



# Variation in frequency and proportion of duration of rainy days in Iran's precipitation

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## Abstract

In any given region, climate change can be manifested in the form of various characteristics of climatic elements. In the present study, the frequency of different duration of rainy days was examined to investigate the precipitation variations as a sign of climate change. To this end, gridded precipitation data were used from 1971 through 2016, and days with more than 1 mm of precipitation were considered rainy days. According to the rainy days' frequency, it was revealed that during the study period, 1 to 36 days of duration occurred in the country. The 1-day duration had the highest frequencies and covered the vastest areas, while 36-day duration had the lowest frequencies and covered the minor areas. Accordingly, the 1-day duration played the most significant role in annual precipitation. The proportion of these rainfall events in some country's dry and semi-dry parts was more than 80%. The findings also revealed an increased frequency of short-term, especially 2-day duration, in large parts of the country and a decrease in the long-term duration. The results showed that latitude and longitude had the most significant impact on the frequency distribution of the duration of rainy days. Latitude had a direct effect (excluding the 1-day duration of annual precipitation), and longitude had an inverse effect (except the 1-day duration of annual precipitation) on the precipitation duration.

## 1 Introduction

As one of Iran's most critical climatic elements, precipitation has always had unique complexities. These complexities are mainly due to the location and geographical features of the country, something which has caused inequalities in the tempo-spatial distribution of precipitation (Alijani et al. 2014). The significant role of precipitation in water supply has drawn the attention of climatologists to this climatic element, its characteristics, and changes. One of the essential features of precipitation in Iran is the temporal and spatial variations of rainy days and their duration, which have been examined only in few studies.

A rainy day is a day in which all atmospheric forcing breads to at least 1 mm of precipitation (Douguedroit 1987; Romero et al. 1998; Lázaro et al. 2001; Kutiel and Trigo 2014; Bichet and Diedhiou 2018; Vaittinada Ayar and Mailhot 2021; Masoudian and Kavyani 2008). Therefore, these features' persistence could cause continuous precipitation

for several days. Examining the duration and the amount of precipitation during consecutive days can provide helpful insight into water resources in any given area. For example, the long-term rainfall duration can significantly impact surface and underground water resources, increase tropospheric moisture, and reduce evapotranspiration (Kavyani and Alijani 2001). The duration of precipitation and its variations have been the center of some worldwide studies' attention (Naseri and Modarres 2009; Singh and Ranade 2010; Ratan and Venugopal 2013; Vinnarasi and Dhanya 2016; Duan et al. 2017; Ye and Fetzer 2019; Nazaripour et al. 2011; Asakereh 2013; Mansuri and Doostan 2019; Gholizadeh and Hamidi 2020). In many studies, the precipitation duration was considered on an hourly basis. In the meantime, some studies, such as Nunn (1929) (concerning the precipitation duration in Baltimore), were conducted based on stations. Nevertheless, most studies were carried out over large areas (Shands 1947; Agha Razi et al. 2007; Behyar et al 2013; Ghafouriam and Telvari 2010; Liu 2011).

Due to variations in precipitation characteristics in recent years leading to flood and drought risks in Iran, the investigation into precipitation is of utmost importance. One of the essential characteristics of precipitation in Iran is the rainy days' duration. The current study investigated the frequency

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of precipitation duration and its tempo-spatial variations based on regression methods using the precipitation database from 1970 to 2016.

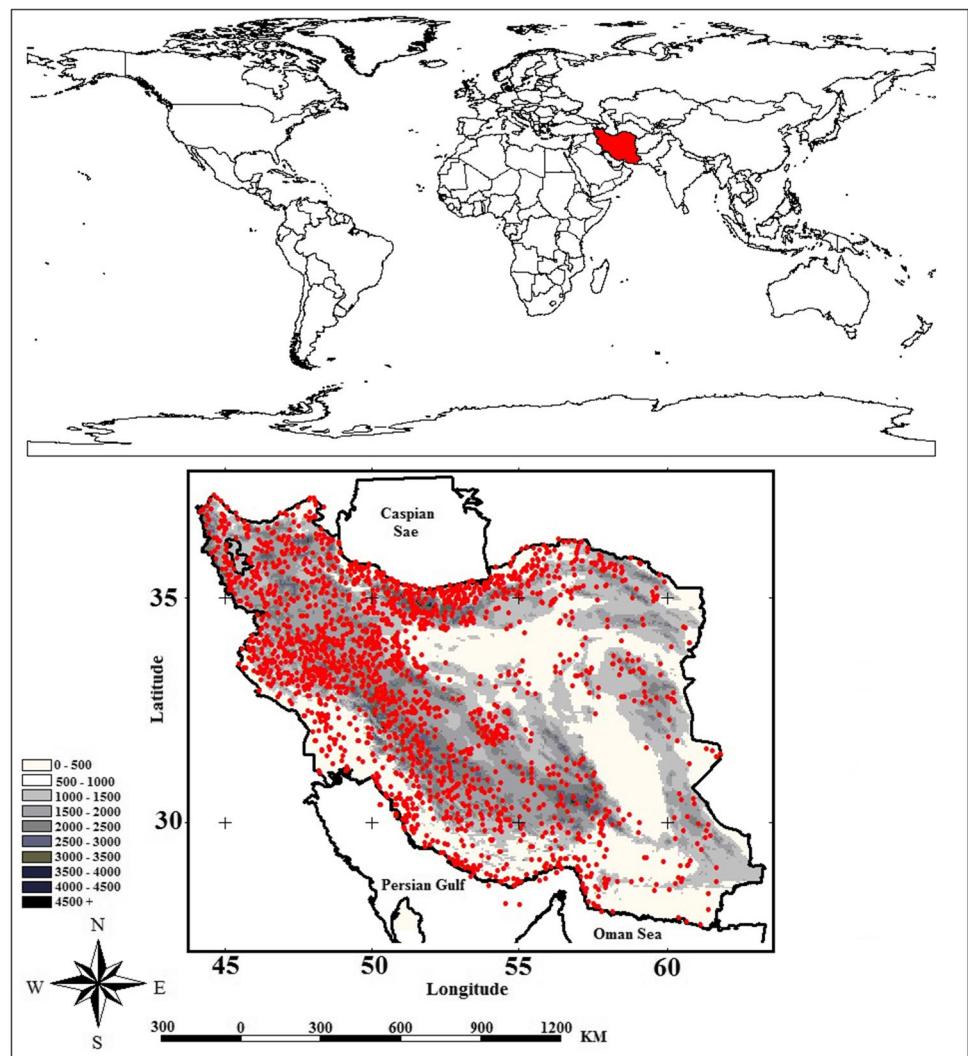
## 2 Data and methodology

### 2.1 Study area

Iran is located in southwest Asia in the desert belt of the planet, where most of the arid and semi-arid regions of the world are located (Alizadeh 2009). Therefore, the significant parts of the country's center, the east, and southeast are arid or semi-arid areas. Figure 1 shows the topographic map of Iran. As shown in Fig. 1, two mountain ranges form the major topographic feature of Iran, including west-east (Alborz mountain range) and northwest-southeast (Zagros mountain range) directions. Each of these mountain ranges plays an essential role in Iran's distribution of moisture and

precipitation. The Alborz range encloses the humidity of the Caspian Sea on the northern slope. The Zagros is a barrier to confine the humidity of the Mediterranean Sea, reaching low-lying areas in the center of Iran. Therefore, the southern terrain aspects of Alborz and the eastern slope aspects of Zagros are different in appearance from their opposite slopes. The northern slope aspects of Alborz and the western slope aspects of the Zagros are regions with high precipitation. Therefore, the distribution of elevations and their orientations control the precipitation distribution in Iran. Accordingly, the borders of Iran's climatic zones are mainly consistent with the topographic borders (Masoudian and Kavyani 2008). The southeastern part of Iran is affected by monsoon systems in the warm season, and parts of precipitation in the region result from these systems. Consequently, the factors involved in rainfall distribution in Iran can be divided into internal (local) and external (atmospheric circulation) factors, each of which contributes to the formation and distribution of precipitation.

**Fig. 1** Iran's location in the world (a), its topography, and distribution of stations adopted in the current study



## 2.2 Data

The daily precipitation data of 2188 synoptic, climatic, and rain gauge stations of Iran's Meteorological Organization were obtained from 1970 to 2016. These data were converted into a matrix of time-station mode. Thus, the matrix dimensions were 16,801 rows (time: days) and 2188 columns (meteorological stations). The average number of active stations per day was 488. For various reasons, the number of active stations was not constant during the under-study period. The spatial density of the stations decreased from west to east and from north to south (Fig. 1). The spatial density of the station varied between zero and 4 per 100 km<sup>2</sup>.

## 2.3 Methods

In order to cover the missing data, it is necessary to convert the station data into gridded data through the interpolation process. Our examination showed that under a significant 15% error, at least 250 stations were required for creating an isohyetal map of Iran. Accordingly, considering the number of active stations per day, it is possible to calculate Iran's isohyetal maps with an error rate of less than 15% for 1970 through 2016 (i.e., 46 years: 16,801 days). Thus, the data were collected from 1970 to 2016. Based on the spatial distribution of meteorological stations and the average distance between the stations, the pixels of Iran's daily precipitation maps were made with a resolution of 10 km. According to previous extensive studies on various interpolation methods conducted on Iran's isohyetal maps (Masoudian et al. 2015; Masoudian 2008; Asakereh 2008), the Ordinary Kriging Interpolation method was considered a proper interpolation method. The projection system of this database was Conical Lambert. Accordingly, the dataset includes dimensions of 167 × 205. The total number of gridded data pixels was 34,235, out of which 16,203 were located within Iran's borders. On the other hand, regarding the start and end of the under-study period (1970 to 2016), the dataset included 16,801 days. Consequently, the final dimensions of the dataset were 167 × 205 × 16,801. The temporal and spatial features of precipitation duration within the Iranian borders were studied using the database.

In this study, the duration of precipitation in Iran was evaluated. To this end, days with precipitation exceeding 1 mm were considered rainy days. After determining the rainy days, the frequency of rainy days was also examined. Consecutive days with more than 1 mm of precipitation were identified as precipitation sequences. After identifying precipitation duration, two approaches were considered to analyze the findings:

1. Frequency analysis of various precipitation duration and the proportion of precipitation of each duration in

the amount of annual precipitation were investigated. In addition, the linear trend of the frequency of maximum duration was analyzed by least square error (Asakereh 2006; Mudelsee 2019). The linear trend function is defined as follows (Box et al. 2016):

$$Z_t = \alpha + \beta t \quad (1)$$

where  $Z_t$  is the amount of precipitation during time  $t$  ( $t = 1, 2, \dots, n$ ).  $\alpha$  is the intercept of the trend line and  $\beta$  is the slope of the trend line.  $\alpha$  and  $\beta$  calculated by using the least squares method.

2. Spatial analysis and modeling of rainy days and their duration were performed based on multivariate regression. Using regression equations, in addition to quantifying the effect of geographical coordinates (longitude ( $\lambda$ ) and latitude ( $\varphi$ )) and topographic factors (altitude ( $h$ ), slope aspect ( $A$ ) and slope terrain ( $S$ )), as independent factors, the effect of each factor on the studied element can be obtained (Asakereh et al. 2021a, b). The effect of these factors on the dependent variable (frequency of precipitation durations and/or share (role) of each duration) was measured by multivariate regression.

Multivariate regression determines the variance of the dependent variable through the variance participation of two or more independent variables. If  $k$  the independent variable,  $x_{ik}$  is used to justify  $y$  in the equation, the multivariate regression equation will be as follows (Asakereh 2011):

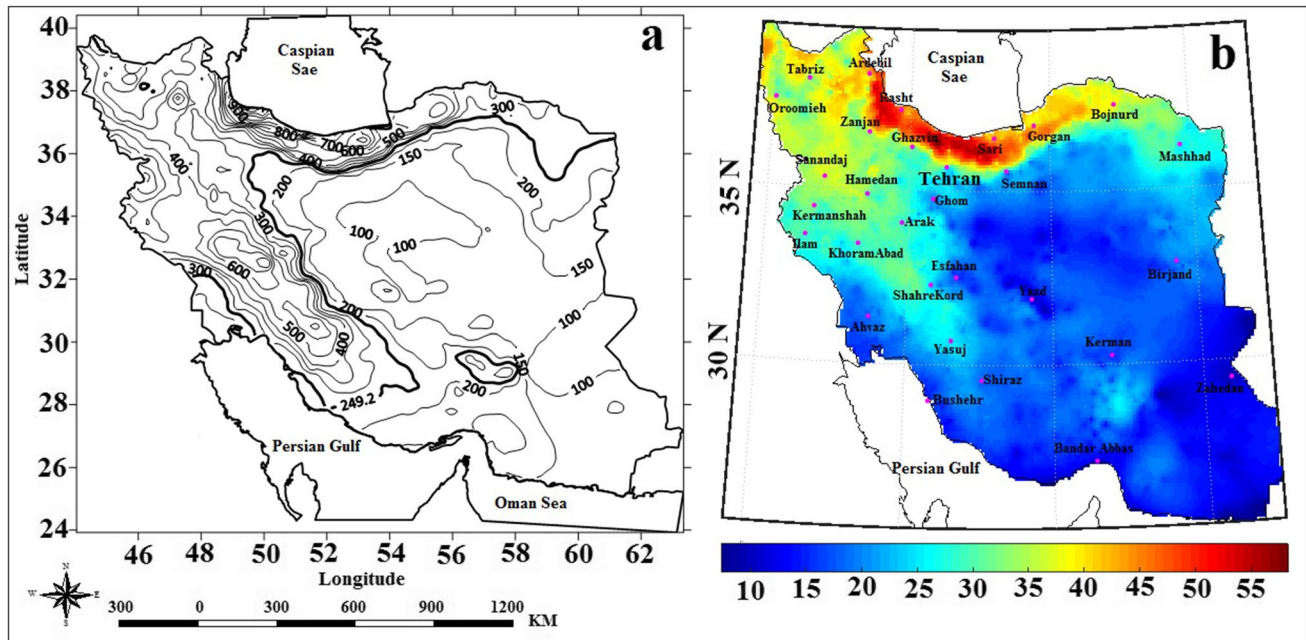
$$y = a + \sum_{i=1}^k b_i x_i + e_i \quad (2)$$

A multivariate model generally shows the dependent variable in a multidimensional space. In this equation,  $a$  is the y-intercept,  $b_i$  is the expected variation for  $y$  per unit change of  $i_{th}$  factor provided that the other factors are constant. Multivariate regression coefficients were estimated using the least squares error method.

## 3 Results and discussion

### 3.1 General characteristics of Iran's precipitation

Figure 2 a depicts the spatial distribution of Iran's annual precipitation in the understudied period. As can be seen, from Fig. 2 a, the elevation distribution played an essential role in the precipitation distribution. The maximum precipitation occurred along the windward Alborz (west-east direction) and Zagros (northwest-southeast direction) mountain ranges. The spatial average of precipitation (249.2 mm) illustrated in the figure follows these mountainous areas. It distinguishes the areas with high precipitation from those



**Fig. 2** **a** Long-term average of annual precipitation (thick line represents the spatial average of precipitation in mm) and **b** annual average of the frequency of rainy spells (days)

with low precipitation in the center, east, and southeast of Iran. According to Asakereh et al. (2021a), generally, precipitation decreases from west to east and from north to south. The maximum precipitation was observed on the Iranian Coast of Caspian Sea (ICCS) and the Zagros summits. Asakereh et al. (2020) attributed the decreasing spatial trend of precipitation in Iran to the reduction of energy and moisture of Mediterranean cyclones and the leeward effect of the Zagros and Alborz ranges. Accordingly, the elevation effectively impacted the spatial distribution of rainy spells in addition to the geographical coordinates.

Figure 2 b shows the average frequency of rainy spells. A rainy spell was considered 1 to  $n$  days during which the rain occurred continuously. Each rainy period is separated from the next by at least 1 dry day. As can be seen from Fig. 2 b, the most prolonged rainy spells occurred on the ICCS. Besides the ICCS, the northwestern and northeastern parts of Iran and the Zagros mountain had the most extended rain spells. Iran's central, eastern, and southeastern parts had the shortest rainy spells. Therefore, the spatial distribution of rainy spells followed the spatial distribution of annual precipitation.

### 3.2 Frequency of rainy days duration

Analysis of Iran's precipitation during the study period showed that the rainy days could last from 1 to 36 days. The study's findings showed that the whole country had 1 to 4 rainy days during the study period, and more than

80% of Iran's territory had 5 to 7 rainy days. As the number of consecutive rainy days increases, the precipitation area decreases. Therefore, in more than 13 days, the receiving area diminished to less than 10% (Table 1), a condition attributed to the heavy rains' locality. Therefore, this paper examines the duration that covers extensive areas. Figure 3 shows the study period's average frequency of 1- to 10-day duration.

One-day precipitation duration had the highest frequency among all the duration of precipitation in the country. The highest frequency of this duration was observed in the northern parts of the country (from northwest to northeast); towards the south, the frequency of the 1-day duration of precipitation decreased (Fig. 3). Due to the Caspian Sea moisture, the westerly direction, and the humidity of these systems, the conditions were more favorable for precipitation in the country's northern half. The frequency of 1-day duration of precipitation was at its minimum level (lower than five times a year on average) in the country's southeast. However, in the highlands of the southern half of Iran, the 1-day precipitation duration frequency was slightly higher than that in the surrounding areas. This spatial difference was ascribed to the slope convection of precipitation in the highlands (Kavyani and Alijani 2001). In some parts of the country, particularly in the central, eastern, and southeastern regions, all annual precipitations were in the form of the 1-day duration of precipitation (Table 1).

The maximum precipitation frequency was limited to the country's northern coasts for 2-day duration. The frequency of



**Table 1** Covered areas by different precipitation days and their proportion in annual precipitation

| Duration (days) | Area covered by duration (%) | Share of duration of annual precipitation in the country |     |      |
|-----------------|------------------------------|--|-----|------|
|                 |                              | Mean   | Min | Max  |
| 1               | 100                          | 50.9   | 5.3 | 100  |
| 2               | 100                          | 27.2   | 0.6 | 94.7 |
| 3               | 100                          | 11.7   | 0.3 | 55.9 |
| 4               | 100                          | 5.1  | 0.2 | 48.5 |
| 5               | 99.8                         | 2.5  | 0.2 | 50   |
| 6               | 95.4                         | 1.3  | 0.1 | 27.5 |
| 7               | 80.7                         | 0.6  | 0.1 | 14.3 |
| 8               | 63.4                         | 0.3  | 0.2 | 25   |
| 9               | 46.3                         | 0.2  | 0.2 | 9.3  |
| 10              | 32.1                         | 0.1  | 0.3 | 12.2 |
| 11              | 21.7                         | 0.1  | 0.2 | 5.5  |
| 12              | 14.8                         | 0  | 0.3 | 5.4  |
| 13              | 11.9                         | 0  | 0.4 | 7.1  |
| 14              | 6.4                          | 0  | 0.5 | 3.5  |
| 15              | 6.1                          | 0  | 0.5 | 7.7  |
| 16              | 3.5                          | 0  | 0.3 | 3.2  |
| 17              | 2.3                          | 0  | 0.6 | 4.3  |
| 18              | 2                            | 0  | 0.6 | 3.1  |
| 19              | 0.8                          | 0  | 0.9 | 1.9  |
| 20              | 1                            | 0  | 0.7 | 3.3  |
| 21              | 1.2                          | 0  | 0.5 | 2.2  |
| 22              | 0.5                          | 0  | 1   | 3    |
| 23              | 0.8                          | 0  | 0.9 | 2.8  |
| 24              | 0.5                          | 0  | 1.1 | 2.7  |
| 25              | 0.4                          | 0  | 0.9 | 2.5  |
| 26              | 0.2                          | 0  | 1.1 | 2    |
| 27              | 0.3                          | 0  | 1.9 | 2.5  |
| 28              | 0.3                          | 0  | 1.4 | 2.9  |
| 29              | 0.2                          | 0  | 1   | 2    |
| 30              | 0.1                          | 0  | 1.1 | 2.2  |
| 31              | 0.006172                     | 0  | 0   | 0    |
| 32              | 0                            | 0  | 0   | 0    |
| 33              | 0.006172                     | 0  | 0   | 0    |
| 34              | 0.006172                     | 0  | 0   | 0    |
| 35              | 0                            | 0  | 0   | 0    |
| 36              | 0.006172                     | 0  | 0   | 0    |

this duration, nevertheless, was less than 1-day duration. The Zagros and Alborz range significantly influenced this duration. Therefore, the Zagros and Alborz, on average, had more than six sets of the 2-day duration of precipitation per year. This frequency increased at higher altitudes by 10 or more days.

The 3-day duration of precipitation occurred most frequently on the country's northern coasts. However, there was less duration in the eastern parts of the coast. In the central and western coasts, the frequency of the 3-day duration of

precipitation was the highest. The Zagros and Alborz mountains also played an essential role in this duration. At the higher parts, the frequency of the 3-day duration of precipitation increased.

From 4- to 10-day precipitation duration in the country's northern coasts, particularly in the southwest of the Caspian Sea, the duration frequency reached the maximum. As the number of precipitation days increased, their frequencies and influenced areas significantly decreased (Fig. 3). In addition, the frequency of higher duration was limited to the mountainous areas. Darand (2018) also showed the role of altitudes in the duration of precipitation in Kurdistan province, Iran.

During the study period, the duration of precipitation equal to or more than 4 days was not observed in large parts of southern and eastern regions. This duration was expected in the northern, northwestern, and highlands.

Figure 4 shows the frequency trend of the 1- to 10-day duration of precipitation. One-day precipitation duration in the country's southeast had a significant increasing trend. Rahim Zadeh et al. (2011) also showed that a noticeable amount of annual precipitation occurred in this region in fewer days; therefore, the relatively heavy precipitation increased. The increase in the frequency of 1-day precipitation can be attributed to the increase in the number of local events due to global warming. There was an increasing trend in the 2- to 3-day precipitation in the country's central, northwestern, and western parts.

### 3.3 The proportion of various duration in annual precipitation

In the current study, the proportion of each precipitation duration is the percentage of the duration to the annual precipitation. Figure 5 illustrates the average proportion of the 1- to 10-day duration of annual precipitation.

Some parts of the country received all of their annual precipitation within the 1-day duration of precipitation. These parts include the central, southeastern, and southern areas, the least wet parts of the country. In the central parts, the distance from water bodies and the Zagros mountain range played an influential role (Alijani 2008). Locating in the Zagros leeward prevents westerly winds' impact on this part of the country (Masoudian and Kavyani 2008; Sotoudeh et al. 2019). In the southern coasts, subtropical high pressure (STHP) is an obstacle to precipitation formation in these areas, as in these parts, even in the cold season, STHP is active (Alijani 1996). Nazaripour et al. (2011) also showed that large parts of Iran experienced the 1-day duration of precipitation. According to their study, precipitation with the 1- to 3-day duration in the eastern regions was more prevalent; a longer duration of more than 3 days in the western half of the

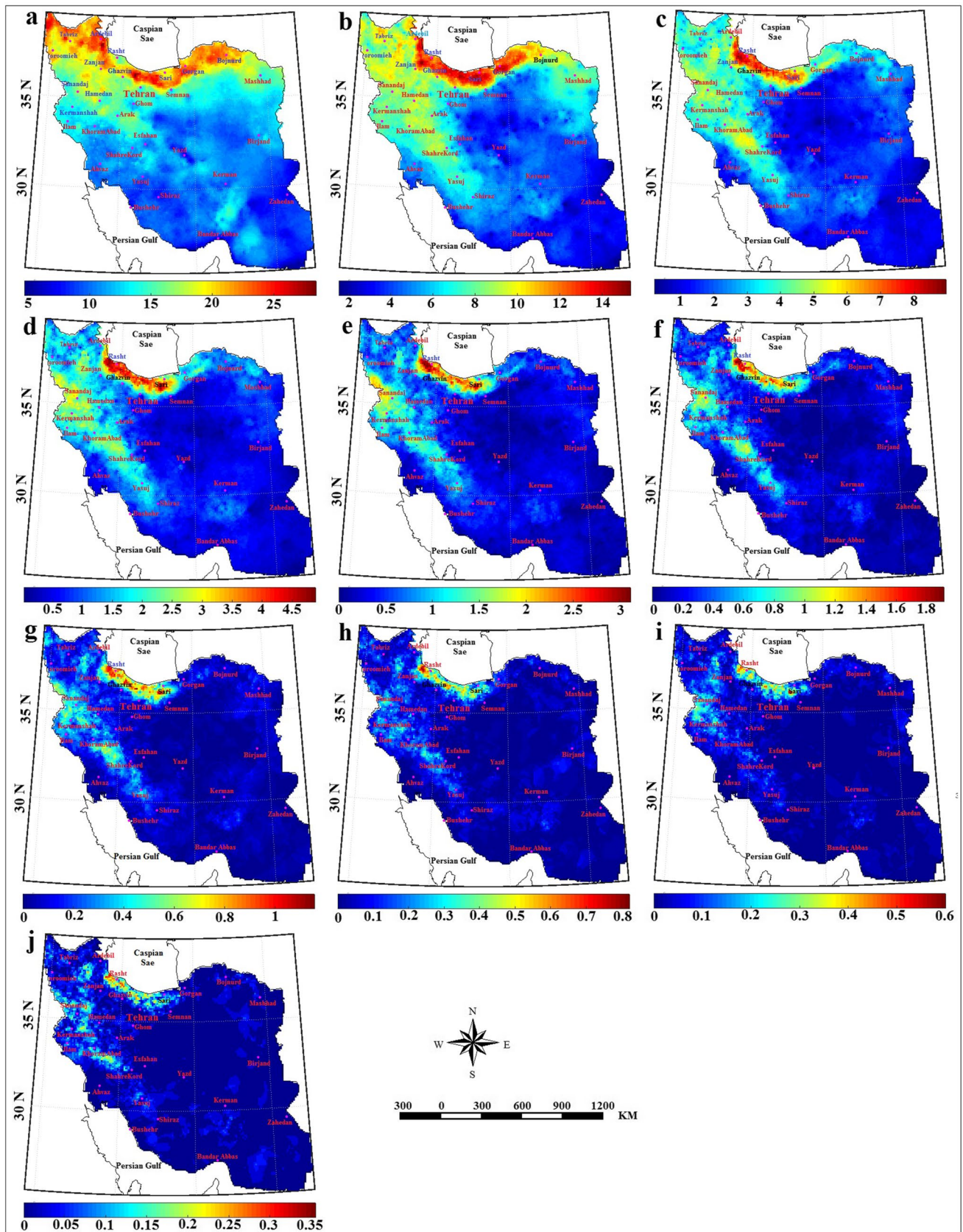


Fig. 3 Average frequency of 1- to 10-day duration of precipitation in Iran



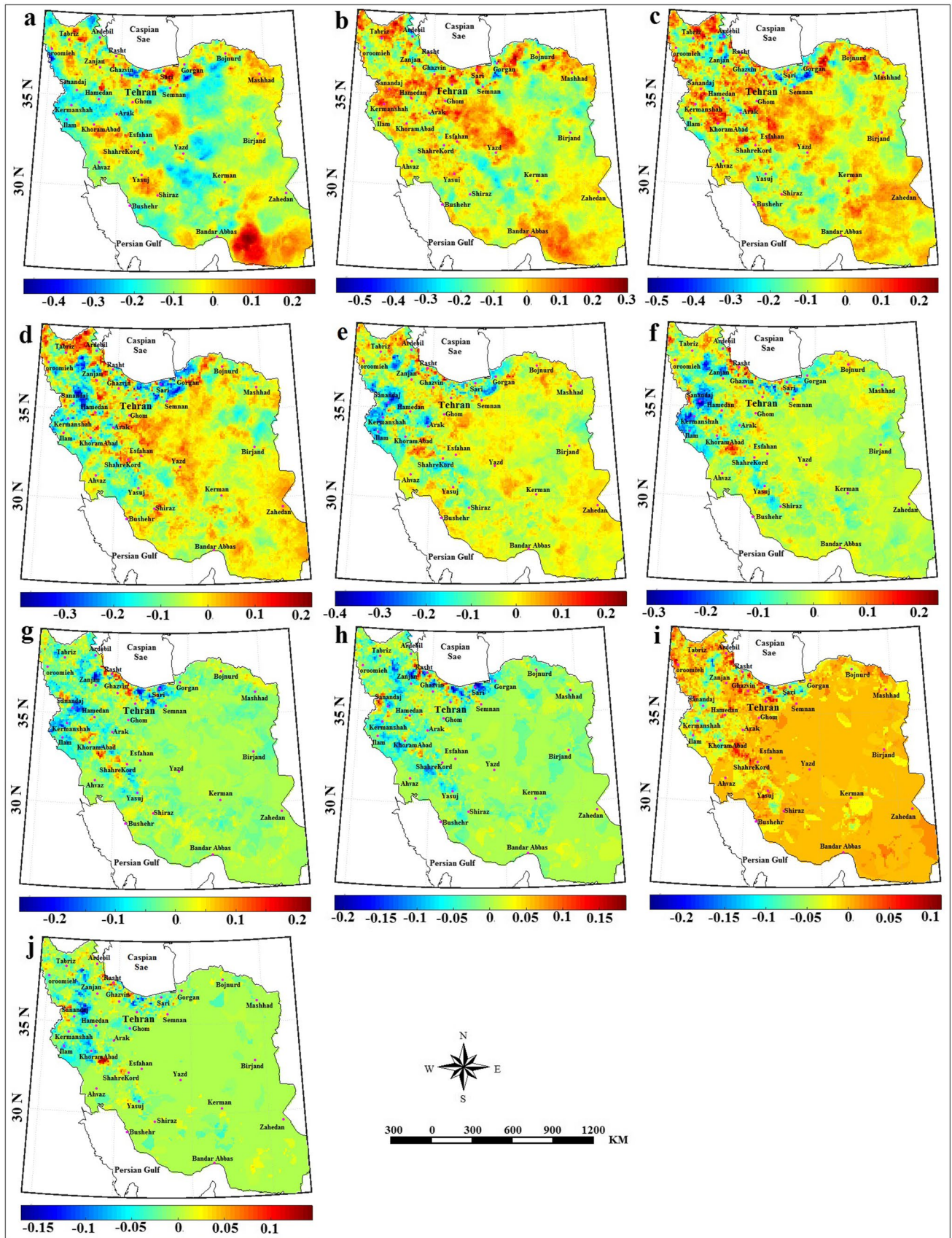


Fig. 4 Frequency of 1- to 6-day precipitation duration in Iran



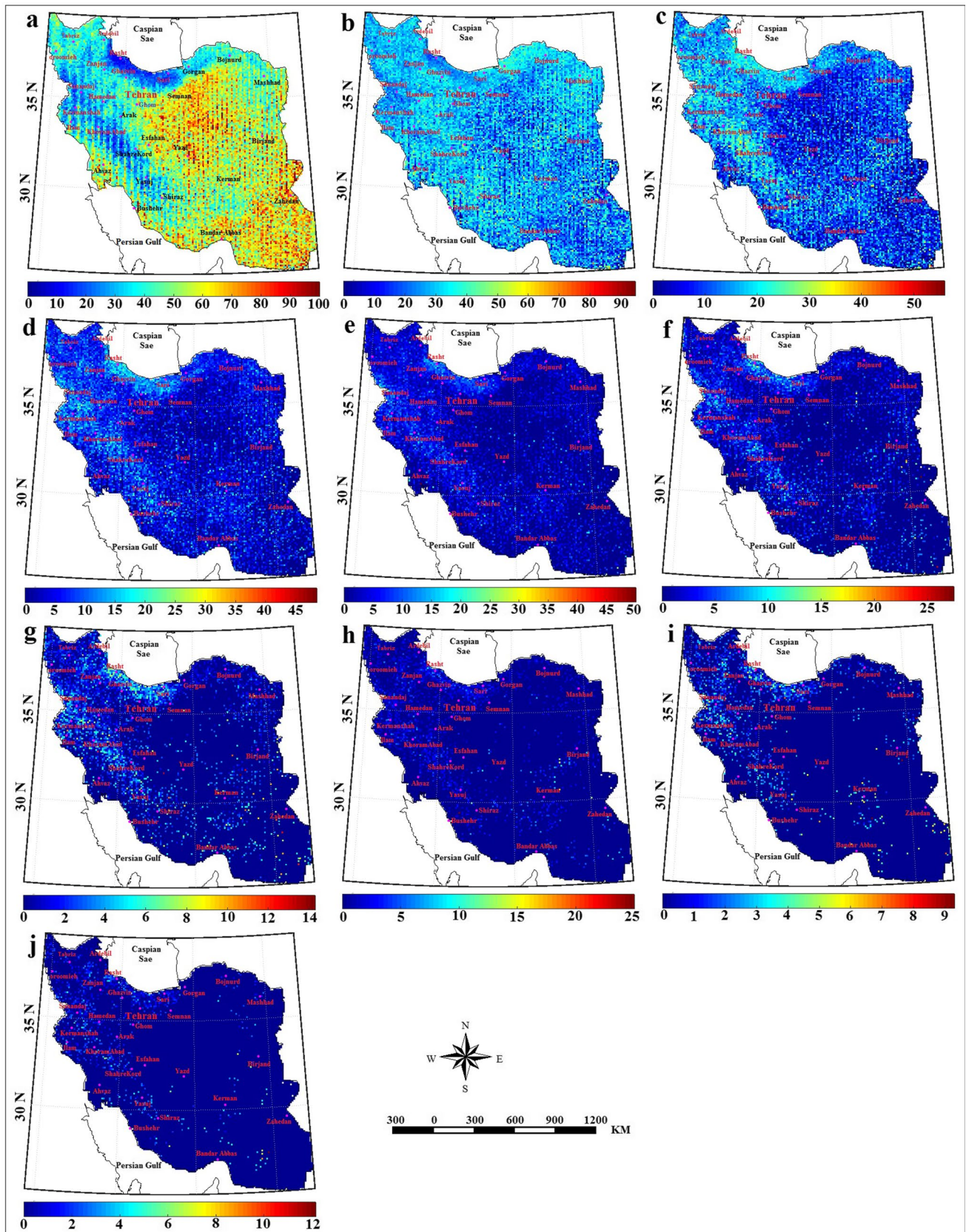


Fig. 5 Average proportion of 1- to 10-day duration in Iran's annual precipitation



country was more common. In the ICCS and the Zagros, the 1-day precipitation duration had the lowest proportion of annual precipitation (Fig. 5). These areas were the rainiest areas of the country, respectively (Alijani et al. 2008), in which the precipitation showed a decreasing trend in the 1-day duration. Therefore, the minimum duration in low-precipitation areas and longer duration in higher-precipitation areas include significant proportions of precipitation amount. The results align with those of Nazari-pour et al. (2011) study. As the precipitation spells lengthened, the proportion of annual precipitation duration decreased. Therefore, this proportion reached the lowest possible value in the maximum duration and was slightly higher than zero. Precipitation with minimal duration appeared to be due to large-scale atmospheric systems, as the short duration of precipitation affected the broader area and accounted for more annual precipitation. Nazari-pour (2014) also showed that the short duration of precipitation included the majority of rainfall and rainy days throughout Iran, and the long duration included a limited number of rainfalls locally.

The increase in the short-duration frequency of west Iran can be attributed to the activity of the Sudanese systems. According to Lashkari and Mohammadi (2019), the increasing trend of short duration in the west of Iran was imputed to the short effect's duration of the Sudanese systems in the region.

A decreasing duration frequency trend could be observed in large parts of the country, a phenomenon ascribed to the decreasing moisture of advection (Dostkamyani et al. 2015). A decrease in the frequency of precipitation duration refers to an increase in dry duration, a phenomenon that Asakereh and Tarkarani (2020) attributed to changes in STHP and cyclones redirections. Asakereh et al. (2019) also investigated the reduction of the frequency of incoming cyclones in Iran. Jahanbakhsh et al. (2021) investigated the redirection of the cyclones entering the country concerning the decrease of precipitation in the southwest. The results of the present study align with those of the study conducted by Fatahi and Hejazi Zadeh (2006). Their study showed that dry and wet periods strongly correlated with the frequency of different air masses. The increase in the frequency of more than 5-day precipitation in many parts of the country in the central, eastern, and southeastern parts was almost without a particular trend since precipitation often lasted fewer than 5 days; therefore, no trend was observed in these areas. According to previous studies (e.g., Nazari-pour and Karimi 2013), the proportion of short-duration increased. Nazari-pour and Karimi (2013) also showed an increasing trend in the proportion of short-duration, which led to a temporal shortening in the country's precipitation.

### 3.4 The trend of the maximum duration of rainy days

During the study period, the highest duration in the country was 36 consecutive days of rainfall. In some parts of the country, the highest duration, mainly in the central parts of the country, was 4 days. The maximum duration of precipitation in large parts of the country was fewer than 10 days. In small parts of the west, northwest, and north of the country, the maximum duration was more than 25 days. In these areas, the maximal duration experienced a decreasing trend. In areas where the maximal duration was short, the number of maximal duration increased. The most prominent increasing trend of maximal duration could be observed in the northwestern border areas and the ICCS. The decreasing trend of maximal duration may be because precipitation occurred in these areas for a few days (minimum frequency) (Fig. 6), which could lead to climatic hazards and cause floods. Approximately 22.6% of the country realm had an increasing trend, and 77.4% experienced a decreasing trend of annual maximal duration. Asakereh et al. (2020) also showed a decreasing trend in the frequency of rainy days based on high percentiles of precipitation. According to their study, the frequency of dry days had an increasing trend. An increase in dry days could concern a reduction in precipitation duration.

### 3.5 Spatial analysis and spatial modeling of precipitation duration

Multivariate regression was adopted to investigate the effect of spatial factors on the frequency of precipitation duration. Spatial factors used in this study are latitude and longitude, altitude, terrain slope, and terrain aspect. Since the higher duration is not spatially continuous, only the multivariate regression equation for the 1- to 10-day duration of annual precipitation was included in Tables 2 and 3. As can be seen from Table 2, latitude and longitude were the most critical factors affecting the spatial distribution of the frequency of 1- to 10-day duration, respectively. The role of these factors was noticeably prominent in a short duration. Latitude and longitude were related to the frequency of precipitation duration in direct and indirect ways, respectively. In other words, with an increase in latitude, the frequency of precipitation duration increase, and with an increase in longitude, the frequency of precipitation duration decrease. The findings of the study conducted by Asakereh et al. (2021a) substantiate those of the present study and the inverse and direct relationship of the country's precipitation with longitude and latitude, respectively. However, longitude had a more significant effect on precipitation. The effect of latitude is more significant on minimal duration than maximum duration. In a longer duration, the role of longitude became

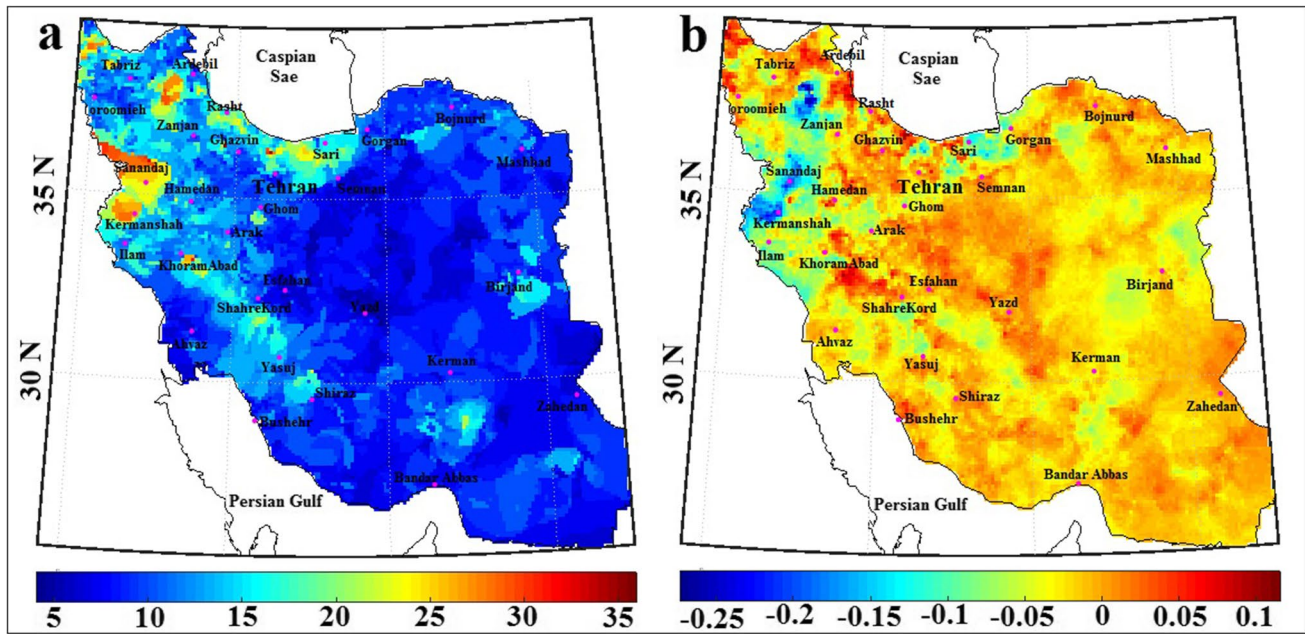


Fig. 6 The longest precipitation duration (days) and its temporal trend (days/year)

**Table 2** Multivariate regression models of spatial factors and frequency of one to ten-day precipitation duration

| Spell (day) | Multi regressions   |
|-------------|---|
| 1           | $P_{S1} = -13.27 + 0.93\varphi - 0.09\lambda + 0.0004h + 0.13S + 0.00002A$      |
| 2           | $P_{S2} = 0.09 + 0.43\varphi - 0.16\lambda + 0.0004h + 0.12S + 0.0008A$         |
| 3           | $P_{S3} = 4.9 + 0.13\varphi - 0.13\lambda + 0.0003h + 0.07S + 0.0003A$          |
| 4           | $P_{S4} = 2.9 + 0.06\varphi - 0.07\lambda + 0.0001h + 0.04S + 0.0002A$          |
| 5           | $P_{S5} = 1.9 + 0.02\varphi - 0.04\lambda + 0.00009h + 0.02S + 0.00008A$        |
| 6           | $P_{S6} = 0.99 + 0.01\varphi - 0.02\lambda + 0.00005h + 0.01S + 0.00004A$       |
| 7           | $P_{S7} = 0.5 + 0.007\varphi - 0.01\lambda - 0.00002h + 0.007S + 0.00001A$      |
| 8           | $P_{S8} = 0.22 + 0.004\varphi - 0.006\lambda + 0.00001h + 0.004S + 0.000004A$   |
| 9           | $P_{S9} = 0.12 + 0.003\varphi - 0.0037\lambda + 0.000006S - 0.000001A$          |
| 10          | $P_{S10} = 0.12 + 0.001\varphi - 0.002\lambda + 0.000004h + 0.001S - 0.000002A$ |

**Table 3** Multivariate regression models of spatial factors and the proportion of 1- to 10-day duration of annual precipitation

| Spell (day) | Multi regression   |
|-------------|--|
| 1           | $Ratio_{S1} = 1.7 - 0.76\varphi + 1.47\lambda - 0.003h - 0.6S - 0.005A$          |
| 2           | $Ratio_{S2} = 23.3 + 0.34\varphi - 0.15\lambda + 0.0005h + 0.04S + 0.001A$       |
| 3           | $Ratio_{S3} = 30.06 + 0.13\varphi - 0.45\lambda + 0.001h + 0.16S + 0.002A$       |
| 4           | $Ratio_{S4} = 18.8 + 0.09\varphi - 0.33\lambda + 0.0007h + 0.15S + 0.001A$       |
| 5           | $Ratio_{S5} = 12.2 + 0.057\varphi - 0.22\lambda + 0.0005h + 0.1S + 0.0003A$      |
| 6           | $Ratio_{S6} = 5.9 + 0.04\varphi - 0.12\lambda + 0.0002h + 0.06S + 0.0004A$       |
| 7           | $Ratio_{S7} = 3.15 + 0.33\varphi - 0.07\lambda - 0.0001h + 0.04S + 0.00001A$     |
| 8           | $Ratio_{S8} = 1.55 + 0.017\varphi - 0.03\lambda + 0.00008h + 0.02S + 0.0001A$    |
| 9           | $Ratio_{S9} = 0.8 + 0.017\varphi - 0.024\lambda + 0.00005h + 0.01S - 0.000006A$  |
| 10          | $Ratio_{S10} = 0.89 + 0.004\varphi - 0.02\lambda + 0.00002h + 0.008S - 0.00003A$ |

more prominent. Regarding the proportion of precipitation caused by each duration, latitude and longitude were the

most critical factors affecting the duration frequency, respectively. A significant finding was the inverse effect of latitude



and the direct effect of longitude in the proportion of the 1-day precipitation duration (Table 3). The proportion of the 1-day duration in annual precipitation decreased as the latitude increased, and it increased as the longitude increased, which indicates the importance of the 1-day precipitations in the water supply of arid regions of the country. In other cases of the duration of rainy days, the opposite was true.

## 4 Summary and conclusion

This study used precipitation-gridded data from 1971 to 2016. A daily data matrix was formed for 16,436 days to investigate the frequency of rainy days and their variations as a characteristic of precipitation. The study showed that the country's precipitation duration was 1 to 36 days in the under-study period. The 1-day duration had the highest number of repetitions and covered the broadest area. In contrast, 36-day duration had the lowest number of repetitions and covered the smallest area. Due to the importance of shorter duration, the 1- to 10-day duration was analyzed in this study. The findings showed that 1-day duration had the highest proportion of annual precipitation. In some parts of low precipitation areas (including the central, eastern, and southeastern), all annual precipitation resulted from the 1-day duration. In other words, areas with low precipitation received a high percentage of annual precipitation from the 1-day duration. The 1-day duration included a small proportion of the annual precipitation of high-precipitation areas. The frequency of short-term duration, especially 2-day duration, was increased in large parts of the country, and long-term duration was decreased in many areas. The proportion of short-term duration also increased. The results showed that latitude and longitude significantly impacted the frequency distribution of rainy-day duration, respectively.

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**Author contribution** We, the authors, contributed to the research. Hossein Asakereh performed the study conception, design, and data analysis. Material preparation and data collection were performed by Saeideh Ashrafi. The first draft (in Persian) of the manuscript was written by Saeideh Ashrafi. The final version of the manuscript (in English) was written by Hossein Asakereh.

**Data availability** The data on daily precipitation was provided from the Islamic Republic of Iran Meteorological Organization (IRIMO) which has been described in detail under the heading of "Section 2.2" in this manuscript.

**Code availability** MATLAB code was used in this study for analyzing the data and preparing the required maps of the study area. The code is written according to the method described in detail under the heading of the "Section 2.3".

## Declarations

**Ethics approval** The manuscript is original and is not submitted to another journal for simultaneous consideration neither has been published elsewhere in any form or language (partially or in full). Results are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation. No data, text, or theories by others are presented as if we are the author's own.

**Consent to participate** We, the authors, understand that any information we submit for this study will be treated as confidential and that we have all contributed to the research.

**Consent for publication** We, the authors, provide our consent for this research to be published in the Theoretical and Applied Climatology journal, which includes maps and information within the text.

**Conflict of interest** The authors declare no competing interests.

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