Rainfall over the Central-Western Mediterranean basin in the period 1951-1995. Part I: precipitation trends

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Summary. — Climatic changes due to the anthropic enhancement of the greenhouse effect could modify the hydrological cycle, resulting in a reduction of the precipitation over the Mediterranean basin. In particular, a negative trend over the Italian peninsula could occur with prolonged periods of dryness as that recorded in the biennium 1988-1990. In order to verify if a climatic variability is already detectable, the pluviometric regime over the Central-Western Mediterranean is here analysed for the period 1951-1995. The analysis indicates that a reduction of about 20% in the total precipitation has occurred, which is statistically significant and can have serious impact on the availability of the water supplies.

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1. – Introduction

Climate modifications, as those connected to the anthropic enhancement of the greenhouse effect, could modify the distribution of the rainfall over the Earth surface, with the consequence that in some regions a reduction of the amount of precipitation could be recorded, which implies a lower availability of water resources, long periods of dryness and risk of desertification, as occurred in our country in the biennium 1988-1990 [1].

Scenario models, based on the use of GCM, pay particular attention to this matter, but do not give uniform results both on global and on regional scale [2, 3] about the trend of precipitations.

In particular, the effected simulations, concerning Southern Europe and the Mediterranean area, are totally discordant, giving results from a forecast of increase of about 0.2 mm/day, produced by the model GISS of NASA [4], to that of a strong decrease by about 0.6–0.8 mm/day, given by the model of the British Meteorological Office [5].

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Due to this large differences it is suitable to face the problem by analysing long-term series of observation data. Different authors agree on a reduction of rainfall in the Northern Hemisphere for latitudes lower than 50°: however, the values are in disagreement [6-8].

Also regional studies have been carried out by using different methodologies and different sample areas. An increasing trend has been found in USA [9, 10], Canada [10] and Eastern Mediterranean basin [11, 12], while in Switzerland [13] and over the Arabian peninsula [14] the trend does not show significant variations.

Analyses of the precipitations over the Mediterranean basin have been carried out by different authors: however, either they are not up to date [15] or they are relative to specific periods [16]. In addition, only few authors give quantitative results [17].

Recently, a research on the signals of climatic change in the Central-Western Mediterranean has been done: climatic parameters have been examined and the results indicate a climate in strong evolution with a reduction of the yearly amount of rainfall [18].

In the present work a systematic analysis of the precipitation trend over the Central-Western Mediterranean basin is carried out by examining data collected in the period 1951-1995 in a network of 59 stations lying along the rim of the basin. In 14 observatories, located in the core area of the basin, monthly data are also available and for this region we could make the analysis at monthly and seasonal time scale. In particular, after a short description of the data set and a recall on the statistical techniques used, the results are presented and discussed. The trend recorded over our country is also analysed and the results indicate a reduction by about 20% of the rainfall amount in the analysed forty-five years.

2. – Data set

Figure 1 shows the location of the meteorological observatories, whose data have been used in the present work. Data are gathered as yearly values for the 59 stations listed in table I. For the 14 stations of table II, that are located in Italy, France, Tunisia

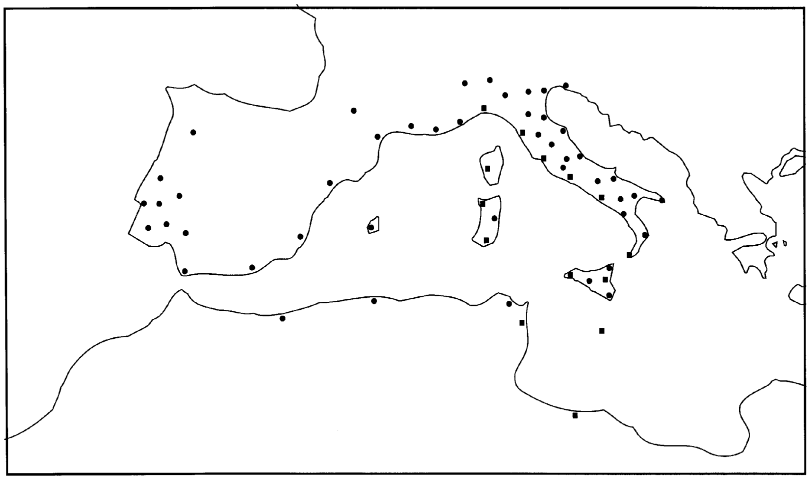

Fig. 1. – Stations used for annual (●) and seasonal (■) precipitation data analysis.

TABLE I. – *Stations used for yearly precipitation analysis.*

Ajaccio (France)
Algeri (Algeria)
Alghero (Italy)
Alicante (Spain)
Almeria (Spain)
Amendola (Italy)
Ancona (Italy)
Arezzo (Italy)
Barcelona (Spain)
Beia (Portugal)
Bellavista (Italy)
Bologna (Italy)
Bragan (Portugal)
Brindisi (Italy)
Cagliari (Italy)
Campobasso (Italy)
Catania (Italy)
Coimbra (Portugal)
Cozzo (Italy)
Crotone (Italy)
Evora (Portugal)
Firenze (Italy)
Genova (Italy)
Gibraltar (Spain)
Ginosa (Italy)
Grosseto (Italy)
Leuca (Italy)
Lisboa (Portugal)
Malta (Malta)
Marseille (France)
Mertola (Portugal)
Messina (Italy)
Milano (Italy)
Napoli (Italy)
Nimes (France)
Nice (France)
Oran (Algeria)
Palinuro (Italy)
Palma (Spain)
Perpignan (France)
Perugia (Italy)
Pescara (Italy)
Piacenza (Italy)
Pisa (Italy)
Portalegre (Portugal)
Potenza (Italy)
Prizzi (Italy)
Ravenna (Italy)
Roma (Italy)
Sevilla (Spain)
Toulouse (France)
Torino (Italy)
Trapani (Italy)
Trieste (Italy)
Tripoli (Libya)
Tunisi (Tunisia)
Venezia (Italy)
Verona (Italy)
Viterbo (Italy)

and Malta, monthly values are available, too: therefore, for the core area of the basin also monthly and seasonal trends have been analysed.

Since we have gathered only monthly and yearly values, we are not able to say anything about daily data. We can say, however, that the monthly and the yearly series do not present missing values and no interpolation was necessary. For Italy, Spain, Portugal, Algeria, Tunisia, data quality control has been performed by the respective Meteorological Services, using a program of reduction or elimination of the error, based on the control of the physical internal coherence and the spatial inter-comparison, as confirmed by the Italian Meteorological Service. Data of other countries have been gathered from the World Climatic Disc, produced by East Anglia University [19].

The sample area has been subdivided into three latitude belts: northern (>42 °N), that includes 23 stations, central (38 °N-42 °N), with 21 stations, and southern (<38 °N) with 15 stations. For both the whole area and each belt statistical analysis has been effected.

TABLE II. – *Stations used for seasonal and monthly precipitation analysis.*

Ajaccio (France)
Alghero (Italy)
Cagliari (Italy)
Catania (Italy)
Genova (Italy)
Grosseto (Italy)
Malta (Malta)
Napoli (Italy)
Pisa (Italy)
Reggio Calabria (Italy)
Roma (Italy)
Sfax (Tunisia)
Trapani (Italy)
Tunisi (Tunisia)

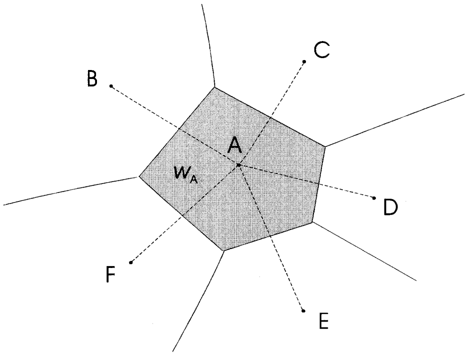

Fig. 2. – Example of Thiessen's polygon construction (B, C, D, E, F = stations next to A, W_A = area of the polygon, expressed as percent of the total area).

3. – Analysis of the trend

To analyse the precipitation pattern over the Central-Western basin a regional series has been realised, from the available data, by Thiessen's technique [20]. This is used

TABLE III. – *Values of the series calculated using Thiessen's technique over Central-Western Mediterranean.*

Year	Precipitation (mm)	Year	Precipitation (mm)
1951	779	1974	577
1952	560	1975	586
1953	660	1976	760
1954	618	1977	617
1955	647	1978	636
1956	628	1979	691
1957	656	1980	579
1958	639	1981	468
1959	735	1982	570
1960	790	1983	513
1961	607	1984	591
1962	636	1985	527
1963	794	1986	552
1964	596	1987	578
1965	657	1988	498
1966	651	1989	539
1967	510	1990	580
1968	593	1991	557
1969	753	1992	559
1970	570	1993	504
1971	631	1994	620
1972	727	1995	577
1973	564		

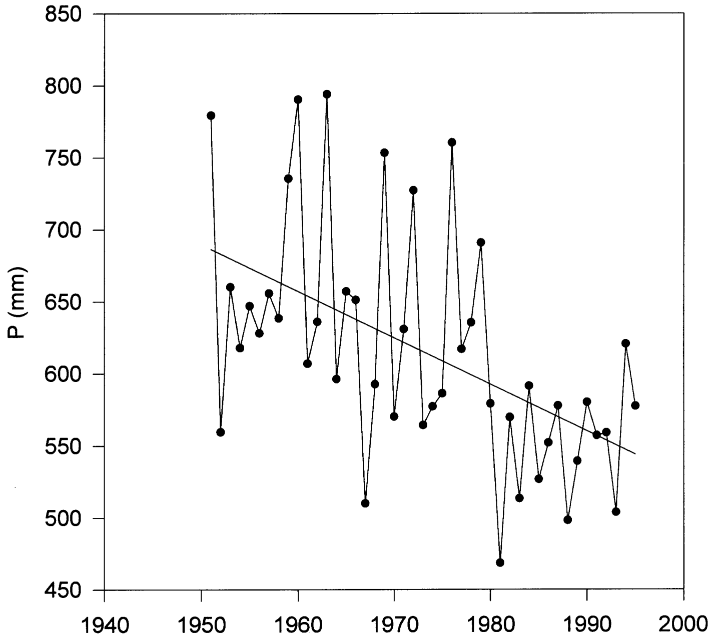

Fig. 3. – Regional precipitation series and relative linear trend over the Central-Western Mediterranean basin, obtained by Thiessen's method. The negative trend is clear.

when, as in our study, the observations are not uniformly spaced over the examined region and consists in weighting the datum of each station by a suitable coefficient.

Each term of the series is given by

$$P_j = \sum_{i=1}^{N} w_j P_{ij} ,$$

where P_j is the regional precipitation amount in the j-th year, N is 59, number of stations, w_i is Thiessen's coefficient for the i-th station, P_{ij} is the precipitation amount in the j-th year at station i-th.

Thiessen's coefficient w_i represents the area, given as percent of the total, of the polygon, in which the i-th station lies, closed by the perpendicular bisectors of the lines joining two nearby stations (fig. 2).

TABLE IV. – *Scale of* SAI *values.*

	$I_j \leqslant$	-0.85	much lower than mean
-0.85	$\leqslant I_j \leqslant$	-0.25	lower than mean
-0.25	$\leqslant I_j \leqslant$	0.25	in the mean
0.25	$\leqslant I_j \leqslant$	0.85	higher than mean
	$I_j \geqslant$	0.85	much higher than mean

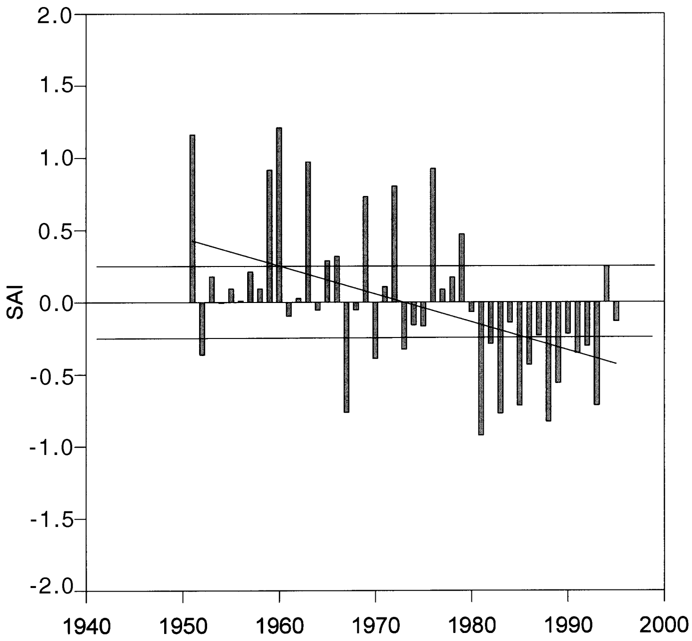

Fig. 4. - SAI precipitation trend over the Central-Western Mediterranean basin.

In table III the data of the obtained series are reported and on them a statistical analysis has been effected to obtain the trend. The obtained results are shown in fig. 3, from which a reduction by a rate of -3.2 mm/year appears, that for the whole period gives a reduction by 142 mm that is a reduction by about 21%.

In order to have further confirmation to these results, the *Standardized Anomaly Index* (SAI) has been computed. This is defined by

$$I_j = \frac{1}{N} \cdot \sum_{i=1}^{N} \frac{(P_{ij} - \overline{P}_i)}{\sigma_i} ,$$

where I_j is the index for the j-th year, P_i is the mean precipitation in the j-th station, σ_i is the standard deviation of the precipitation in the i-th station, while N and P_{ij} have the already seen meaning.

This index can be evaluated since the yearly values of the precipitation can be assumed to follow Gaussian distribution [21]. Nicholson [22] realised the scale of this parameter, shown in table IV, having established a correspondence between these values and the quintiles of the distribution.

The results are shown in fig. 4: the SAI in the examined period goes from a value higher than 0.25 to values lower than -0.25, with a variation statistically significant. They confirm what found by the above-mentioned scientists that claim for a reduction of the rainfall for latitudes lower than 50°. In addition, this negative trend of the rain seems to be correlated to the pressure increase over the western basin, recorded both at surface and upper levels, during the same period [18, 23-25]. However, although the

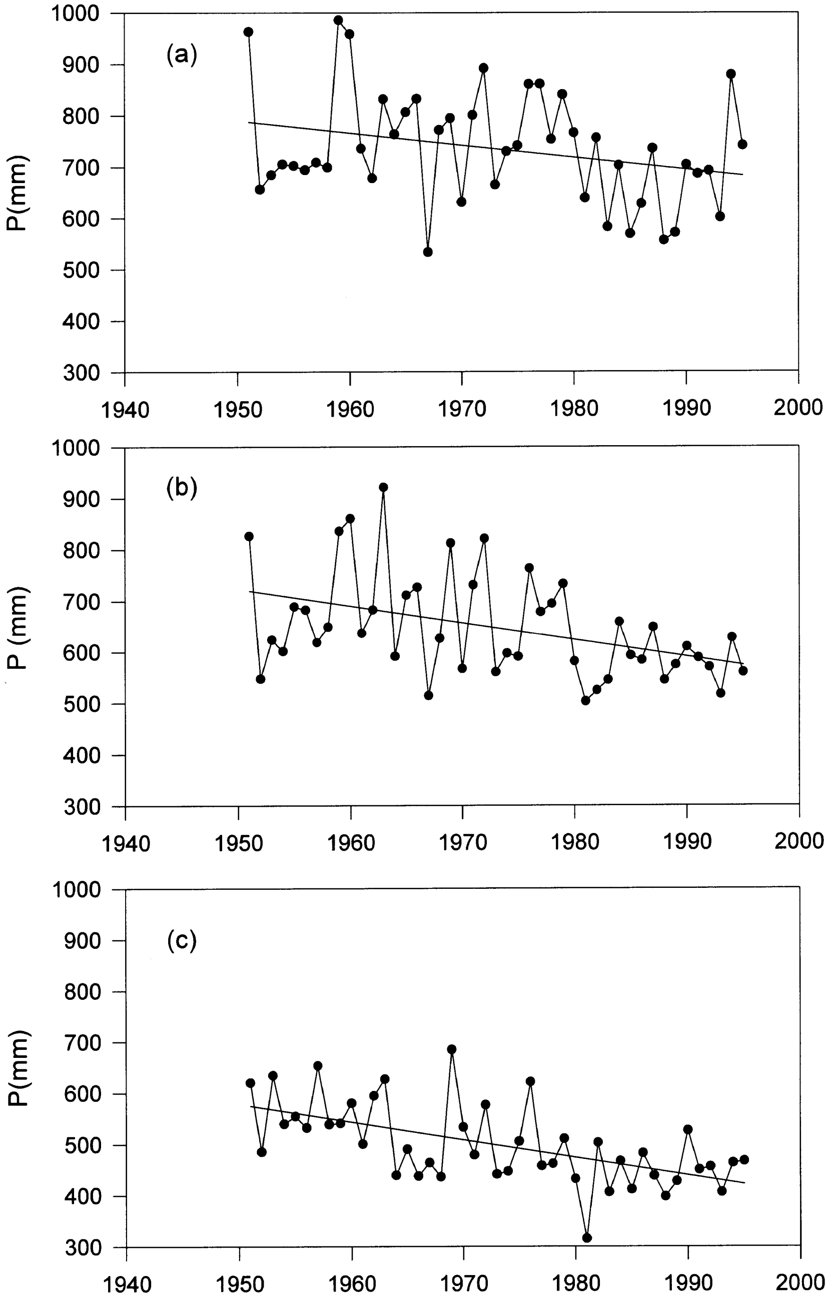

Fig. 5. – Thiessen's regional precipitation series and relative linear trend in the Northern latitudinal belt (a), in the Central belt (b) and in the Southern belt (c).

high-pressure persistence implies a lower number of rainy days, the total amount could be not modified since the intensity of the rainfall could be stronger.

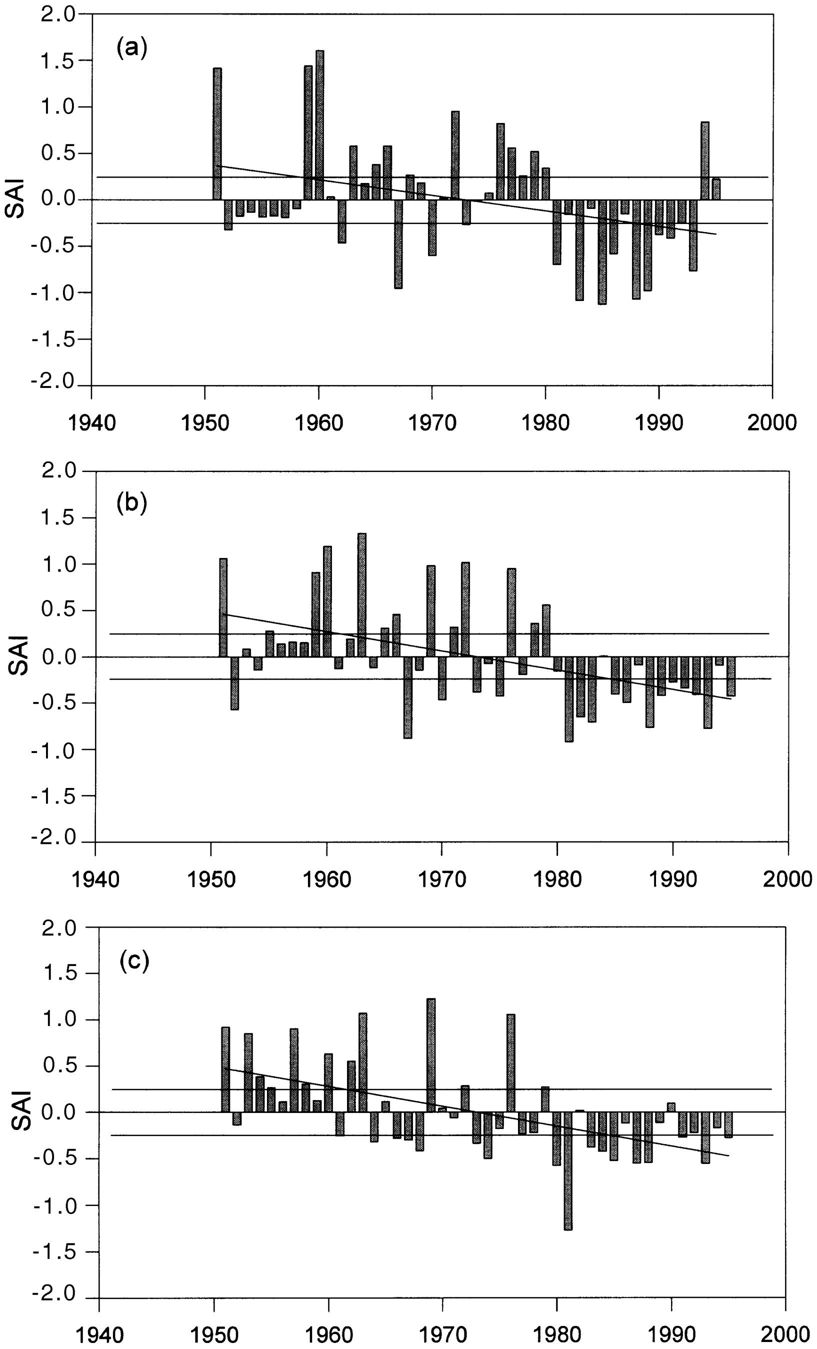

Fig. 6. – SAI precipitation trend in the Northern latitudinal belt (a), in the Central belt (b) and in the Southern belt (c).

TABLE V. – *Variations in the yearly rainfall in the Central-Western Mediterranean basin and in the three latitudinal belts, in the period 1951-1995.*

	ΔP (mm)	ΔP(%)	Trend (mm/y)
Whole basin	-142	-20.7	-3.2
Northern belt	-107	-13.3	-2.4
Central belt	-148	-20.3	-3.3
Southern belt	-157	-26.5	-3.5

After the analysis relative to the whole region, the trend in each latitude belt has been computed by the above-seen technique. Figures 5a), b), c) show the results relative to the three sub-regions: a clear negative trend is found. The highest decrease occurs in the Southern belt, where a reduction by 26% is recorded (table V).

In fig. 6 a), b), c), the SAI indices are shown, that confirm the above-mentioned results.

The strongest reduction in the Southern belt could be sign of an expansion towards the north of the desert drought and of a possible desertification, according to the self-induction mechanism proposed by Charney [26], which could be enhanced by the anthropic activity.

4. – Analysis of the seasonal monthly data

Seasonal and monthly precipitations have been investigated in the core area of the Mediterranean basin, using the data of the 14 stations of table II.

The seasonal analysis of the regional rainfall patterns indicates in all the seasons a decrease of the rain amount as shown in table VI, with the highest reduction recorded in winter, when it reaches the value of 29%.

This result is obvious in some sense: the Mediterranean climate, in fact, is characterised by mild and rainy winter and sunny summer, hot and dry. Köppen defined as Mediterranean a climate in which the winter rain R_w and the summer ones R_s were tied by the relationship $R_w > 3R_s$ [27]. Since the summer precipitations are very low, the greater reduction could occur essentially in the winter rainfall.

Figures 7a), b) and 8a), b) show SAI indices for the different seasons and the reduction in winter is confirmed since only in this season the SAI index goes from a value higher than 0.25 to a value lower than -0.25, with a statistical significant variation. In other seasons the trend is decreasing, but the value is even in the limit of the mean. In table VII the mean monthly values of the variation in the rain amount are

TABLE VI. – *Variations in the seasonal precipitation amounts in the period 1951-1995.*

	ΔP (mm)	ΔP(%)	Trend (mm/y)
Autumn	-32.1	-12.4	-0.7
Winter	-70.8	-29.0	-1.6
Spring	-11.2	-8.2	-0.2
Summer	-3.5	-6.7	-0.1

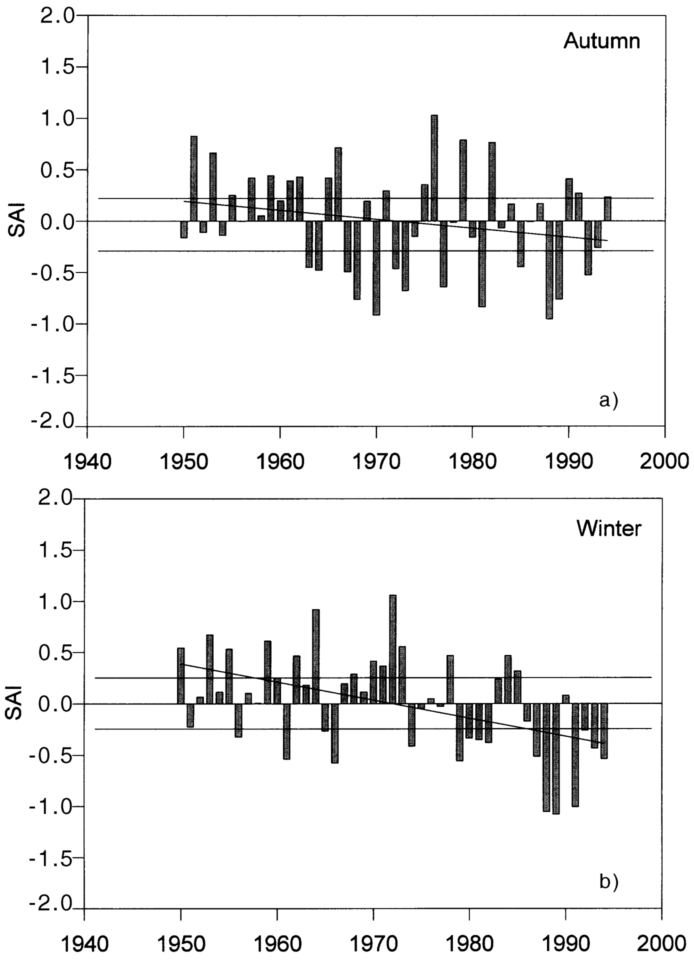

Fig. 7. – SAI precipitation trend during autumn (a) and winter (b).

TABLE VII. – *Variations in the monthly precipitation amount in the period 1951-1995, in the core area of the Mediterranean basin.*

	ΔP (mm)	ΔP(%)	Trend (mm/y)
September	+ 4.9	+ 9.4	+ 0.12
October	− 23.8	− 22.4	− 0.53
November	− 17.1	− 16.9	− 0.42
December	− 21.6	− 24.0	− 0.50
January	− 30.5	− 35.5	− 0.68
February	− 19.2	− 26.8	− 0.44
March	− 10.2	− 16.7	− 0.23
April	+ 7.5	+ 16.0	+ 0.21
May	− 8.4	− 21.1	− 0.20
June	− 3.1	− 13.9	− 0.13
July	− 1.2	− 9.2	− 0.03
August	+ 1.0	+ 6.2	+ 0.02

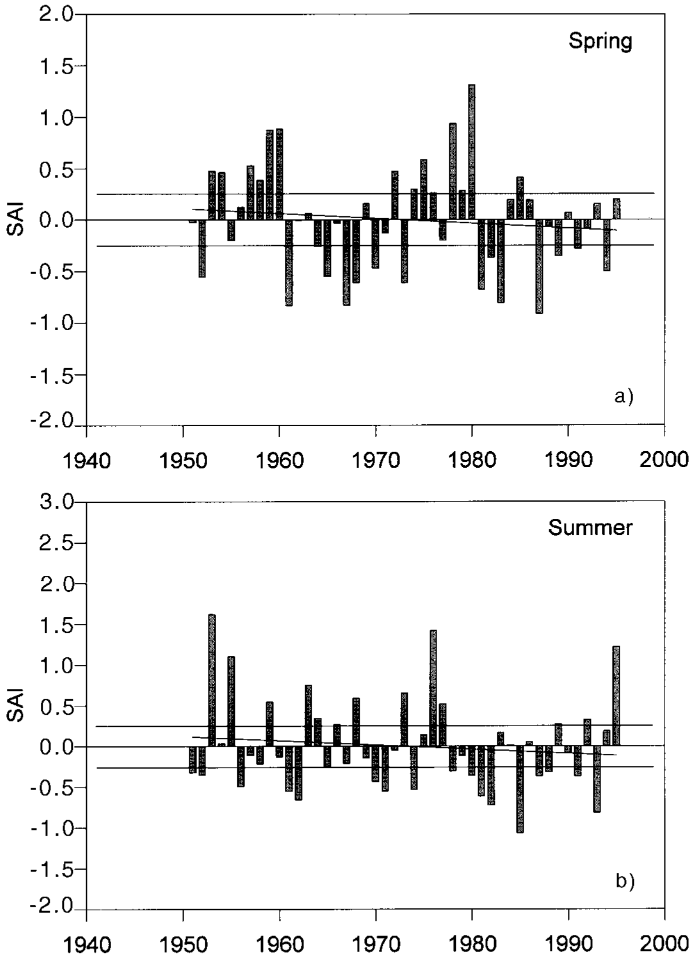

Fig. 8. – SAI precipitation trend during spring (a) and summer (b).

finally reported: almost all the months, with the exception of August, September and April, show a decreasing rate and also in this case the winter months are those in which the reduction is larger.

5. – Outline of the pattern recorded over Italy

After the analysis on regional scale and that concerning the latitude belts, the pattern relative to Italy was also studied. In this case as well, Thiessen's method was adopted to obtain a series representative of the whole country using data relative to the 35 Italian stations. Figure 9 shows the pattern of the rainfall with the relative trend: the reduction rate is −3.4 mm/year that corresponds for the whole period to −150.8 mm, equivalent to −20%. The SAI index, fig. 10, stresses that this reduction is

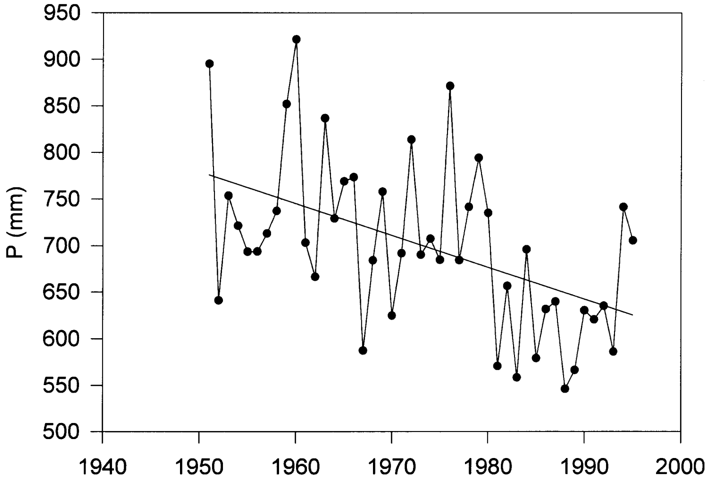

Fig. 9. – Precipitation series and relative linear trend over Italy.

statistically significant. These values confirm those relative to the Central-Western basin and are interesting also because they seem to continue a negative trend that starts around 1920. In a work concerning the behaviour of the precipitations from 1834 to 1950, Mennella [28] finds that, while before 1920 dry and wet periods were more or less equivalent, after that year the dry periods were neatly prevailing. Therefore, it may be that the negative trend began back in time and this could bring a serious damage to the water resources of our country.

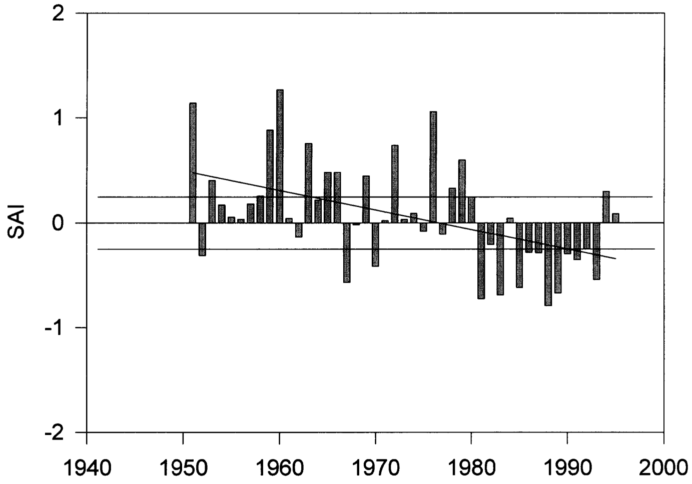

Fig. 10. – SAI precipitation trend over Italy.

6. – Conclusions

From the above data the following conclusions can be drawn:

i) in the examined period 1951-1995 the trend of rain amount over the Central-Western Mediterranean basin is decreasing;

ii) the reduction increases from North to South and this could imply an advancement of desertification towards higher latitudes;

iii) the precipitation trend seems to be anticorrelated to that of the pressure field, that is increasing in the same period;

iv) the seasonal and monthly analyses indicate that the largest reduction is recorded during winter;

v) the analysis relative to Italy confirms what found with the study both over the whole region and the latitudinal belts.

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