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Impacts of climate change on rangelands vegetation under different climate scenarios in Iran

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Abstract

Rangelands contribute to the livelihood of millions of people worldwide and are important providers of ecosystem services. These systems are potentially at risk of climate change; however, the extent and magnitude of the potential impacts are poorly understood. Climate change and its effects on temperature and rainfall are one of the most important human-environmental issues and have been the subject of many studies in recent years. In this study, evaluation of the effects of climate change on temperature and precipitation in Iran was performed using LARS-WG statistical microscale model under climate scenarios A2, A1B, and B1, based on the base period (1984-2013) and three future periods (2037-2011, 2069-2046, 2080-2099) were examined. For this purpose, after initial analysis of data from 33 synoptic stations using 5 general atmospheric circulation models (GCMs) including IPCM4, MPEH5, GFCM21, HADCM3 and NCCCS, under three emission scenarios A1B, A2 and B1, the minimum and maximum temperature parameters and precipitation were simulated. Also, the arithmetic means method was used for group execution of models and a comparison of means for minimum temperature, maximum temperature and precipitation parameters was performed by the LSD (least-significant-difference) method. The results of this study indicate that the minimum and maximum temperatures will increase in all stations by 2099. However, the amount of precipitation varies according to the station, period and scenario used and does not follow the same pattern as the temperature parameter. Given that changes in climatic variables can drastically impact biotic and abiotic processes in rangelands, using these results in natural resource and rangeland vulnerability management can help with reducing damage and preparing for exposure to the destructive effects of climate change.

Introduction

Rangeland systems are vulnerable to climate change. The dynamics of pasture vegetation, and thus livestock production, are very sensitive to climate, the average climate trend, and most importantly climate diversity. Rangelands' sensitivity to climate patterns has been identified at the global scale through modeling studies.

Pastures with high year-to-year precipitation variability support lower livestock stocking rates than less variable regions (Sloat et al 2018). Rising global average temperatures and increased temperature variations have been shown to be reliable indexes of climate change. Changes in climate parameters including precipitation and temperature will lead to consequences such as floods, droughts, and biodiversity and production loss (Asante et al.2014; Sayemuzzaman et al. 2014). The two important parameters studied under climate change are hydrology and water resources, and temperature and precipitation. The impact of climate change on these two parameters has been the subject of many studies, including general atmospheric circulation models, one of the best ways to estimate these effects.

In this study, the LARS-WG model was used to study the effects of climate change on meteorological drought. The LARS-WG model has been used for the microscopic survey of general circulation models to predict climate change and its effects (Akbari et al 2016; Bahri 2013; Jahantab 2012; Osman 2016; Nikbakhshahbazi 2017; Haghtalab et al. 2013). According to past research, the occurrence of climate change will have many effects, especially on the climatological and hydrological parameters in a region; therefore, it is necessary to investigate the effects of climate change on the climate parameters and hydrology of basins in future periods (Nazari Poya et al. 2016; Jahanbakhsh et al. 2016). Given that climate change driven changes are themselves subject to variation in time and space, it is necessary to separately evaluate how these changes occur differently in different basins. Deeper understanding of the interplay between climatic variables and biological processes depends partly on a more detailed understanding and more reliable predictions of how changes in climate can impact biological elements such as vegetation. Recent studies predict climate change will contribute to increased prevalence of wildfires and abundance of invasive species in rangeland ecosystems. Decreased precipitation might also alter the species composition in rangelands towards more drought tolerant species (Reeves et al. 2018). Such findings show how a clear understanding of future climate change can contribute to sustainable management of natural ecosystems such as rangelands in the face of climate change. Therefore, in the present study, the effect of climate change on climatic variables of temperature and rainfall were studied in 33 synoptic stations in Iran using five general circulation patterns including IPCM4, MPEH5, GFCM21, HADCM3 and NCCCS under climatic scenarios A_2, A_1B and B_1. Climatic parameters including rainfall and temperature are the most important factors affecting vegetation and rangeland production. Therefore, attention to rainfall and temperature is important in rangeland management.

Methods and Study Site

Iran is located in Southwest Asia between 25° to 40° N and 44° to 64° E, with an area of 1648195 square kilometers. Data on daily minimum and maximum temperature, daily radiation, and precipitation for 33 synoptic stations in the country (Fig.1) were obtained from Iran’s Meteorological Organization and was pre-processed. Stations with a common statistical period of 30 years were used for statistical analysis. A common statistical time base was considered from 1984 to 2013, then a homogeneity test was performed for the selected synoptic stations using the runs test method and incomplete data were reconstructed. For this purpose, the data of the 33 synoptic stations were simulated using the LARS-WG statistical microscale model of the parameters considered in the previous statistical periods and future climate. The LARS-WG model consists of three main parts: calibration, evaluation and production or simulation of meteorological data for the coming decades. In the calibration stage, the model uses a file containing past conditions. Using the daily data for precipitation, minimum temperature, maximum temperature and radiation, the synoptic stations were studied by considering 1984-2013 as the basic period. Based on five GCMs models (IPCM4, MPEH5, GFCM21, HADCM3, and NCCCS) under three emission scenarios (A_1B, A_2, and B_1) precipitation, minimum temperature, maximum temperature, and radiation were predicted for future three periods (2011-2030, 2040-2069, and 2070-2099), shown in the results with the abbreviations F1, F2 and F3, respectively.

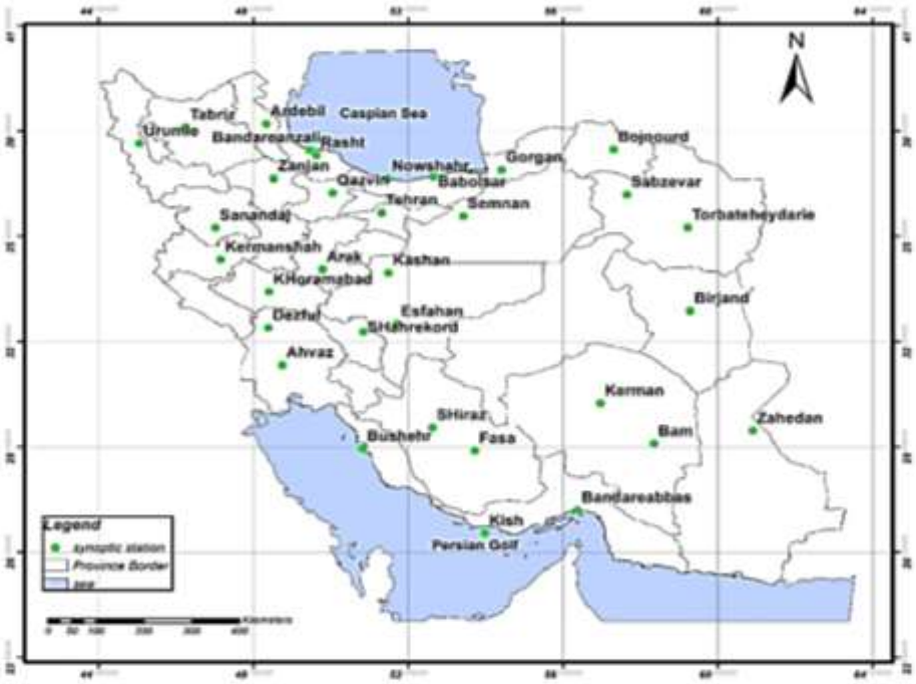

Figure 1. location of the studied stations

Running models and comparison of means

According to the latest IPCC recommendation, the use of multiple models in climate simulations, rather than the individual implementation of models, can be effective in reducing uncertainties in the model. As a result, the arithmetic mean for the results of the five GCMs mentioned above was calculated in R to analyze climatic changes. Finally, the comparison of average minimum temperature, maximum temperature, and rainfall with the base period was done using the LSD method in SAS.

Results

Temperature Changes in the future under different scenarios

The difference between the average value and the base period (1984-2013) showed the greatest increase in the minimum and maximum temperature in scenario A_2 during the period 2070-2099 (F3) for all stations. At the Arak, Ahvaz, Bam, Bandar Abbas, Birjand, Bushehr, Dezful, Isfahan, Fasa, Kashan, Kerman, Kermanshah, Khorramabad, Kish, Sabzevar, Sanandaj, Semnan, Shahrekord, Shiraz, Torbatt Heydarieh and Zahedan stations (most of which have a warm and dry climate), the least effect on minimum and maximum temperature was observed in scenario B_1 during the period 2011-2039. Scenario A_2 during the period 2011-2039 (F1) had the least effect on the minimum and maximum temperature at Ardebil, Urumieh, Zanjan, and Tabriz stations (which have a cold and humid climate). Comparison of the mean of climate scenarios showed that scenario A_1B during the period 2011-2039 (F1) predicts the least effect on the minimum and maximum temperatures in Babolsar, Bandar Anzali, Bojnourd, Gorgan, Noshahr, Qazvin, Rasht, and Tehran stations. The diagrams for two stations are presented as examples. For all stations, predictions for minimum and maximum temperatures made under all scenarios show an increase by 2099 in comparison with the base period.

Changes in rainfall in the future under different scenarios

The results show that in 16 stations (Ahvaz, Bam, Bandar Anzali, Birjand, Bojnourd, Bushehr, Fasa, Gorgan, Kashan, Qazvin, Rasht, Sanandaj, Semnan, Shahr-e-Kord, Tehran, and Zahedan) estimated future periods of precipitation disagreement do not have a meaningful base course. Under the A_2 scenario and compared to the base period, rainfall was predicted to increase at Arak (69.52%), Ardebil (3.19%), Kish (30.52%) and Sabzevar (1.00%) stations and to decrease at Babolsar (3.68%) and Urmia (2.55%) stations over the 2011-2040 period. According to the A_1B scenario during the 2011-2040 period, precipitation in Arak (65.3%), Ardebil (2.36%) and Khorramabad (12.74%) stations were higher than the base period. Also, precipitation for Babolsar (3.7%), Esfahan (15.9%) and Urmia (6.63%) stations was significantly lower than the base period. According to the B_1 scenario, during this period rainfall was lower at Arak (70.12%), Ardebil (2%), Bandar Abbas (28.49%), and Khorramabad (19.91%) stations and was significantly higher at Babolsar station (30.04%) compared to the base period. The largest decrease was observed in scenario B_1. Due to the large number of synoptic stations, the results are presented in a graph for each parameter (Figures 2 and 3).

At Arak (76.56%), Dezful (26.58%), and Khoramabad (19.29%) stations, precipitation increased from the baseline in scenario A_2 during 2046-2065; at Babolsar, Noshahr, and Urumia stations precipitation decreased by 6.35, 5.98 and 12.65% respectively. Based on the A_1B scenario during this period, precipitation in Babolsar (9.1%), Isfahan (16.66%), Kermanshah (14.84%), Noshahr (9.25%), Sabzevar (9.56%), Torbat Heydarieh (11.4%), and Urmia (14.7%) stations is significantly lower than the base period. The B_1 scenario during this period had the least effect on rainfall estimation for the upcoming periods, and only in two stations (Arak and Ardebil) there was a significant increase (61.07% and 3.8% respectively).

Also, in the B_1 scenario during 2080-2099, precipitation at Babolsar (8.79%), Isfahan (20.45%), Kerman (16.07%), and Noshahr (9.75%) stations was lower than the base period, and was significantly higher at Arak station (52.7%). In the A_2 scenario during the 2080-2099 period, precipitation at Babolsar (8.6%), Kermanshah (22.05%), Noshahr (10.72%), Sabzevar (11.61%), Sanandaj (15.41%), and Tabriz (15.22%) stations was less than baseline and significantly higher (30.8%) than the baseline at Khoramabad station. The results of analysis of variance for rainfall data under the A_1B scenario during the 2080-2099 period (F3) showed a significant difference at Babolsar (6.64%), Isfahan (14.31%), Kermanshah (15.2%), Noshahr (7.97%), Tabriz (11.51%) and Urumieh (29.18%) stations, less than that of the base period and more than that of Arak station (54.38%). The average of the baseline period (1984-2013) at all stations had the highest effect on minimum and maximum temperature in scenario A_2 during 2070-2099 (F3).

Rainfall in the A_1B scenario was higher than the base period (1984-2013) at synoptic stations in Ardebil, Isfahan, Babolsar, Bam, Bandar Abbas, Birjand, Bojnourd, Dezful, Fasa, Gorgan, Kashan, Kerman, Kermanshah, Noshahr, Sabzevar, Semnan, Shiraz, Tehran, Torbat Heydarieh, Urumia, and Zanjan. Rainfall will be lower at Ardebil, Babolsar, Bandar Abbas, Birjand, Bojnourd, Isfahan, Fasa Gorgan, Kashan, Kerman, Kermanshah, Noshahr, Sabzevar, Semnan, Tehran and Torbat Heydarieh stations during 2046-2069. Also, at Arak, Khorramabad, Kish, Qazvin, Rasht, Bandar Anzali, Sanandaj, Shahrekord, Tabriz and Zahedan stations, rainfall increased over the 2011-2039 period (F1) compared to the base period and 2040-2069 (F2), and 2070- 2099 (F3).

Scenario A_2 estimates the precipitation at Arak, Bam, Bandar Abbas, Shiraz and Zahedan station to be more than the base period in all future periods. This scenario predicts a decrease in precipitation for stations in Ahvaz, Bandar Anzali, Bushehr, Dezful, Fasa and Shahrekord during 2070-2099 (F3). Also, rainfall at Babolsar, Isfahan, Kashan, Kerman, Kermanshah, Noshahr, Semnan, Torbat Heydarieh, Tehran, Urmia and Zanjan stations will decrease compared to the base period, this decrease will the most severe over the 2070-2099 (F3) period . The scenario also predicts that precipitation levels in Ardebil, Bojnourd, Gorgan, Qazvin, Sabzevar, Sandjeh and Tabriz stations will increase during 2011-2039 (F1) compared to the base period and will decrease in future periods.

Scenario B_1 estimates that the precipitation at Birjand, Isfahan, Kashan, Kerman, Kermanshah, Noshahr, Semnan, Tehran, Torbat Heydarieh and Urmia will be less than the base period in all future periods, with 2070-2099 (F3) showing the greatest reduction. Also, this scenario predicts an increase in precipitation during 2070-2099 (F3) for Ahwaz, Ardebil, Bandar Anzali, Bushehr, Fasa, Kish, Sanandaj, Shahrekord, Tabriz and Zahedan stations. However, precipitation will decrease compared to the base period in other periods. In the Arak, Bam, Dezful, Khorramabad, Qazvin, Rasht, and Shiraz stations rainfall will increase compared to the base period. This scenario predicts that during 2040-2069 (F2) precipitation will increase at Babolsar, Gorgan, Sabzevar and Zanjan stations relative to the base period and will decrease in other periods (Figures 2 and 3).

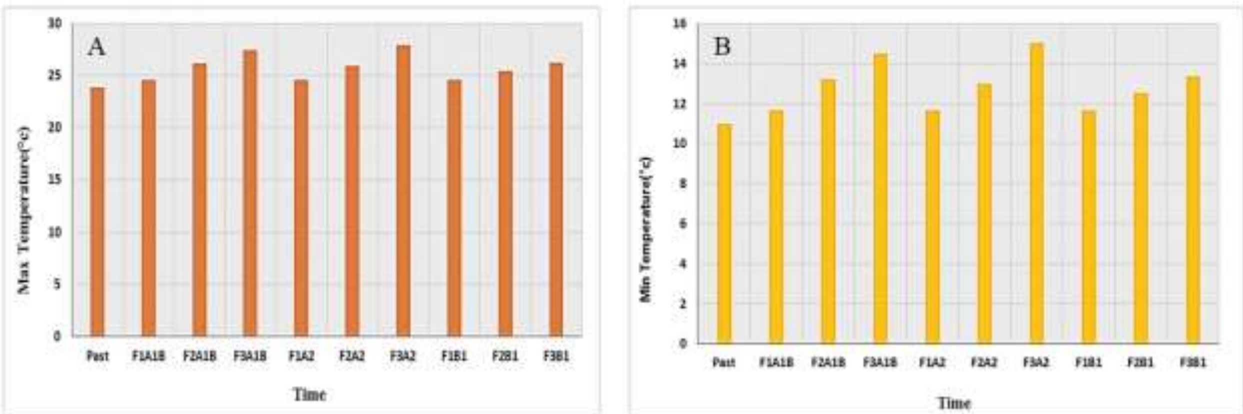

Figure 2. Comparison of maximum (A) and minimum (B) temperature for stations in the past and under different future scenarios

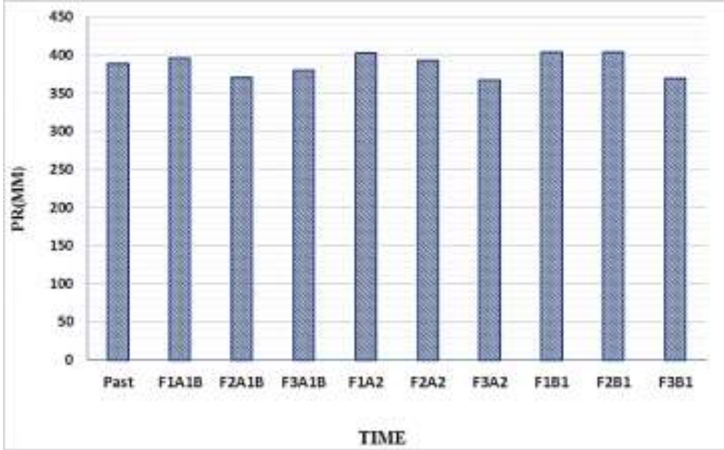

Figure 3. Comparison of precipitation for stations in the past and under different future scenarios

Discussion and Conclusion

Climate change and its effects on ecosystems are among the most important challenges of the forthcoming century. In this research, changes in temperature and rainfall by the end of the century were evaluated under five models and three scenarios using a group of models based on data from selected stations in Iran. The present research evaluated the effects of climate change on temperature and precipitation under different climate scenarios in Iran using the LARS-WG general flow model for 33 synoptic stations using data from 1984 to 2013 as well as an average comparison for all stations. Overall, the results show that the minimum and maximum temperature will increase at all stations; however, depending on the station, the period, and the scenario used, the rate varies and does not follow a general pattern.

The findings of this study can be used to predict the variation in vegetation cover across the study area since drought and reduced precipitation can affect the growth and development of plants and change the relationships between climatic variation and changes in vegetation cover (Joneidi et al 2021). A focus on vulnerability and resilience accompanied by monitoring and assessment of observable conditions on the ground can supplement the information provided by climate projections and help provide the critical information required by managers to adaptively manage rangelands under uncertain climate futures.

The results show that climate change causes changes in temperature and rainfall parameters in the country, but the rate of change and its effects vary in different regions. We observed some variability within the general increasing trend in temperature in Iran which will lead to harmful effects, especially on the water cycle. In general, changes in rainfall and temperature due to climate change will reduce rainfall and increase runoff on the one hand, and reduce vegetation on the other, which in turn adversely impacts the amount of pasture forage. Projected temperature increases are expected to increase evaporative demand and pose greater overall stress (Polley et al. 2013). Despite the lack of focused studies on the effects of climate change on rangeland vegetation and the considerable uncertainty in projections, there are a few elements of climate change that are increasingly recognized as potential outcomes. Predicted changes in rainfall and temperature patterns could lead to reduced vegetation and increased rangeland vulnerability (Morgan et al. 2008). These changes will lead to drier soils, particularly in summer when plants are physiologically active (Polley et al. 2013; Bradford et al. 2014; Palmquist et al. 2016). However, winter precipitation is projected to increase 10–

20% (Reeves et al. 2018), which may compensate for increasing droughts. As a result, changes in temperature and precipitation under different scenarios will make rangelands susceptible to erosion. Recent studies have shown how changes in climatic variables such as precipitation can drastically impact biological variables in rangelands such as vegetation cover (Joneidi et al 2021). Such changes can spill over into other concerns about the future of rangeland ecosystems by dramatically affecting the ability of rangelands to provide goods and services to the society, and in extreme cases rendering activities such as ranching unsustainable (Holechk et al. 2020). Therefore, it is essential to have dependable climate projections when developing strategies and plans for the management of natural ecosystems, including rangeland ecosystems. The inadequate density of stations, especially in the eastern part of the study area, could be one of the limitations of this study, and future works should incorporate more detailed inputs in order to enhance the results of modelling. Using these results in natural resource and rangeland vulnerability management can help with reducing damage and preparing for exposure to the destructive effects of climate change. In general, studies indicate that Iran will be exposed to climate change and the effects of rising temperatures and possibly lower rainfall over the coming years. Managers can mitigate these effects through proper rangeland management planning and crisis prevention.

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