



# Analysis of daily rainfall concentration in northeastern Algeria 1980–2012

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Received: 30 August 2022 / Accepted: 4 June 2023 / Published online: 27 June 2023  
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## Abstract

This article analyzes the spatial distribution of the values of six daily precipitation concentration indexes in the northeastern part of Algeria. The used indexes were the concentration index (CI) and the Gini index (GI) with the resolution of precipitation amounts 1, 5, and 10 mm. The values of the six indexes are calculated for the period 1980–2012 with 22 stations, and on the other hand, the correlations of the CII concentration index with geographical and rainfall variables are analyzed. The values of CII, CI5, and CI10 and IG1, IG5, and IG10 have been mapped using the tools of the ArcGis10.02 programs. The CII concentration index correlates significantly with all the geographic and rainfall variables considered. A negative linear correlation was observed with a linear correlation coefficient  $r = -0.67$  ( $p$  value = 0.0006) between CII and altitude. The correlation between CII and the distance to sea with a linear correlation coefficient  $r = -0.47$  ( $p$  value = 0.026), the correlation between CII and latitude is positive with  $r = +0.40$  ( $p$  value = 0.032). On the other hand, CII is significantly positively correlated with average annual precipitation, the coefficient of variation, and the number of rainy days in the same period:  $r = 0.52$  ( $p$  value = 0.023);  $r = -0.25$  ( $p$  value = 0.049) and  $r = 0.49$  ( $p$  value = 0.022), respectively.

**Keywords** Spatial distribution · Daily precipitation · Concentration Index · Gini Index · North-East Algeria

## 1 Introduction

Precipitation in the Mediterranean region shows a compulsive character. It can be absent for many days and intervene with a high intensity for a few hours or even minutes. Its convective and torrential character especially during the warm half of the year explains the high intensity and frequency of showers. The effects of the high temporal concentration of precipitation are at the origin of many phenomena among which floods,

torrential avenues and erosion are examples of disasters and harmful effects on socioeconomic spheres. The low vegetation cover in many regions favors sudden runoff and often generates rapid floods (flash floods); Due to the hydrological problems resulting from the high intensity and poor temporal distribution of precipitation, the analysis of the latter with a daily resolution is delicate especially since there is a flagrant lack of automatic weather stations over large areas of Algeria.

The analysis of rainfall with a daily resolution is a subject of great interest in Algeria. This interest is not only climatological, but it also affects other areas of the environment and society. The study of daily precipitation has not aroused much interest among scientists especially on the southern shore of the Mediterranean; only a few articles have been published on the statistical structure of precipitation with daily resolution conducted on Algeria (Benhamrouche et al. 2015; Ghanim 2016; Bessaklia et al. 2018). On the Mediterranean Sea basin, there are several (De Luis et al. 1996, 1997; Martín-Vide 2004; Sánchez-Lorenzo and Martín-Vide 2006; Benhamrouche and Martín-Vide 2011, 2012, 2017; Serrano-Notivoli et al. 2018; Sarricolea et al. 2019) as well as other studies carried out in the rest of the world as in Iran (Alijani et al. 2008) for all Europe (Cortesi

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et al. 2012), in China (Zhang et al. 2009; Li et al. 2011) and finally at a global scale (Monjo and Martin-Vide 2016).

In this paper, we will approach the study of daily rainfall in northeastern Algeria in order to determine the relative impact or percentage impact of the different classes of daily rainfall and especially and evaluate the weight of the largest amounts of rainfall in relation to the total accumulation. For this purpose, a statistical study was carried out.

The concentration index was proposed by Martin-Vide (2004). Given that this index is very sensitive to the quality of raw data by requiring the accounting of all daily rainfall amounts, however small they may be, and their framing in very fine classes, 1 mm in length. In this article, new proposals of the index, with other class intervals, are presented in total. Six different indices are compared with the corresponding maps. Secondly, the correlations between the different calculated indices and the geographical and rainfall variables in northeast Algeria for the period 1980–2012 are analyzed.

## 2 Study area

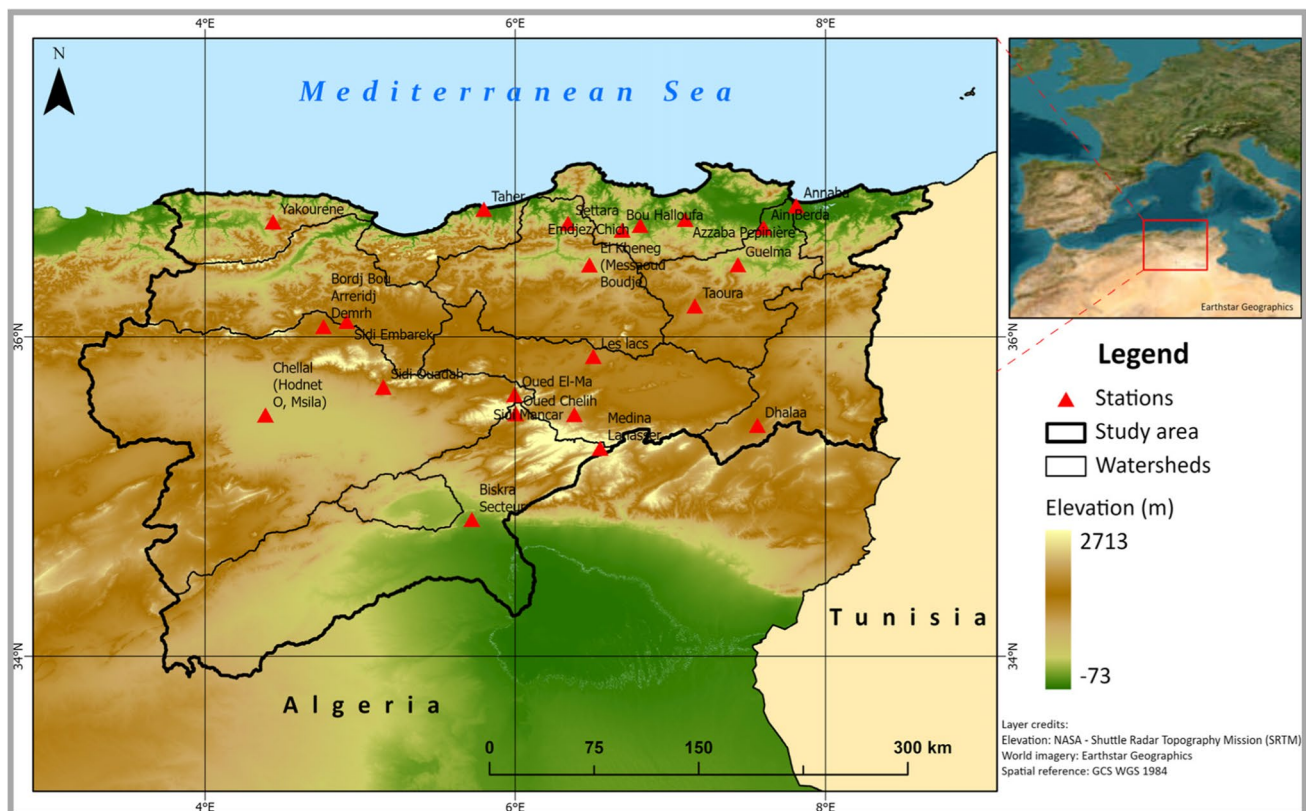
The study area is located in the northeastern part of Algeria. It is bordered to the north by the Mediterranean Sea, to the east by Tunisia, to the west by the small Kabylie region, and to the south

by the Saharan. The study area covers an area of approximately 89,554 km<sup>2</sup>. It is between the longitude 3.5° E and 8.5° E and latitude 34° N and 37.5° N (Fig. 1). The coastal area covers about 495 km<sup>2</sup>. It is characterized by a mild climate. Humidity is relatively high, and rainfall varies between 200 mm in the south and 1200 mm in the north. The Tellian Atlas begins with the chain of the small Kabylie extended by the chain of Babors. It ends in the vicinity of Tunisia by the Mounts of Constantine. Through these mountains, the circulation is easy thanks to the transverse valleys which cut them and which allow to pass from the coast to the high plains. The latter extend between the Atlas Tellien in the north and the Atlas Saharien in the south. They are very narrow in the Constantine region and high (600 to 800 m) and narrowed by the approach of the two chains.

## 3 Data and methodology

### 3.1 Data

The twenty-two meteorological stations used in this research are relatively homogeneously distributed across northeastern Algeria (Fig. 1). The period of analysis spans from 1980 to 2012. These stations are managed by the Algerian National Meteorological Office (ONM) and the Algerian



**Fig. 1** The geographical location of the study area

National Water Resources Agency (ANRH). The daily rainfall data series used are of high quality and complete. From these daily precipitation data, we calculated for each measurement location the values of the six Gini indices (GI) and of the daily precipitation concentration in classes of 1, 5, and 10 mm (CI). These indices are calculated following the methodology defined by Martín-Vide (2004) and Benhamrouche and Martín-Vide (2012).

### 3.2 Methodology

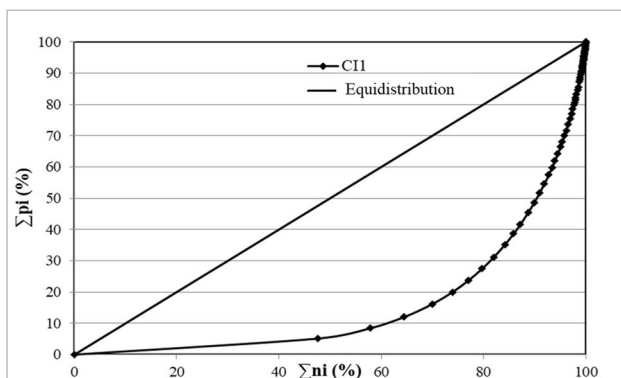
It is known that the frequency distribution of daily precipitation amounts is adjustable by negative exponential curves (Brooks and Carruthers 1953) as there are many days with rare precipitation. Less than 1 mm and few heavy rains decrease the frequency exponentially. In order to evaluate the relative contribution of rainy days, the approach applied in this study was established by adapting the methodology presented by Martín-Vide (2004) and also using the Gini index and some applied to statistics Lorenz curves (Fig. 2). The indices used are C1 (concentration index with a class interval of 1 mm), CI5 (class interval of 5 mm), CI10 (class interval of 10 mm), IG1 (Gini's index with a class interval of 1 mm), IG5 (class interval of 5 mm), and IG10 (class interval of 10 mm).

The example of the station of Taher (Table 1) illustrates the first calculations for the CI1.

## 4 Results

### 4.1 Comparison of the daily concentration according to the different indices

The values of the indices CI1, CI5, CI10, IG1, IG5, and IG10 of the 22 stations for the period from 1980 to 2012



**Fig. 2** GINI-LORENZ curve of the Taher meteorological station (1980–2012)

were calculated (see Table 2). Note that  $CI1 > CI5 > CI10$  in all cases and similarly  $IG1 > IG5 > IG10$ .

If we compare CI1 and IG1, the values with two decimal places are identical or the Gini index exceeds the former by one cent with the sole exception of Les Lacs where IG1 exceeds CI1 by five cents.

The range of values increases as class length increases. Thus, for the study period, the extremes of CI1 are at 0.47 and 0.68 (21 hundredths of a variation), CI5 at 0.51 and 0.65 (14 hundredths), and CI10 at 0.44 and 0.55 (11 hundredths). In the IG1 cases, the extremes are between 0.47 and 0.68 (21 hundredths); IG5, 0.41 and 0.57 (16 hundredths); and IG10 between 0.21 and 0.47 (26 hundredths).

Table 3 shows the Pearson  $r$  correlation coefficients between the six indices of the 22 stations for the period from 1980 to 2012. The values show very high correlations in all significant cases ( $p < 0.000$ ) between CI1, CI5, CI10, and IG1, and not significant correlations between IG5 and IG10, and the other indices.

In particular, CI1 and IG1 show nearly perfect correlations. Consequently, the maps resulting from the representation of the values of each of the indices of the 22 stations do not present great differences with the north of the study area as the areas with the highest values except for those of IG5 and IG10 although this fact is unclear (Fig. 3).

The maps of CI1, CI5, CI10, and IG1 (Fig. 3) are very similar to those found in Benhamrouche et al. (2015) and Benhamrouche and Martín-Vide (2017). The highest IC1 value for the entire period is 0.68 (Taher) followed by Yacourene and Azzaba Nursery (0.62) and Annaba (0.60), where these values coincide with the highest concentrations of daily precipitation, are found in the north-east and north-west of the study area, see Fig. 3 (CI1). The value of CI (0.68) in the station of Taher means that a few days account for a high percentage of the annual precipitation.

In view of Table 3, only four of the six indices CI1, CI5, CI10, and IG1 clearly reflect spatial differences in daily precipitation concentration in the studied territory. If the daily precipitation data is of good quality and complete, there is no objection to the evaluation of the daily precipitation concentration by means of CI5 or CI10 although the range of values is different from the CI1.

The values of CI1 found for the 22 stations studied compared with those obtained with the same method for Spain (Benhamrouche and Martín-Vide. 2012) and the Western Mediterranean Sea Basin (Benhamrouche and Martín-Vide. 2017) allow us to affirm that the daily concentration of precipitation in the central northern fringe of the study area is high.

Finally, from a methodological point of view, the values of the CI5 and CI10 can be accepted as useful when there is not great precision in the recording of the tenth of precipitation although with complete or almost

**Table 1** Frequency distribution of 1 mm class of the number of rainy days and accumulated frequencies (*X*) and corresponding cumulative percentages of the contributed precipitation (*Y*) at Taher (1980–2012)

lim.sup	Ma	<i>N</i>	<i>Sn</i>	ma*n	Sma*n	% <i>Sn</i> = <i>X</i>	% <i>Sma</i> *n = <i>Y</i>
0.9	0.5	3369	3369	1684.5	1684.5	47.69	5.15
1.9	1.5	718	4087	1077	2761.5	57.85	8.44
2.9	2.5	471	4558	1177.5	3939	64.52	12.05
3.9	3.5	388	4946	1358	5297	70.01	16.20
4.9	4.5	276	5222	1242	6539	73.91	20.00
5.9	5.5	218	5440	1199	7738	77.00	23.66
6.9	6.5	192	5632	1248	8986	79.72	27.48
7.9	7.5	161	5793	1207.5	10,194	82.00	31.17
8.9	8.5	156	5949	1326	11,520	84.20	35.23
9.9	9.5	117	6066	1111.5	12,631	85.86	38.63
10.9	10.5	97	6163	1018.5	13,650	87.23	41.74
11.9	11.5	108	6271	1242	14,892	88.76	45.54
12.9	12.5	82	6353	1025	15,917	89.92	48.67
13.9	13.5	75	6428	1012.5	16,929	90.98	51.77
14.9	14.5	62	6490	899	17,828	91.86	54.52
15.9	15.5	62	6552	961	18,789	92.74	57.46
16.9	16.5	47	6599	775.5	19,565	93.40	59.83
17.9	17.5	39	6638	682.5	20,247	93.96	61.91
18.9	18.5	40	6678	740	20,987	94.52	64.18
19.9	19.5	37	6715	721.5	21,709	95.05	66.38
20.9	20.5	25	6740	512.5	22,221	95.40	67.95
21.9	21.5	34	6774	731	22,952	95.88	70.19
22.9	22.5	21	6795	472.5	23,425	96.18	71.63
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
71.9	71.5	1	7061	71.5	32,338	99.94	98.89
72.9	72.5	1	7062	72.5	32,410	99.96	99.11
83.9	83.5	1	7063	83.5	32,494	99.97	99.36
84.9	84.5	1	7064	84.5	32,578	99.99	99.62
123.9	123.5	1	7065	123.5	32,702	100.00	100.00
			7065		32,702		4986.61

\*Class of daily precipitation  $\geq 0.1$  mm and  $\leq 0.9$  mm. *X<sub>i</sub>*, center of the class. *N<sub>i</sub>*, number of rainy days in the class. *P<sub>i</sub>*, total precipitation of the class ( $= X_i \times N_i$ ).  $\sum N_i$  and  $\sum P_i$ , sum of *N<sub>i</sub>* and sum of *P<sub>i</sub>* of the class and previous classes. The last two columns on the right express  $\sum N_i$  and  $\sum P_i$  corresponding to the class, with respect to respectively to the total number of rainy days and to the total precipitation over the entire period studied

complete records. In this case, there will be few erroneous assignments of values between classes.

### 4.2 Correlation of the concentration index (CI1) with geographical and rainfall variables

In this section, we find the correlations of the CI1 with geographical and rainfall variables of the 22 stations in the whole study area for the period 1980–2012 using Pearson’s *r* coefficient and the *p* value.

#### 4.2.1 Correlation analysis between CI1 and the geographical coordinates (longitude, latitude, altitude, and distance to the sea)

The concentration index CI1 is significantly correlated with all the geographical variables except the longitude variable (Table 4). The relationship of the CI1 and altitude is shown in Fig. 4. Where a negative linear correlation is observed with a linear correlation coefficient  $r = -0.67$  (*p* value = 0.0006), which corresponds to a strong and negative correlation, significant even at the 99.94% confidence

**Table 2** CI1, CI5, CI10, IG1, IG5, and IG10 index values for the 22 observatories analyzed for the period 1980-2012

Stations	CI1	CI5	CI10	IG1	IG5	IG10
Annaba	0.60	0.55	0.49	0.61	0.49	0.33
Yakourene	0.62	0.58	0.55	0.62	0.57	0.47
Taher	0.68	0.58	0.52	0.68	0.47	0.28
Bou Halloufa	0.54	0.50	0.49	0.55	0.48	0.37
Emdjez Chich	0.54	0.52	0.49	0.54	0.50	0.38
Azzaba Pepiniere	0.62	0.55	0.50	0.63	0.47	0.30
Chellal (Hodnet O. Msila)	0.50	0.49	0.46	0.51	0.49	0.27
Bb Arreridj Demrh	0.58	0.53	0.49	0.59	0.44	0.25
Oued El Ma	0.52	0.50	0.48	0.52	0.48	0.37
Oued Chelih	0.53	0.52	0.49	0.54	0.46	0.29
Biskra Secteur	0.53	0.52	0.49	0.54	0.42	0.22
Medina Lanasser	0.54	0.53	0.52	0.54	0.51	0.38
Les Lacs	0.56	0.44	0.44	0.61	0.49	0.33
Sidi Mancar	0.53	0.51	0.50	0.53	0.46	0.29
El Kheneg (Messaoud Boudje)	0.54	0.50	0.46	0.55	0.47	0.32
Settara	0.52	0.50	0.47	0.52	0.50	0.45
Taoura	0.54	0.52	0.49	0.54	0.44	0.25
Dhalaa	0.54	0.53	0.50	0.54	0.44	0.25
Guelma	0.56	0.52	0.49	0.56	0.48	0.34
Ain Berda	0.57	0.54	0.50	0.58	0.50	0.36
Sidi Embarek	0.47	0.45	0.46	0.47	0.45	0.35
Sidi Ouadah	0.54	0.53	0.50	0.54	0.41	0.21

**Table 3** Pearson correlation coefficients between different daily concentration indices from 22 stations in northeast Algeria for the period from 1981 to 2012 ( $p < 0.000$ )

1980–2012	CI1	CI5	CI10	IG1	IG5	IG10
CI1	1	0.76	0.58	0.97	0.27	0.03
CI5		1	0.88	0.62	0.2	-0.01
CI10			1	0.43	0.28	0.14
IG1				1	0.27	0.01
IG5					1	0.87
IG10						1

level, this means that the daily precipitation concentration (CI1) increases with decreasing altitude, coinciding with the decrease of CI1 in the highlands. With respect to the relationship between CI1 and distance to the sea, a negative linear correlation is shown in Fig. 5 with a linear correlation coefficient  $r = -0.47$  ( $p$  value = 0.026) which means a fairly negative correlation, significant even at the 97.4% ( $1 - 0.026 = 0.974$  or 97.4%) confidence level. This correlation allows us to indicate that according to the sample studied that the daily concentration of precipitation increases as the areas are very close to the sea which corresponds to that observed in Fig. 3 in which we appreciate an increase of CI1 on north of the study area and in the southern Aurès. These results contrast with that observed by Benhamrouche (2014). The Pearson’s  $r$  correlation between the CI1 and latitude is 0.40 ( $p$  value = 0.032)

(Table 4). This positive linear correlation is clearly significant at the 96.8% confidence level (Fig. 6).

In contrast for the longitude factor,  $r$  is 0.05 ( $p$  value = 0.1) not significant. This non-significative correlation can be explained by the low impact of this factor on the daily precipitation concentration in the study area (Fig. 7).

**4.2.2 Correlation analysis between CI1 and the rainfall variables (mean annual precipitation, coefficient of variation (CV%), and number of rainy days)**

The correlations between the concentration index CI1 and the average annual precipitation, the coefficient of variation (CV%), and the number of rainy days in the same period are 0.52 ( $p$  value = 0.023), 0.25 ( $p$  value = 0.049), and 0.49 ( $p$  value = 0.022), respectively (Table 5). These correlations are



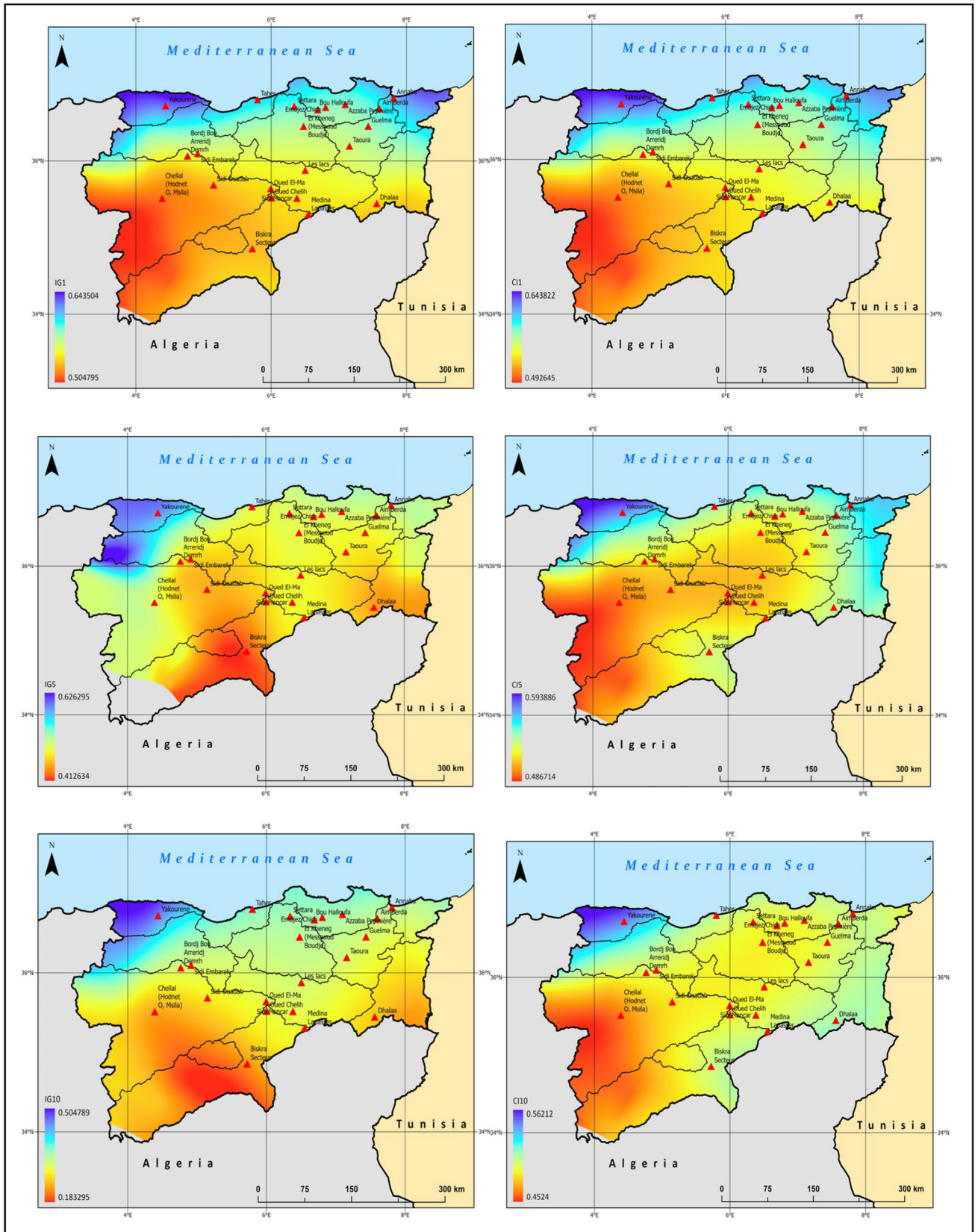
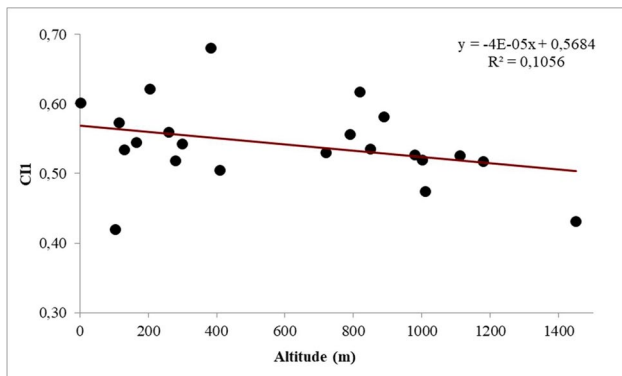


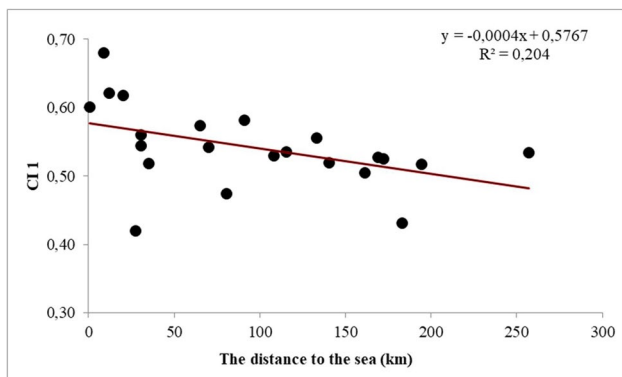
Fig. 3 Spatial variability of CI1, CI5, CI10, IG1, IG5, and IG10 indices of northeastern Algeria the period from 1980 to 2012

**Table 4** Analysis with Pearson’s *r* value and *p* value between the precipitation concentration index (CII) and the geographical factors: longitude (°E), latitude (°N), elevation (m), and distance to the sea (km) in the entire study area for the period 1980–2012 (significant values with  $\alpha=0.05$  in bold)

	Correlation	Longitude (°E)	Latitude (°N)	Altitude (m)	Distance to the sea
CII	<i>r</i>	0.05	<b>0.4</b>	<b>-0.67</b>	<b>-0.47</b>
	<i>p</i> value	0.1	<b>0.032</b>	<b>0.0006</b>	<b>0.026</b>

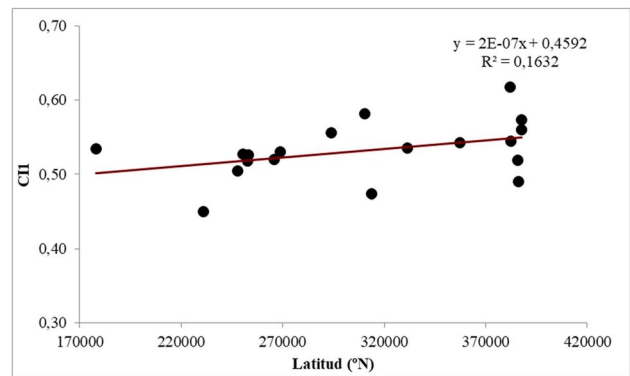


**Fig. 4** Correlation between CII and elevation (m) for 22 stations across the study area

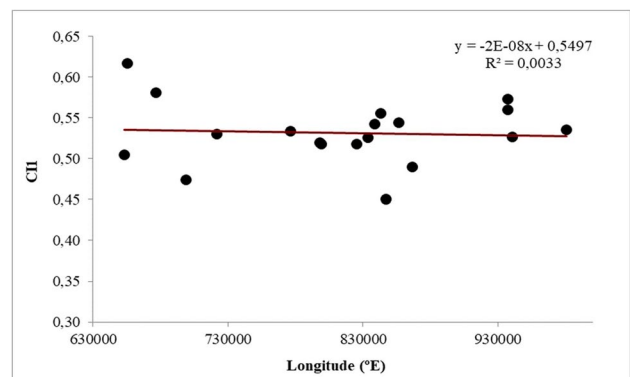


**Fig. 5** Correlation between CII concentration index and distance to the sea (km) for the 22 stations throughout the study area

clearly significant. These results are in total contrast with those observed by Benhamrouche (2014). Moreover, the results obtained also are different in the case of the correlation between CII and CV% on the one hand and between CII and the number of rainy days on the other hand in Peru according to Zubietta and Saavedra (2009). However, these authors found a significant correlation between CII and annual rainfall. Our results are the opposite than those observed in China by Li et al. (2011). They obtained a significant negative correlation between CII and annual



**Fig. 6** Correlation between CII concentration index and latitude (N°) for the 22 stations throughout the study area

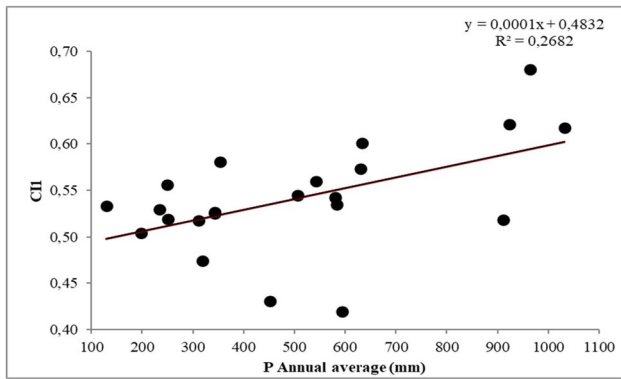


**Fig. 7** Correlation between concentration index CII and longitude (E°) of the 22 stations from throughout the study area

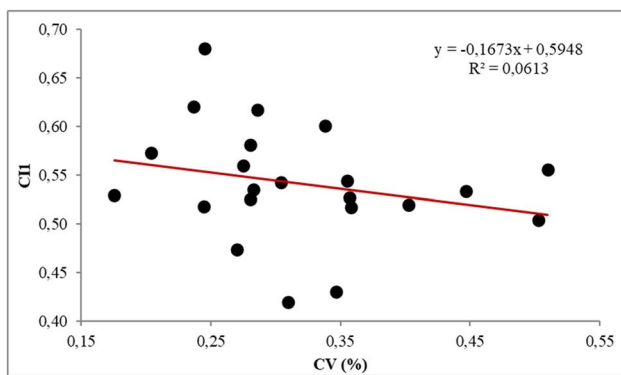
**Table 5** Correlation analysis with Pearson’s *r* value and *p* value between concentration index (CII) and rainfall variables

	Correlation	<i>P</i> annual averages (mm)	CV (%)	<i>N</i> rainy days
CII	<i>r</i>	<b>0.52</b>	<b>-0.25</b>	<b>0.49</b>
	<i>p</i> value	<b>0.023</b>	<b>0.049</b>	<b>0.022</b>

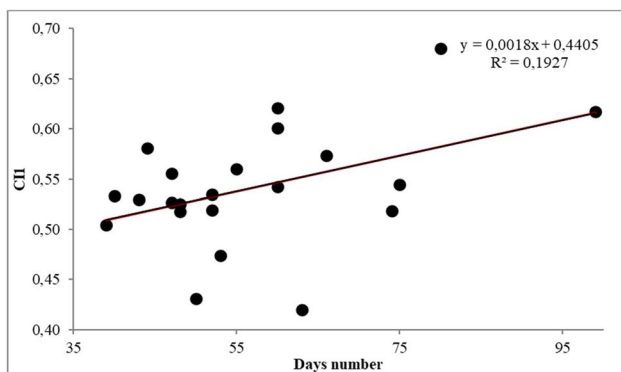
precipitation and the number of rainy days. Comparing our results with those of Martín Vide (2004) in Spain, we observe the non-significant correlation between CII and annual precipitation as well as between CII and the number of rainy days and a coincidence between CII and CV% despite the opposite trend. It is expected from these results that annual precipitation and average annual rainy days are not clear indicators of precipitation time compression since similar annual values could be obtained with different daily distributions. Figures 8, 9, and 10 show the correlations between the concentration index CII and annual precipitation, CV%, and the number of rainy days.



**Fig. 8** Relationship between the CI concentration index and the average annual precipitation (mm) for the 22 stations studied



**Fig. 9** Relationship between CI and the coefficient of variation of precipitation (CV%) for the 22 stations studied



**Fig. 10** Relationship between CI concentration index and number of rainy days for the 22 stations studied

## 5 Discussion

There are already a number of studies on different regions, continents, or even the world, at different spatial scales,

using the CI (Martin-Vide, 2004; Alijani et al. 2008; Zhang et al. 2009; Li et al. 2011; Cortesi et al. 2012; Monjo and Martin-Vide 2016; Royé and Martin-Vide 2017; Serrano-Notivoli et al. 2018, Caloiero et al. 2019, among others), so it is possible to compare the values obtained for regions with different climates. The CI values for the study area are not very high in relation to other regions analyzed. Only 3 of 22 stations (Taher, Yakourene, and Azzaba Pepiniere) have a CI value equal to or greater than 0.61. This value was considered the threshold for distinguish the high daily precipitation concentration in mainland Spain (Martin-Vide 2004). If 0.60 is considered, only 4 stations have high concentration. Benhamrouche et al. (2015) found CI values in northern Algeria between 0.59 and 0.63 per coastal region and between 0.57 and 0.62 in the highlands (except for the Biskra region, CI=0.70). In the present study, only 5 of the stations have a CV value in the interval 0.57–0.63, most have less than 0.57. Note that the periods of analysis, as well as the study areas, are different, the work of NE Algeria in the present study between 1980–2012 and the other of the entire country between 1970 and 2008 Benhamrouche et al. (2015). In another study, over a fairly similar area of NE Algeria during the period 1970–2010 (Bessaklia et al. 2018), only 4 of 23 stations had CI values of 0.61 or higher, a result quite similar to the obtained in the present study. Comparing the values of the few common stations analyzed in the two investigations, our values are slightly lower than those of Bessaklia et al. The values obtained are clearly lower than those of eastern Spain and southern France (Martin-Vide 2004; Cortesi et al. 2012), in the same western basin of the Mediterranean Sea.

The value of Sidi Embarek (0.47) is very low, so some low daily precipitation amounts probably have not been recorded at this station. The CI index is very sensitive to the quality and the number of data. If it is very low compared to the values of other nearby stations, we can suspect the series have missing records (Benhamrouche and Martin-Vide 2012). By the way, to avoid this problem with the data and allow to compare values, it is useful to use CI5 and CI10. In the case of Sidi Embarek, the values of these two indices are consistently close to those of other stations.

Most of the studies that use the CI analyze the relationships between the CI values and geographic and climatological variables, such as latitude, altitude, mean precipitation, and number of rainy days. In most studies, the correlation between the number of rainy days and CI is negative and statistically significant; that is, the lower the number of rainy days, the higher CI values. This is not the case in the present study. Probably the explanation for this is the fact that the study area is in the transition between the Mediterranean climate and the tropical desert climate, with a marked gradient of average annual precipitation and average annual rainy



days from north to south (Salhi et al. 2022). In this last area, the number of rainy days is very low, and the CI does not make much sense. The same occurs in Chile, where the CI values in the arid Mediterranean zone are higher than those corresponding to the desert zone (Sarricolea et al. 2019). The same explanation can argue for the positive correlation between the average annual precipitation and the CI. The negative correlation between the coefficient of variation and the CI is at the limit of significance, so it does not deserve any comment.

The positive correlation between latitude and the CI and the negative correlation between the distance to the sea and the CI are consistent with the aforementioned observation of the transition from Mediterranean to desert climate. The negative correlation between altitude and the CI was also found in a region of Vietnam (Benhamrouche et al. 2022). Finally, the geographic longitude does not contribute to modify the CI, since the study area is far from the Atlantic Ocean to the west.

## 6 Conclusion

The daily precipitation concentration is a climatic variable of great interest because it expresses the irregularity of daily precipitation values and especially the concentration or accumulation of precipitation in a few days. The concentration indices which allow a precise evaluation can be statistically analyzed and correlated with other rainfall variables. In addition, these concentration indices are useful indicators of the erosive capacity of precipitation the risk of flooding and its torrentiality.

In light of the available studies, the daily concentration of precipitation in the central part of northeastern Algeria is high with concentration index (CI) values close to 0.70 reflecting the fact that a few very rainy days contribute to a high percentage of annual precipitation. The maximum values of the four daily precipitation concentration indices considered are found in the eastern coastal part of the study area and in the southern Aurès, while the lowest values are found in the stations located south of the study area.

Therefore, there is no objection to use classes of 5 and 10 mm and the corresponding indices CI5 and CI10 in the analysis of daily concentration. They can allow the study of some observatories without precision in the record of tenths of precipitation. From a methodological point of view, the CI5 and CI10 concentration index values of the observatories can be accepted as good. On the other hand, Gini indices with classes of 5 and 10 mm introduce significant biases so they should not be used.

The hypothesis proposed in this research is rejected in relation to the fact that the correlations between all the indices empirical (Gini) and adjusted (those of concentration

using the exponential curve) must be high given their definitions except the correlations between CI1 and IG1 that is almost perfect.

Finally, the annual precipitation concentration index CI1 is acceptably correlated with latitude mean annual precipitation and number of rainy days (positive correlation) and with distance to the sea coefficient of variation of precipitation (CV%) and altitude (negative correlation). In contrast, no significant correlation was found between CI1 and longitude in the study area.

**Acknowledgements** This study was achieved within the framework of the PRIMA (BENEFIT-Med) project, together with Climatology Group (UB) and Project PID2020-116860RB-C21 (Spanish Ministry of Science and Innovation).

**Author contribution** Conceptualization: Rokia Azioune, Aziz Benhamrouche, Quoc Bao Pham; methodology and software: Aziz Benhamrouche, Hafiza Tatar; writing-original, draft preparation: Rokia Azioune, Javier Martin-vidé; visualization: Rokia Azioune, Aziz Benhamrouche; supervision: Aziz Benhamrouche, Quoc Bao Pham.

**Data availability** The data that support the findings of this study are available from the author [Quoc Bao Pham, quoc\_bao.pham@us.edu.pl] upon reasonable request.

## Declarations

**Ethical approval** Not applicable.

**Consent to participate** Not applicable.

**Consent to publish** Not applicable.

**Competing interests** The authors declare no competing interests.

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