *et al.*, 2012) and therefore take different forms.

Responses that aim at Drivers take the form of prevention. If they control the pressure over the environment, they will be mitigation responses. Also, they may be in the form of restoration responses to maintain the state of the environment. Finally, to help overcome impacts, we have adaptation responses (Fig. 1).
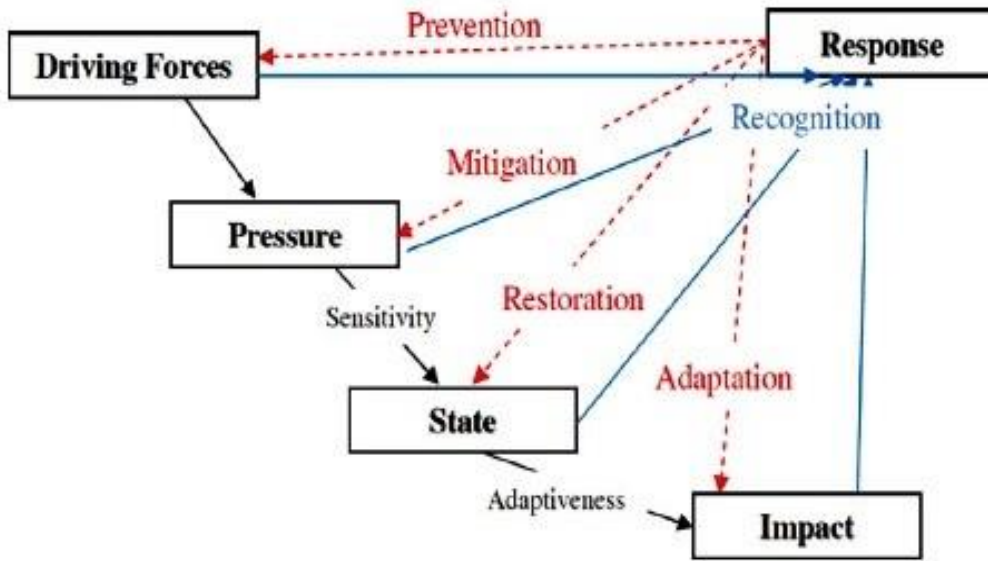

Fig. 1. the extended DPSIR model (Sangenberg et al., 2015)

In this research, first, different issues and aspects of climate change in Tehran are identified according to the DPSIR framework. Later, those issues are translated to relevant indicators and quantities form those indicators are obtained from statistics and other reliable sources. The indicator derivation is carried out on different levels. First they are classified into categories, and then related issues and finally indicators and relevant values are presented. It is mentionable that not for all issues quantitative indicators could be presented. Therefore for some parts of the causal chain of DPSIR, only descriptive information is presented. After the framework is completely presented, Responses and strategies are proposed for issues that show warning trends according to the analysis.

RESULTS AND DISCUSSIONS
As it was stated before, driving forces refer to the fundamental processes in society, which lead to activities that have impacts on the environment. Tehran is the capital of Iran and produces nearly 30 percent of national GDP, which makes it a magnet for population. Increase in population density along with unplanned urban development causes increasing demand for transportation and consumption of fossil fuels, which lead to emission of greenhouse gases and heat. Many people that work in Tehran, live in marginal settlements and therefore are not registered in formal statistics of Tehran, but produce environmental pressure in this area (Fig.2).
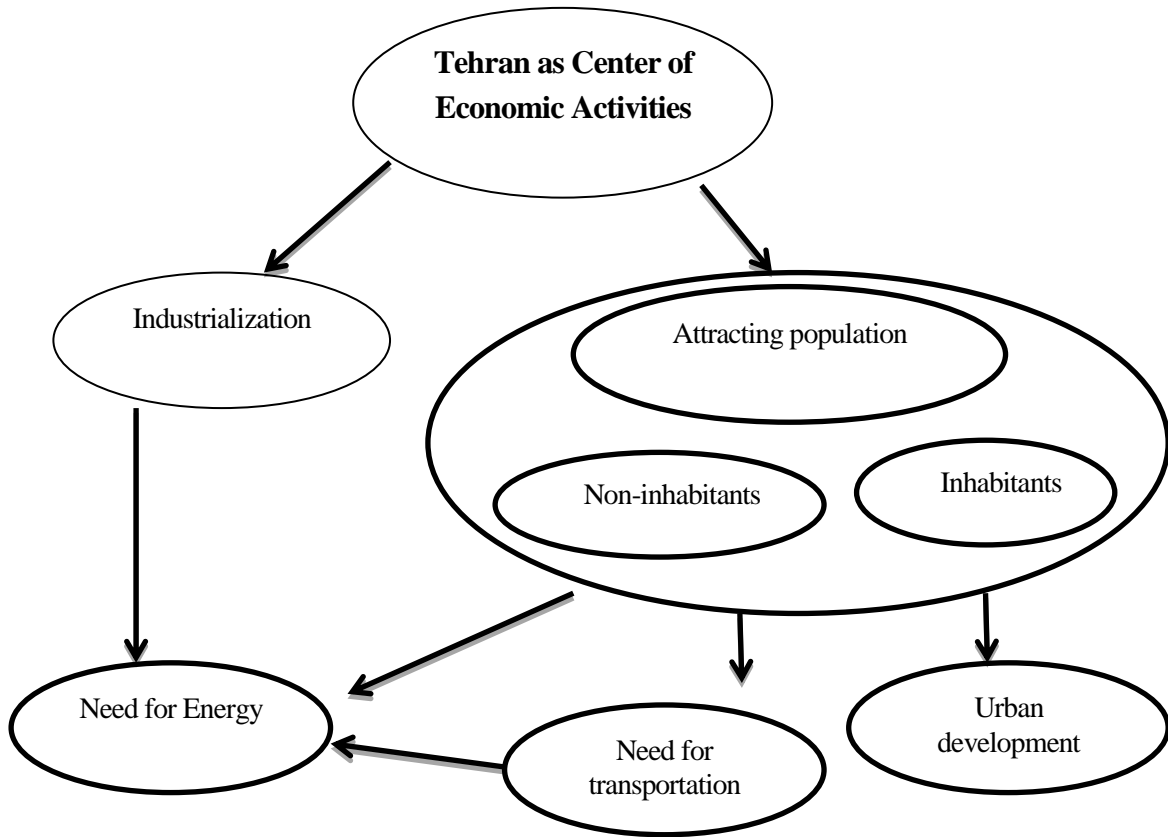
Fig. 2. different aspects anthropogenic drivers affecting climate situation in Tehran

Table 1. Driving forces affecting on Tehran's air pollution

Category	Issue	Indicator	Value
Social	Population	Total Population	8154051
		Average Annual Growth (%)	0.86
		Population Increase	341984
	Household	Number of households	25433313
		Average size of household	3.2
	Urbanization	Urbanization Rate (%)	99
Pollution sources	Mobile sources	Total number of motor vehicles in city of Tehran	4130044
		Number of automobiles in city of Tehran	3621346
		Motor vehicle capitation	0.51
		Urban Trips (per day)	15.8 million
Stationary sources	Industries	Percentage of industries in Tehran from the whole country (%)	23

Pressures

In the DPSIR framework, pressures represent exploitation of resources and production of pollution and wastes. In the city of Tehran, pressures that affect climate parameters are consumption of fossil fuels, use of motor vehicles, production of air pollutants and greenhouse gases and changes in structure of landscape (in the form of increase in built and reduction of green and open spaces). In Table 2 a summary of the most important indicators referring to pressure is presented.

One of the factors affecting the increase in temperature in urban areas, are increase in heat island due to increase in built areas.

Therefore, an increase in built area surfaces can be an indicator for heat island in Tehran. In this research, for deriving such indicator, satellite images of Tehran belonging to 1988 and 2010 were interpreted and the result of changes in built area in different municipal districts is presented in the following chart. Accordingly, the most increase is in district 1 with 34 (%) and district 5 with 32 (%) (Fig. 3).

Table 2. Indicators presenting pressure over climatic parameters in Tehran

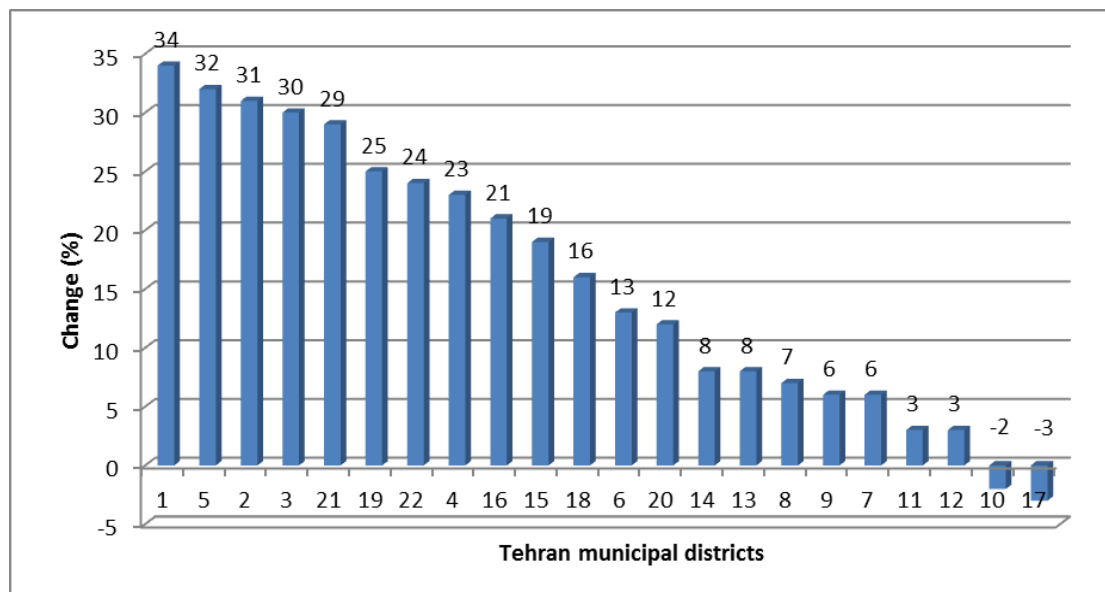| Category	Issue	Indicators	Value	
			Amount in 2010	**Annual Growth Rate (%)**
Consumption	Fossil fuels	Gas	3570 million liter	0.11
		Gas oil	1689 million liter	-3.34
		Natural Gas	13875 million cubic meter	-0.41
	Land Cover Change	Built Area	58.25%	1 %
Pollution and Waste	Emissions	Share of Mobile Air Pollution Sources	92.73 %	0.76

Fig. 3. changes in percentage of built area in 22 districts of Tehran from 1988 to 2010

State

In order to look for the changes in the state of climatic parameters in the city of Tehran we analyze the existing records of Mehrabad station (West of Tehran). We tracked changes in annual records for temperature, precipitation and wind.

As it is demonstrated in the Figure 4, the average annual temperature of Tehran during the period of 1951 to 2010 has a meaningful increasing trend and the correlation coefficient is r=0.76. Therefore, it can be said that Tehran is getting warmer.

Also statistics from I.R. of Iran Meteorological Organization were obtained and analyzed for changes in precipitation. The average annual precipitation for the period of 1951 to 2010 is 230 mm. The change trend of this indicator is not sensible in this period (Fig. 5).
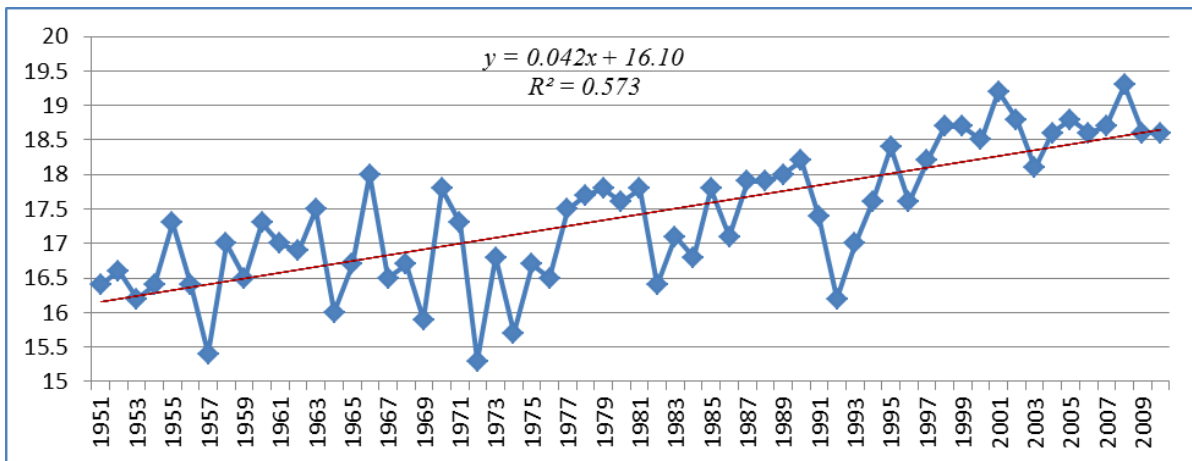
Fig. 4. Changes in Average Annual Temperature of Tehran from 1951 to 2010 according to Iran Meteorological Organization
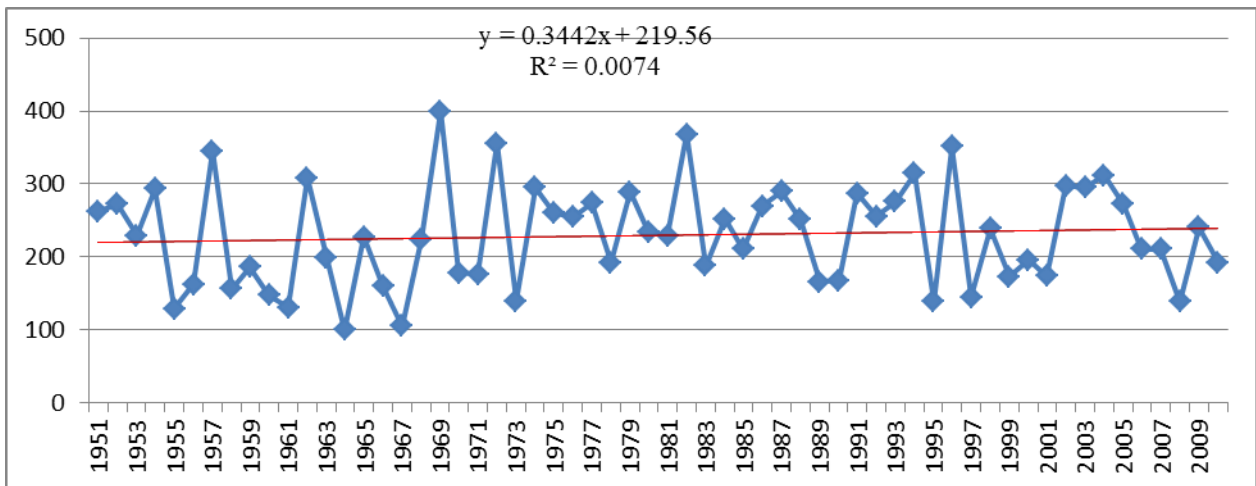

Fig. 5. Changes in Average Annual Precipitation in Mehrabad Station from 1951 to 2010 according to Iran Meteorological Organization

Wind is the most important climatic factor that reduces the air pollution concentration in Tehran. Also, it scatters and dilutes air pollutants and particulate matters and reduces the greenhouse effect in urban areas. Tehran area is mostly affected by local wind of the mountains to the plain which has an important role in its air quality; therefore any cause of reduction in wind speed can have consequences on the quality of air.

According to the Figure 6 the average annual percentage of calm days (which has a negative relationship with windy days) has a meaningful increasing trend with the correlation coefficient r=0.84. Therefore, it can be said that wind blowing has decreased in Tehran and in 40 percent of days Tehran has a calm weather, which means a higher potential for air pollution.

In Table 3, the trend of changes in status of climatic parameters in city of Tehran are summarized, which indicates meaningful increase in the temperature and percentage of calm days.
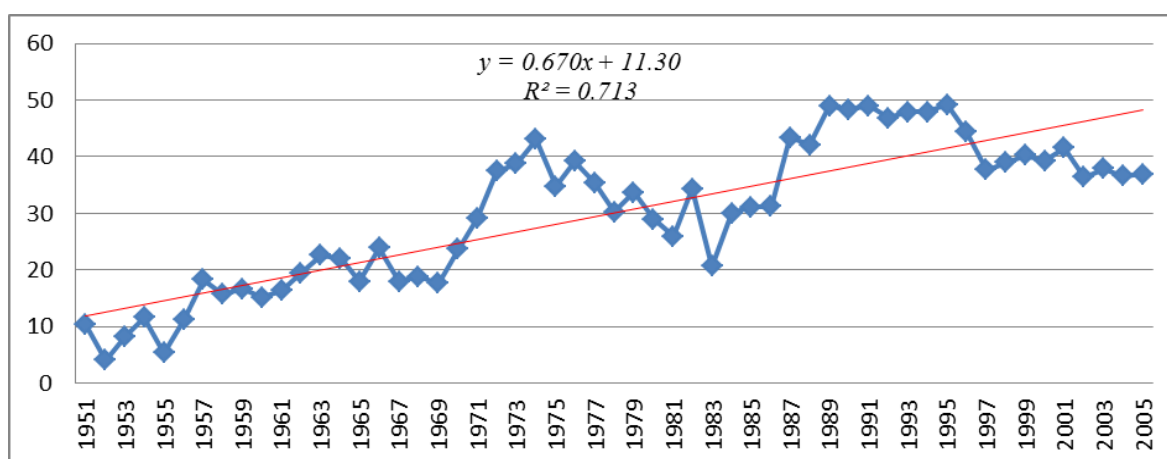
Fig. 6. changes in percentage of calm days in Tehran in Mehrabad station according to Iran Meteorological Organization

Table 3. Summary of changes in status of climatic parameters in city of Tehran

Category	Issue	Indicator	Value (Correlation Coefficient (r))
Main Climatic Parameters	Temperature	Average Annual Temperature	0.76
	Precipitation	Average Annual Precipitation	0.08
	Wind	Calm days (%)	0.84

Impacts

Due to its location in the southern foothill of Alborz Mountains, City of Tehran is in a relatively closed climatic condition. Therefore the prevailing wind which blows from the west direction cannot discharge the air pollution. Also increase in calm condition and reduction of wind blowing, result in increasing the stability of air condition and inversion, which has an important role in increase of air pollutant concentration near earth surface and causes important consequences on citizens' health. Research indicates that 73 to 85.5% of the Tehran's air pollution is the consequence of inversion phenomenon (Yavari and Saligheh, 2011).

As one of the most important factors affecting plants growth, changes in climatic parameters have consequences on their life cycle and even its possible that many of plant species that are used in green spaces in Tehran, have lost their suitability in new climatic condition. Also climate change will cause changes in plants growth needs and the first consequence of likely future warmer climate will be the increase in water requirement, which is very difficult to meet because of the water shortage in the area. Therefore, green land, its growth context and the required resources management in Tehran should be revised. It is obvious that increase in overall air temperature and pollution will have negative effects on green land cover in Tehran. Also moving toward desertification will cause changes in plant species of the area and also increase in temperature will bring more need for irrigation and will increase growth in pests and plant diseases.

Gradual increase in air temperature and reduction of wind will cause a warmer and more polluted situation which is not desirable for Tehran's inhabitants.

Responses

Existing responses

Resolutions, legislations and laws are among the most important existing responses to climate change. The government of Islamic Republic of Iran has resolutions that can help reduce the impacts of climate change in city of Tehran, such as: decentralization of Tehran, moving governmental employees from Tehran, moving military bases and centers from Tehran, and moving disturbing and polluting industries from Tehran.

Also in an international context, in 2005 The Kyoto protocol, which is an international agreement linked to the United Nations framework convention on climate change, was approved in Islamic Parliament and in 2009 Council of Ministers approved the executive regulations, which emphasized that Iran's policies and strategies should be determined in a way that the amount of greenhouse gases emission should be estimated and reported regularly.

Moreover, in order to reduce the trend of emission of these gases, emphasizes are on policies like increasing the share of low carbon energy resources by means of development and directing investments toward producing renewable energy, new and environmental friendly technologies, attempt to gain more share from world environmental funds and banks, efficient use of regional and international co operations.

Using renewable energies and environmental friendly technologies to produce energy can be a very important response that reduces fissile fuel consumption. In Table 4, the capacity of power plants that consume renewable energy in Tehran province is demonstrated. It is obvious that only a small amount of energy is obtained from renewable sources.

Table 4. Proposed responses according to the DPSIR model

Response Category	Responses	Strategies
Prevention	Reducing Tehran's population and decentralization	Strengthening other regions by moving important political, economic and educational centers from Tehran Revising the land use planning of Iran and relocating the population and activity centers. Providing motivations for migration from Tehran.
Mitigation	Reducing the consumption of fossil fuels	Increasing the share of renewable energies in total energy consumption in Tehran. Improving the public transportation Decreasing the need for urban trips by urban planning and design Enforcing strict traffic regulations for using automobiles in polluted regions of the city
Mitigation	Controlling the rise of temperature	Reducing the heat island effect by using eco-friendly construction materials Increasing green spaces and roof gardens with consideration of water scarcity Reducing urban travels by improving public transport
Mitigation	Improving the situation for wind blow	Identifying the zones that construction of tall buildings interfere the direction of winds, and prohibiting the construction of such buildings. Protecting natural land covers and land forms that produce local winds.
Restoration	Monitoring and documentation	Monitoring and documenting the changes of climatic parameters and inversion days.
Adaptation	Monitoring and documentation	Tracing the trend of desertification and changes in plant and animal species. Tracing the changes of surface water bodies and ground water levels.

Conclusion

Urbanization or the increase in urban population, deals with two distinct processes: changes in humans living patterns and the conversion of natural to built surfaces. The first phenomenon deals with urban function and a pattern of activities that leads to a special land use and creates a specific flow of matter and energy. The second implies the form of city and a combination of topography and physical characteristics of it that leads to a specific land cover; urban areas.

Although only 3 percent of the earth surface consists of built areas, they contain 50% of the world population, according to the statistical center of Iran; this figure is 71.4% for Iran and 92.8% for Tehran province.

Urbanity is a type of lifestyle that brings lots of negative environmental consequences. For example, production of polluting and greenhouse gasses and heat from motor vehicles and reflection from built areas and asphalt, result in an increase in temperature in urban areas, so as in reports of different international organizations, the role and importance of urban areas in reduction of greenhouse and polluting gases in order to control climate changes in large scales are mentioned (World-Bank, 2010).

In Tehran megacity, the likely changes in climatic factors can have significant impacts on many of the prevailing environmental conditions. Likewise, moving towards warmer and more arid climate will cause less water stock and potentials for future threats which should be noticed in urban planning. Furthermore, less wind blow due to construction of tall buildings can lead to more stable and polluted air condition. The sum of the mentioned factors can affect the plant cover and its water requirement, energy consumption etc. Therefore, climate and climate change play an important role in the environmental state in the city of Tehran.

The urban sprawl in Tehran and an increase in built areas have been considerable in the last 22 years, which means the potential for creating heat island. Also factors such as increase in air pollution and heat from motor vehicles and reduction in air flow due to construction of tall buildings can affect the climatic factors in the city of Tehran. In the meantime, the increase in air stability and calm air condition and increase in temperature is considerable in city of Tehran, which in the long term can cause undesirable living condition in Tehran and also unwanted consequences on urban biodiversity. The most effective responses to this situation should be focused on reduction in usage of motor vehicles and production of greenhouse gases from one hand, and controlling the construction of tall buildings especially in air flow corridors in the other hand.

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