GEOGRAPHICAL FACTORS AFFECTING THE PRECIPITATION REGIME IN IRAN

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ABSTRACT. - Geographical factors affecting the precipitation regime in Iran. This study compares the precipitation regime by using harmonic analysis during the last four decades (1965-2004).We used interpolated precipitation data from different weather stations distributed across Iran by applying 15x15 km spatial grids for the interpolated data. Data validations were employed by statistical tests. In this study three harmonies of precipitation variances were evaluated. Variability of precipitation regime was explored by using three-harmonic analysis method. In addition, the effect of geographical factors (altitude, latitude, longitude) affecting to the precipitation regime was verified. Analysis of the first harmonic method proved that the main precipitation regime in Iran occurs in winter season as result of large scale Mediterranean systems passing over Iran in the mentioned season. Moreover, the fluctuations of the seasonal precipitation regime were found to be different, so that in one region led to the appearance of the new regimes and in other region caused change or disappearance of the regimes. In all three harmonics, variances of precipitation were mainly a function of the geographical factors. This effect was more evident in the third harmonic, in such a way that the increases in latitudes (moving to northern region) caused higher precipitation variance. This means that precipitation regime in northern sites are more exposed to local factors and seasonal precipitation than those of southern sites. The results of this research can be used in land–use projects, environmental plans and water resources management.

Keywords: precipitation regime, harmonic analysis, three variable regression, Iran.

1. INTRODUCTION

Iran with the area of 1,648,000 km^2 is recognized among the arid and semi-arid countries in the world from a climatic perspective. There is also a desert belt crossing the country to make aridity as a permanent specification. Changes and displacements in seasonal precipitation caused by geographical factors (e.g. longitude, latitude and altitude) are important indicators defining the precipitation regime of Iran. This subject has been less noticed as a major geographical issue. Study of this kind of change would make water resources plans easier in addition to providing a reliable precipitation pattern. In addition to the quantity, temporal-

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spatial distributions of precipitation are major factors for decision making, planning and evaluating hydrologic models and management and water-based programs. Temporal-spatial variations of precipitation over different geographical areas have various effects on management and planning of water resources across a water basin and in a national scale. Precipitation as a very variable element and as a major element in water balance relations has been always of interest for climatologists and hydrologists. Assessment of precipitation regime has always been of interest for researchers and numerous works have been conducted in this subject in Iran and around the world.

Bello (1996) determined the characteristics of starting and termination of precipitation in Nigeria using precipitation and potential evapotranspiration over a 35-years period (1959-1993) obtained from four selected stations. Domroes et al. (1998) recognized three major components and five precipitation regimes by performing the main and cluster components analysis method on Iran's monthly precipitation. They evaluated the precipitation regime and produced the iso-hyet maps for 70 sites.

Buffoni et al. (1999) analyzed Italy's precipitation. In order to study the seasonal and annual precipitation of Italy for a period of 164 years, they gathered the precipitation data of 32 stations throughout Italy which were grouped into two homogeneous groups. Unkasevic et al. (2000) studied the average of monthly precipitation and maximum daily precipitation of Belgrade based on statistic analysis. They showed that throughout the year except for May, July and June the frequency of maximum daily precipitation is larger for 10 to 20 mm range. Stafford et al. (2000) determined the 50 years trends of temperature and precipitation and showed that summer precipitation in most stations has increased. Romos (2001) analyzed distribution patterns of precipitation and its changes in Mediterranean regions and concluded that arid and hyper arid years were not reported over the period of study and most years were categorized as normal arid or normal humid years. Rodrigo (2002) studied precipitation and its variability in a case study in San Fernando (Spain). To determine the dry and wet seasons, he used seasonal precipitations recorded in San Fernando over the period of 1821-2000 and calculated the percents of return periods of 10, 25, 75 and 90 for 1961-1990. Tomozeiu et al (2002) investigated the winter precipitation fluctuations of 40 hydrometry stations in Italy. They found out that almost all the studied stations showed a significant decreasing trend in winter. Tarawneh, and Kadoglu (2003) studied the precipitation season in Jordan. They used harmony analysis methods and concluded that 90 percent of variability is appeared in the first and second harmonics. Domonkos (2003) studied the precipitation trend in the Netherlands. He analyzed monthly precipitation time series from the Hungry sites during 1901 to 1998 to determine the long term changes in the specifications of the twenty century precipitation. In this study he took into account the changes over the recent decades and their relationship with large scale atmospheric changes in Europe and the Atlantic Ocean.

Bodri et al. (2005) studied the precipitation changes trend in Czech Republic from 1994 to 2001. They determined the variability of precipitation between two individual periods using the absolute difference method. The results revealed a total increase of precipitation variability over the study area. Tosic et al. (2005) studied Belgrade's precipitation time series and it showed that Belgrade's precipitation is under the influence of the Northern Atlantic Oscillation in winter, but during spring it is influenced by the oscillation of the Southern Atlantic. Qian and Lin (2005) analyzed the regional trend of precipitation indices in China. They observed a decreasing trend in the annual precipitation from the southern part of the north-east of China to the lower half of the Yellow River Valley and Yangtze River Valley.

In another study, Livada et al. (2006) studied characteristics of the 24-hour precipitation of Greece by the harmony analysis methods. They found that the maximum percent of precipitation changes is explained by the first harmonic. Odekunle (2006) determined the commencement and end of the precipitation season in Nigeria with the emphasis on the quantity and number of rainy days and found out that the number of rainy days gets more realistic dates for the beginning and ending of precipitation. Karagianndis et al. (2008) analyzed some characteristics of European countries rainfall. Using the harmonic analysis, they showed that the sum of the first and second harmonics describes the annual average of precipitation regime. Ashabokov et al. (2008) studied precipitation regime changes in Russia. The results showed that a noticeable increase in the intensity of the winter precipitation in the flat region is seen.

Asakereh (2008) studied annual precipitation of 232 synoptic and climatology stations of Iran during 1961 to 2003. He found that the statistical characteristics of precipitation have remarkably changed during 1986 to 2003. Many other researchers have conducted such investigations. To avoid lengthy paper, the details are not described here. This research is aimed to determine the spatial factors influencing the precipitation regime in various regions of Iran using different harmonic analysis, Fourier and three-variable regression in the past 40 years.

2. MATERIALS AND METHODS

In this study, the daily precipitation observations of 428 weather stations across Iran were used. Statistic period of 40 years (1965-2004) was chosen. We used Kriging interpolation method to maps of average daily precipitation with spatial resolution of 15km*15km. As a result, mean monthly and seasonal precipitation were produced for more than 8000 point over Iran. The maps were plotted based on the Global Positioning System (GPS). The run-test was carried out to check validity and uniformity of the precipitation data. To study the variability of precipitation regime throughout the country, harmonic analysis was used. To do this, the average monthly precipitation of the four decades and the interpolated data of every decade were exploited. In addition, harmonics of precipitation and periodical behaviors were analyzed using the Fourier series. To run a harmonic

analysis, the average monthly precipitation was analyzed in Matlab. Harmonics were constructed using the Taravneh and Kadoglu (2003). For this study, the variance values of the first three harmonics were used. Generally, the variance of the first harmonic describes an individual annual cycle of the observations, and the variance of the second harmonic expresses the tendency to a change of semi-annual precipitation. The variance of the third harmonic reveals more details of annual precipitation regime variations (Tarawneh 2003). To characterize the effects of geographical factors affecting the precipitation regime, the standard correlation and three-variable regression approach were employed. Figure 1 shows the geographical location of Iran on the world map. In this study, the daily precipitation observations of 428 weather stations across Iran were used. The annual areal weighted precipitation mean of the country is 253 mm.

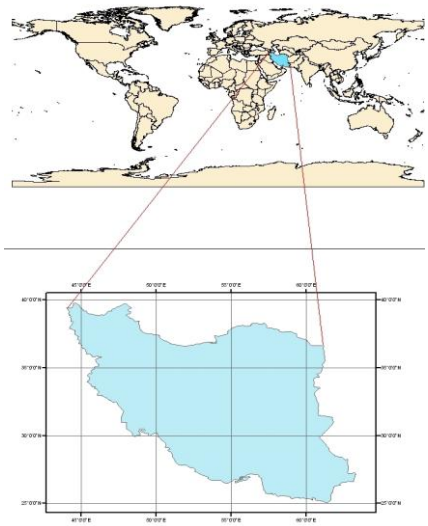

Fig. 2. ***Geographical location of Iran on the world map***

In this section, the general characteristics of seasonal and annual precipitation are discussed. In addition, the three-variable regression equations between precipitation and geographical factors are derived. Finally, the role of the geographical factors (longitude, latitude and altitude) affecting the precipitation regime and its variability is studied.

2.1. Seasonal and annual regression equations

As seen, in Table 1, the highest correlation coefficient (r) belongs to the longitude (λ). This shows that the longitude has an important role in the variation of the annual precipitation. The negative sign of the correlation coefficient means the higher the longitude the lower the precipitation (i.e. precipitation decreases from west to the east).

By contrast, the latitude (φ) shows positive correlation with the annual precipitation. It's positive sign means that the higher the latitude the more the annual precipitation. Compared to the mentioned geographical factors, the altitude (H) has the least effect on the annual precipitation. In spring, the value of the three-variable correlation is about 0.79 which is larger than the other seasons (Table 1). It means that about 79% of the precipitation variations can be explained by geographical factors.

Based on the standard correlation coefficient (0.43), the effect of the (φ) is more than (λ) and (H). As shown in Tab. 1, during spring the altitude (H) has the highest positive effect (0.15) on precipitation than other seasons.

2.2. Correlation of geographical factors with variances of the harmonics

To demonstrate the impact of geographical factors on precipitation variability, the correlation between latitude, longitude and altitude with variance of the first three harmonics were also determined. The calculations are performed for 4 different decades during 1965 to 2004, but due to the page limit of the extended abstract, results are not shown here.

This could be the main reason for the lowest (0.26) three-variable correlation coefficient which observed in summer (Table 1). As seen, altitude (H) in summer months has negative impact the rainfall, because adequate humidity is not available in high lands.

With the exception of winter, in other seasons, the correlation between (φ) and P is positive (the higher the latitude, the more rainfall). This can be explained by the significant rainy days in coastal regions of the Caspian Sea throughout the year.

During winter, the correlation between P and (φ) has the opposite sign (r = -0.27). This is due to the entrance of moist winter Mediterranean frontal system to the lower latitudes of Iran. In general, spring rainfall was more sensitive to all geographical factors than other seasons.

The first three harmonics were also analyzed in this study. For the third harmonic (which is mainly governed by local factors (i.e. topography, height of the site, etc.), differences are seen in some regions of the country. This result highlights the fact that in recent decades the precipitation regime in the aforementioned regions was not affected by local and geographical factors.

Based on the results of the present research, it was revealed that analysis of the precipitation time series in mountainous and semi-arid region of Iran is possible by using the first three harmonics. To explain precipitation climatic (long-term) variations, some researchers (e.g. Tarawneh and Kadoglu, 2003) believe that only the first and second harmonics are enough to explain the precipitation variations.

Table 1. ***Seasonal and annual regression statistics between P and geographical factors***

Precipitation (P)	Geographical factors	Standard Correlation	Three-variable Regression equation	Three-variable Correlation (r)
Winter	λ	-0.6	P=815.7 – 9.5λ -5.8φ + 0.008 H	0.53
	φ	-0.27		
	H	-0.07		
Spring	λ	-0.42	P =104.5 – 4.6λ +6.3φ + 0.012 H	0.79
	φ	0.43		
	H	0.15		
Summer	λ	-0.04	P =28.5 – 0.22λ +1.8φ - 0.005 H	0.26
	φ	0.24		
	H	-0.12		
Autumn	λ	-0.5	P =347 - 6.9 λ +2.8 φ - 0.006H	0.58
	φ	0.15		
	H	-0.07		
Annual	λ	-0.53	P =1233.8 - 21.2λ +5φ + 0.008 H	0.6
	φ	0.09		
	H	0.03		

However, to study precipitation temporal-spatial characteristics in mountainous areas, few researchers (e.g. Livada 2008) emphasizes that analysis of the third and even fifth harmonics is necessary (in addition to the first and second harmonics). This study showed that the geographical factors have prominent influence on spatial and temporal precipitation variability over Iran. Identification of these variations in local and meso-scale is an important key point for water resources management and weather forecasters.

3. CONCLUSIONS

In this study, the effect of the geographical factors on annual and seasonal precipitation was determined. The results suggest different precipitation regimes throughout the year. In general, the dominant regime of the country is winter precipitation regime. Main reason for this can be the large sale synoptic systems originated from Mediterranean and North Atlantic sources which are determinant in winter months (November-March). The findings of this research highlights that Iran's precipitation regime tends to be more concentrated in one specific season. The seasonal (intra-annual) and local precipitation regimes are also associated with significant fluctuations which mainly originated from the second and third harmonics variances in the last decades. The geographical factors showed various effects on local precipitation over Iran. The results highlighted that the first harmonic is able to describe the large scale systematic precipitation for all decades. In contrast, the second harmonic explained stronger contribution for convective and local precipitation. Analysis of precipitation variances for the third harmonic revealed that the northern latitudes are more sensitive to the local geographical factors than the southern latitudes. More studies need to be carried out on the precipitation variations and geographical factors affecting these variations. To

evaluate the role of geographical factors on precipitation variations in more details, comparison over longer period of time is suggested.

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