Journal of Humanities The University of Isfahan
Vol. 30, No.2, 2008
P.P. 69-80

On Precipitation Mapping in Iran

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Abstract

Investigating the spatial behavior of precipitation of Iran shows that preparation of a reliable precipitation map requires a deep knowledge of the spatial behavior of the precipitation before starting interpolation. No data areas, Topographic complexity, complexity of precipitation mechanisms, isotropicity, number of stations, and pixel size are the most important pre-interpolation aspects of digital precipitation maps for Iran. This study shows that minimum number of stations needed for preparation of a reliable precipitation map is about 500 and the best pixel size is about 14 kilometers.

Keywords: precipitation, mapping, interpolation, pixel

Introduction

Systematic observation of precipitation in Iran is not longer than 50 years, however, in few stations there are precipitation records for more than a century. Ganji (1968) for the first time published a precipitation map of Iran based on some sparse stations with short -term records. In addition, from the early beginning and for a long period of time no sign of a clear spatial variation theory in climatic mapping could be seen in Iran. Especially precipitation mapping was partly based on crude and qualitative relation between precipitation and elevation. For this reason isohythes had been drawn mainly on topographic maps by hand. These arbitrary vector maps whose accuracy depends on personal knowledge and drawing skills of experts were dominated in Iran for years. Nowadays , computer-assisted mapping along with the appearance of spatial variation theories place some big questions before the traditional method of climate mapping.

In fact traditional climate mapping follows the following procedure:

. Gathering climatic observations

. Controlling quality of data

. Controlling sufficiency of data (temporal and spatial density)

. Filling gaps

. Averaging data over the same period of time

. Plotting averages on a topographic base map

. Drawing isohyets by hand

Filling gaps by itself is a very challenging step especially in arid regions where the temporal variation of precipitation is very high. For example, in BandarLengeh (Lon. 54 53 Lat. 26 34) in Iran two rainfall events have been recorded during about 40 years. During one of these events about 200 mm of precipitation occurred just in a day. Meanwhile mean annual precipitation of the station is about 100 mm. there fores in regions with a high temporal variation filling gaps may result in the loos of accuracy.

Besides the arbitrary nature of traditional climatic mapping techniques there are two mayor problems which limit the accuracy of climatic maps.one of these problems arises from the vector nature of hardcopy precipitation maps that makes the mathematical combination of them impossible. So we have to either fill the gaps using statistical schemes or omit such stations. By omitting the stations, data density reduces and map quality remains low again.

Secondy , even if you have no problem to fill the gaps, you should select the same period of time for averaging and some stations with short time recording will be omitted. To avoid these difficulties another procedure may be suggested as follow:

. Gathering data

. Controlling quality

. Determining limits of working space

. Determining spatial behavior of the variable

. Dividing the space into reasonable number of cells

. Choosing the best interpolator

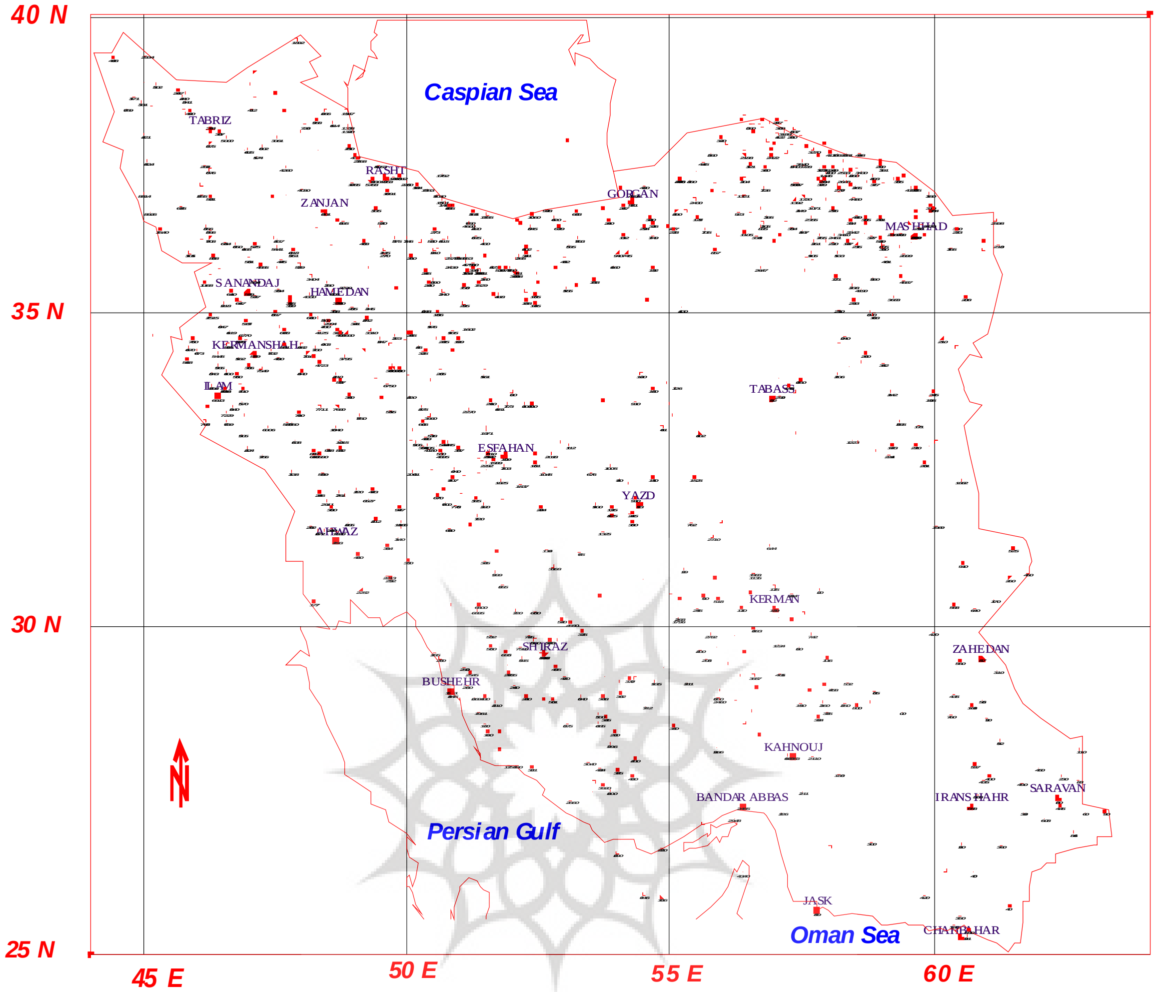
. Interpolating the variable

Nevertheless this procedure has its own problems. For in stance a reasonable quantization of the space that determines the spatial resolution of the map needs a great deal of data exploring effort. Spatial resolution depends largely on the spatial behavior of the variable , Among the climatic variables spatial behavior of precipitation is the most complex. Here we attempt to discuss some important aspects of the spatial resolution of precipitation maps.

No data areas

Geographical barriers like vast unsettled hot deserts and steep, cold mountainous regions have limited establishing climatic stations. So the problem of no data areas is a crucial issue in such regions. The highest station of the country is not higher than 2600 meter above sea level. It means that we have no climatic data for about 50 000 square Kilometer of mountainous regions of the country . In other words , in the most important , part of the country, from hydrological point of view, we know nothing about precipitation amount (Fig. 1).

Fig. 1) spatial distribution of stations used in calculation of precipitation map for 1993



The same problem exists in desert areas of the country. In these areas precipitation is mainly low extent, intense and convective and needs very high density recording sites to capture them. Meanwhile spatial data density in this part of the country is very low and there is no climatic station in about 150 000 square kilometer at all (Fig. 1).

Topographic Complexity

Iran is topographically very uneven (Fig. 3). Alborz Range which runs from west to east acts as a barrier and does not allow the moist air of Caspian coast to penetrate central Iran. Along the Caspian shore, a strong inverse relationship between precipitation and elevation is dominant especially in western parts (Fig. 4). Zagros Range, however, runs from northwest to southeast and force westerly synoptic systems to rise. So a strong direct relationship between precipitation and elevation persists on windward slopes and more or less on lee sides of Zagros (Fig. 5). On the othere hand , other isolated small mountains have apparently no significant role in precipitation. Thus from topographic point of view there are at least three different climatic regions in the country that should be treated in accordance with , their own precipitation-elevation models.

Fig. 2) Topography of Iran

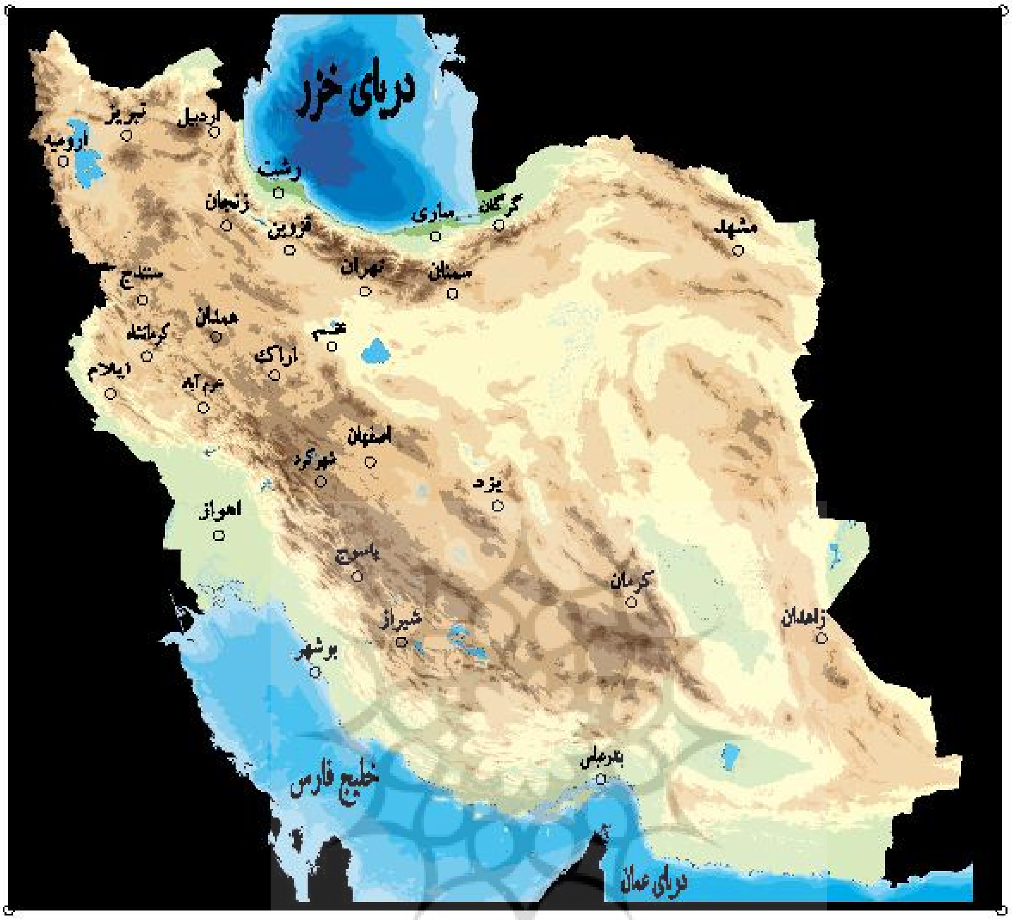


Fig. 3) percentage area frequency of elevation of Iran

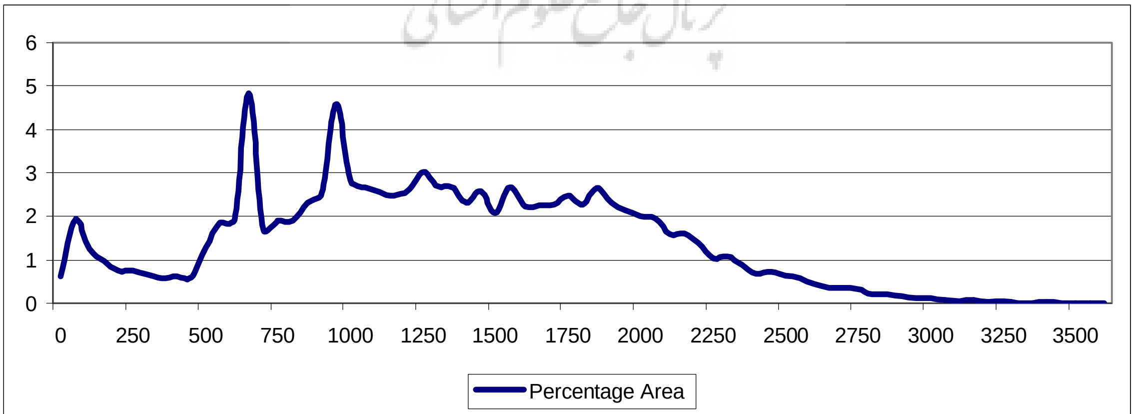


Fig. 4) Precipitation – elevation relationship across Alborz

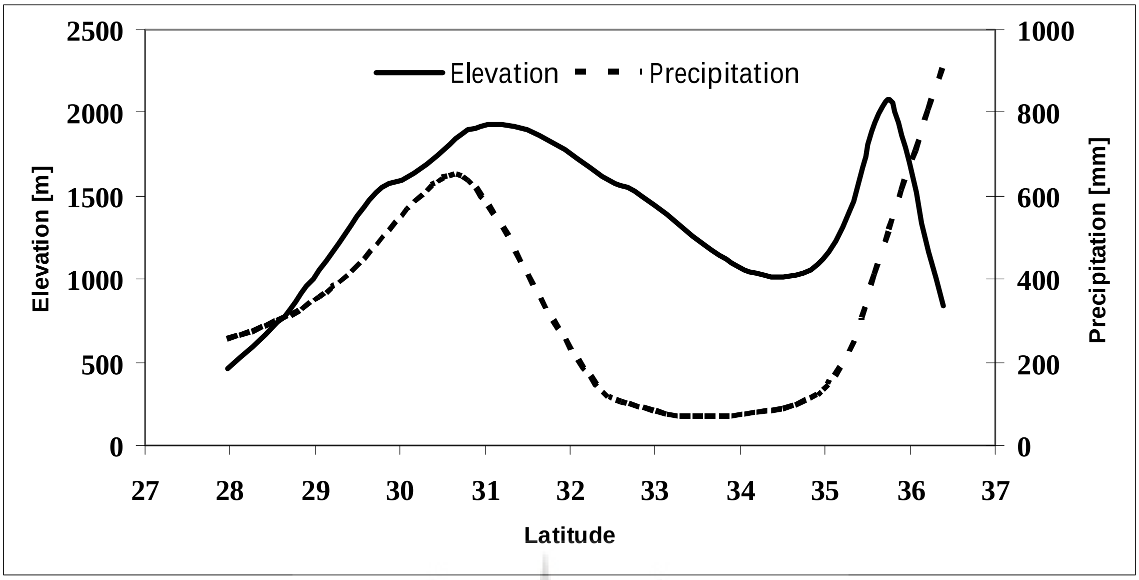
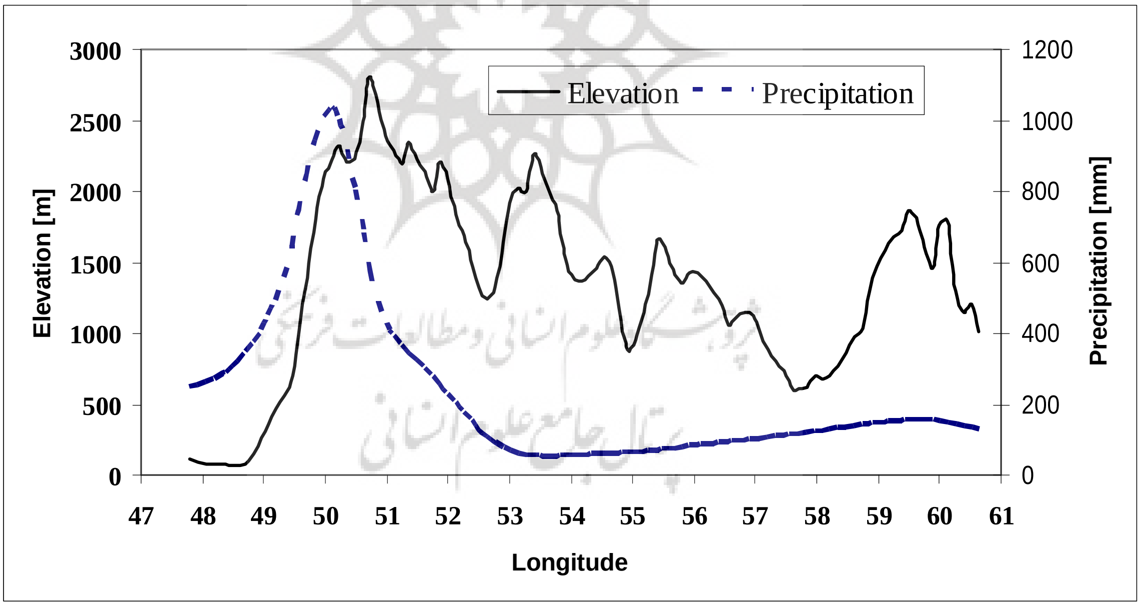


Fig. 5) Precipitation – elevation relationship across Zagros



Complexity of precipitation mechanisms

Spatial distribution of precipitation in Iran is really uneven. This is partly because of topography and partly it is the result of different mechanisms of precipitation affecting Iran. In the northern parts of the country ,Caspian Sea along with high pressure systems crossing the region play a great role in temporal and spatial distribution of precipitation. The difference in friction, characteristics between land and sea seems to be important too. In this region precipitation is very high and mainly occurs during midsummer to early fall (Fig. 6). In addition to this humid region Zagros heijhts are considered to be the second humid part of the country. Unlike the northern parts Mediterranean systems along with orographic effects are active here and precipitation occurs mainly during mid fall to early spring (Fig. 7). In the northwestern part of Iran, precipitation mainly occurs during spring in which the role of the Black Sea is important (Fig. 8).

Fig. 6) First precipitation region of Iran

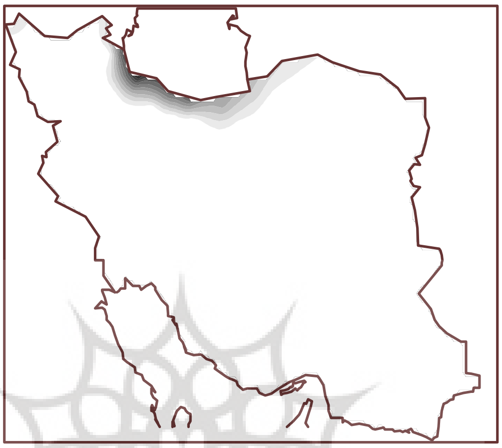


Fig. 7) Second precipitation region of Iran

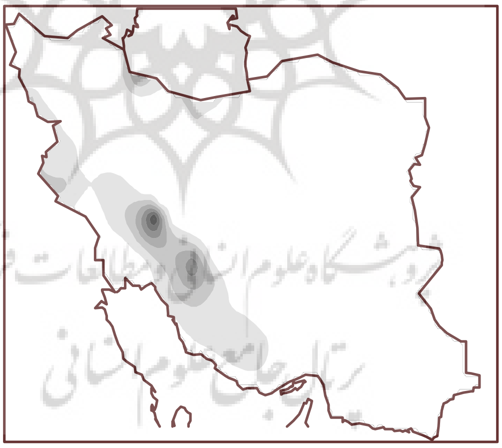
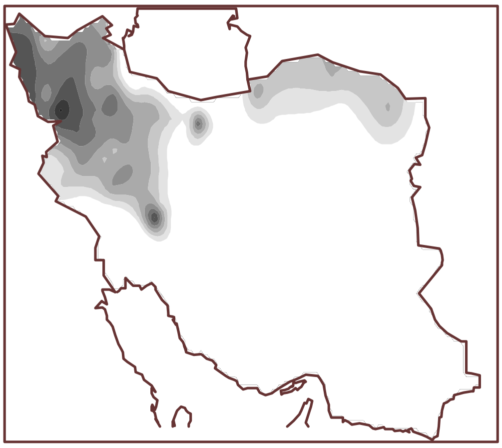


Fig. 8) Third precipitation region of Iran



The effect of variogram range on spatial resolution

Many researches suggested that the amount of precipitation in a given station is not simply related to the elevation of the station. But the structure of topography in a given distance around the station determines amount of precipitation falls on a given point. In other words, we can define an imaginary radius around a climatic station that affects the precipitation amount falls on that station. In Iran variogram range is about 250 kilometer. So for preparation of a precipitation map we need to have reasonable number of stations in vicinity of each node in interpolation grid. Variogram determines the limits of vicinity that in this case is about 250 kilometer (Fig.9 and Fig. 10). Fig. 9 and Fig. 10 show that the variogram range for precipitation is more or less stable.

Fig. 9) Standard variogram of mean annual precipitation of Iran

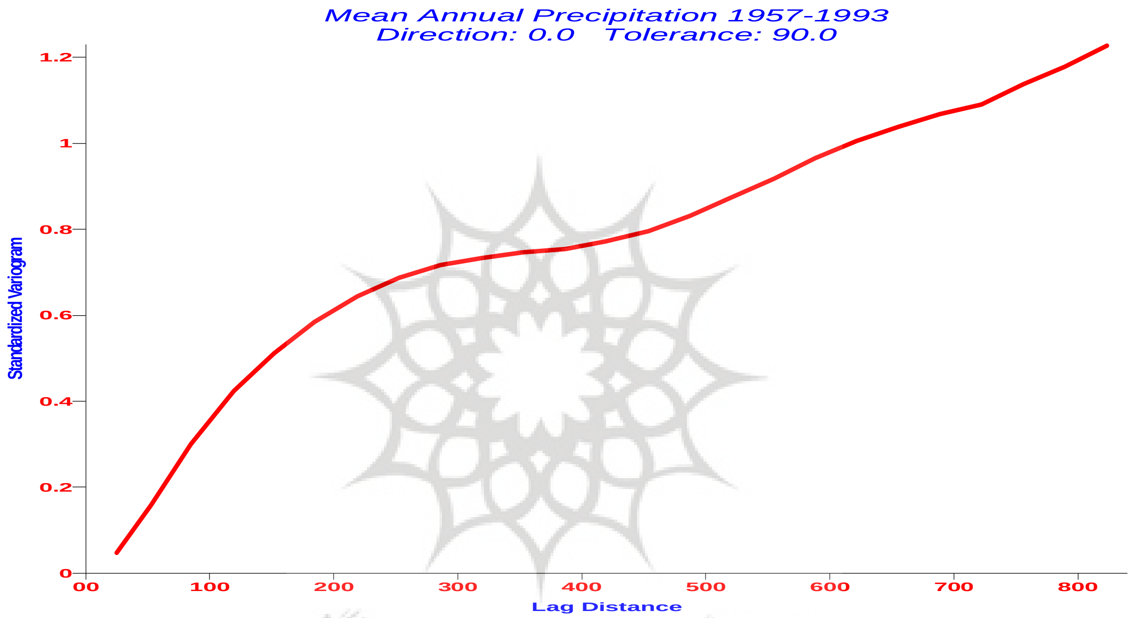
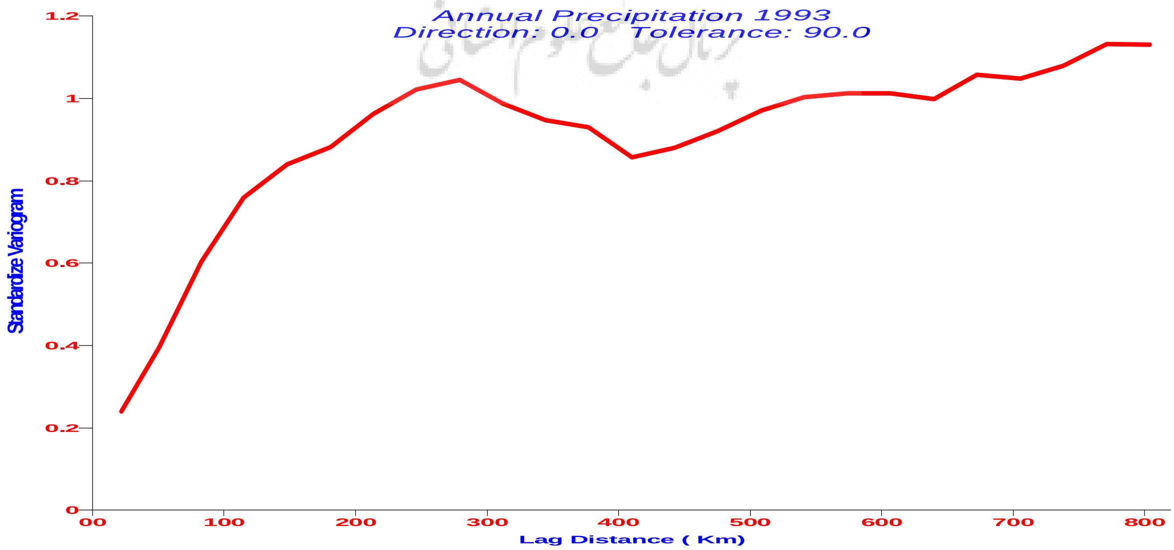


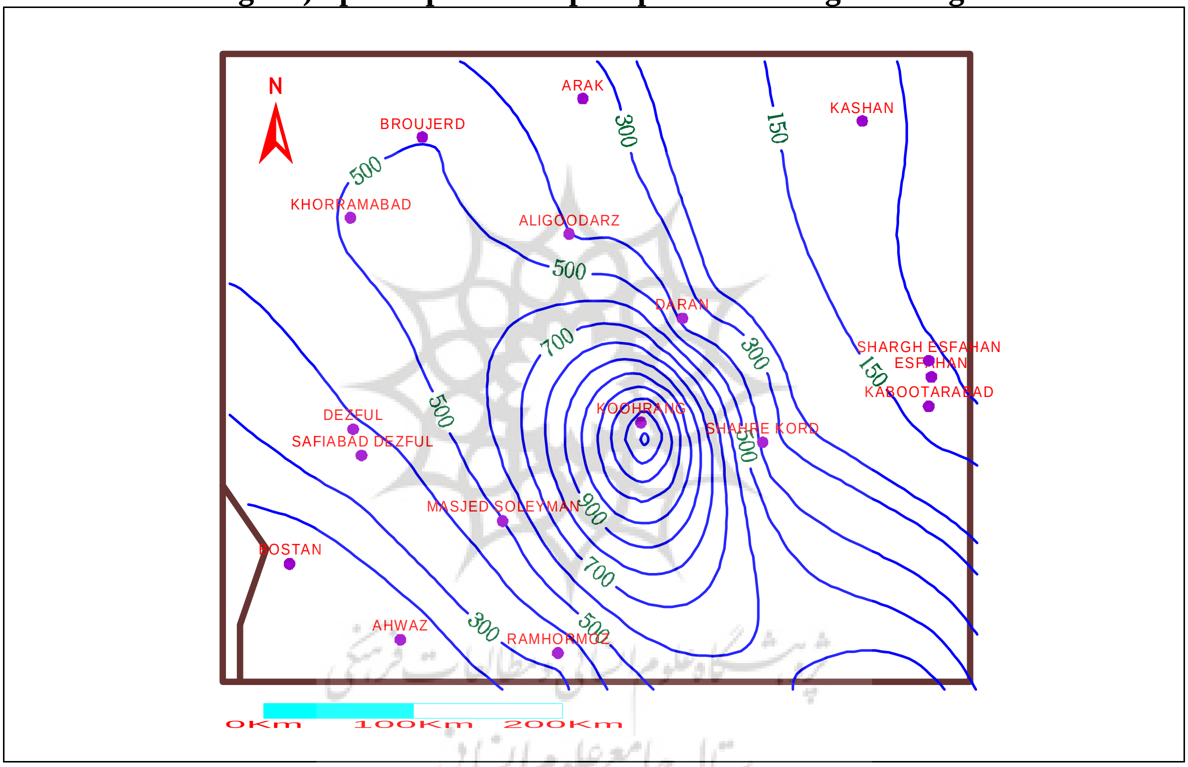
Fig. 10) Standard variogram of annual precipitation of Iran in 1993



Isotropicity

Another important aspect of interpolation procedure depends on isotropicity of the spatial behavior of the variable. In an isotropic space, variations are the same in all directions and a randomly spaced station situation is suitable. In practice ,because of the mountainous nature of the country and the diversity of precipitation mechanisms precipitation is rarely isotropic. As an instance, horizontal precipitation gradient in windward slopes of Zagros is lower than the lee sides (Fig. 11). This means that in directions with greater gradient , we need more stations to capture the spatial behavior of precipitation. As a result for a reliable precipitation map, more stations are needed in lee side slopes of Zagros and in southwestern shores of Caspian Sea.

Fig. 11) Spatial pattern of precipitation in Zagros Range



Number of stations

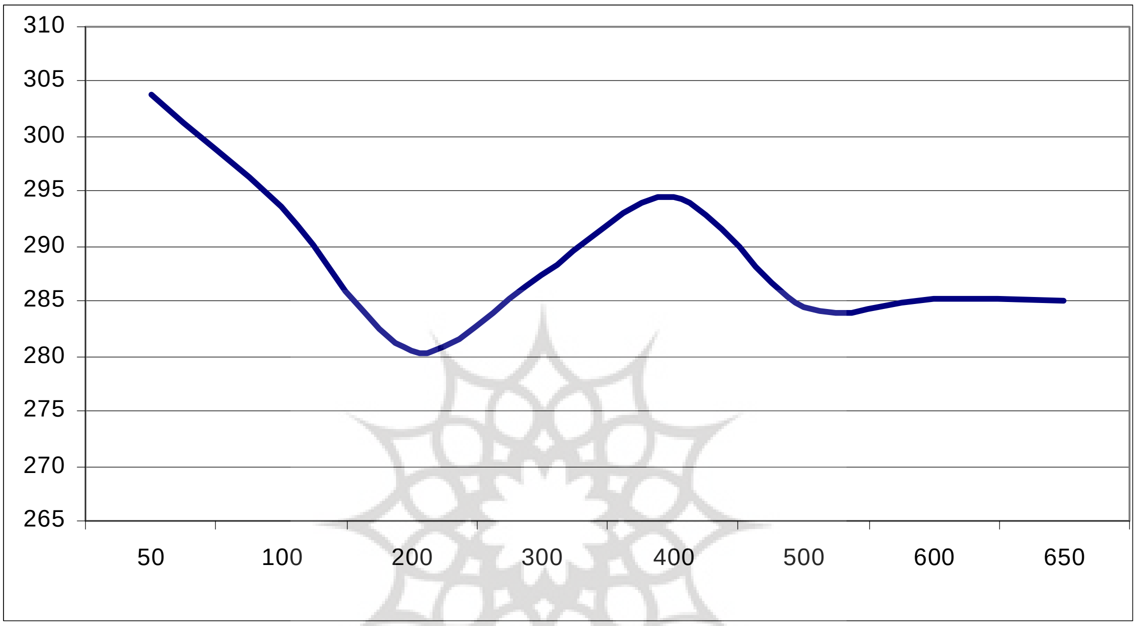
Another very important step before starting interpolation is to find the relationship between number of stations involved in the interpolation and areal mean of the interpolated spatial variable. To examine this relationship ,we chose annual rainfall of 1993 as the base data and prepared a series of maps with different number of randomly selected stations size. With rejard to these observations ,a 159*101 precipitation matrix was prepared. About 8144 pixels of the matrix occur within the boundaries of Iran. The Arithmetic mean of these values then plotted against the number of stations to measure the correlation (Fig. 12)

Table 1) the effect of number of stations

50	Number of Stations
303.7714	Average
245.4824	Standard Deviation
8.96195	Minimum
1443.3	Maximum
100	Number of Stations
293.6628	Average
218.6494	Standard Deviation
17.5987	Minimum
1792.89	Maximum
200	Number of Stations
280.5662	Average
220.3542	Standard Deviation
4.08511	Minimum
1918.09	Maximum
300	Number of Stations
287.4574	Average
224.6448	Standard Deviation
6.5988	Minimum
1831.22	Maximum
400	Number of Stations
294.4557	Average
248.9227	Standard Deviation
2.3295	Minimum
2106.33	Maximum
500	Number of Stations
284.4495	Average
240.9076	Standard Deviation
2.51707	Minimum
2086.09	Maximum
600	Number of Stations
285.2637	Average
248.8558	Standard Deviation
2.76568	Minimum
2136.77	Maximum
650	Number of Stations
285.0127	Average
246.2418	Standard Deviation
2.88396	Minimum
2128.87	Maximum

As the fig. 12 shows interpolation with less than 500 stations result to unstable estimation of mean areal precipitation within the boundaries of Iran. When the number of stations exceeds this minimum level mean areal precipitation becomes more stable and reliable. The same procedure may suggested to investigate the effect of number of stations included in interpolation and other statistics of spatial variable like standard deviation and skewness.

Fig. 12) number of stations included in interpolation against mean areal precipitation of Iran in 1993



Pixel size

Pixel size is a measure of the quality of any digital map. The question is what the sice of digital map could be in respect to spatial behavior of the variable and data density. Here we try to find the relationship between spatial resolution (Pixel Size) and areal mean of the interpolated spatial variable. To examine this relationship, we chose annual rainfall of 118 stations as the base data and prepared a series of maps with different pixel sizes. With respect to these 118 observations a variable size precipitation matrix was prepared. Among the matrix those pixels located within the boundaries of Iranhave been selected (Table 2). Arithmetic mean of these values then plotted against the pixel size to measure the correlation (Fig.13). As this figure shows, the best pixel size for precipitation mapping in Iran is about 14 kilometer. Pixel sizes larger than 14 kilometer are not able to detect spatial behavior of precipitation and result inunstable mean areal precipitation.

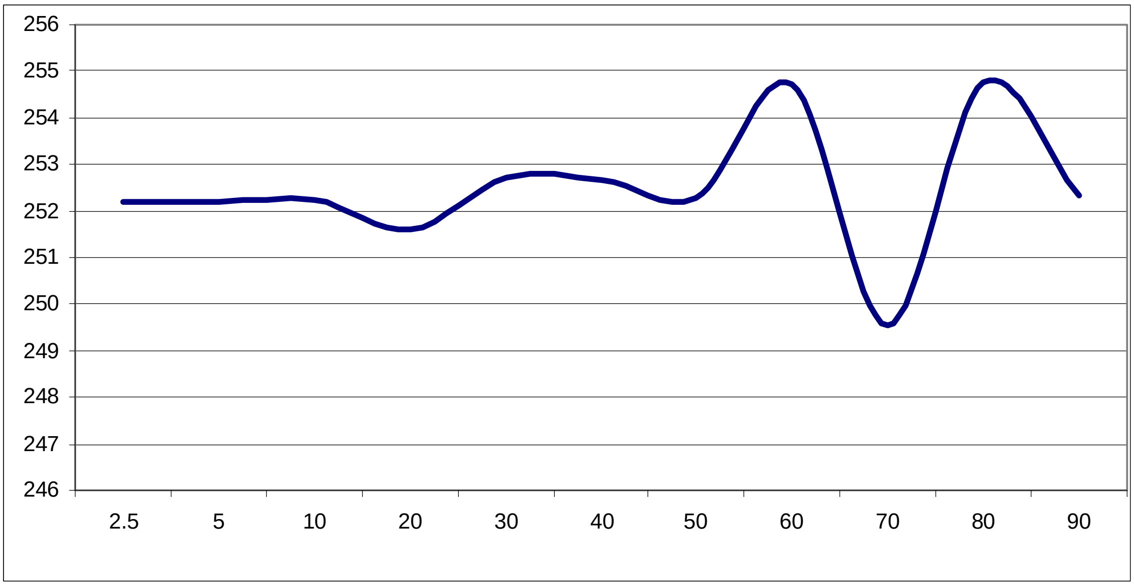
Conclusion

Tho investijation of the spatial behavior of precipitation of Iran shows that preparation of a reliable precipitation map requires a deep knowledge of the spatial behavior of the precipitation before starting interpolation. No data areas, Topographic complexity, complexity of precipitation mechanisms, isotropicity, number of stations, and pixel size are the most important pre-interpolation aspects of digital precipitation maps for Iran. This study shows that minimum number of stations needed for preparation of a reliable precipitation map is about 500 and the best pixel size is about 14 kilometers.

Table 2) the effect of pixel size

Pixel Size	Number of numeric cells	Average	Standard Deviation	Minimum	Maximum
2.5*2.5 Km	259614	252.1923	195.5346	2.69811	1873.13
5*5 Km	64910	252.1879	195.5703	2.71294	1852.83
10*10 Km	16233	252.2221	195.5929	2.73578	1808.15
20*20 Km	4098	251.6037	193.9671	3.04536	1586.33
30*30 Km	1800	252.7126	196.6448	2.71666	1588.95
40*40 Km	1011	252.6725	196.4421	2.96708	1528.45
50*50 Km	651	252.2841	195.3721	3.9304	1347.62
60*60 Km	462	254.711	203.3385	3.86962	1688
70*70 Km	328	249.5293	189.6899	3.67586	1313.78
80*80 Km	260	254.784	201.8967	4.26816	1522.85
90*90 Km	207	252.3216	197.4892	11.7376	1231.74

Fig. 13)The effect of pixel size on areal mean of interpolated precipitation of Iran in 1993



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