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Precipitation analysis over southwest Iran: trends and projections

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Abstract Analysis of trends and projection of precipitation are of significance for the future development and management of water resource in southwest Iran. This research has been divided into two parts. The first part consists of an analysis of the precipitation over 50 stations in the study region for the period 1950–2007. The trends in this parameter were detected by linear regression and significance was tested by t test. Mann–Kendall rank test was also employed to confirm the results. The second part of the research involved future projection of precipitation based on four models. The models used were Centre National de Recherches Meteorologiques (CNRM), European Center Hamburg Model (ECHAM), Model for Interdisciplinary Research on Climate (MIROCH) and United Kingdom Meteorological Office (UKMOC). Precipitation projections were done under B1 and A1B emissions scenarios. The results of precipitation series indicated that most stations showed insignificant trend in annual and seasonal series. The highest numbers of stations with significant trends occurred in winter while no significant trends were detected by statistical tests in summer precipitation. No decreasing significant trends were detected by statistical tests in annual and seasonal precipitation series.

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The result of projections showed that precipitation may decrease according to majority of the models under both scenarios but the decrease may not be large, except according to MIROCH model. Autumn precipitation may increase with higher rates than other seasons at the end of this century.

1 Introduction

Changes in climate have had significant impacts on ecosystems, environments, water resources, as well as the health of human beings during the past several decades (Zhang et al. 2005). The rise in temperature and its associated effects, both direct and indirect, have caused countless problems throughout the world, specifically social, economic and environmental problems (Karaburun et al. 2011). Global warming causes snow cover retreat and changes in the patterns of precipitation in the world. Trend identification has become important for climatologists to investigate precipitation series and improve climate impact research. Variations in precipitation over daily, seasonal, annual, and decadal time-scales influence water balance. Thus, it is important to understand recent changes in precipitation patterns as part of the long-term behavior of these processes, e.g., to predict changes in other hydrological processes. Therefore, it is important to investigate the changes in precipitation data and give projections for the future. Increasingly reliable regional climate change projections are now available for many regions of the world due to advances in modeling and understanding of the physical processes of the climate system (IPCC 2007). The changes in projections of precipitation are not certain, but these projections are critical for decision-making

regarding water resources in the future. In Iran, investigations of trend analysis and projections of precipitation are not receiving enough attention despite serious environmental, agricultural and water resources problems. Trend analysis and projections regarding precipitation have become important both locally and globally in the last few decades.

Trend analysis and projections of precipitation series have been investigated by many researchers throughout the world (Zhang et al. 2005; Partal and Kahya 2006; Feidas et al. 2007; Larsen et al. 2009; Roy et al. 2009; De Lima and De Lima 2009; Karpouzos et al. 2010; Obot and Onyeukwu 2010; Revadekar et al. 2011; Yilmaz et al. 2011). Analysis of precipitation data has been attempted by various Iranian scientists. A study by Boroujerdy (2008) for the period 1960–2001 indicated that annual precipitation had a decreasing trend at stations in the west, northwest and southeast, whereas increasing trend was registered in other parts of the country. Decreasing the data length to last 30 years, Shirgholami and Ghahraman (2005) found that very few stations registered significant trend in precipitation. Investigation of variability in annual rainfall, number of rainy-days per year and monthly rainfall in arid and semi-arid regions of Iran did not show any significant climate variability during the period 1950–2004 (Modarres and da Silva 2007). Recently, Tabari et al. (2012) investigated spatio-temporal characteristics of drought and rainfall in arid and semi-arid regions of Iran for the period 1966–2005. For the same time period, based on precipitation and evapotranspiration trends, Tabari and Aghajanloo (2013) evaluated variations in aridity index in Iran. Using effective sample size method to eliminate the effect of lag-1 serial correlation in the Mann–Kendall test, Tabari and Hosseinzadeh Talaee (2011) observed significant negative trend during 1966–2005 in annual precipitation at seven stations. Delju et al. (2013) found an increase of 9.2 % (from 1966 to 2005) in mean precipitation of Urmia lake basin. Other studies related to rainfall are reported by Soltani et al. (2011) and Rahimzadeh et al. (2009). Survey of variability in precipitation and other climatic variables in Iran in the period 1951–2009 is also found in research carried out by Raziei et al. (2013). Future projection of precipitation by Roshan and Grab (2012) based on the MAGICC/SCENGEN 5.3 compound model revealed that by the year 2100 the mean precipitation may increase by 36 % relative to that for 1961–1990.

While forming national policies, details of changes at regional level can give additional information which could prove to be significant for policy makers. Therefore, this study is aimed at investigating spatio-temporal changes over southwest Iran, which is also an important water resource area for the country. Some earlier studies in Iran were carried out for the country as a whole and others for some specific areas. Razei (2008) employed data of 170 stations for western Iran. Boroujerdy (2008) utilized 38 stations for the whole of Iran. Shirgholami and Ghahraman (2005) used 34 synoptic stations for the whole of Iran. Modarres and da Silva (2007) considered 20 stations for trend detection in arid and semi-arid regions of Iran. Tabari et al. (2012) employed 10 stations for the eastern half of Iran. Tabari and Hosseinzadeh Talaee (2011) used 41 stations for the whole of Iran. Rahimzadeh et al. (2009) used 27 stations for the whole country. Thus, it is understood that even for country as a whole researchers have used between 20 and 40 stations for trend analysis. In the present study, data of 50 stations have been analyzed to study rainfall variability over southwestern Iran. More number of stations would help in understanding regional variability much better. Most of the earlier studies, except few (for example, Roshan and Grab 2012), concentrated on trend detection, whereas in this paper both trend detection and future projections have been attempted. Though some research has been carried out on future projections, it is essential that more efforts should be taken to project future scenarios using different models which can help in making generalizations over specific areas. This study will be one of the contributions in this direction. In this study, future projections of precipitation changes are done using four models and two scenarios, whereas earlier study considered only one scenario. Trend analysis for precipitation change was done at annual and seasonal scale. Models used for future projections were Centre National de Recherches Meteorologiques (CNRM), European Center Hamburg Model (ECHAM), Model for Interdisciplinary Research on Climate (MIROCH) and United Kingdom Meteorological Office (UKMOC) under B1 (lowest) and A1B (medium) emission scenarios. The B1 emission scenario also known as the 550-ppm stabilization experiment envisions the slowest growth of anthropogenic greenhouse gas concentrations, followed by the A1B experiment, or the 720-ppm stabilization experiment, with somewhat more rapid forcing (IPCC 2007). Kripalani et al. (2007a, b) and Sabade et al. (2010) have outlined more details of the models used in the study.

2 Methodology

2.1 Study area and data

The study area covers southwestern part of Iran, particularly the provinces of Isfahan, Chaharmahal and Bakhtiari, Kohgiluyeh and Boyer-Ahmad, Lorestan and Khuzestan. The region is spread over 231,547 km^2, which is about 14 % of the country's area. The latitudinal extent of the area is from 29°56′ to 31°9′ northern latitude and the longitudinal extent is from 51°25′ to 55°33′ eastern
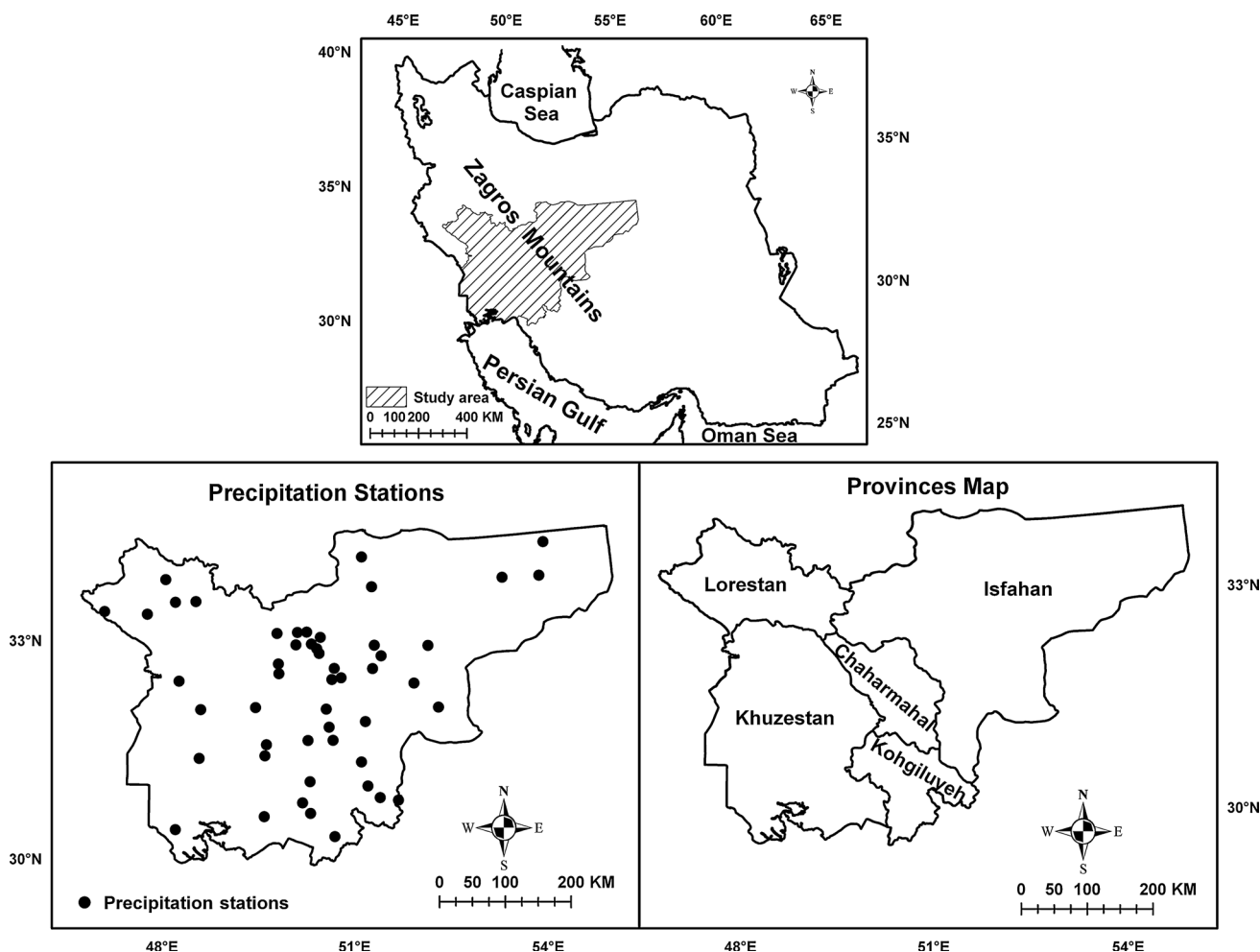
Fig. 1 Location of the study area, provinces and spatial distribution of the stations

longitude. The population of region is 11,768,150 persons, which is about 17 % of the total country's population. From geological point of view, this region can be divided into eastern and western plains, south western plain and the Zagros Mountain range. The elevation ranges from 0 m in the coast of the Persian Gulf to over 4,430 m in the Dena Mountain.

The precipitation data for the period between 1950 and 2007 for 50 stations obtained from Islamic Republic of Iran Meteorological Organization (IRIMO) and Iranian Water Resources Management Organization were considered for statistical analysis. Spatial distribution of the 50 stations is illustrated in Fig. 1 and data availability is presented in Table 1. Monthly precipitation data were used to construct seasonal and annual series for every station. Seasons were defined as follows: winter (January, February, March), spring (April, May, June), summer (July, August, September) and autumn (October, November, December).

The data for the stations were carefully analyzed for homogeneity and for missing data. For homogeneity test,

we applied the standard normal homogeneity test (Alexandersson 1986) Pettitt's test (Pettitt 1979) and the standard normal homogeneity test by Alexandersson and Moberg (1997). The result of the homogeneity test indicated that the data are fairly homogeneous.

2.2 Statistical analysis

For spatial and temporal computations of precipitation trend linear regression analysis, t test and Mann–Kendall rank test (MK test) were applied. The presence of a monotonic increasing or decreasing trend was analyzed by the MK test, a non-parametric test. Linear regression was used to find trends and rate of change in precipitation over time.

2.2.1 Linear regression

The linear regression method was used to find long-term trends in precipitation series. In the present study, the magnitude of the trends was derived from the slope (value

Table 1 Geographic characteristics of the stations used in the study

Station	Latitude (N)	Longitude (E)	Altitude (m a.s.l)	Length of recorded period	Type of station
Ab Shirin	30°51′	50°40′	380	39	Rain gauge station
Abadan	30°36′	48°25′	6	56	Synoptic
Abyaneh	33°56′	51°58′	2,234	29	Climatology
Agh Mal	32°58′	50°00′	1,100	30	Rain gauge station
Ahwaz	31°33′	48°66′	22	50	Synoptic
Aminabad	32°76′	51°56′	2,050	30	Rain gauge station
Anarak	33°56′	53°71′	1,050	40	Rain gauge station
Armand	31°68′	50°76′	1,050	36	Rain gauge station
Aznaveleh	33°00′	50°00′	2,400	41	Rain gauge station
Badijan	33°00′	50°33′	2,300	31	Climatology
Barez	31°51′	50°41′	825	35	Rain gauge station
Batari	30°85′	51°33′	1,520	39	Rain gauge station
Behbahan	30°66′	50°28′	333	39	Rain gauge station
Bi bi jan Abbad	30°18′	50°76′	400	40	Rain gauge station
Chelgard	32°45′	50°00′	2,400	39	Rain gauge station
Deh e Sadat	31°48′	49°75′	450	30	Rain gauge station
Deh Molla	30°50′	49°66′	32	40	Rain gauge station
Dezful	32°40′	48°38′	143	46	Synoptic
Emam Gheis	31°73′	51°35′	2,195	43	Climatology
Endack	30°95′	50°41′	560	37	Rain gauge station
Faridan Chadegan	32°76′	50°63′	2,100	31	Climatology
Faridan Damaneh	33°00′	50°48′	2,300	42	Climatology
Isfahan	32°61′	51°06′	1,550	56	Synoptic
Isfandaran	31°86′	52°53′	1,520	29	Rain gauge station
Jandagh	34°00′	54°43′	1,200	43	Rain gauge station
Jo Kang	31°33′	49°71′	330	40	Rain gauge station
Kalbal	32°83′	50°30′	2,290	31	Rain gauge station
Kashan	33°98′	51°45′	982	40	Synoptic
Kashkan Afrineh	33°33′	47°90′	820	40	Rain gauge station
Kelishadorokh	32°35′	51°00′	2,050	41	Rain gauge station
Kesht Karoon	32°00′	48°71′	59	31	Climatology
Keta	31°18′	51°25′	1,600	34	Rain gauge station
Khorremebad	33°48′	48°36′	1,125	56	Synoptic
Kordeolya	32°91′	50°70′	2,350	39	Rain gauge station
Kouhpayehe	32°71′	52°43′	1,800	41	Rain gauge station
Lordegan	31°50′	50°81′	1,580	37	Rain gauge station
Mansoorkhani	30°63′	51°80′	2,100	40	Rain gauge station
Naghan	31°93′	50°73′	2,400	41	Rain gauge station
Neyestanak	33°55′	54°31′	1,000	40	Rain gauge station
Peykan	32°21′	52°16′	1,300	41	Rain gauge station
Pol zamankhan	32°48′	50°90′	1,810	43	Climatology
Razveh	32°83′	50°55′	2,200	31	Rain gauge station
Sad e Abasspour	32°00′	49°60′	820	37	Rain gauge station
SarabeSeyed Ali	33°80′	48°21′	1,520	40	Rain gauge station
Shah Mokhtar	30°68′	51°51′	1,730	39	Rain gauge station
Shahre Kord	32°33′	50°85′	2,061	51	Synoptic
Tad	32°45′	51°51′	1,700	41	Rain gauge station
Tangeh Seayab	33°38′	47°20′	880	36	Rain gauge station
Yanchesh	32°70′	50°66′	2,100	31	Rain gauge station
Zefreh	33°48′	48°70′	2,000	49	Rain gauge station

Table 2 Climate models and their key references participating in the IPCC AR4 experiments

No.	Originating group	Country	IPCC ID	Abbreviation	References
1	Meteo-France = Centre National de Recherches Meteorologiques	France	CNRM-CM3	CNRM	Salas-Melia et al. (2006)
2	Max Planck Institute for Meteorology	Germany	ECHAM5/MPI-OM	ECHAM	Jungclaus et al. (2006)
3	Center for Climate System Research (The University of Tokyo) National Institute for Environmental Studies and Frontier Research Center	Japan	MIROC3.2(hires)	MIROCH	K-1 Model Developers (2004)
4	Hadley Centre for Climate Prediction and Research = Meteorological Office	UK	UKMO-HadCM3	UKMOC	Jones et al. (2004)

of 'b') of the regression line. The value of 'b', which represented the rate of change per year for the climatic parameter under consideration was further multiplied by 10 to find the decadal change. These trends were then tested for statistical significance by employing t test.

2.2.2 Mann–Kendall rank test

The MK test is widely used to detect significant trends in meteorological parameters. It is a non-parametric test, suitable for data that do not follow normal distribution. In this study, it is used to find temporal changes in annual and seasonal series. It also served the purpose of confirming the results obtained by linear regression. The value of τ (Mann–Kendall rank statistic) can be used as the basis of a significant test by comparing it with:

$$\tau = 0 \pm t_g \sqrt{\frac{4N + 10}{9N(N - 1)}},$$

where t_g is the desired probability point of the Gaussian normal distribution. In the present study, t_g at 0.05 point has been taken for comparison.

The results of the linear regression and MK test were tested at 95 % confidence level.

2.3 Model outputs

The IPCC standard output from coupled ocean atmosphere GCMs was collected and archived by the WGCM (Working Group on Coupled Models) Climate simulation panel and the Program for Climate Model Diagnosis and Intercomparison (PCMDI) at the Lawrence Livermore National Laboratory, USA. The coupled climate models, whose data were available, along with key references are listed in Table 2. The major components of the coupled models such as atmosphere, ocean, sea ice, land and vegetation were interactive, while the interaction of other components such as atmospheric chemistry, biogeochemistry, and aerosols varies from model to model. Most of these models did not use surface flux corrections at the ocean–

atmosphere interface (Kripalani et al. 2007b). The projection of precipitation over southwestern Iran was done under B1 (lowest) and A1B (medium) emission scenarios. Four models were used which are CNRM, ECHAM, MIROCH and UKMOC. Climate Modeling groups around the world had performed comprehensive, systematic, well designed and well-coordinated set of 20th to 22nd century climate change experiments for the IPCC AR4 (Inter-governmental Panel on Climate Change Fourth Assessment Report). Twenty-five modeling groups around the world participated in this exercise. Most of these models were unable to simulate monsoon variability over the Asian domain. Only a few models were able to simulate reasonably well this variability (Kripalani et al. 2007a, b). We selected these four models, which simulate monsoon variability over the Asian domain reasonably well. Furthermore, these models represent leading international groups: CNRM from France, ECHAM from Germany, MIROCH from Japan and UKMOC from the United Kingdom. Future projections from these models were simulated for the period 1981–2100. One of the previous studies carried out for Iran used MAGIC/SCENGEN 5.3 compound model using single scenario known as P50, which is the average of SRES or emission scenarios (Roshan and Grab 2012). Such approach is also advisable, but we thought it proper to simulate for two scenarios since it will help in comprehending the range of changes that can be expected.

3 Result and discussion

3.1 Annual rainfall characteristics

In southwestern part of the Iran, most of the rainfall occurs between October and April, and is produced by the cyclonic circulations originating from Mediterranean Sea (Alijani 1995). Therefore, rainfall occurring in this region is limited to a few months when subtropical high pressure is retrieved to south of Persian Gulf. Generally, rainfall amount distribution and variability in the study area are

Fig. 2 Annual rainfall zones
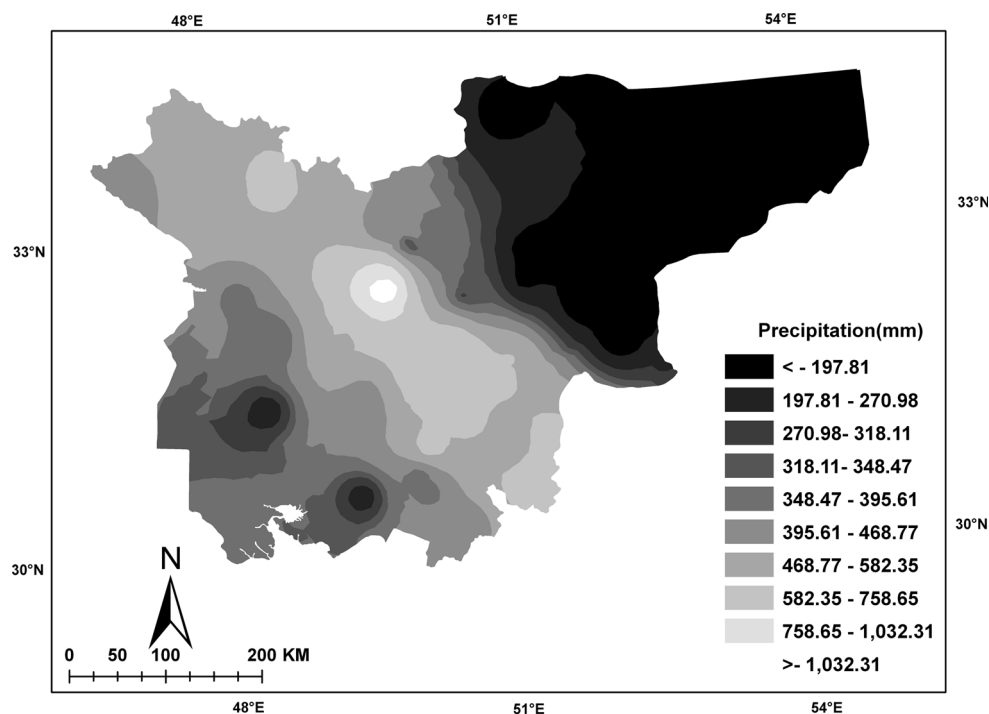
highly influenced by topography. Mean average annual precipitation from 1950 to 2007 was 432.29 mm. Seasonal means were 122.90 mm in autumn, 73.90 mm in spring, 1.24 mm in summer, and 261.50 mm in winter.

Coefficient of variation (CV) was computed for all stations to investigate spatial pattern of variability of rainfall over study area. All stations in Zagros Mountains show less CV as compared with other stations in the east and west part of the area. The largest CV values could also be seen in the east study area where the rainfall amount is low. The result of CV indicated that winter shows less CV compared to other seasons and summer shows the largest CV. The average CV for annual rainfall is 32 %, for autumn 63 %, for spring 69 %, for summer 331 % and for winter 40 %. Annual rainfall zones and annual CV are depicted in Figs. 2 and 3, respectively.

3.2 Trend analysis

It was observed that for annual as well as seasonal series, both the tests gave almost similar results (Fig. 4). Since the linear regression also indicates the rate of change, maps indicating spatial pattern of precipitation changes were prepared based on the results of this technique. Rate of change observed per year was converted into decadal rate and maps that indicate decadal change in seasonal and annual precipitation were prepared which are presented in Fig. 5. Both positive and negative trends were detected by linear regression and MK test in annual precipitation series. However, most of the trends in annual precipitation series

were positive insignificant (68 %) at the 95 % confidence level. One of the reasons for so many insignificant trends could be non-availability of century scale data for the selected stations. Raziei (2008) also observed insignificant positive trends over southwest part of Iran. Shifteh Some'e et al. (2012) also found insignificant trends in annual precipitation series at most of the stations in Iran. The insignificant trends detected in annual series are also in good agreement with the results of Modarres and da Silva (2007), Soltani et al. (2011), Tabari and Hosseinzadeh Talaee (2011) and Tabari et al. (2011a). All of the significant trends detected in annual and seasonal precipitation series were positive at the 95 % confidence level. The positive trends in annual precipitation series were significant at eight stations. Spatial distribution of annual precipitation trends showed that positive tendencies occurred in the central parts of the study area with rates ranging between +20 and +100 mm/decade (Fig. 5).

As shown in Fig. 5 majority of the trends in seasonal data occurred in winter. Largest contribution to annual precipitation is from winter season. The result of linear regression and MK test for winter indicated that eight stations had positive trend and majority of them are from central part with rates ranging between +20 and +80 mm/decade. But, Abadan station situated in the coastal area of Persian Gulf also experienced positive trend with a rate of 10 mm/decade.

In spring, two stations showed positive significant trend. Abyaneh (+25 mm/decade), and Razveh (+15 mm/decade) stations from central part recorded significant increase

Fig. 3 Spatial pattern of coefficient of variation (CV) of annual rainfall
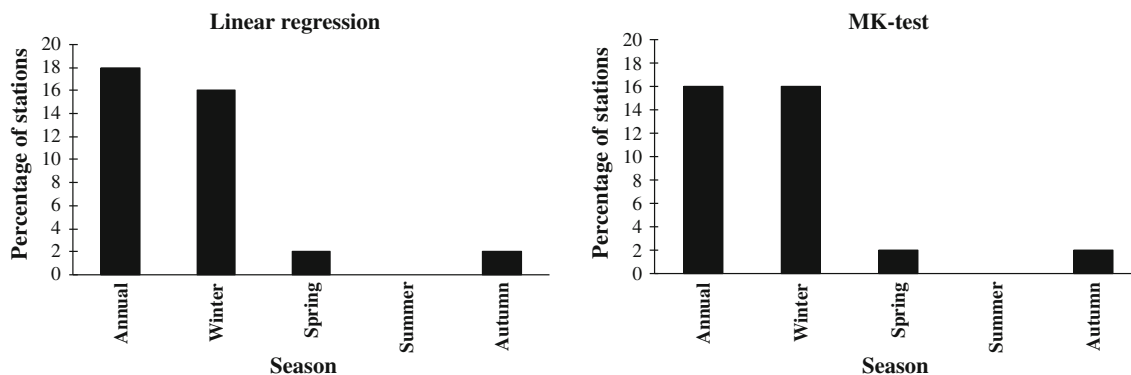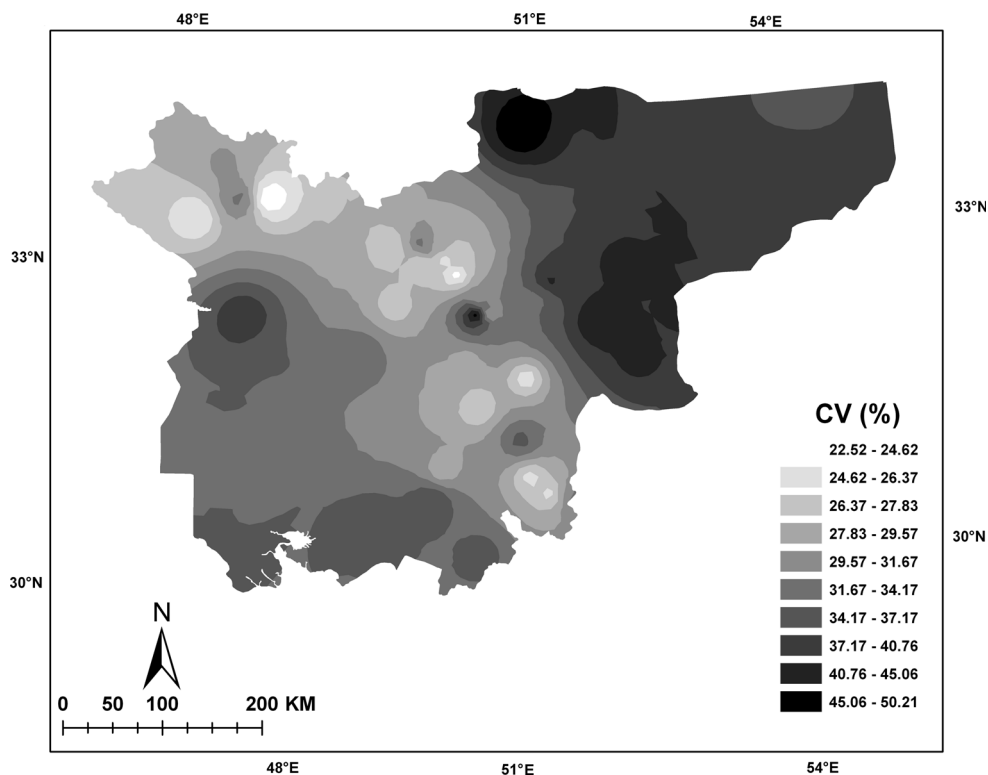
Fig. 4 Percentage of stations with significant trends at 95 % confidence level by linear regression and MK test for annual and seasonal precipitation series

in rainfall. In this season, eight stations from west of study area indicated downward insignificant trends. Some stations in central parts registered negative insignificant trends. In summer, no significant trends were observed. Most stations in east of study area showed negative insignificant trends in summer. During autumn season, upward trend was detected at only one station. Kouhpayehe, from central region of the area, indicated a positive trend in autumn (+60 mm/decade). Most of stations from the west of study area showed positive insignificant trends (48 %) and majority of stations from the central and east registered negative insignificant trends. Tabari et al. (2011b) found insignificant positive trends at

the stations located on the northern coasts of the Persian Gulf and the Oman Sea.

4 Precipitation projection

As suggested by the IPCC AR4 panel, the mean climate of each model will be determined by the last 20 years of the "20c3m" experiments. Simulated climatology is compared with the observed climatology based on the 1981–2000 period. The average precipitation (mm) for each month and season and model data are depicted in Fig. 6. Winter is the season receiving highest
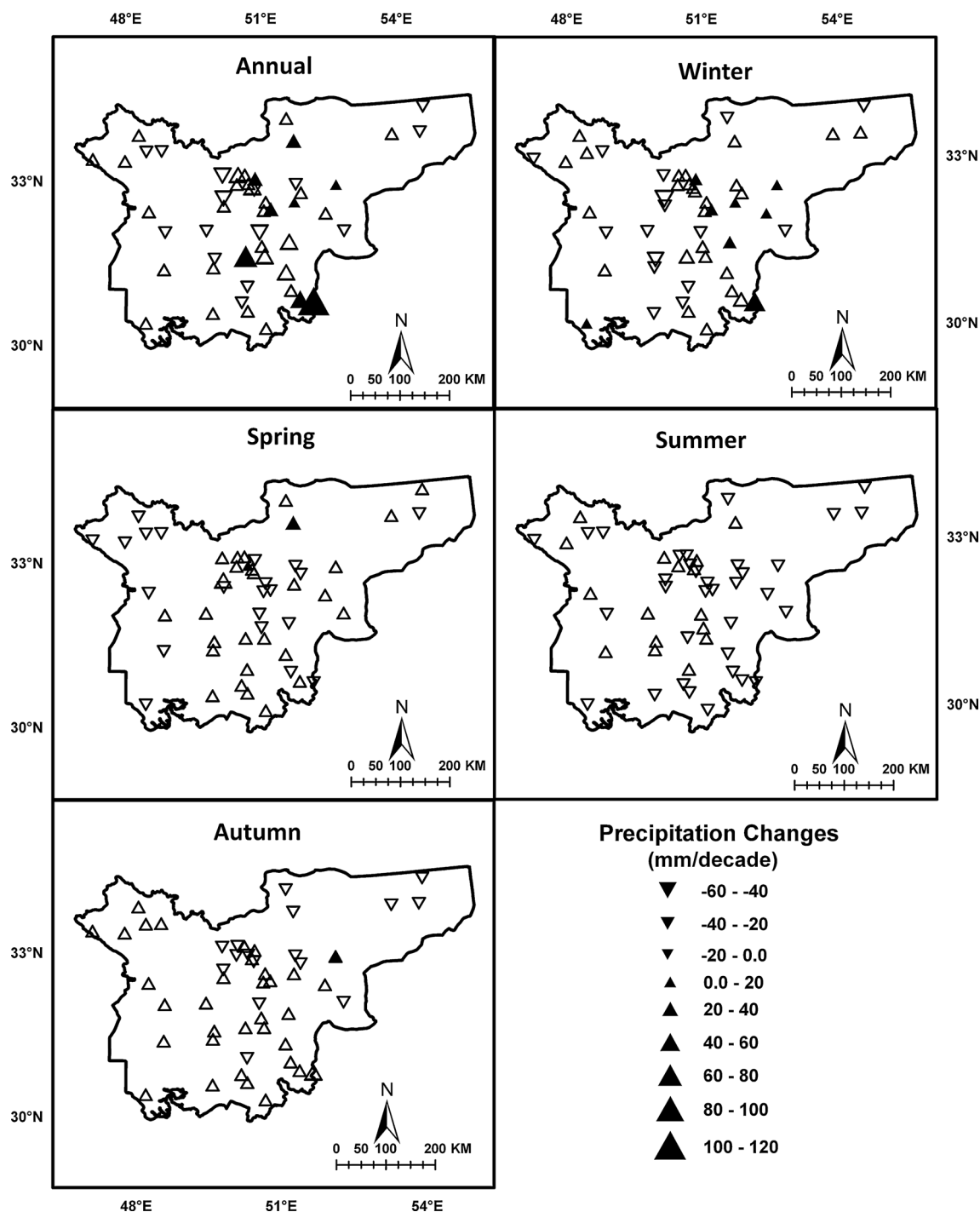
Fig. 5 Trends (mm/decade) in annual and seasonal precipitation. *Hollow triangles* indicates insignificant trends

precipitation according to the model and observed data. On comparison with the observed data, the models data can be classified into two categories: CNRM and ECHAM models show annual precipitation less than the observed data. MIROCH and UKMOC models show annual precipitation more than the observed data. Results of annual and seasonal precipitation projections

using four models under B1 ad A1B scenarios for years 1981–2000, 2001–2020, 2021–2040, 2041–2060, 2061–2080, 2081–2100 are depicted in Figs. 7, 8, 9, 10, 11. They indicated that precipitation may decrease in most of the models under both the scenarios at the end of the twenty-first century (Table 3). Furthermore, it was also observed that precipitation projection using CNRM,
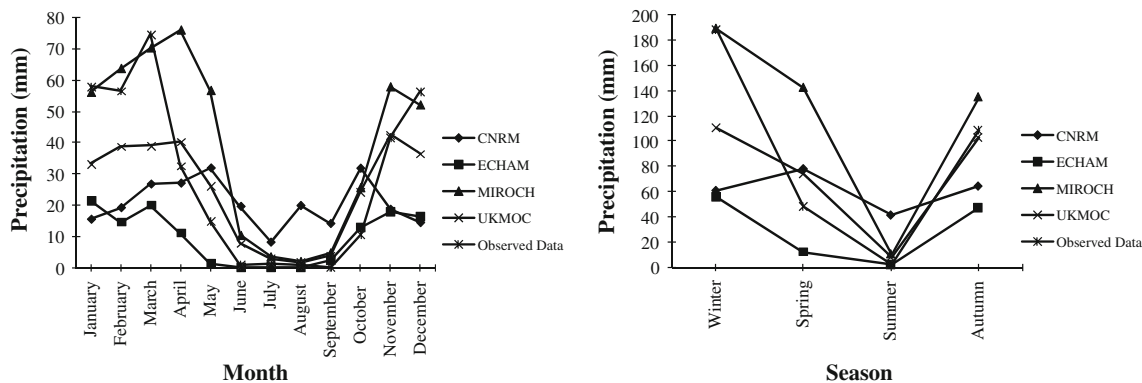
Fig. 6 The average of observed data (monthly and seasonal) and simulated by the four models from 1980 to 2000
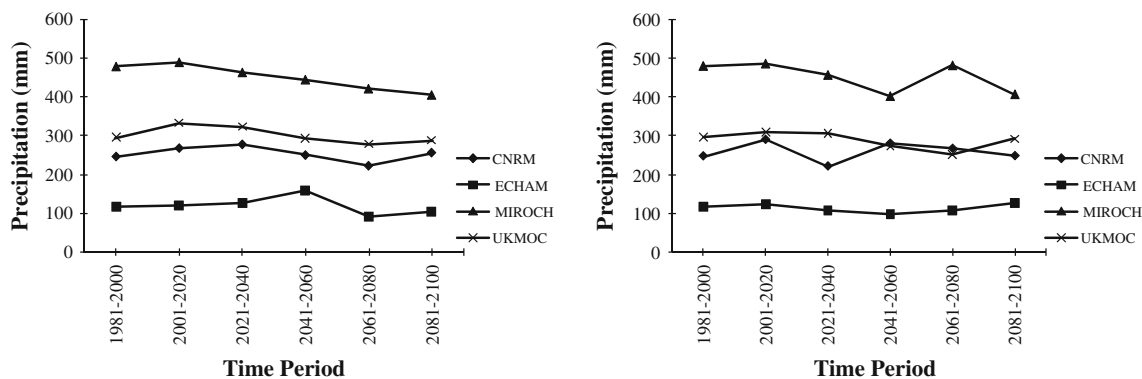

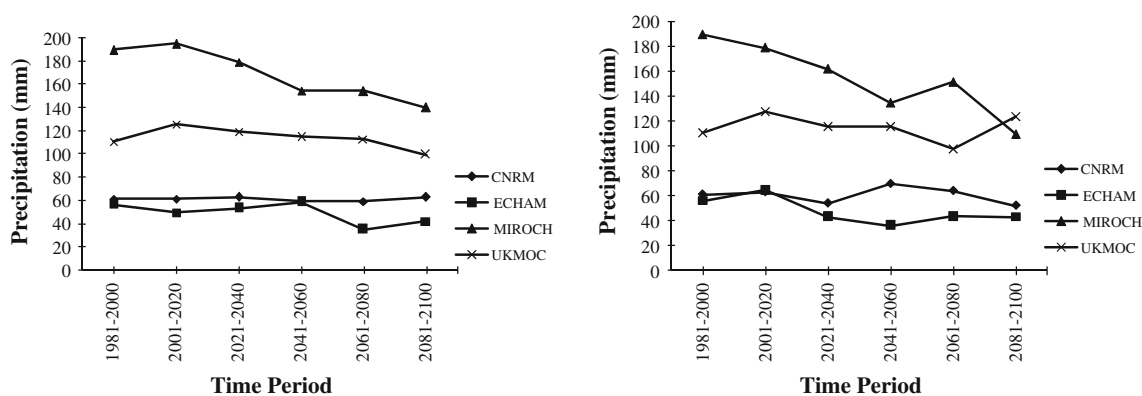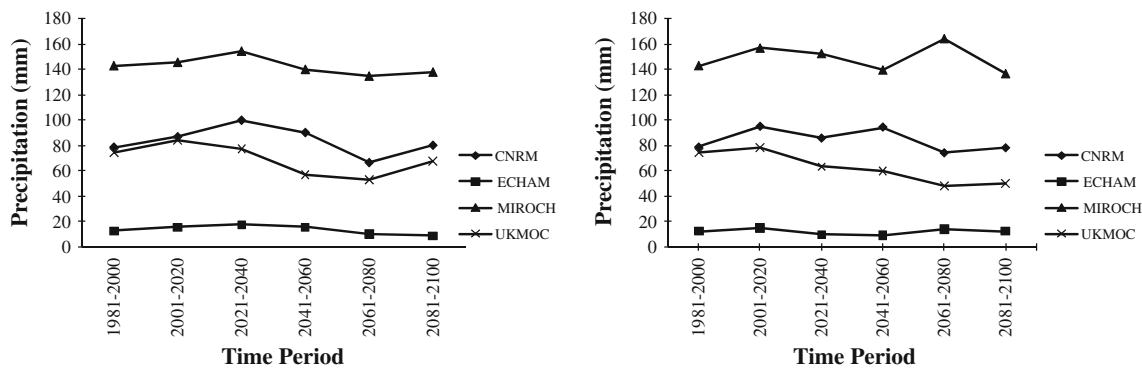**Fig. 7** Projections for annual precipitation

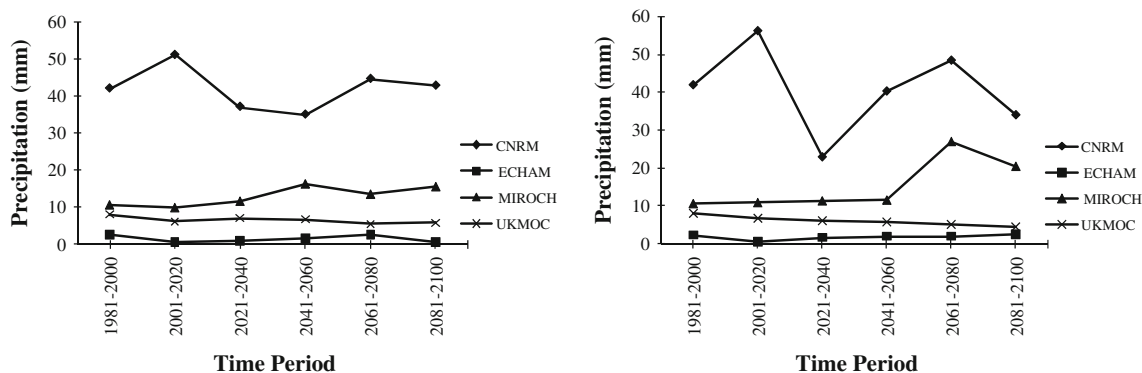**Fig. 8** Projections for winter precipitation

ECHAM and UKMOC models under A1B and B1 scenarios in study area does not indicate substantial future changes as compared to MIROCH model.

Figure 7 shows future projections of the annual mean precipitation. The projected precipitation shows decrease for both scenarios in most of the models. The result of the CNRM model shows that precipitation may increase by 4.01 % in 2100 according to the B1 scenario. However, the A1B scenario indicates that precipitation may increase only

by 0.23 % in 2100. The result of the ECHAM model shows that precipitation may decrease by −11.39 % in 2100 according to the B1 scenario but in the A1B scenario precipitation may rise by 7.24 % in 2100. The result of the MIROCH model indicates precipitation decrease of −15.25 % in 2100 according to the B1 scenario but the A1B scenario shows precipitation may decrease by −14.87 % in 2100. The result of the UKMOC model shows decrease in precipitation by −2.79 % in 2100 according to the B1

Fig. 9 Projections for spring precipitation

Fig. 10 Projections for summer precipitation
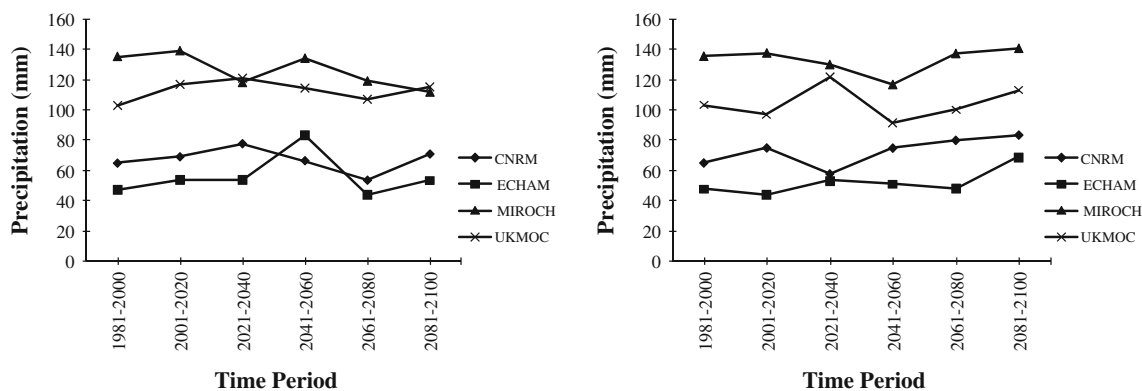
Fig. 11 Projections for autumn precipitation

scenario but in the A1B scenario the precipitation decrease will be −1.44 % in 2100. Roshan et al. (2012) observed that changes in annual precipitation for 2025 and 2050 compared to that in 2005 indicated an increase of 25.19 and 26.4 %, respectively. Roshan and Grab (2012) also report projected mean precipitation increase of 36 % for the year 2100, relative to that for 1961–1990. The results of previous studies are generally based on only one model simulation; however, here we have used outputs of four leading international center models.

The simulations of seasonal precipitation series do not indicate substantial future changes except for MIROCH model. It was noticed that mean precipitation may decrease during most of the seasons, but may increase during autumn under both scenarios. Borna and Arbabi (2011) observed that precipitation may increase by 52.83 mm in 2050, 43.75 mm in 2075 and 88 mm at the end of 21st century in Iran.

Taking into consideration different projected periods, different seasons and years for the scenarios, the highest

Table 3 Precipitation changes (%) for the period 1981–2100

	A1B					B1				
	Winter (%)	Spring (%)	Summer (%)	Autumn (%)	Annual (%)	Winter (%)	Spring (%)	Summer (%)	Autumn (%)	Annual (%)
CNRM	14.1	−0.47	−18.8	28	0.2	2.5	1.9	1.8	9.4	4
ECHAM	−23	−0.4	20.8	45.5	7.2	25.1	−23	−45	13	−11.3
MIROCH	−42	−4.4	93	3.8	−14.8	−26	−3.4	45	−17.3	−15.2
UKMOC	11.5	−4	−43.9	9.5	−2.7	10.4	−28.2	−2.2	11.7	−1.4

average precipitation is projected by the MIROCH model. The CNRM model shows less change in precipitation than the ECHAM, MIROCH and UKMOC models. The results of four models are not similar, because these four models are of different resolutions (latitude × longitude). Whereas MIROCH is a high-resolution model (1.1° × 1.1°), UK-MOC is a low-resolution model (3.7° × 2.5°). Besides, the convection schemes for each model are different (Kripalani et.al 2007a, b). These factors could result in different results by these four models.

5 Conclusions

Most of the earlier studies did not yield any concrete conclusion on Iran's annual precipitation. In this study also majority of the stations indicated insignificant trends in annual precipitation over southwest Iran. Same can be said about seasonal rainfall. It was also observed that, no significant negative trends were present in annual and seasonal precipitation. Furthermore, at seasonal level, the highest number of stations with significant trends in precipitation occurred in winter while no significant trends were detected in summer precipitation. In general, it can be said that the area did not witness any significant change in precipitation during the last four decades.

A section of this area also includes Zagros Mountain ranges where some of the main rivers of Iran originate, therefore, it was essential to know whether there would be any changes in precipitation in the future. It is also important to know how the water resources would be affected by the future changes. For this reason, future projections of precipitation under B1 (lowest) and A1B (medium) emission scenarios were simulated using four models: CNRM, ECHAM, MIROCH and UKMOC. The simulated monthly and seasonal precipitation by these models was quite accurate. Future projections of annual precipitation under B1 scenario revealed that precipitation may decrease by 1.4–11.3 % according to ECHAM, MI-ROCH and UKMOC. Under A1B scenario, UKMOC and MIROCH models indicate decrease by 2.7 and 14.8 %. On an average, the annual precipitation may decrease by 6 %

under B1 scenario and 2.5 % under A1B scenario. This result is not in agreement with previous study which indicated an increase in precipitation over Iran. On seasonal scale, on an average, winter precipitation may decrease by 9.9 %, spring precipitation may decrease by 2.3 %, summer precipitation may increase by 13 %, and autumn precipitation may increase by 21 % under A1B scenario. Under B1 scenario, the precipitation may increase in winter by 12 %, decrease in spring by 13.2 %, decrease in summer by 0.1 % and increase in autumn by 4.2 %. Comparison of projections from these four models reveals that the results of CNRM and UKMOC models are more or less similar under both scenarios. Based on the results of these two models, it can be expected that annual precipitation may not change much at the end of this century. But, winter and autumn precipitation may increase by about 10 % by the end of this century. Considering the fact that this area may experience increase in temperature by about 1.69–6.88 °C by the end of the twenty-first century (Zarenistanak et al. 2013), it would be logical to expect losses such as evapotranspiration to increase. This may increase water demand, particularly from agricultural sector. Therefore, the planners have to consider this while outlining future strategies for water resource management. More investigations in this regard are required to be taken up to find impact of climate change on various sectors.

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