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Desertification in Forest, Range and Desert Landuses of Tehran Province, Under the Impact of Climate Change

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Abstract

Persistence of widespread degradation in arid and semi-arid region of Iran necessitates using of monitoring and evaluation systems with appropriate accuracy to determine the degradation process and adoption of early warning systems; because after transition from some thresholds, effective reversible function of ecosystems will not be very easy. This paper tries to monitor the degradation and desertification trends in three land uses including range, forest and desert lands affected by climate change in Tehran province for 2000s and 2030s. For assessing climate changes of Mehrabad synoptic stations the data of two emission scenarios including A2 and B2 were used using statistical downscaling techniques and data generated by SDSM model. The index of net primary production resulting from MODIS satellite images was employed as an indicator of destruction from 2001 to 2010. The results showed that temperature is the most effective driver force which alters the net primary production in rangeland, forest and desert ecosystems of Tehran province. On the basis of monitoring findings under real conditions, in the 2000s, over 60 % of rangelands and 80 % of the forests have been below the average production in the province. On the other hand, the long-term average changes of NPP in rangeland and forests indicated the presence of relatively large areas of these land uses with production rate lower than the desert. The results also showed that, assuming the existence of circumstances of each emission scenarios, the desertification status will not improve significantly in the rangelands and forests of Tehran province.

Key words: Land Degradation, Global Climate Change, NPP, Trend, Scenario.

1 Introduction

Land degradation and its manifestation in drylands (arid, semi-arid and dry sub-humid areas), desertification, are still widespread jeopardizing livelihoods and sustainable development (Fleskens & Stringer, 2014; Reynolds & Stafford, 2002). Drylands cover approximately 41 % of the Earth's surface and approximately 10-20 % of these regions are facing degradation and desertification processes, resulting in a decline in agricultural productivity, biodiversity loss and the ecosystems breakdown (Keesstra, 2007). Land degradation is an environmentally harmful process which has been defined in different ways by different researchers. Desertification is defined as general reduction in agricultural production and land potential (Foster, 2006) or long term reduction in ecosystem function. (Bai et al. 2008). Other researchers believe that desertification is diminution or negative changes in land resources caused by human activities across the time (UNEP & Thomas, 1992; Stocking & Murnaghan, 2001; Bisaro et al., 2014; Miao et al., 2014). In spite of these differences in specific conditions, but the feature of biologic productions reduction is common in all of them. This phenomenon is accelerated by negative human activities, especially in rural region (Barbero-Sierra et al., 2015). Land degradation begins with impact on eligible ecosystems and then as it gradually develops, changes become observable. This gradual impact is inconsiderable until the destruction generally is exacerbated. However if the degradation occurs completely, the efforts to deal with this problem can be long lasting and expensive and even unsuccessful in some cases. Land degradation has three different aspects: soil degradation, plant cover degradation and water degradation. Investigation of each three aspects requires the

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specific environmental criteria. Considering the widespread and threatening aspects of desertification in all around the world, many researchers have tried to analysis it by means of experimental models and methods (Prince et al., 1988; Ladisa et al., 2011; Liu & Yang, 2003), remote sensing methods (Symeonakis et al., 2014; Helldén & Tottrup, 2008; Hill et al., 2008; Rasmussen et al., 2001), and modeling (Nicholson et al., 1998; Salvati & Zitti, 2009; Santini et al., 2010).

In most different studies in land degradation and desertification, vegetation cover is used as an important criterion (Helldén & Tottrup, 2008; Hill et al., 2008). Even in some researches, the vegetation cover has been used as the only criterion for assessing desertification and destruction of land (Wessels et al., 2008; Rasmussen & Madsen, 2001).

In several recent studies, new methods have been used to monitoring the degradation. These methods are used based on the observation of time-series trends to producing product against the land degradation changes. However, this approach has had little success, because it has not created a clear relationship between production and land degradation (Lal et al. 1998). Recently net primary production index derived from remote sensing data is used to improve the relationship (Wessels et al., 2008; Prince et al., 2009). Net Primary Production (NPP) is one of the main components of the carbon cycle and it represents an increase in plant biomass after deducting the amount used by autotrophic. NPP or the absorption rate of CO2 through photosynthesis is the basic link between the atmosphere and biosphere. Human activities release a lot of CO2 into the atmosphere and have direct effects on NPP through changing weather patterns (Greer et al. 1995, Nakićenović et al., 2000). Furthermore, human currently consumes almost a quarter of potential NPP (Haberl et al., 2007). Awareness of the global carbon emissions is necessary for development of global policies on climate change (Wofsy et al., 2002; Piao et al., 2008a; Schulze et al., 2000). Plant biomass reduction decreases quality and fertility of the soil and it causes a reduction in agriculture capacity and livestock. So, NPP has important role in human welfare as they are the basis of food, fiber and timber productions. It should be noted that changes factors are different in natural resources area. According to a report presented by FAO in the 1990s, the main factors of forest changes in different continents of the world are mainly land use changes (Jafari, 2013). In Asia, about 23% of changes in forest area depend on other factors that climate change can be considered under this category. Climate changes such as changes in temperature and rainfall effect on phonology and plant growth timing (Jafari, 2007). On the other hand, climate change has been observed in different parts of Iran and it is also predicted that the changes will be occurred in future. Climate change causes a biomass production change in natural ecosystems (Jafari, 2013). So, prediction of NPP in natural areas, understanding the climate change effect on global ecosystems, products and services sustainability are the fundamental issues that many researchers have addressed them (Fang et al., 2003; Ei-Masri et al., 2013; Hemming et al., 2013; Piao et al., 2005b; Zhao et al., 2010).

Liang et al. (2015) investigated the spatial and temporal patterns of annual, seasonal and monthly changes of NPP index. They also studied the climatic factors controlling it at the national biome level during 1982 to 2010 in China. The results showed that the NPP has increased under the influence of precipitation from the north to the south of China; and the temperature was introduced as a control factor of net primary production in all biomes except dry biome. Raich et al. (1991) monitored the potential of net primary production in relation to climatic variables for different land uses in South America. Their results showed that seasonal NPP has a positive correlation with the amount of available moisture in most vegetation cover, but seasonal difference in cloudiness has strongly affected the NPP in tropical evergreen forest. Li et al. (2015) have used NPP, NDVI and rainfall index (RUE) in order to investigate the dynamics of land degradation in Beijing-Tianjin area in the first decade of the 21st century. Their results showed that, according to the NPP index in the period time of 2000 to 2010, Beijing-Tianjin area has been extensively degraded at a rate of 52.7 %, while the reported destruction based on RUE was 65.2 %.

Choosing the appropriate tools that can be able to predict the impact of climate change on net primary production has been always a challenge. The most reliable tools for evaluating the effects of this phenomenon on different systems is climate variables which are simulated by coupled atmosphere-ocean general circulation models (GCM) of the atmosphere (Haghtalab et al., 2013). Along with the emissions scenarios greenhouse gas which was codified by the Intergovernmental

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Panel on Climate Change (IPCC), the atmospheric general circulation models have been developed by different emissions assumptions such as B2, B1, A2, and A1 to determine the climatic conditions in the next decades. One of the main problems of current evaluation studies in a regional level is the prediction extent of variables in these models (the study of areas around 5000 km^2). Due to the topography and climate changes in this area, the results cannot be used directly in station scale. In other words, the model considers similar conditions to surface cover, topography and climate for a grid with dimensions of several hundred kilometers, while real situation of surface area can be completely different in the study area. To address this shortcoming, various methods have been created to generate climate scenarios at regional scale named downscaling. Reeves et al. (2014) investigate the effects of potential climate change on NPP by predicting the climate regime under global change scenarios A1, B1, A2 and B2 in the grassland of America, from 2001 to 2100. The results showed that up to 26% of the NPP will be increased by 2030, but NPP will be significantly declined after this year. Bachelet et al. (2001) have tried to modelling the relationship of vegetation changes under the influence of temperature and precipitation in the United States of America and then the future vegetation cover of America has been illustrated by using emission scenarios.

Some factors such as the lack of policies and guidelines to combat land degradation help to expand it (Bai et al., 2008). Also, some countries have no specific policies for addressing land degradation (Lestrelin, 2010; Lestrelin & Giordano, 2006). In other words, they lack a national strategy and guidelines for control degradation and also protect the areas which have not been destructed yet. So, some studies to develop and implement national strategies can be useful to combat and monitoring degradation in these countries. The methods used for monitoring land degradation and desertification in Iran have been on the basis of expertise and field measurement such as MEDALUS, IMDPA, FAO-UNEP and ICD method (Khosravi & Zehtabian, 2012), Which can be used to evaluate the progress of land degradation (Oldeman et al., 1991; Stocking, 1995). Although these studies are accurately appropriate to determine initial destruction features, but some challenges such as not simply for users, high volume data entry and low repetitions in depended area and loss of accuracy in region with a large surface area cause a lot of problems (Omuto, 2008).

The aim of this study is monitoring land degradation and desertification in three land use types including rangelands, forest and desert lands of Tehran province, Iran affected by climate change.

2 Materials and Methods

2.1 Study area

Tehran Province located between 35˚14' to 36˚ 17' north latitude and 50˚14' to 53˚6' east longitude. The area of this region is 1368800 hectares. 0.03, 63 and 20.8 % of the province are covered by forests, rangelands and deserts, respectively. The average rainfall is 230 mm and average temperature is 17 degrees Celsius. The climate of this area changes from Humid, semi-humid and cold with very cold winters in highlands to semi-arid and arid in lowlands. Fig. 1 shows location of Tehran in Iran and its different land uses.

2.2 Climate data and SDSM models

The data has been used in this study include the average, minimum and maximum of rainfall, and temperatures in Mehrabad synoptic stations from 1961 to 2005. Hadcm3 model under emission scenarios A2 and B2 were used to determine GCM model and appropriate scenarios according to the region. Each these different scenarios present the future climate condition. For example, the A2 storyline is characterized heterogeneously by the continued growth of population and regional

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economic growth (Nakićenović, 2000). B2 scenario shows a separate world but eco-friendly. It considered an average economic development, steady increase of population which emphasizes on regional solutions for sustainable development and slower and dissimilar growth of technologies than A1 and B1 scenarios (Rahman et al., 2011). In the study area the scenario which has had the highest accuracy under Hadcm3 models was selected as a scenario that has more similarities with basin. Finally, downscaling model data and observational data were analyzed in order to select the suitable general circulation climate models and scenarios.

NCEP and GCM predictive variables are calibrated and analyzed by the SDSM model. SDSM is a two-phase sampling and conditional method. In this method at the first predicator variable of temperature and precipitation are downscaled by using regression methods and a generating random meteorological method and then, precipitation is produced at the station again. The SDSM is combination of statistical weather generating method (Taei Semiromi et al., 2014). The statistical downscaling processes of climate variable are done by SDSM Software as follows:

1. Data quality control and data transformation, 2.Selecting the best predictor variables, 3. Calibration the model, 4. Climate models, 5. Statistical analysis, 6. Graphical output model 7.climate scenarios production (by using the predictor model).

2.3 The climate change trend

Mann-Kendall test and Sen's estimator slope method were used to assess the climate change trend under emissions scenarios. This test was presented firstly by Man in 1945 and then developed by Kendall in 1975. One of the advantages of this method is the suitability of its application for time series that don't follow a specific statistical distribution. This method is less affected by the limit values observed in some time series. Calculating process of this method is explained in the following (Equations 1, 2, 3, 4 and 5):

$$S = \sum_{i=2}^{n} \sum_{j=1}^{i=1} sign(X_i - X_j) \quad (1)$$

Where, $sign(X_i - X_j)$is the number of samples. For n sorted sample values X_i *and* X_j are defined as following (equation 2 and 3):

$$\begin{aligned} sign(X_i - X_j) &= -1, for(X_i - X_j) < 0 \\ sign(X_i - X_j) &= 0, for(X_i - X_j) = 0 \\ sign(X_i - X_j) &= 1, for(X_i - X_j) > 0 \end{aligned} \quad (2)$$

$$Var(s) = \frac{n(n-1)(2n+5) - \sum_{p=1}^{q} t_p (t_p - 1)(2t_p 5)}{18} \quad (3)$$

$$E(s)=0 \quad (4)$$

Var(s) and E(s) mean variance and average, respectively.

Where, tp is the node number for p and q is the number of nodes, the standard value of Z is calculated by equation 5:

$$\begin{aligned} &\frac{S-1}{\sqrt{Var(s)}}, if \rightarrow S > 0 \\ &0 \rightarrow if\ , S = 0 \\ &\frac{S-1}{\sqrt{Var(s)}}, if \rightarrow S < 0 \end{aligned} \quad (5)$$

In this test, when the Z scores are higher than 1.96 and 2.58 show a significant trend at 5% and 1% level respectively. Positive values of z show increasing trend whereas negative z values indicates decreasing trend. The null hypothesis that

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there is no trend in data was rejected for z values which are greater than $Z_{1-p/.2}$. In this study, the significant levels of 0.01% and 0.05% have been used.

The Sen's Slope estimator method is a nonparametric technique for estimating a linear trend. The trend value was estimated by eq. 6:

$$Q = Median(\frac{x_j - x_1}{j - i}), \forall i < j \quad (6)$$

In this formula, x_l and x are data values in j and 1 (j> 1) times. Also, the median is the middle value of u. If the number of u be even, median is the arithmetic mean of two data in the middle of a data series related to u in ascending or descending order; and if u be odd, median is the number in the middle of the data in ascending or descending order. It is assumed that the data trend is linear and the slope unit of trend line is equal to studied variable unit in a year. In eq. 10, Q is for the slope of trend line and xl is the recorded number for l observed number in history order. Positive and negative values of Q indicate an increasing and decreasing trend.

2.4 Net Primary Production NPP

Satellite images used in this study are related to MODIS sensor on the Terra satellite. This sensor is getting and sending the images to the terrestrial receivers every day from 2000. In all EOS satellites, MODIS radiometer is a key tool. This sensor has continuous and broad spectral and spatial coverage. Two bands have a resolution of 250m and five bands have a resolution of 500m and other 29 bands have a spatial resolution of 1000m. So, studying and evaluating short-term and long-term changes in the sea, land and atmosphere are possible by MODIS. The spectral range of these 36 bands is between 0.4 - 14.4 micrometer. MOD17 algorithms provide the first calculation which is close to the reality of global GPP and NPP by EOS MODIS sensor. This algorithm has two sub-categories: 1) MOD17A2 which is an 8-day combination of net photosynthesis that does quality control (QC). 2) MOD17A3 that includes annual NPP and quality control (QC). It should be noted that MOD17A2 is summation of the 8-day GPP and net photosynthesis (PsnNet) and MOD17A3 includes the NPP and annual GPP. Mod17A3 is a set of net land data and net primary production with a resolution of 1 km obtained from Terra spacecraft and MODIS. Net photosynthesis was defined as equation 7:

$$PsnNet = GPP - R_{ml} - R_{mr} \quad (7)$$

Where, R_{ml} is breathing leaves and R_{mr} is breathing roots. The annual NPP is calculated by Eq. 8.

$$NPP = \sum_{i=1}^{365} PsnNet - (R_{mo} + R_g) \quad (8)$$

Where, R_{mo} is respiration by other organisms except leaves and R_g is breathe growth.

Gross primary production (GPP) is storage capacity and carbon and energy absorption during photosynthesis (Heinsch et al., 2003; Running et al., 2004) GPP is derived from the estimation of net ecosystem exchange (NEED) and ecosystem respiration (Reco). Net primary production (NPP) is the net stored carbon after subtraction plant respiration of autotrophs from GPP. A part of the annual NPP in ecosystems may be lost by events such as strong winds and fire. And it is a need for ecosystem services such as fuel, food, feed, fiber and materials for the purposes of the metabolism.

In this study, Annual NPP was acquired from Global MODIS data (MOD17A3) with a resolution of 1 km in the period of 2001-2010. NPP obtained from MODIS (MOD17A3) based on the light useable model (LUE) and annual NPP provides the evaluation of the temporal and spatial variations in production and land behavior in annual scale. For the calculation of image processing to obtain the NPP and determine land use in the study area, the ENVI4.9 software was used.

In order to evaluate the effect of climatic factors on net primary production in Tehran province, first, a logical relationship was calculated between decrease and increase of (NPP) and both variations of the temperature and precipitation annual average in 2001-2010. Then, the decreasing or increasing changes of NPP were calculated in the 2030s per unit changes in rainfall and temperature portrayed by emission scenarios HADCM3 model (A2 and B2).

3 Results

3.1 Prediction of climate trends

Table 1 shows the results of the annual temperature variations in both emission scenarios A2 and B2 for Tehran synoptic stations. The results of temperature average using the Mann-Kendall and age estimator methods showed a significant increasing trend in both scenarios. The annual temperature average of Tehran station in comparison to base decade of under emission scenario A2 showed 0.004 percent reduction, 0.05 and 0.15 percent increase 2000 for the decades of 2030, 2060 and 2090 respectively, and have the slope trend of 0.05 (Fig. 2). This amount for emission scenarios B2 was 0.02, 0.001 and 0.1 percent increase respectively. As can be seen, consecutive changes of temperature increase has happened for three decades under B2 scenario and has a rising slope about 0.03 percent (Fig. 2). The temperature reduction in the A2 scenario happened in the 2030s and in 2060 the rate of changes of the increasing temperature has been more than B2 scenario. The maximum temperature rise was in A2 emission scenario, which will happen in early 2090. To evaluate the significant difference between the results of two scenarios for imaging the average temperature, t-test of 2 samples was used. According to the Sig. 0.02 in the test which was lower than the intended significant amount (0.05), it is concluded that there is a significant difference between the results of the two emission scenarios. The results of trend test for the imagined amount of the rainfall average by two emission scenarios A2 and B2 has been shown in Table 2. The results of both the Mann-Kendall and Sen's slope estimator represent a significant decreasing trend in rainfall amounts between 2006 and 2099. Also, rainfall changes percentage was studied for three decades of 2030, 2060 and 2090 compared to the base decade of 2000 based on two scenarios A2 and B2. The Results showed that the rainfall average in A2 scenario has increased 0.27 and 0.32 percent in decades of 2030 and 2060, respectively. But in 2090s the amount of rainfall average has decreased by 0.15 percent, but in general, from 2006, average annual rainfall has decreasing slope of -1.12. Under this scenario, the rainfall annual average will be variable between 362.4 and 412mm in coming eight decades. These amounts in scenarios B2 have increased 0.16, 0.07 and 0.09 percentages for three decades of 2030, 2060 and 2090, respectively. Also, based on the results of this scenario the trend line slope of -0.06 has been seen from. The rainfall annual average will be variable between 423.9 and 382.4 mm in Tehran synoptic station in the next eight decades (Fig. 3). Using two sample t-tests showed that no significant differences between the results of two time series of rainfall obtained by HADCM3 model (A2 and B2). The results showed that in both scenarios, the rainfall annual average will decrease from the 2030s, while the results of temperature changes are in contrast and incremental changes in temperature will happen from the 2030s.

3.2 NPP trend

Given that the Mann-Kendall and Sen's slope estimator is not suitable to determine the trend of short time series (Sheng, 2004), so in this study the map of the deviation from the average of NPP was used to evaluate the changes in net primary production. In other words, the 10-year average of NPP for three land uses of forest, grassland and desert was estimated separately and then the annual changes of every pixel to 10-year average of that pixel were evaluated. For this aim, changes were classified in eight classes: (0-0.04 c), (0.04-0.08 d), (0.08-0.12 e), (0.12-0.16f) and 0.16 < (kg Cm $^{-2}$ yr $^{-1}$) are related to positive amount and increase of NPP to the long-term average. Classes of (-0.04-0 b) and (<-0.04 a) are in relation to the amounts of decrease to the long-term average. Fig. 3 shows the percentage of each class in three mentioned land uses for the period 2001 to 2010. The results of NPP changes from annual long-term average for range land use showed that, in 2007 over 60 percent of range land area had been placed in class of c (0 to -0.04). This means that production had been declined in these years. But from 2008, these changes have been more balanced, and the percentage of area having production more than zero to 0.04 has become equal with the class of b (-0.04 to 0). It is necessary to note that, in 2008, the whole areas of Tehran rangeland have had zero to 0.04 NPP growth compared to the annual long-term average.

In forest land use, the percentage of changes area of NPP to long-term average has been variable in each year (Fig. 4) So that, in 2001, more than 90 percent of forest land has the production in class of b ((-0.04 to zero). In other words, the decline in the production of most forest lands has occurred. However, in 2002, the percent of this class has been zero. Instead percentage of the classes that have had more production than the average has been increased. After that, more than 35 percent of forests have had less productive than the average by 2005; and in areas where production has increased the production amount has been in class of zero-0.04. But in 2006, approximately 80 percent of the forest area had the production more than the long-term NPP. There has been a dramatic change in these fluctuations in 2007 and 2008 and over 80 percent of forest land has had a decline in net primary production. In 2009 and 2010 the forests production has increased compared to the average.

The trend of net primary production changes in deserts of Tehran province is quite different with forests and range lands. So that in the 10-year studied period, except in 2003 at other years the production changes to long-term average has been reduced. In the 2000s, more than 80 percent of desserts area have had reduction in the production to – 0.04 (kg C m^{-2} - yr^{-1}) compared to the long-term average (Fig. 5). Although, the net primary production is low in areas with rainfall less than 100 mm per year, but in many semi-arid ecosystems, net production on land may also reach approximately the same production of temperate forests (Whitford, 2002). So, decrease change in initial production of the desert areas of Tehran province cannot just be related to the land use type and the reasons for this reduction should be determined.

Fig.7 shows the average of net primary production changes in the range, forests and deserts land uses in Tehran province. The variation range of average NPP in range landuse is variable from zero to 0.37 (kg C /m -2 yr -1). This range for forest and desert landuses, has changed between zero to 0.21 and zero to 0.39 (kg C m -2 yr -1), respectively. But it should be noted that based on previous studies, except for some microclimate considering as spots production of forest landuse has been higher than range and desert landuses because of the vegetation amount (Barnes et al., 1998). On the other hand, given the definition of land degradation include reduction of productivity and ecosystem functioning in a long-term period (Bai et al., 2008), which is often related to the reduction in plant cover and biomass (Wessels et al., 2007; Salvati & Zitti, 2009). With these descriptions and based on the map of the different land uses average NPP (Fig.7), the process of desertification is for forest and less intense for the range landuse undeniable in the 2000s. So that more than 50 percent of range land have zero production (kg C m^{-2} yr^{-1}) in Tehran province (Fig.7). Despite the small forest area, but in some areas forest has zero production and also the maximum amount of net primary production average of forest is 0.21(kg C m^{-2} yr^{-1}). This maximum production is placed in the range of the desert NPP (Fig.7).

3.3 The relationship between climate change and NPP

One of the important impacts of climate change on forest ecosystems, range lands and desert is the effects of changes in temperature and precipitation on net primary production of vegetation. The impact of changes in precipitation (per mm decreasing or increasing) or temperature (for each degree of increase or decrease) on net primary production were separately determined in rangeland, forest and desert ecosystems of Tehran province.

The results showed that the range of temperature changes has been varied between 18.1 and 19.6 °C in the 2000s in Tehran synoptic station. Fig.8 shows the relationship between NPP and the annual average temperature for range, forest and desert landuses. In range landuse in most years, every time the temperature has increased or decreased, the NPP has been decreased or increased, respectively (Fig.8). Only in 2002-2003, while the temperature has decreased 0.7°C, the NPP amount has been decreased 0.0026 (kg C m^{-2} yr^{-1}) per unit decrease in temperature. But in other years, per unit reduction in temperature (1°C) net range land production has been increased 0.0118 (kg C m^{-2} yr^{-1}). Also, per unit increase in average temperatures in range lands, net primary production of the range lands has been declined 0.0015 (kg C m^{-2} yr^{-1}). So, based on this relationship and the portrayed values of emission scenarios A2 and B2, changes in net primary production in the 2030s were estimated based on the annual average temperature variable. Also, the rainfall range has varied between 174 and 311.7 mm in the 2000s. Net primary production changes were aligned with rainfall changes unlike temperature. In the other words, whenever precipitation has increased or decreased, the amount of NPP has increased or decreased, respectively. Obtained pattern showed that with a one unit increase or decrease in rainfall (1 mm), the NPP increases or decreases 0.00016(kg C m^{-2} yr^{-1}) in range lands. Such as temperature, based on the relationship between changes in precipitation and NPP in the 2000s, net primary production changes in the 2030s was estimated in different emission scenarios A2 and B2.

The imaged results of the primary production of range ecosystem, under the A2 emission scenario showed that it has been reached the highest amount of itself in the 2030s (Fig. 10A). Under this scenario, changes in precipitation and temperature have increased the NPP in the 2030s to the 2000s. However, assuming the existence of the B2 scenario, production changes of range lands will be declined in the 2030s (Fig. 10A). The changes have been in such a way that the production average of range lands (in both precipitation and temperature patterns), will be decreased under B2 scenario in 2038 and 2039 to 2000s. It should be noted that based on the rainfall in scenarios B2, the lowest NPP will happen in range lands of Tehran province. Under these conditions, the annual average of net production in 2030s will reach the same production rate in the deserts landuse during the 2000s.

The Results of NPP in forest have had significant changes just under temperature patterns of two emission scenarios A2 and B2. While, the NPP amount have had no significant changes under rainfall patterns of two scenarios, and the results were very similar (Fig.10B). In scenarios A2 and under the temperature changes, the production amount will reached from 0.118 (kg C m^{-2} yr^{-1}) in 2030 to 0.191 (kg C m^{-2} yr^{-1}) in 2039, and the average of production will had rising trend in the entire decade (Fig. 10B). However, imaged results of the net primary production under temperature change of scenario B2 shows the relatively decreasing trend for NPP amount in forest landuse (Fig. 10B). It is important to note that if there are conditions of scenario B2 and even under rainfall pattern of A2 scenario, the annual average of NPP for forest landuse in the 2030s will be in the range of the lowest levels of production (desert production in the 2000s).

The forecasting results of production changes in the desert landuse showed assuming the temperature conditions of B2 scenario, NPP amount has decreased sharply and it will be reached from 0.014 *(kg C m^{-2} yr^{-1}*) in 2031 to zero in 2033 (Fig. 10c). However, due to the amount of average annual rainfall generated in this scenario" (between 316 to 520 mm), occurrence such a mode of production is not reasonable in desert landuse and it would be more correct to consider production changes under precipitation conditions of this scenario. The study of Seely (1987) on Namib Desert production indicated that the annual rainfall changes between 12.5 to 95 mm has caused the production among 0.00075 to 0.50 *(kg C m^{-2} yr^{-1}*). He attributed this amount of production in driest desert of the world to the perennial grasses with developing root systems that allow them to respond quickly to soil moisture, and thus they can be better able to take advantage of rainfall. So, judgment about the occurrence of such cases depends on the precise knowledge about the desert flora. Production changes has fluctuated between 0.01-0.025 *(kg C m^{-2} yr^{-1})* under the temporal of A2 scenario. In terms of rainfall under both scenarios, the desert production was 0.017 *(kg C m^{-2} yr^{-1})*, which is less than the annual average of the 2000s (Fig. 10c).

4 Discussions

Understanding the complex relationships between environmental factors effects on net primary production and biomass recoverable is essential to avoid over harvesting (leading to desertification) (Whitford, 2000) .In this study, the effects of climate change on net primary production of range, forest and desert landuses of Tehran province, Iran were studied. For this purpose, the NPP index derived from MODIS satellite images was used to monitor degradation over the period of 2001 to 2010 in each landuses. The scenarios of HADCM3 model also were used to investigate the climate changes. Climate assessment results showed that both A2 and B2 scenarios have the most similarity to actual amount of climate parameters.

The changes trend of temperature and precipitation variables were evaluated under each scenario by using the Mann-Kendall and Sen Slope estimator methods. The results showed that the rising trend of temperatures and reducing trend of rainfall were significant for both emission scenarios in the period of 2006 to 2099. The results are consistent with Haghtalab et al. (2013) findings in Tehran and Mazandaran. The annual production deviation to long-term average was used to study the NPP changes trend in each landuse. The results showed that more than 60 % of range lands in Tehran province have had production less than average by 2007. More than 80 % of the forests has had production less than the long-term average in half of the 2000s. More than 80 % of desert lands the amount of net primary production less than the average amount in the 2000s except in 2003. The results showed that net primary production in some areas of forest are equal or even less than the desert regions production in this decade. In some desert spots, there are some microclima that cause an increase in the net primary production, but certainly in most desert areas, the production is at the lowest amount in comparison with other landuses (Tietjen et al., 2010). According to the desertification definition (desertification is defined as the impairment or destruction of the biological potential of land) by Whitford (2002) and by comparing the results of the long-term average NPP in tree landuses of range, forest and desert (Fig.7), the desertification trend of forest and range can be considered in the 2000s in Tehran province. This result is consistent with Haghtalab et al. results (2013). In this study, the annual average rainfall and temperature variables were used as the most effective factors on net primary production to find a suitable relation between climate change and production in different landuses. The imaging of net primary production was done in range, forests and deserts landuses in Tehran province for the 2030s. The results showed that the amount of production has increased in the range lands under the rainfall and temperature pattern in A2 scenario that is consistent with the results of Reeves et al. (2014). But under B2 scenario, the production amount of ranges has declined. The temperature pattern in A2 emission scenario has the greatest influence on the variability of net primary production of forest landuse. The net primary production changes in the desert is pretty low under the rainfall pattern in both scenarios, and under the temperature pattern in the A2 scenario also change sinuously in a range of 0.01 to 0.025 ($kg\ C\ m^{-2}\ yr^{-1}$). The Notable point will happen for desert NPP in the 2030s; the net primary production level will be reached to zero from 2033 onwards. This situation would be logical only if there is no vegetation in desert areas and also has been completely destroyed in previous years for any reason. It is recommended that NPP illustration should not be done under the influence of one climate pattern such as temperature.

In this study, the temperature were detected as the most effective driving force of change in net primary production in the range, forest and desert ecosystems correspond with the results of Liang et al. (2015) in China. Rainfall variable have made fewer changes than temperature in these ecosystems.

5 Conclusions

The results indicate that NPP index can be used as the key criterion for monitoring the environmental features. This index shows the stress magnitude logging to the environmental characteristics, degree of stress which ecosystem can be exposed or degree of ecological response to the stress. The index of NPP has reduced in all natural areas of Tehran province. Also increasing trend production and reducing land degradation cannot be imagined under the terms of the climate emissions scenarios A2 and B2 in the region.

It is worth noting that, all models are as a simplification form of the reality and interpretation of the results depend on uncertainty, inputs and model assumptions. In this study, the issues related to climate scenarios verified properly on the basis of actual data. But due to lack of field measurement of net primary production in Iran, the validation of NPP amounts has not been done in the base period (2001-2010). Given the destruction continuity in arid and semi-arid area of Iran, determination of the destruction process and early warning systems are very important. This purpose can be obtained using monitoring and evaluating the systems with reasonable accuracy. Given that the monitoring function is a time consuming process, so it is recommended that terrestrial sampling of net primary production must be done in different landuses of Tehran province and generally in the whole country and adequate data should be provided for the status of each ecosystem in its geographical scope. So in the future they can be used to check the accuracy of satellite images results. This will cause costs reduction and saving time for monitoring of desertification trend in ecosystems through remote sensing method.

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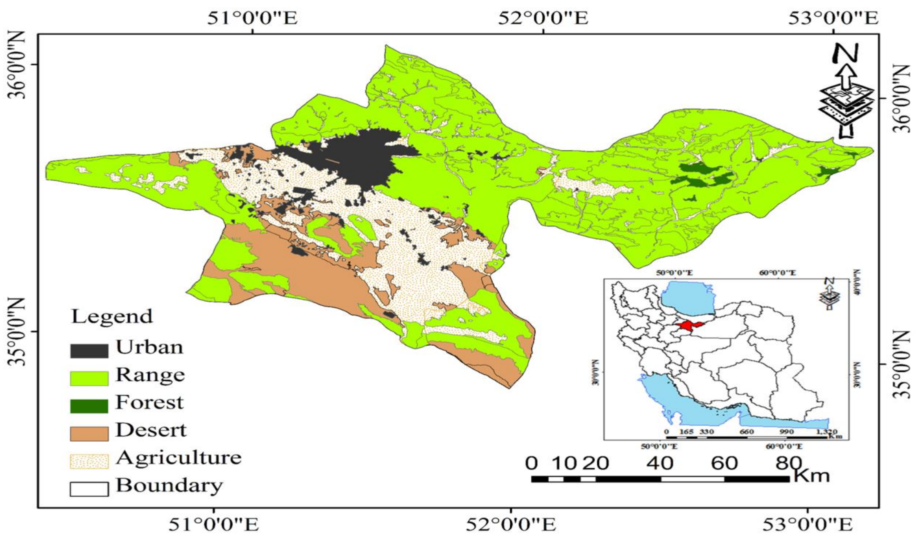

Figure 1. Location of Tehran and its different land uses

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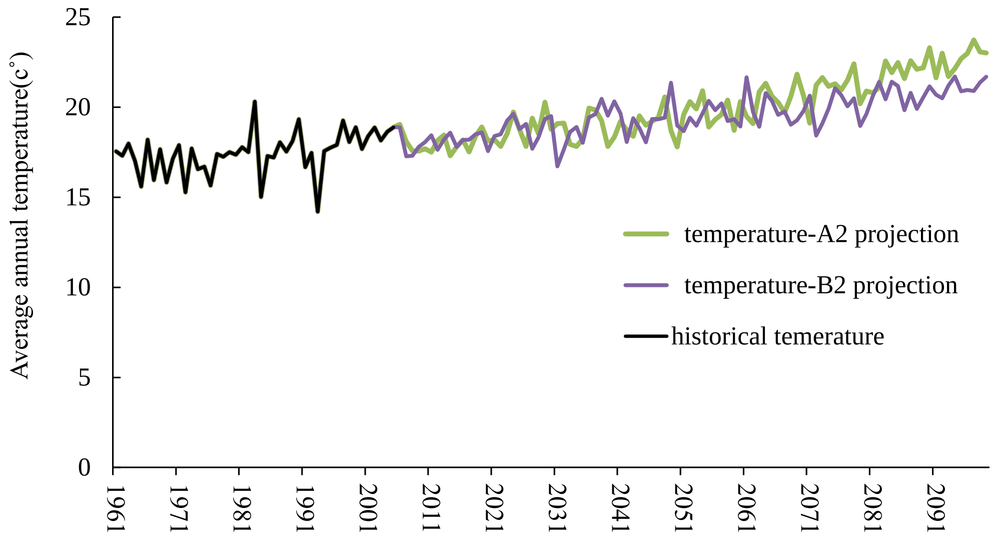
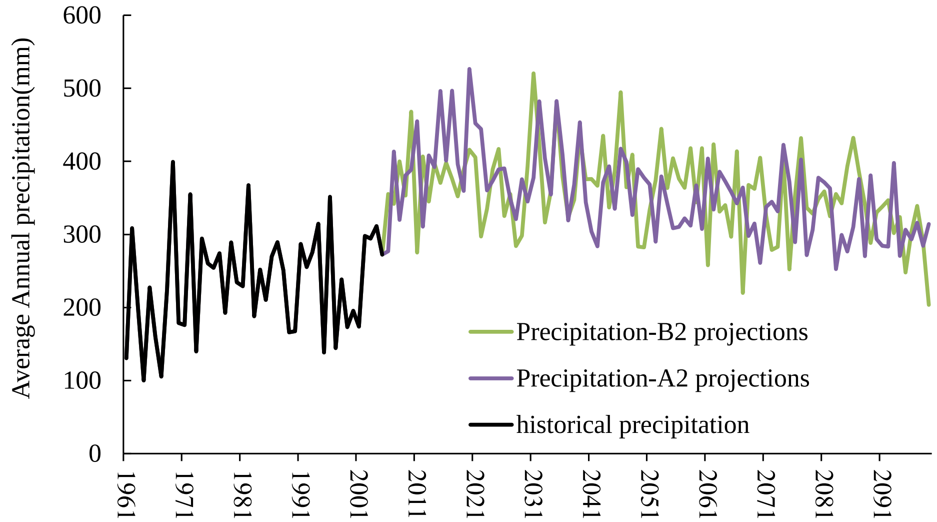


Figure 2. The average temperature in A2 and B2 scenarios for the synoptic station of Tehran



5 **Figure 3.** The average precipitation in A2 and B2 scenarios for the synoptic station of Tehran

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Figure 4. Percentage of changes in range land area or the deviation from the long-term average of net primary production. (0-40 c), (40-80 d), (80-120 e), (120-160f) and (160 <) are related to positive amount, Classes of (-40-0 b) and (<-40 a) are in relation to the amounts of decrease to the long-term average

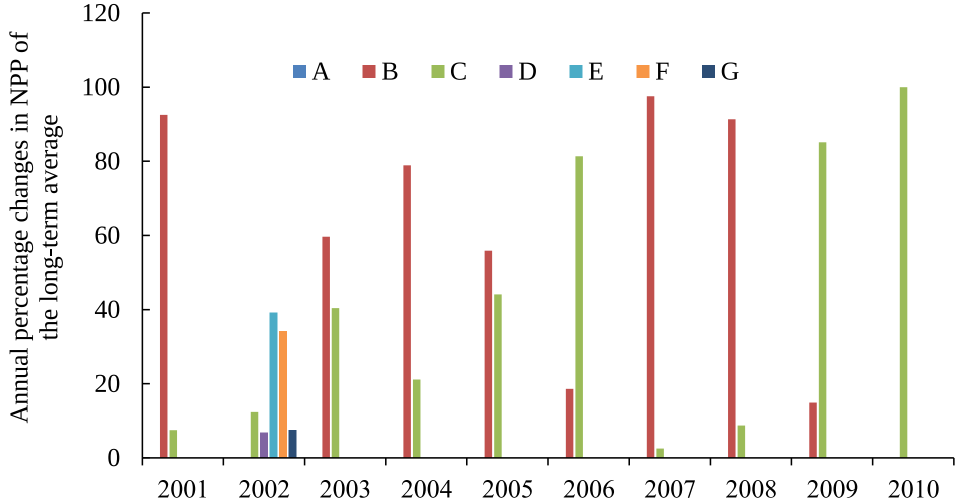

Figure 5. Percentage of changes in forest area or the deviation from the long-term average of net primary production

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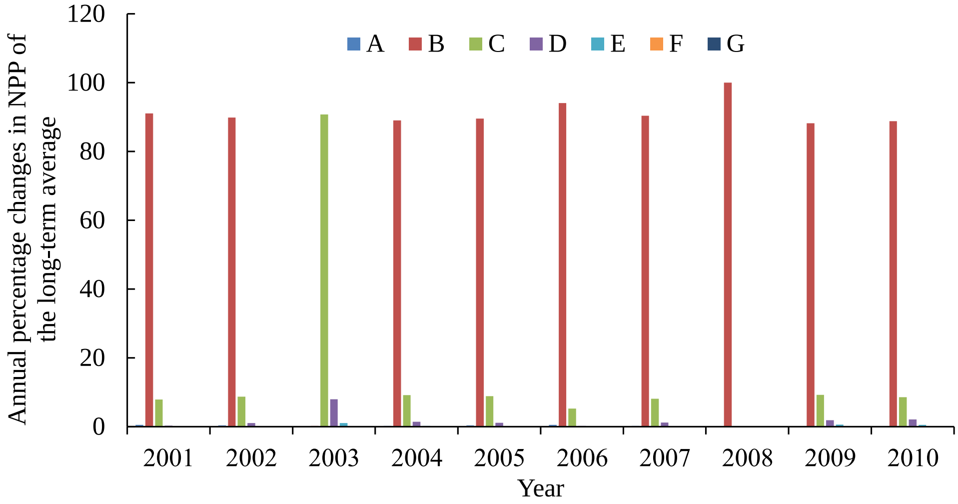

Figure 6. Percentage of changes in pasture land area or the deviation from the long-term average of net primary production

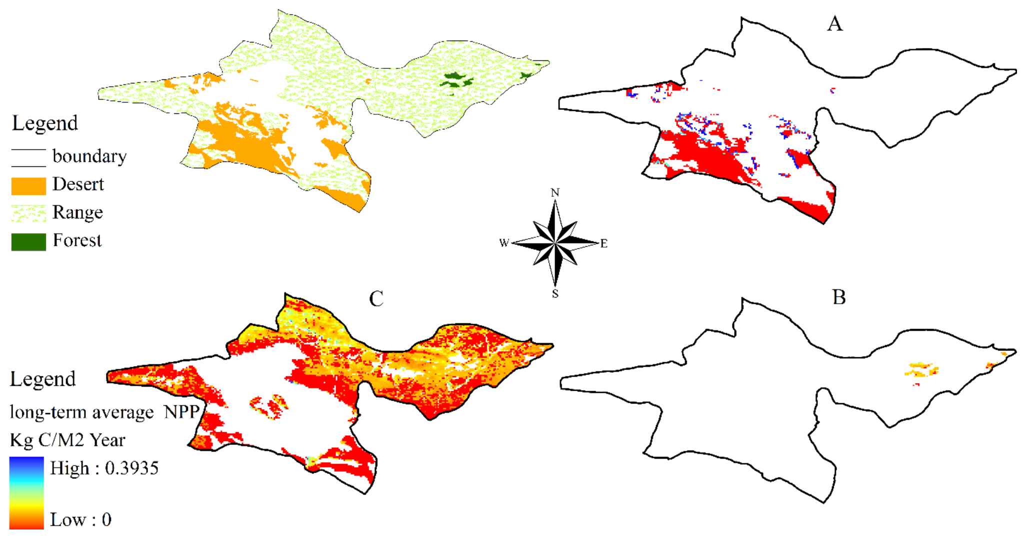

Figure 7. The long-term average of net primary production in deserts (A), forests (B) and ranges (C) landuses

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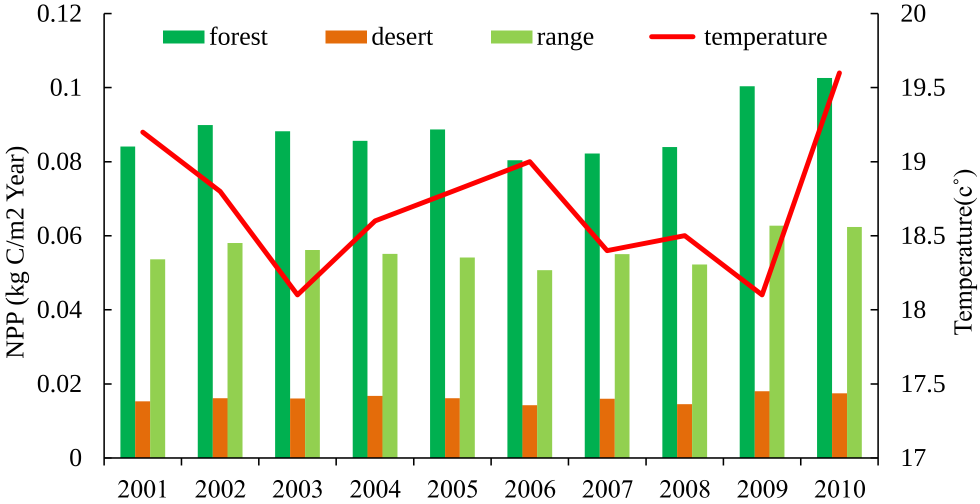
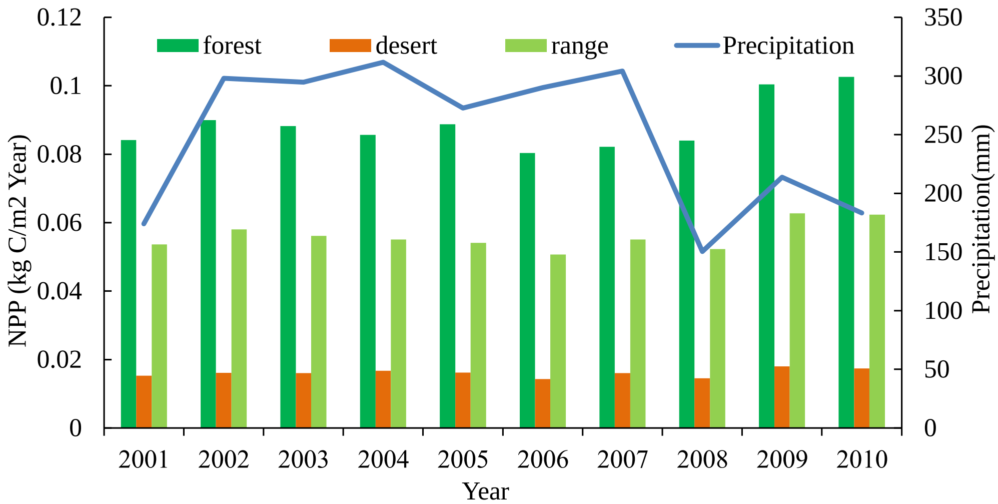


Figure 8. Average NPP changes of every landuse regarding the annual average temperature changes



5 **Figure 9.** Average NPP changes of every landuse regarding the annual average rainfall changes

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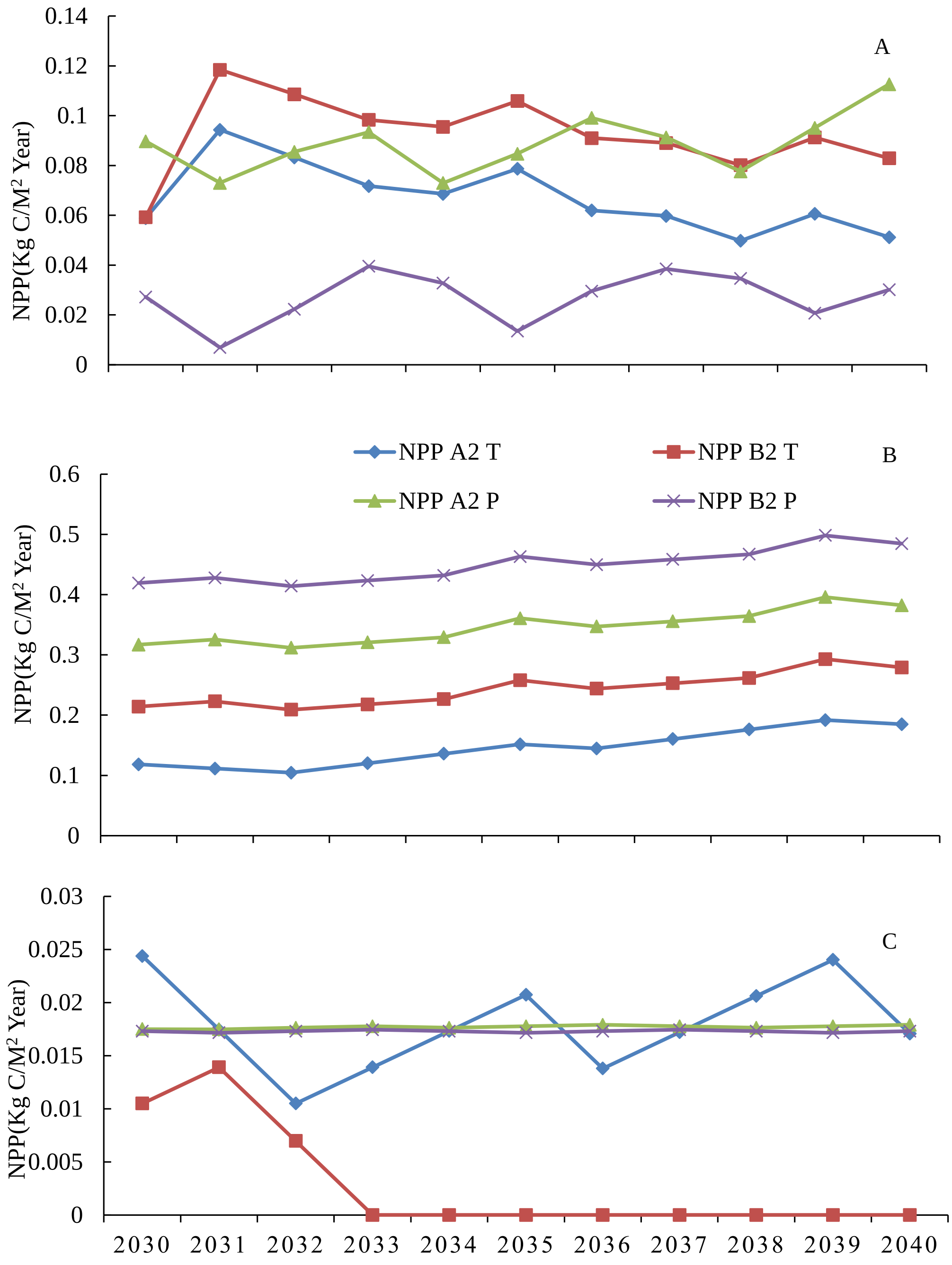

Figure10. The NPP annual average in range lands (A), forests (B) and deserts (C) in 2030, (NPP B2T) net primary production under the thermal pattern on B2 emission scenario, (NPP A2 T) net primary production of thermal under A2 emissions scenario, (NPP A2 P), the net primary production of thermal under A2 emissions scenario, (NPP B2 P), the net primary production model under thermal emission B2 scenario.

Table I. The amount of Z and trend slope of the temperature average in Tehran synoptic stations in 2006-2099

	Mann-Kendall trend	Sen's slope estimate

Time series	First year	Last Year	n	Test Z	Significant level	Slope trend
temperature-A2 projection	2006	2099	94	10.23	0.01	0.05
temperature-B2 projection	2006	2099	94	8.61	0.01	0.03

Table II. The amount of Z and trend slope of the rainfall average in Tehran synoptic stations 2006-2099

				Mann-Kendall trend		Sen's slope estimate
Time series	First year	Last Year	n	Test Z	Significant level	Slope trend
precipitation-A2 projections	2006	2099	94	-5.23	0.01	-1.12
precipitation-B2 projections	2006	2099	94	-3.11	0.01	-0.67