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M. J. Nazemosadat
Shiraz University, Iran

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ENSO's Impact on the Occurrence of Autumnal Drought in Iran

Introduction

Recent extreme rainfall events and the frequent occurrence of worldwide droughts and their associated natural disasters (i.e., devastating bushfires in Australia, Indonesia, and Italy during 1997; the current severe drought in Iran) have increased the scientific community's interest in the broad characteristics of rainfall variation and the potential for rainfall prediction.

On the basis of the Koppen climate classification (Ahrens, 1998), the Islamic Republic of Iran (Figure 1) is categorized as generally having arid (BW) and semiarid (BS) climates. This signifies that the annual precipitation is less than the potential annual loss of water through evapotranspiration. The occurrence of rainfall is unreliable and deviations from the mean are generally more than 40%. The average annual precipitation over the country is estimated to be about 250 mm (about one-third of global annual precipitation).

Iran, with an area of 1,648,000 km^2, lies predominantly within a portion of the Alpine–Himalayan chains, including the major mountain systems of the Alborz and Zagros ranges (Figure 2). As indicated in this figure, the central part of Iran, which is surrounded by these ranges, comprises two uninhabited deserts, Dasht-e Lut and Dasht-e Kavir. In spite of severe dry conditions over these regions, the Zagros and Alborz highlands, like the coastal strip of the Caspian Sea, are classified as having a Mediterranean climate (Csb) and usually receive moderate precipitation.

The occurrence of droughts and floods is common, and the severity and hardships of these natural

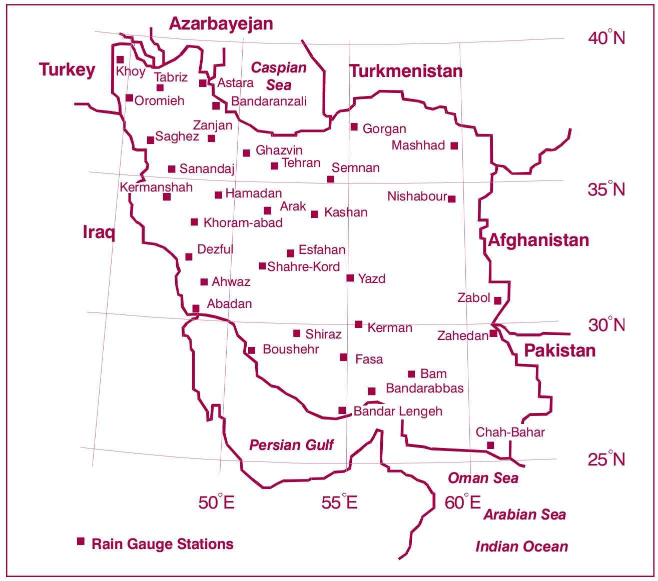

Figure 1. The geographical location of Iran and the position of rainfall stations whose data were analyzed in this study.

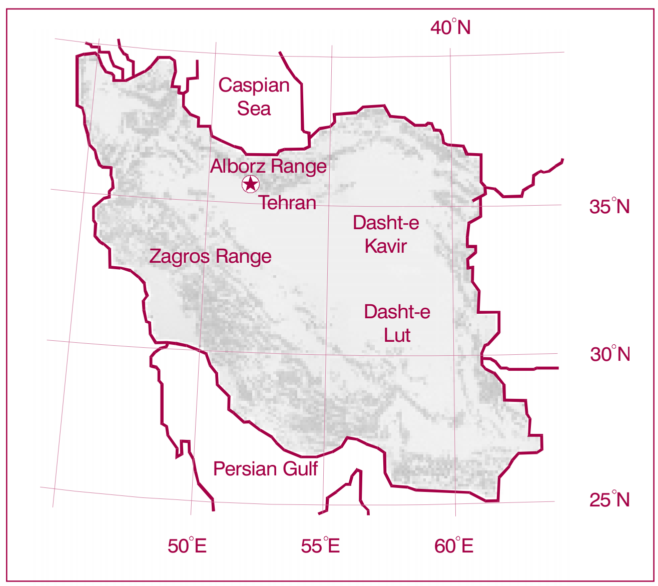

Figure 2. Relief map of Iran. The Alborz and Zagros ranges and the two main deserts (Dasht-e Lut and Dasht-e Kavir) are shown.

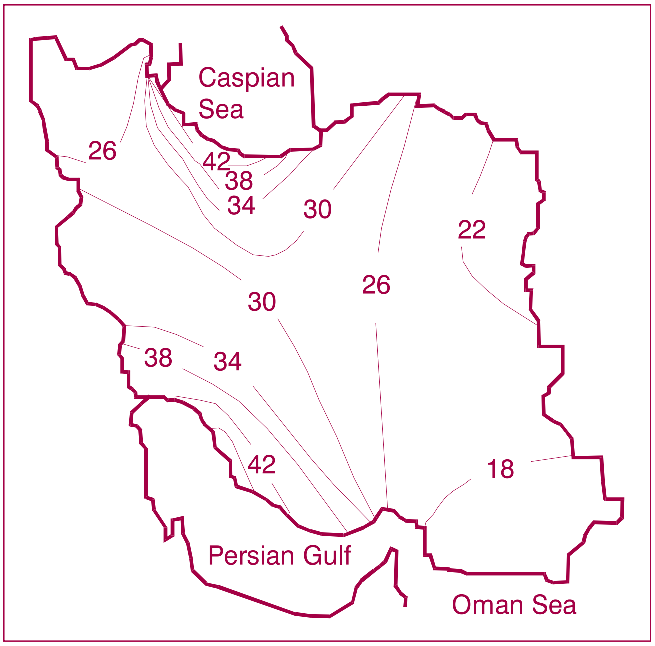

Figure 3. The ratio of autumn rainfall to annual precipitation for different parts of Iran (in percentage). For the western coast of the Caspian Sea, the percentages reach a high of 48.

disasters have frequently affected rural regions as well as urban areas. Drought limits the cultivation of dry farming crops and affects the productivity of irrigated lands. Moreover, due to massive overgrazing, extensive soil erosion can occur during dry periods.

A number of recent studies have confirmed that the El Niño-Southern Oscillation (ENSO) phenomenon has a significant impact on rainfall variability over different parts of the globe (e.g., Lough, 1997; Nazemosadat and Cordery, 1997; Hoedt, 1997). Nazemosadat and Cordery (1999) have recently investigated the influence of ENSO on autumn rainfall in Iran. They have shown that this rainfall is significantly influenced by the Southern Oscillation events. In the present study, the impact of ENSO events on the occurrence of autumnal drought is investigated.

Methodology

The basic data used in this study are mean monthly total rainfall data for 36 synoptic stations (Figure 1) for the period 1951–95, taken primarily from the Meteorological Yearbooks, the official publications of the Iranian Meteorological Organization. Autumn rainfall contributes 16%–48% of the annual precipitation over different parts of the country (Figure 3). As indicated in Figure 3, for the western half of Iran, the ratio of autumn rainfall to annual precipitation is larger than the same ratio for the eastern half of the country. The ratio is relatively higher for the areas near the northern part of the Persian Gulf and western side of the Caspian Sea coasts (42%–48%). The Troup's Southern Oscillation Index (SOI) data, which have been used as the ENSO indicator, were supplied by the Australian Bureau of Meteorology.

The autumn rainfall time series was obtained by averaging the three-month values of precipitation. Best results were obtained by defining autumn as October to December. The same averaging procedure was performed to provide the seasonal time series of SOI data.

A sequential correlation analysis (SCA) was used to examine the strength and temporal stability of the relationship between rainfall and SOI (Nazemosadat and Cordery, 1997). The data lengths employed for the correlation analysis varied from a minimum 15-year window to the total period of available data for every station. For each selected window, coefficients were calculated for continuous data periods of the whole record. For example, for 25-year windows, correlations between Tehran rainfall and SOI were calculated for the periods 1951–75, 1952–76, ..., and 1971–95.

Results

Figures 4a through 4c show the sequential correlation coefficients between the SOI and autumn rainfall for Tehran, Shiraz, Tabriz, Zanjan, Kermanshah, Oromieh, Bandarabbas, Bandaranzali, and Zabol. A 25-year window was used in the correlation analysis. The stations were selected subjectively, with no attempt made to illustrate the SOI-rainfall relation-

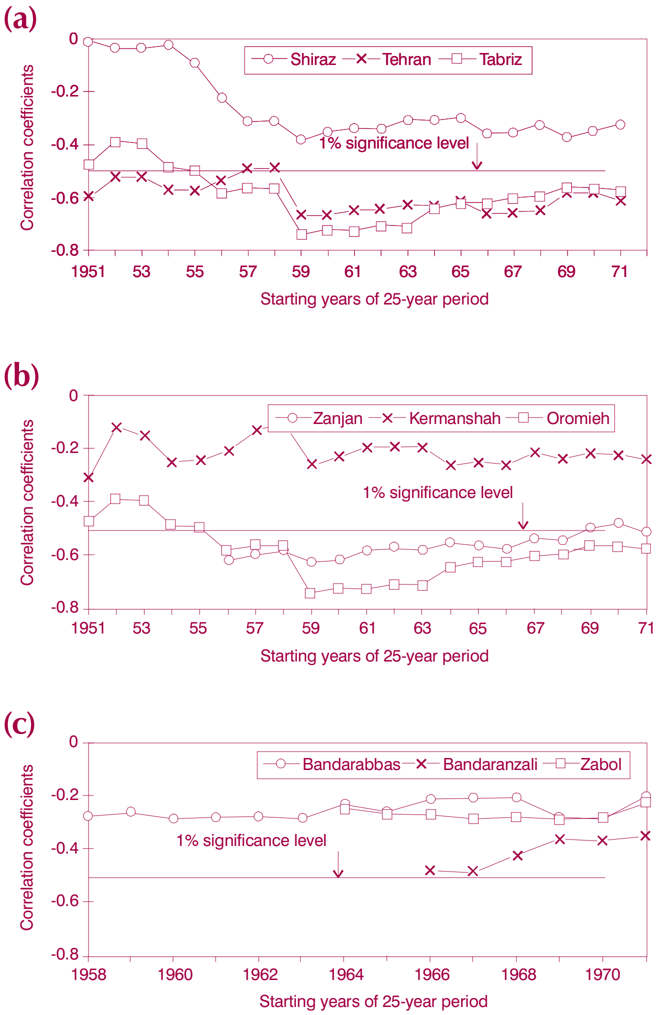

Figure 4. Sequential correlation coefficients between autumn rainfall and (a) Shiraz, Tehran, and Tabriz; (b) Zanjan, Kermanshah, and Oromieh; and (c) Bandarabbas, Bandaranzali, and Zabol. A 25-year window is used. The first years of the sequences are shown in the horizontal axes.

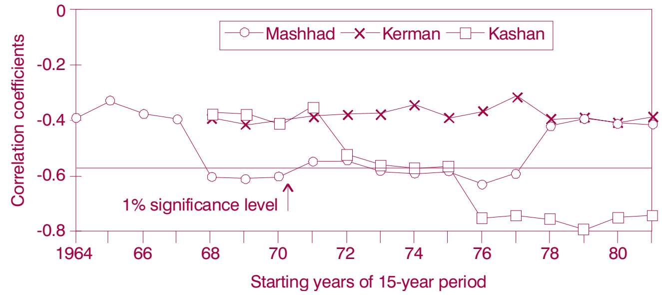

Figure 5. Sequential correlation coefficients between autumn rainfall and Mashhad, Kerman, and Kashan. A 15-year window is used. The first years of the sequences are shown in the horizontal axis.

ships in different locations. Since the starting dates of the available rainfall data were varied, the years of the start of the 25-year windows (horizontal axes in Figure 4) are not the same for all stations. To assess the impact of record length on the strength and stability of the correlations, the SCA was also performed with different window lengths. Figure 5 depicts the correlation coefficients between SOI and rainfall in Mashhad, Kerman, and Kashan for 15-year windows. Similar results were generally found when the record lengths were changed.

As indicated in Figures 4 and 5, correlations are generally significant for some stations, such as Oromieh, Tehran, Tabriz, Kashan, and Zanjan. However, autumn rainfall in Shiraz, Kerman, Kermanshah, Zabol, and Bandarabbas is not significantly correlated with the SOI. As indicated in Figure 4c, the SOI–rainfall relationships are also significant (at the 5% significance level) for Banadaranzali, situated over the western margin of the Caspian Sea coasts (Figure 1). In Mashhad, the SOI–rainfall correlations are significant for some spells and weak for others. The results of the SCA suggest that, regardless of window length and geographical location of the rainfall stations, autumn rainfalls over different parts of the country were negatively correlated with the SOI.

The spatial distribution of the correlation coefficients between the SOI and rainfall is presented in Figure 6. The regions with reasonably strong rela-

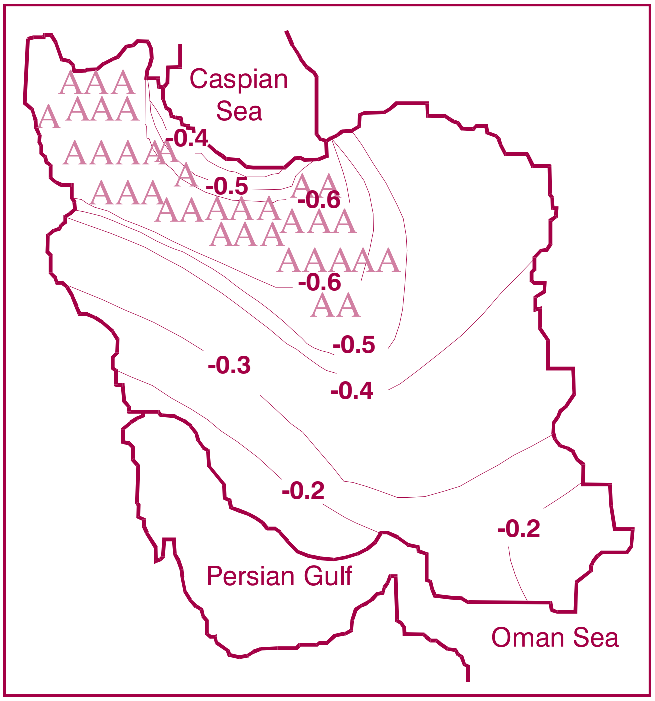

Figure 6. Spatial distribution of the sequential correlation coefficients between SOI and autumn rainfall in Iran. A 25-year window is used. The 5% and 1% levels of significance are 0.34 and 0.47, respectively. Regions with good coherence are denoted by 'A'.

tionships (denoted as Region A) are mainly situated over southern slopes of the Alborz Mountains and the northwestern part of Iran, where the Alborz and Zagros ranges come together (Figure 2). Autumn rainfall over western portions of the Caspian Sea is also negatively associated with the SOI.

Droughts are therefore expected during positive SOI, and abundant precipitation tends to occur when the SOI is negative. The study has also found that severe and widespread autumnal drought is expected during extreme La Niña episodes, when seasonal SOI is larger than 5. For such periods, droughts with extensive socioeconomic hardships are generally anticipated.

Acknowledgments

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M. J. Nazemosadat
Irrigation Department
Agriculture Faculty
Shiraz University
Iran
e-mail: nazem@succ.shirazu.ac.ir

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