

## Article

# Precipitation Variability and Probabilities of Extreme Events in the Eastern Mediterranean Region (Latakia Governorate-Syria as a Case Study)

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**Abstract:** This study aimed at analysis of the general-index change for the mean annual and seasonal precipitation in six stations in Latakia Governorate (Syria). The data of precipitation were collected for 40 consecutive years (1970–2010) in order to figure out the extent of the changes and variability in precipitation rates and the impact of this change on changes in the potential density that might cause extremely high or low precipitation rates according to Gumbel distribution of the extreme precipitation rates. Results revealed a decrease of the annual precipitation rates in all stations, the reduction in precipitation ranged from 46 to 210 mm during the whole period of the study. Spring, however, recorded the highest and statistically significant reduction, which reached 46–210 mm, while winter precipitation increased by 21–82 mm. Spring also has witnessed a decrease of about 3–9% of the total annual precipitation as compared to winter precipitation which increased by 5–8% of the total. The potential density of extremely high winter precipitation rates increased in all stations as indicated from Gumbel distribution in winter, and a greater increase took place in the probabilities of occurrence of the extremely low spring precipitation rates. This shows significant probability of occurrence of drought during spring season. By contrast, probabilities of winter precipitation rates increased more, thus winter is relatively more humid than before and spring is relatively drier than before.

**Keywords:** climate change; Gumbel distribution; extreme precipitation; Latakia; probability of occurrence; eastern Mediterranean



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## 1. Introduction

Fluctuations in precipitation could cause socio-economic and natural problems [1,2] such as reduction in agricultural areas and its effect on related economic and social aspects. Additionally, the climate change variability or the change of the climate system, specifically rainfall, directly affects the hydrology of an area as well as the general hydrologic cycle [3–5]. Since the late seventies, the increase in the average global mean temperature caused an increase in the events with extreme climate conditions such as the temperate in tropical areas [6–8]. Increasing temperatures also led to higher rates of evapotranspiration and increased the plant water requirements [9]. On global and regional scales, many studies forecasted a greater increase in extreme events of precipitation that is related to the current global warming, especially when such precipitation is compared to the mean values [10,11].

During the last three decades, many studies have indicated a decreasing trend in precipitation and an increasing in temperature trends over the Mediterranean and Middle East regions [12–20]. This climate change is considered also as a main driving factor for the occurrence of more drying conditions in the Mediterranean region [20–22]. On the other hand, the accelerated development and urbanization processes into the Levant countries, has caused more climate changes with related soil degradation, desertification,

water scarcity, overpopulation, and large-scale changes in land use and land cover [23]. In total, such changes brought further pressure on the available and limited natural resources, especially land and water.

The precipitation in the Mediterranean region is characterized by irregular distribution in both temporal and spatial terms. Of this precipitation, 55% of its total water resources that equals to  $600 \text{ km}^3/\text{year}$  occurred in Turkey and Northern Mediterranean Countries, while southern and eastern Mediterranean countries suffer from chronic shortage of water up to  $100 \text{ m}^3/\text{person}/\text{year}$ , in some parts of the Mediterranean the shortage could reach  $500 \text{ m}^3/\text{person}/\text{year}$  [24]. In eastern Mediterranean (EM) region, the reduction is about 20% from annual rainfall that is expected by the year 2050 [25–27]. For example, Syria is one of the countries that are more vulnerable to climate change due to the dependence of more than 62% of its agricultural lands (equivalent to about  $14,258 \text{ km}^2$ ) on rainfall as the main source of plant requirements [28]. In addition, rainfall represents 68.5% of all available water resources, and the agricultural water requirements were expected to increase by 6% in 2020 [29]. Jordan is considered the fourth poorest water-resourced country. According to the Ministry of Water and Irrigation (MWI), water availability has declined from  $3600 \text{ m}^3/\text{year}$  per capita in 1946 to  $145 \text{ m}^3/\text{year}$  per capita in 2007 [30]. This may be important particularly in rainfed areas, like Syria; due to the lack of irrigation possibilities.

The Arab Forum for Environment and Development indicated that the Arab countries contain less than 1% of the world's freshwater volume, despite the fact that the area of the Arab countries reaches 10% of the total world land area. These countries, including Syria, suffer from chronic shortage of water because of the lack of rainfall and water resources. In addition, the increase in mean annual temperature affected these countries, where an increase in drought accompanied by a decrease in the mean annual precipitation occurred, with a repeated and successive drought periods that has not been reported in the past. Such changes made it important to identify the differences in precipitation amount and its extreme rates and events, which could affect some key sectors including agriculture, and though the results could help in securing enough water for different activities. In Lebanon, Hussein found that the water discourse and crisis in Lebanon is often addressed as a national security issue, and that the issue of water scarcity in the country is strongly related to transboundary water control and governance. In addition that the Syrian Refugee in Lebanon created tensions due to blaming the refugees as the cause of water scarcity, unemployment and instability in Lebanon [31]. Zeitoun found that water in the Middle East provides a powerful new perspective on the Palestinian-Israeli water conflict. Zeitoun adopted a new approach to understand this water conflict. He showed that the conflict is much deeper than one thought, and he revealed negative relationship between existing tactics to control water and the possibility to make peace; especially with the continued domination of water resources by the stronger countries. Such domination tend to play down negative effects on peaceful and non-violent water-related issues and conflict, leaving weak or no cooperation between countries often and could cause serious conflict between them. This hydro-hegemony reveals the hidden changes and dynamics of water conflict into the Middle East water problem [32].

Knowledge on the effect of regional climate changes, on temperatures changes and precipitation averages, is not the only reason to study the importance of such data on climate change, changes in extreme values of precipitation and its probabilities is also important [33]. Low amounts of precipitation is one of the key features of extreme weather events with which drought could increase, which signifies its effects in a region that is originally suffering from the lack of water resources and has extreme summer drought. This requires taking all precautionary measures to counteract the effects that may cause this change. The Arab Forum for Environment and Development (AFED) and the Intergovernmental Panel on Climate Change (IPCC) [6,34] reported that the increasing drought as a result of increasing temperature will increase the need for irrigation water, and the crops rotation and periods will ultimately change.

To understand the precipitation changes and occurrence of drought in the study area, a study has been done to achieve the following objectives:

- (i) To analyze the general trends of the mean annual and seasonal precipitation in six weather stations of Latakia governorate during the period (1970–2010);
- (ii) To quantify the mean annual precipitation change with its statistical significance;
- (iii) To identify which seasons and periods have witnessed the highest changes in precipitation; and
- (iv) To analyze the changes in the probabilistic density of extreme rates using Gumbel distribution of extreme precipitation events.

## 2. Methodology

This research depends on the monthly rainfall for the period 1970–2010 and in six weather stations in Latakia governorate, which is located on the coastal region of Syria (Figure 1). The weather stations have different altitudes ranging from 7 m to 1173 m above sea level (Table 1). The stations are Latakia, Al- Qirdaha, Al- Hafa, Salanfa, Qastal al- Ma’af, and Al- Basel Airport (Figure 1).

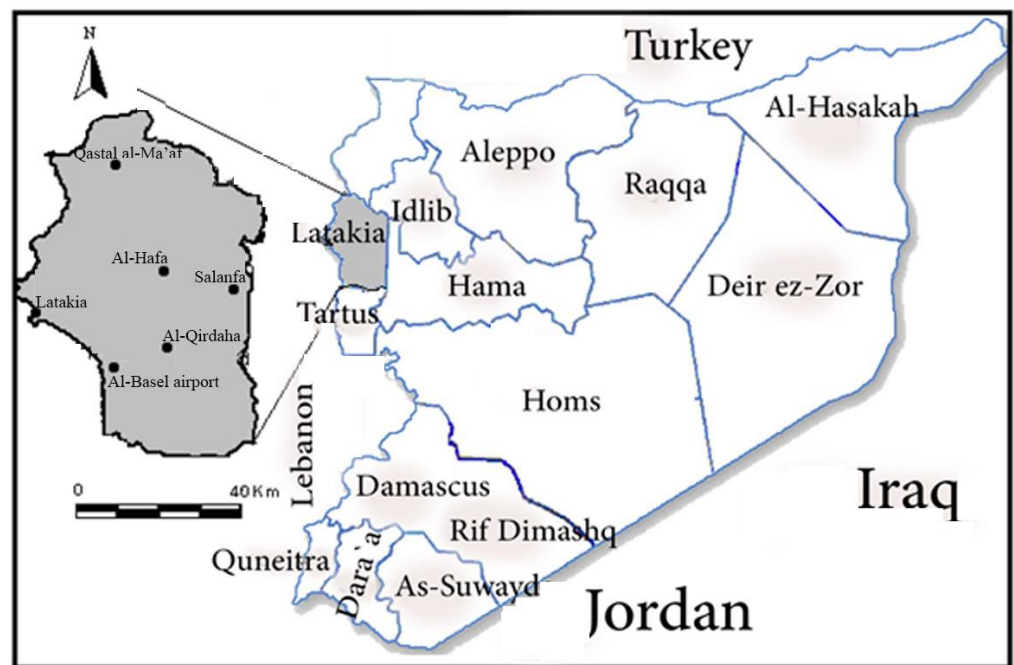


Figure 1. Location of Latakia Governorate in Syria, with the location of the six weather stations.

Table 1. Names, locations, and altitudes of weather stations used in the study area.

Weather Station	Latitude	Longitude	Altitude	Station Type	Available Rainfall Data Time Series
Latakia	35.78	35.52	7	S <sup>1</sup>	2010–1970
Al- Basel airport	35.94	35.41	48	S	2010–1970
Al- Qirdaha	36.05	35.45	300	S	2010–1970
Al- Hafa	36.05	35.61	335	C <sup>2</sup>	2010–1970
Qastal al- Ma’af	35.94	35.83	675	C	2010–1970
Salanfa	36.19	35.57	1173	C	2010–1970

Source: General Directorate of Meteorology-Syria. <sup>1</sup>: S denotes synoptic station at which observation are made for the purpose of synoptic analysis. <sup>2</sup>: C denotes climatic station at which normal measurements of different climatic parameters that used for local or regional analysis.

Latakia governorate was chosen as a case study because of the availability of enough and well-distributed meteorological stations over the whole area of the governorate. This will prevent insufficiencies of case selection by randomization; hence the selection of purposive case (Latakia) will be though strong. Such purposive selection can make an important contribution to the inferential process of climate change by enabling the application of the results to the whole area of case study (Latakia) as well as any area with similar conditions and circumstances [35].

Time series linear regression equation was done to reveal changes in the general slope of the general precipitation trend line, and therefore changes in the seasonal and annual precipitation, including the statistical significance of such changes. The data was then divided, based on the seasons, into two time series; the first time series is from 1970 to 2000 (31 years), and the second time series is from 2001 to 2010 (10 years). Such division was done in order to identify the changes in the mean precipitation during the first decade (10 years) of the twenty first century as compared to the last three decades of the last century (31 years), because the 31 years period represents by itself a climatic cycle. The reason behind choosing two time series is that 11 years out of 12 years within the period (1996–2005) had the highest average temperatures since the beginning of the global temperature measurements in 1850 (according to the report of the Intergovernmental Panel on Climate Change [6]. The following measurements of the IPCC indicted also that the years from 2007 and beyond were hotter, and its peak occurred in 2010 that is considered the highest in the historical global temperature measurements.

The *t*-test was conducted to measure the statistical significance of the changes in the mean annual precipitation (2001–2010) compared to the mean for the period (1970–2000), with a 95% degree of confidence and according to the following formula:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}} \quad (1)$$

where:

$\bar{X}_1$  and  $\bar{X}_2$ : The averages of the precipitation during the two time-periods.

$\sigma_1$  and  $\sigma_2$ : The standard deviation of the precipitation during the two time-periods.

$n_1$  and  $n_2$ : The number of years in each time-period.

Gumbel distribution was used to analyze the potential density of extremely high and low precipitation rates, because its effect is identified from two directions [36]. This distribution has significant importance in hydrological and climatic studies, which depends on studying the effect of rainfall intensity on drought or flood periods [37], therefore the possibility of storing water in wet periods and using it in droughts period for irrigating plants and for other different uses. Gumbel distribution is calculated using the following formulas [38]:

$$F(x) = e^{-e^{-\frac{(x-c)}{d}}} \quad (2)$$

where:  $c = \bar{X} - 0.5772.d$  and  $d = \frac{\sqrt{6}}{\pi} s_x = 0.7797.s_x$

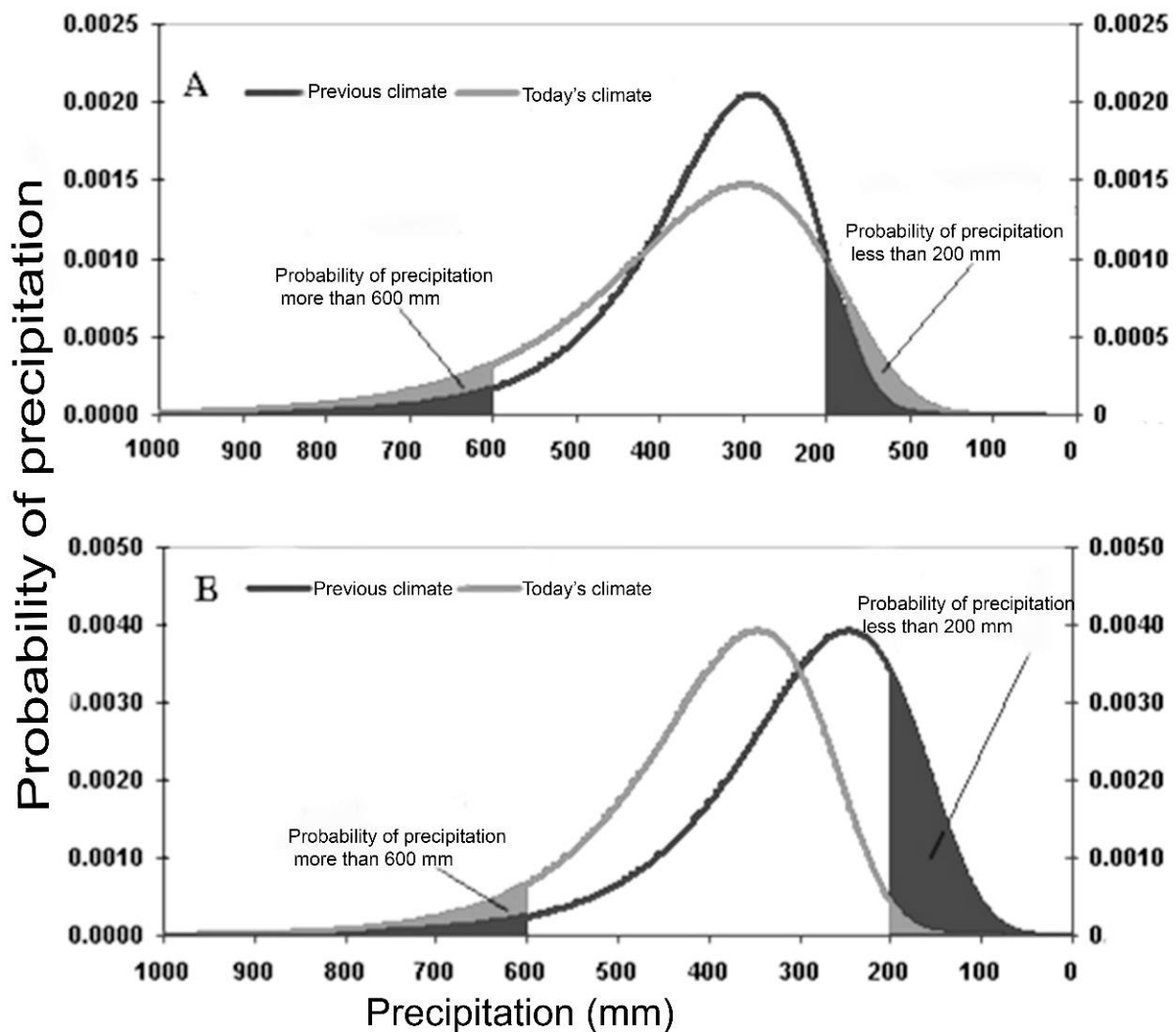
$S_x$  Standard deviation of precipitation

$x$  Amount of precipitation

$\bar{X}$  Arithmetic mean for precipitation

In the calculation of Gumbel distribution, the area under the distribution curve equals to 1 unit or 100%; as the increase in the arithmetic mean for precipitation causes accompanied changes in potential density of precipitation, especially the extreme ones. This change is clear when compared with previous time-periods (Figure 2A). Figure 2A shows the changes in the precipitation averages in a hypothetical station during two periods. The figure reveals an increase in the flattening of the grey curve that represents today's climate (the most recent time-period). Such flattening caused an increase in the scattering of the precipitation and an increase in its standard deviation from the averages, which means an increase in the probability of extremely low rains occurrence, which is equal to

200 mm in Figure 2A. Moreover, the increase in the probability that precipitation reaches amounts more than 600 mm as compared to the amounts in previous time-period can also be calculated. Figure 2B shows an increase in precipitation average where the probabilities of extremely high rain has increased and at the same time the probabilities of extremely low precipitation has decreased. The current research will focus on extremely high or low precipitation averages which constitutes either more than or less than 10% of the total annual rainfall [39] during the period from 1970–2000, and at the same time to observe the probabilities of rainfall change in second time-period from 2001–2010.



**Figure 2.** Two different models for Gumbel distribution to compare precipitation changes between two time-periods (A): probability of extremely low rains and (B): probabilities of extremely high rains.

### 3. Results and Discussion

Generally speaking, a decrease in the annual precipitation regression line during the first period 1970–2010 for the six meteorological stations is observed. Figure 3 shows a moderate decrease in annual precipitation amounts from the beginning of the first period (1970), which reached 125 mm in Latakia station, 175 mm in Al- Basel airport, 52 mm in al- Qirdaha, 75 mm in Salanfa. The highest and riveting decline occurred in Al-Hafa and Qastal al-Ma'af stations, with an annual decline rate of 325 mm and 263 mm, respectively.

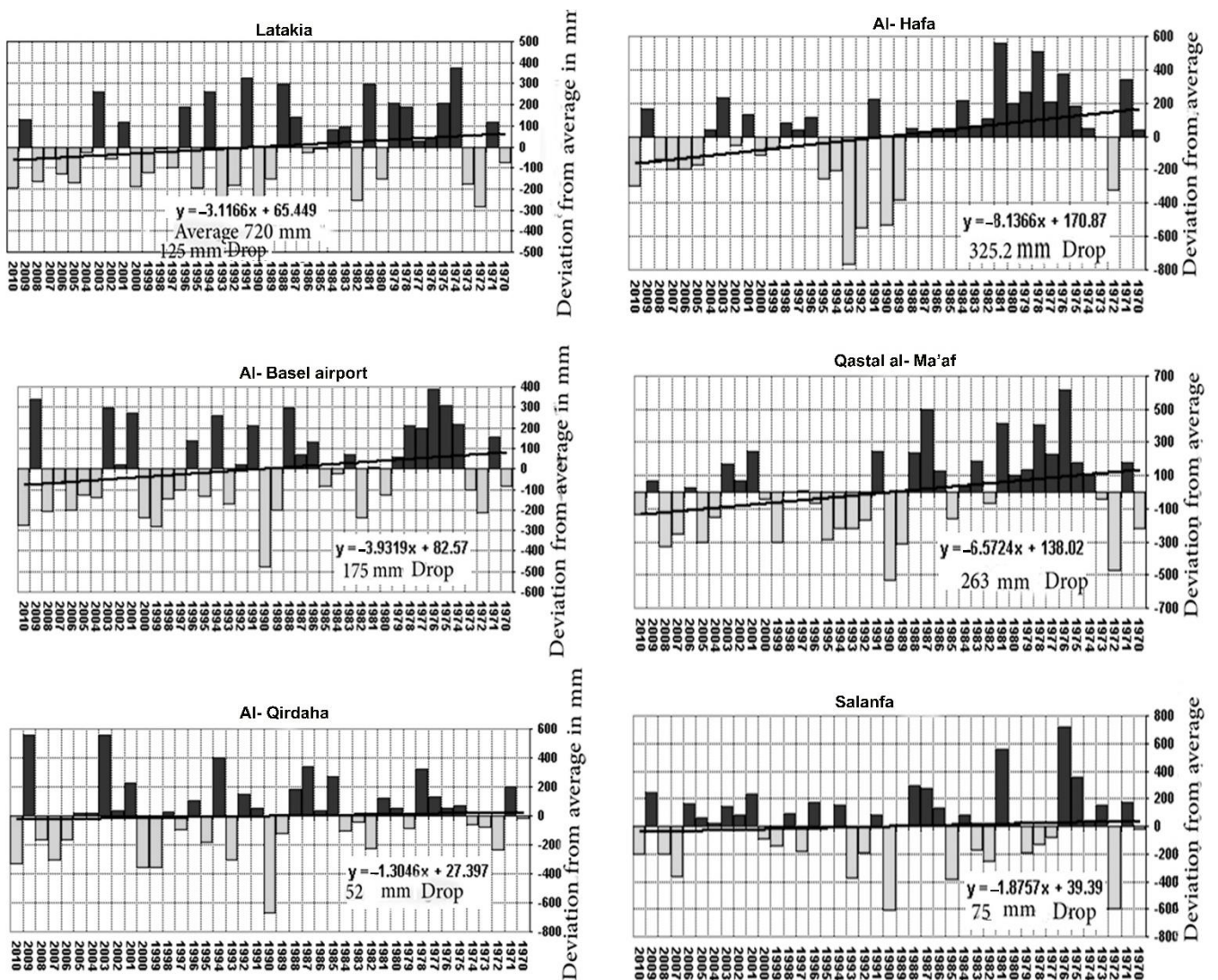


Figure 3. General trend of the mean annual precipitation from 1970–2010.

Table 2 shows no large change in the mean annual precipitation during the second period from 2001–2010 as compared to the first period from 1970–2000, and this is mainly because the precipitation rates in all the stations witnessed a minor decline ranging from 14–79 mm, however this decline was not statistically significant. The stations that witnessed a slight increase in the precipitation rate are Salanfa and al-Qirdaha stations (23 mm and 58 mm, respectively) but the increase was not statistically significant (Table 2). Prominent statistically significant decline in the slope of the precipitation regression line is noticeable during spring season in all the stations. This decline reached its maximum in Al-Hafa station with 210 mm decline during the whole period of the study (1970–2010); with an average annual decline of 5.3 mm. The second station in decline of rainfall occurred in Qastal al-Ma'af with a total decline of 164 mm during the entire period and an average annual decline of 4.1 mm. The decline in al-Qirdaha station during spring reached 116.4 mm (2.9 mm/year) and it was statistically significant. Similarly, a statistical significance decline in spring precipitation in Latakia that reached 86.1 mL (2.2 mm/year). Statistical decline in the precipitation average during spring season was evident in all the stations. The second important change was during winter in all the stations; where there were increases in the precipitation ranged from 20 to 86 mm in the second period (2001–2010) compared to the first period (1970–2000), however the increases were not statistically significant.

**Table 2.** The slope of the regression line for precipitation and the statistical significance of the slope of the precipitation regression line with the averages.

Statistical Significance of the Change between the Two Precipitation Averages (1970 to 2000 and 2001 to 2010)	Precipitation Change (mm)	Precipitation Average 2001–2010 (mm)	Precipitation Average 1970–2000 (mm)	Statistical Significance of the Change in the Slope of the Regression Line for the Precipitation Amount 1970–2010	The Change in the Slope of the Regression Line for the Precipitation Amount 1970–2010 (mm)		Season	Station
					Per Year	Entire Period		
—	−38	691	729	—	−3.1	−124.7	Annual precipitation	Latakia
—	−2	104	106	—	0.5	18.1	The summer half	
—	−36	587	623	—	−3.6	−142.8	The winter half	
—	20	413	393	—	−1.0	−41.5	Winter	
++	−61	99	160	++	−2.4	−94.6	Spring	
—	4	14	10	—	0.1	4.2	Summer	
—	−3	164	167	—	0.2	7.3	Autumn	
—	−14	795	809	—	−4.1	−157	Annual precipitation	Al-Basel airport
—	−26	105	131	—	−1.5	−56	The summer half	
—	12	690	678	—	−2.7	−101	The winter half	
—	57	492	435	—	0.6	21	Winter	
+	−45	137	182	+	−3.2	−123	Spring	
—	−2	14	16	—	−0.2	−9	Summer	
—	−24	152	176	—	−1.2	−46	Autumn	
—	58	1040	982	—	−1.3	−52.2	Annual precipitation	Al-Qirdaha
—	−4	165	168	—	−0.5	−19.3	The summer half	
—	62	875	813	—	−0.8	−32.9	The winter half	
—	86	590	504	—	1.4	57.8	Winter	
—	−42	209	251	++	−2.9	−116.4	Spring	
—	12	37	25	—	0.4	16.1	Summer	
—	2	204	202	—	−0.2	−9.8	Autumn	

Table 2. Cont.

Statistical Significance of the Change between the Two Precipitation Averages (1970 to 2000 and 2001 to 2010)	Precipitation Change (mm)	Precipitation Average 2001–2010 (mm)	Precipitation Average 1970–2000 (mm)	Statistical Significance of the Change in the Slope of the Regression Line for the Precipitation Amount 1970–2010	The Change in the Slope of the Regression Line for the Precipitation Amount 1970–2010 (mm)		Season	Station
					Per Year	Entire Period		
—	−64	907	971	++	−8.1	−325	Annual precipitation	Al-Hafa
—	−34	139	173	—	−2.0	−78	The summer half	
—	−30	768	798	+	−6.2	−248	The winter half	
—	36	515	479	—	−2.1	−82	Winter	
++	−100	166	266	++	−5.3	−210	Spring	
—	−11	16	27	++	−0.8	−32	Summer	
—	11	210	199	—	0	−1	Autumn	
—	−79	953	1032	—	−6.6	−263	Annual precipitation	
—	−56	148	204	—	−2.5	−101	The summer half	Qastal al-Ma'af
—	−22	806	828	—	−4.1	−164	The winter half	
—	17	522	505	—	−1.3	−50	Winter	
++	−73	207	280	+	−4.1	−164	Spring	
++	−15	9	24	+	−0.7	−28	Summer	
—	−8	215	223	—	−0.6	−22	Autumn	
—	23	1204	1181	—	−1.9	−75.0	Annual precipitation	Salanfa
—	−3	186	189	—	−0.4	−14.5	The summer half	
—	26	1018	992	—	−1.5	−60.5	The winter half	
—	69	672	603	—	1.2	48.1	Winter	
—	−28	307	335	+	−1.6	−64.2	Spring	
—	5	29	24	—	−0.5	−19.1	Summer	
—	−22	197	219	—	−1.0	−39.8	Autumn	

(+): Significant at the 95% level; (++): Highly significant at the 99% level; (—): Statistically insignificant.



Generally speaking, Table 2 shows a strong and negative change in the slope of the precipitation regression line in all the stations. Such changes are due to the reduction in the mean annual precipitation in the second period (2001–2010) compared to the first period. The exception is in al- Qirdaha and Salanfa stations where there was slight increase in the average annual precipitation.

Abu Hammad found a reduction in the annual precipitation in Jerusalem Governorate during the period from 1980–2018. The reduction in precipitation was more in winter season compared to spring season, but both reductions (winter and spring) were statistically significant. The results are similar for spring season as the current study although in Abu Hammad’s study, the reduction was significant, but in this study the reduction is not statistically significant during winter but significant during spring season. The difference in significance between both studies might be due to different spatial characteristics of the tow study areas. In Latakia governorate, it is considered as a coastal and semi-coastal area with quasi-humid climate; as a result, any change in precipitation should be large enough to show significance. In Jerusalem governorate (Palestine), it has a semi-arid climate with lower precipitation compared to Latakia, hence, any change in precipitation even if it is small will show statistical significance compared to the total annual precipitation [40,41].

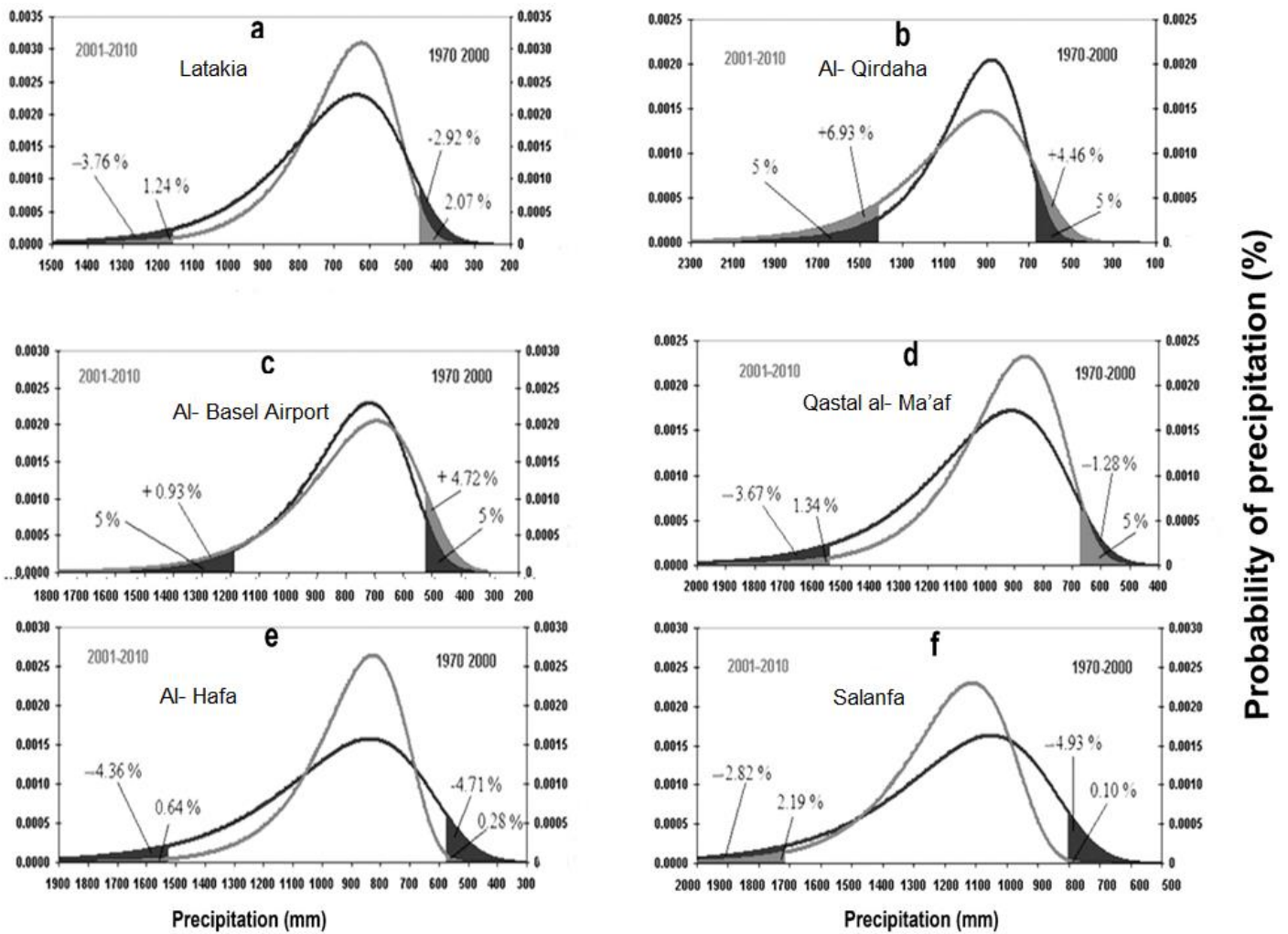
The decline in the spring precipitation and the increase in the winter and autumn precipitations caused a relative difference in the distribution of precipitation during different seasons (Table 3). Table 3 shows that the spring’s share from the total annual precipitation declined by about 3–9%, compared to an increase in winter precipitation rates between 5–8%. The most and prominent change was in Al- Hafa station that witnessed a decline in spring rainfall by 9%, and an increase in winter rainfall by 8%. A study on the climate of Palestine and its changes has ensured an increase in the temperature and drought periods by about 0.74 °C during the period from 1905–2010, which provides a further indication of the existing change in climatic condition. The study also revealed changes in the mean annual rainfall [12,14]. Trevor also found that winter season rainfall over the northern part of the Mediterranean has decreased over the last four decades [42]. The decline is almost similar to what has been found in the current study, the decrease has been explained based on the local enforcement by the decrease in the intensity of cyclogenesis events in the Mediterranean region.

**Table 3.** Percentage of seasonal precipitation from the total during the two periods (2001–2010 and 1970–2000).

Autumn	Summer	Spring	Winter	Precipitation Percentage during the Two Periods	Station
23%	1%	22%	54%	1970–2000	Latakia
24%	2%	14%	60%	2001–2010	
22%	2%	22%	54%	1970–2000	Al- Basel airport
19%	2%	17%	62%	2001–2010	
21%	3%	26%	51%	1970–2000	Al- Qirdaha
20%	4%	20%	57%	2001–2010	
21%	3%	27%	49%	1970–2000	Al- Hafa
23%	2%	18%	57%	2001–2010	
22%	2%	27%	49%	1970–2000	Qastal al- Ma’af
23%	1%	22%	55%	2001–2010	
19%	2%	28%	51%	1970–2000	Salanfa
16%	2%	25%	56%	2001–2010	

Gumbel distribution represents potential values of the changes in the mean extreme precipitation amounts (more or less than 5% from each side) during the period 2001–2010

compared to 1970–2000. Using the Gumbel distribution, one can trace out the presence of different models for the changes in potential density of precipitation in the six stations (Figure 4). Figure 4a shows that in Latakia station, the probability of extreme precipitation values that is less than 461 mm/year has declined by 2.92% (decreased from 5% to 2.07), which is shown by the line with grey color on the right side of the curve. Moreover, the probabilities of extreme annual rainfall that is higher than 1141 mm in Latakia have declined by about 3.76% (from 5% to 1.24%), shown as the black color on the left side of Figure 4a. The situation seems to be similar in Al- Hafa station as the probability of annual extreme low precipitation less than 580 mL has declined by 4.71% (The grey line to the right), and the probability of extreme high annual precipitation more than 1529 has declined by 4.36% (The black line to the left of Figure 4e). Both Salanfa and Qastal al- Ma’af high-altitude stations witnessed a decline in the probability of extremely high and low annual precipitation values; the decline in extreme low precipitation value of less than 803 mm in Salanfa reached 4.93%, and the extreme high precipitation (more than 1720 mm) reached 2.82% (Figure 4f). Similar trend can be observed in Qastal al- Ma’af station where the probability of extreme precipitation less than 674 mm declined by 1.28%, and the probability of extreme precipitation higher than 1542 mm has declined by 3.67% (Figure 4d).



**Figure 4.** Changes in the potential probability of the annual precipitation average during both time-periods. (a) Latakia; (b) Al- Qirdaha; (c) Al- Basel airport; (d) Qastal al-Ma’af; (e) Al- Hafa; (f) Salanfa.

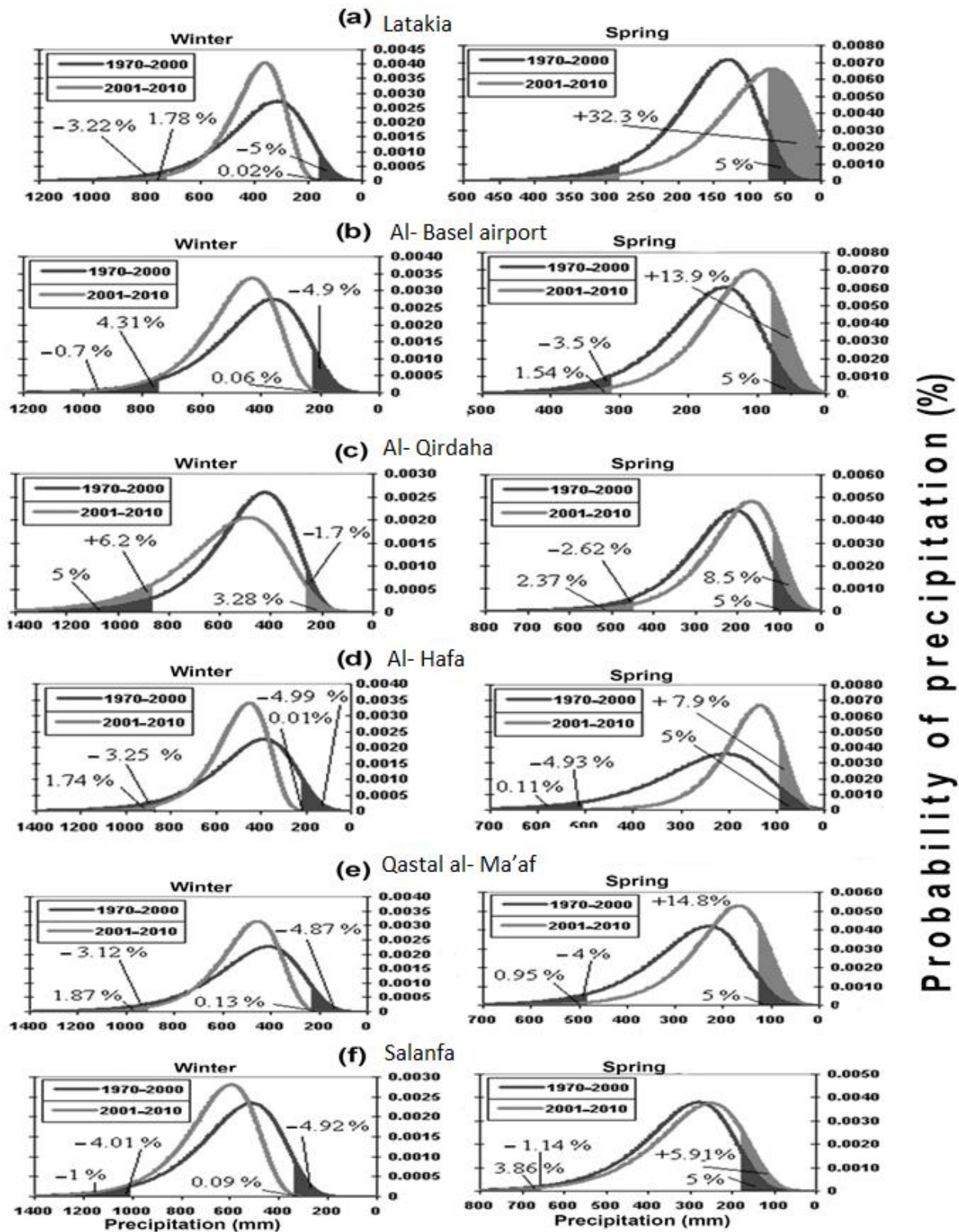
The situation is different for Al- Basel airport and Al- Qirdaha stations. This is because of the increase in the probability of extremely high and low precipitation values. For example, in Al- Basel airport station, the probability of extreme precipitation less than 540 mm/year increased by 4.72% (the grey color on the right side of Figure 4c), also the probability of extreme annual precipitation of more than 1192 mm/year slightly increased by 0.93%, represented by the grey color on the left side of Figure 4c. In Al- Qirdaha station, the probability of extreme annual precipitation of less than 681 mm/year increased by 4.46% (right side of Figure 4b) and the probability of extreme precipitation with more than 1410 mm/year (Figure 4b) increased by about 6.93 (has changed from 5% to 11.93%).

Generally speaking based on the aforementioned results, it could be said that the climate is improving in any station where a decrease in probability of extreme low precipitation than a certain value occurred (like in Latakia, Al- Hafa, Salanfa and Qastal al- Ma'af). Similar generalization could be applied when the probability of extreme value of precipitation more than a certain value increases (like what happened in Al- Basel airport and al- Qirdaha). On the contrary, when the probability of extreme low value of precipitation than a certain level increases (like in Al- Basel airport and al- Qirdaha stations) or the probability of extreme high value than a certain level decreases (like in Latakia, Al- Hafa, Salanfa and Qastal al Ma'af), then it could be said that the climate is deteriorating. As a result, the only stations that witnessed an improvement in the precipitation and its probability during the second time-period (2001–2010) are Al- Basel airport and Al- Qirdaha stations, whereas the other four stations witnessed a deterioration of the climatic conditions in the second time-period. The stations that have witnessed an improvement in the precipitation (Al- Basel and Al- Qirdaha) are located in the southern part of Latakia governorate (Figure 1). Hence, this improvement can be attributed mainly to two reasons; the first is that these two stations are located in low-altitude plains with no topographic obstacles to precipitation; and the second is that there is no interfering high mountains areas to the rainy clouds from the eastern parts of the Mediterranean. Hence, for the four stations (Latakia, Al- Hafa, Salanfa and Qastal al Ma'af) that witnessed a decrease in precipitation, there are high mountainous areas that could prevent rich-water vapor clouds and the associated precipitation from reaching the area of such these stations.

On a seasonal level, Figure 5 represents the changes in the probability of precipitation based on Gumbel distribution during winter and spring in all the stations. The analysis focused only on spring and winter seasons because they have witnessed the most prominent changes in precipitation. Previous analysis showed a decline in the precipitation during spring, and within this season, there is an increase in the probability of extremely low precipitation amounts between 5.91% and up to 32.3% (Figure 5) during the period 2001–2010 (the grey color on the left side of the curve). These amounts did not have a probability of more than 5% during the period 1970–2000. The highest percentage of decline in the probability of extremely low spring precipitations has been witnessed in Latakia station (Figure 5a), and this is because the probability of precipitation of less than 73 mm increased by almost 6.4 times that in the first time-period (changed from 5% to 37.26% with an increase of 32.3%). In addition, the probability of low marginal values of precipitation has increased by 14.8% in Qastal al- Ma'af and 13.9% in Al- Basel airport. In the rest of the stations, the decrease is less than 9%, hence it one can conclude from the previous reductions that spring is continuously becoming drier, with a shorter wet period and a more integration of spring with the summer.

On the other hand, probabilities of extremely low precipitations during winter has witnessed a decline by 5% in all the six stations except for al- Qirdaha station, in which the decline in winter precipitation did not exceed 1.7% (Figure 5c). The probability of extreme precipitation with less than 169 mm in Latakia, less than 210 mm in Al- Basel airport, less than 207 mm in al- Hafa, less than 267 mm in al- Qirdaha, less than 233 mm in Qastal al- Ma'af, and less than 340 mm in Salanfa has reduced. In this way of change, the precipitation becomes higher during winter especially that the probabilities of low marginal values of precipitation that did not exceed 5% probability declined in all of the stations during winter

season except for al-Qirdaha station. Such a decline in probabilities means an increase in winter precipitation rate, as compared to the total annual precipitation during the period 2001–2010 in comparison with 1970–2000 period.



**Figure 5.** Changes in the potential probability of the annual average precipitation during spring and winter seasons in both time-periods. (a) Latakia; (b) Al-Basel airport; (c) Al-Qirdaha; (d) Al-Hafa; (e) Qastal al-Ma'af; (f) Salanfa.

Kutiél found in a study of four stations in the eastern Mediterranean during 1864–1991 [40] an increasing tendency in precipitation in Jerusalem (400 km south of Latakia) during winter season and a decreasing tendency of precipitation during spring season, which are almost similar results as the current research. Kutiél also found that the most important and longest dry sequence occurred during the last 14 years of the study (1980 onward). The drying conditions started in the southern station of Jerusalem, and then has progressed northward to Athens [43]. In a study on the occurrence of extreme precipitation in the eastern Mediterranean region, the study employed three climatic indices; the maximum number of consecutive wet days, the maximum number of consecutive dry days, and the proportion of precipitation amount of wet days to the number of wet days of the period. These indices were taken in the current time as well as for future period, and on a seasonal and annual basis. The study found general future tendency of dryness into the eastern Mediterranean, with a reduction in rainfall intensity. Longer dry periods are expected in all seasons with the exception of autumn season, and the largest increase in dryness was in the southern part of the Mediterranean [44].

#### 4. Conclusions and Recommendations

Based on the aforementioned discussion, the following conclusions are important to be mentioned:

1. Negative change in the mean annual precipitation in most of the stations occurred, but the changes were non-significant. The decrease in the mean annual precipitation occurred in Latakia, Al- Basel airport, Al- Hafa and Qastal al- Ma'af stations, which ranged from 14 mm in Latakia to 79 mm in Qastal al- Ma'af. Whereas in Salanfa and al-Qarirdaha stations, there was an increases of 23 and 58 mm, respectively.
2. The regression line of spring precipitation has declined during the period 2001–2010 in all the stations, and this decline was statistically significant in Al- Hafa, Qastal al- Ma'af, Latakia, and Al- Basel airport. The decline was not significant in Salanfa and al-Qirdaha stations.
3. Statistical insignificant increase in winter precipitation in all of the stations that ranged between 17–86 mm.
4. A decline in spring's share from the total annual precipitation of about 3–9%, but an increase in the winter precipitation of 5–8%, with the most prominent change occurred in Al- Hafa station.
5. Gumbel distribution for extremely high and low marginal precipitation values during the periods 2001–2010 compared to 1970–2000 showed a decline in the probability of high and low precipitation in Latakia, Al- Hafa, Salanfa, and Qastal al- Ma'af stations, while Al- Basel airport and Al- Qirdaha stations have witnessed an increase in the probability of extremely high and low values. Based on this, the only stations that witnessed an improvement in the precipitation and its probability during the second time-period (2001–2010) were Al- Basel airport and Al- Qirdaha stations, whereas the other four stations witnessed a deterioration of the climatic conditions.
6. A decline in the precipitation during spring is noticeable. This decline was accompanied with an increase in the probability of extremely low precipitation of 5.91–32.3%; the highest probability of extremely low spring precipitations decline was in Latakia station, and this lead to conclusion that the spring-wet period is shorter with more integration into summer.
7. On the other hand the probabilities of extremely low precipitation values has witnessed a decline during winter by 5% in most of the stations, so that the precipitation became concentrated more in winter, which contributed to an increase in mean winter precipitation from the total annual precipitation during the period 2001–2010 compared to the period 1970–2000.

### Recommendations

1. The current study analyze only the precipitation extremes in some stations of Latakia governorate without analyzing the changes in temperature. This warrant studying temperature changes and its relation to drought and precipitation changes, which will give more accurate results about seasonal and annual level of dryness.
2. Researchers are advised to expand the study to include more stations than those studied in the current research, in order to produce accurate spatio-temporal rain and temperature maps, which can provide an insight on the spatial distribution of dryness and humidity into the governorate.
3. Due to the extended drying conditions in spring, researches on the consequences on land use and associated tools to release and suiting up effects to new land uses are essential.

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