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Article

Temperature Trend Analysis and Investigation on a Case of Variability Climate

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Abstract: Climate change is now evident on a global scale. In some regions, the phenomenon is especially amplified, generating different consequences for man and the environment. Sicily is one of the Mediterranean regions, the biggest in terms of area, where climatic variations produce significant effects. In this study, temperature trends on monthly time scales are examined in the time frame 1925–2015. The cluster analysis technique (Ward's method) was used to homogenize the temperature series. The results show four statistically significant clusters, confirming the presence of climatic variability in the region. The non-parametric Mann–Kendall test was used to determine temperature trends. The non-parametric estimator Sen's slope was used to quantify the variation of trends. The results showed the presence of statistically significant trends. A worrying and unexpected increase in temperatures was found during the winter period. This scenario was presented in three clusters, highlighting a mutation in the winter season, attributable to the climatic changes in progress rather than to territorial factors. If the trends maintain an increasing monotone character, in the coming decades there will be, in many areas of Sicily, a constant loss of fertile soil for the agricultural sector and the advancement of phenomena such as drought and desertification, to which the island is already predisposed. All of this will have serious socio-economic repercussions. Considering that a large part of the region's economy is based on the agricultural sector, these repercussions will be followed by serious environmental implications that will negatively affect the ecological sustainability of the region.

Keywords: temperature trends; climate variability; non-parametric tests; hierarchical clustering; Mediterranean region

MSC: 26C05; 26D15

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1. Introduction

Many studies agree that temperatures are rising on a global scale. The Mediterranean area, especially in the last decade, is particularly sensitive to ongoing climate changes [1–4]. The impacts caused by climate change can generate repercussions on human health, especially for the most vulnerable members of the population, as well as endanger the entire local agricultural sector [5–8]. The spatial variability of temperatures and precipitation, even over short distances, can cause variations in the equilibrium of habitats, generating a change in the behavior of animal and plant species [9].

Containing global warming below 1.5 °C instead of below 2 °C can significantly reduce some risks, allowing humans and ecosystems to have a greater chance of adapting to changing climatic conditions [10,11]. In Europe, unchallenged climate change would have serious consequences on the economy, infrastructure, food production capacity, public health, biodiversity and political stability [12]. The climatic variations of the past and the present and the estimation of those future observations may be the indispensable prerequisite for the assessment of climate impacts and for the definition of strategies and plans for adaptation to such changes. Several studies have been conducted in order to identify the presence of significant trends for some climatic variables, measuring in more or less broad geographical domains [13–18].

In this study, an analysis of the temperatures, measured in the Sicilian region from 1925 to 2015, is conducted, in order to identify trends and quantify their rate of change. In the Sicilian region, the orography shows overall contrasts between the northern, southern, western and eastern parts, so it follows that a consequent climatic variability will occur. For this reason, it is necessary to identify homogeneous climatic areas.

The homogenization of the temperature series was performed by means of cluster analysis applying Ward's method [19–21], frequently used in the climatic field [22–25]. The obtained results show an aggregation into four clusters, having a similarity level of over 95% (Table 1).

For each cluster, the monthly average temperature was calculated using the data of the stations belonging to the respective cluster. Following this methodology, it was possible to obtain a time series of the average monthly temperatures, relating to the period 1925–2015. The elements of the time series were grouped according to the month; then, the temperature trend and variability were observed, for each of the 12 months, over a period of 90 years.

To verify the presence of significant trends in the clusters, the non-parametric Mann–Kendall test (MKT) was applied [26,27]. MKT allows us to quantify the significance of trends in time series; for this reason, it is used for analysis of environmental time series [28–34].

To quantify the variation in trends, the non-parametric approach of Sen's slope [35] was applied. The Sen slope estimate is widely used for the study of hydrometeorological time series [36–39]. The results show, overall, a significant trend towards increasing temperatures in three out of four clusters. In the remaining cluster, the opposite trend can be seen because the temperature values during the summer are decreasing. The increase in temperatures encountered during the winter period is worrying and unexpected.

Caused by the increase in temperatures during the winter period, attributable to climate change rather than to territorial factors, there could be a loss in crops and vegetation. If the growing monotonous character of the trends remains constant, the increase in temperature during the winter season would induce alterations in the vegetative rest. This would contribute significantly to the desertification process the island is facing. Additionally, in the spring period, there are growing trends with a significant rate of increase, negatively affecting the conditions of the soil.

Significant, but expected, is the tendency for temperatures to increase, which occurs during the summer, exacerbating the phenomenon of drought. The autumn period is the one that, while maintaining a growing trend, has the lowest rate of variation.

An important aspect that is shown in this paper, through a method of hierarchical aggregation, is the climatic variability of Sicily, the biggest island of the Mediterranean area. Climate variability can be affected by factors such as orography, proximity to the coast, and height above sea level, and is capable of producing significant differences even for small portions of the territory [40,41]. Additionally, the climatic changes that occur have an impact.

These changes are amplified in the Mediterranean region, causing anomalous increases in temperature. Through the statistical approach adopted in this study, the need emerged to direct mitigation and adaptation actions towards the areas most exposed to the consequences of climate variability; this would allow one to protect the agricultural sector and consequently the economy of the region.

This study can be considered as the first in this direction; we intend to continue it in the future and extend it to wider areas, not only in Sicily but also at the same latitudes in Greece and Spain.

2. Materials and Methods

2.1. Study Areas and Data Collection

Sicily is the biggest island in the Mediterranean sea, has a total area of about 25,000 km^2, and extends in latitude between about 36° and 38° North and in longitude between about 12° and 15° East. It is a predominantly hilly region; for 62% of the territory, 24% is mountainous and the remaining 14% is flat.

Overall, the Sicilian orography shows sharp contrasts between the northern portion, which is mainly mountainous, and the central-southern and south-western portions, which are essentially hilly; the south-eastern area is mainly a plateau, and the eastern part is volcanic. From a climatic point of view, Sicily, according to the macroclimatic classification of Köppen, can be defined as a region with a temperate-humid climate, of type C (average of the coldest month below 18 °C but above −3 °C). However, this definition has only a macroclimatic value, as on a regional scale the climate is strongly influenced by local factors, such as the conformation of the territory, the proximity to the coast and the orography.

According to [42,43], if we pass to the analysis of what can be found within the temperate climate of type C of Köppen, we can already distinguish several subtypes: temperate subtropical, temperate climate warm, sublitorial temperate, subcontinental temperate, and cool temperate, Each of these can be found in the different areas of Sicily. The territorial diversity of Sicily, consequently, produces a complex climatic variability during the year in terms of temperature distribution and rainfall. As regards the temperature data used in this work, the database of the Observatory of Waters-Authority of the Sicily hydrographic district basin was used.

As a function of the temporal continuity of the measurements, data from 200 thermometric stations were used. The time series obtained, for each of them, represent the values of the average monthly temperatures, from January 1925 to December 2015.

2.2. Homogenization of Temperature Data

Depending on the climatic variability present in Sicily, the identification of climatically homogeneous areas was carried out. The homogenization of the temperature series was carried out using an objective classification method such as cluster analysis. The statistical units tend to be grouped into classes (clusters) not defined a priori, but obtained from the classification algorithm based on the characteristics of the data themselves.

The goal of cluster analysis is the partitioning of statistical units into groups, so that units belonging to the same group are very similar to each other with respect to certain characteristics of the data, while units belonging to distinct groups are very dissimilar to each other.

In this work, a cluster analysis was performed using Ward's method, which is frequently used in the climate field. This method achieves a hierarchical classification by minimizing the variance of the variables within each group. This technique allows one to generate groups of relatively equivalent size, minimizing a function.

Using this function, groups are created that have maximum internal cohesion and maximum external separation. The total deviance of the p variables is broken down into *deviance within groups* and *deviance between groups* (Equation (1)):

$$Dev_{Tot} = Dev_{within} + Dev_{beetween} \tag{1}$$

Given a partition of G groups having variable numerosity n_g (with $g = 1, 2, 3, \ldots, G$), the total deviance of the p variables corresponds to the sum of the deviations of the single variables with respect to the corresponding general mean $\overline{x_k}$ (Equation (2)):

$$Dev_{Tot} = \sum_{g=1}^{G} \sum_{i=1}^{n_g} \sum_{k=1}^{p} \left(x_{ikg} - \overline{x_k} \right)^2 = \sum_{s=1}^{n} \sum_{k=1}^{p} (x_{sk} - \overline{x_k})^2 \tag{2}$$

The deviance within groups is given by the sum of the deviances of each group (Equation (3)):

$$Dev_{within} = \sum_{g=1}^{G}\sum_{i=1}^{n_g}\sum_{k=1}^{p}\left(x_{ikg} - \overline{x_{kg}}\right)^2 = \sum_{s=1}^{n}\sum_{k=1}^{p}\left(x_{sk} - \overline{x_{kg}}\right)^2 \tag{3}$$

The deviance between groups is given by the sum of the deviations of the group means with respect to the corresponding general mean (Equation (4)):

$$Dev_{beetween} = \sum_{g=1}^{G}\sum_{k=1}^{p} n_g\left(\overline{x_{kg}} - \overline{x_k}\right)^2 \tag{4}$$

At each step of the hierarchical procedure, the groups are aggregated with each other, resulting in the smallest increase in deviance in the groups, Dev_{within}, and the greatest increase in deviance between the groups, $Dev_{between}$, to obtain the greatest possible internal cohesion, and, as a consequence, the greatest external separation. The sequence of aggregations produced is represented by a dendrogram in which the various statistical units object of the classification process appear on the axis of abscissae and the similarity that unites the various clusters on the ordinate axis [44].

2.3. Trend Analysis Methods

In order to verify the presence of any trends, the Mann–Kendall test (MKT) was applied to the available time series. It is a non-parametric test, and therefore it does not assume any a priori distribution for the data. It allows us to quantify the significance of trends in time series; for this purpose, it is often used for the analysis of the environmental time series. In MKT the null hypothesis (H_0) is that there is no trend in the observed series. The alternative hypothesis (HA) is, instead, such that the series follows a monotonous, increasing or decreasing, trend over time. The MKT statistic, denoted by S, is calculated using Equation (5):

$$S = \sum_{i=1}^{n-1}\sum_{j=i+1}^{p} sgn\left(x_j - x_i\right) \tag{5}$$

where x_j and x_i are, respectively, the values of the j-th year and i-th year, where $j > i$, n is the length of the series and the *sign*-function. Equation (6), is defined as follows:

$$sgn(x_j - x_i) = \begin{cases} 1 & if \quad x_j - x_i > 0 \\ 0 & if \quad x_j - x_i = 0 \\ -1 & if \quad x_j - x_i < 0 \end{cases} \tag{6}$$

If the series is sufficiently long ($n \geq 10$), the statistic S can be approximated to a normal distribution, Equation (7), having zero as average and variance equals to:

$$Var(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{i=1}^{g} t_i(t_i - 1)(2t_i + 5)\right] \tag{7}$$

The second term is introduced to make the necessary correction in the presence of groups of equal observations that generate the so-called nodes, in particular g is the number of nodes and t_i is the number of nodes in the i-th group. The statistics of the test Z_S is applied to calculate the significance of the trend- The Z_S test allows to verify the null hypothesis H_0. If $|Z_S|$ is bigger than $Z_{\frac{\alpha}{2}}$, where α represents the chosen level of significance (e.g., with $\alpha = 0.05$, $Z = 1.96$), then the null hypothesis is not true. This fact implies that the trend of the series is significant. The statistics, Z_S, are calculated as follows (Equation (8)):

$$Z_S = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} & if \quad S > 0 \\ 0 & if \quad S = 0 \\ \frac{S+1}{\sqrt{Var(S)}} & if \quad S < 0 \end{cases} \tag{8}$$

The sign of Z_S denotes the direction of the trend; we have an increasing trend if Z_S is positive, and a decreasing trend if Z_S is negative [45]. If we consider the series to show a significant trend, it is possible to calculate the rate of variation through a non-parametric approach of the Sen slope. For every pair of values (x_i, x_j) for $j > i$, all the possible slopes d_k are calculated (Equation (9)):

$$d_k = \frac{x_j - x_i}{j - i} \tag{9}$$

The Sen slope is calculated as median of all slopes; the higher and lower quantiles, respectively, Q_{inf} and Q_{sup} are calculated as follows (Equation (10)):

$$\begin{cases} Q_{inf} = \frac{N - C_\alpha}{2} \\ Q_{sup} = \frac{N + C_\alpha}{2} \end{cases} \quad where \quad N = \frac{n(n-1)}{2} \quad and \quad C_\alpha = Z_S \cdot Var(S) \tag{10}$$

where n is the numerosity of the temporal series and C_α represents the confidence interval; $Var(S)$ is defined in Equation (7) and Z_S is defined in Equation (8).

3. Results

The series of monthly mean temperatures were homogenized using cluster analysis. From the results obtained by Ward's method, four clusters with a similarity level higher than 95% are highlighted, by means of a dendrogram (Figure 1). This made it possible to identify climatically homogeneous areas on which to perform the monthly characterization of temperature trends for the time interval 1925–2015. In order to verify the presence of any monthly trends, the non-parametric Mann–Kendall test (MKT) was applied to the available time series, with a significance level of 95%.

It is shown below, see Table 1, that the rate of temperature variation in the analyzed series was quantified by means of Sen's slope. The results of the tests highlighted different scenarios for each cluster, underlining the climatic diversity present in Sicily. In Figure 2 is shown the spatial distribution of the Clusters.

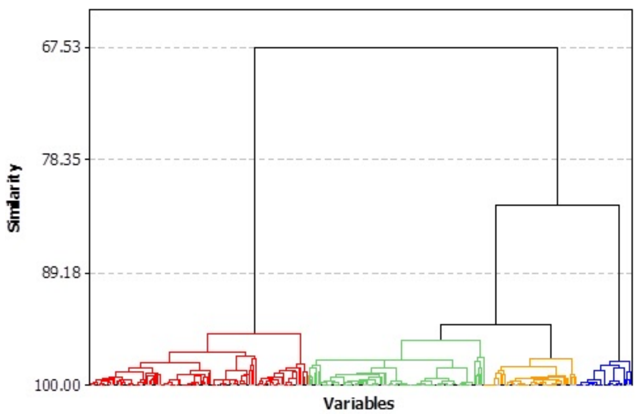

Figure 1. Dendrogram obtained from Ward's agglomerative method; is pointed out the presence of 4 clusters with a similarity level greater than 95%.

Table 1. Results of the Mann-Kendall test for temperature data in every Cluster.

	Month	Number Obs.	Min	Max	Mean	Std. Dev.	Statistic (Zs)	*p*-Value	Sen's Slope	Test Interpretation (α = 0.05)	Trend
	Jan	90	7812	13,615	11,052	1152	+4273	<0.0001	0.019	Reject H_0	Increasing
	Feb	90	8055	14,167	11,249	1313	+2412	0.0159	0.014	Reject H_0	Increasing
	Mar	90	9831	16,558	12,852	1168	+2774	0.0055	0.011	Reject H_0	Increasing
	Apr	90	12,724	17,701	15,321	0936	+3248	0.0012	0.012	Reject H_0	Increasing
	May	90	16,558	25,997	19,200	1394	+4461	<0.0001	0.021	Reject H_0	Increasing
CLUSTER 1	*Jun*	90	20,645	28,420	23,249	1288	+3304	0.0010	0.018	Reject H_0	Increasing
	Jul	90	23,295	28,966	26,022	1099	+3869	0.0001	0.017	Reject H_0	Increasing
	Aug	90	23,954	29,451	26,302	1172	+4583	<0.0001	0.021	Reject H_0	Increasing
	Sep	90	20,783	26,464	23,545	1015	+2140	0.0324	0.008	Reject H_0	Increasing
	Oct	90	15,297	22,897	19,758	1360	+2593	0.0095	0.015	Reject H_0	Increasing
	Nov	90	12,215	18,213	15,762	1062	+1791	0.0732	0.008	Acept H_0	No Trend
	Dec	90	9203	19,672	12,683	1653	+3534	0.0004	0.017	Reject H_0	Increasing
	Jan	90	4096	10,516	7768	1351	+4308	<0.0001	0.022	Reject H_0	Increasing
	Feb	90	4045	12,407	8108	1622	+1969	0.0489	0.013	Reject H_0	Increasing
	Mar	90	6174	15,248	10,100	1503	+1805	0.0710	0.009	Acept H_0	No Trend
	Apr	90	10,134	15,633	12,999	1191	+1757	0.0790	0.008	Acept H_0	No Trend
	May	90	14,170	24,923	17,516	1646	+2997	0.0027	0.018	Reject H_0	Increasing
CLUSTER 2	*Jun*	90	18,908	27,480	22,107	1448	+1534	0.1252	0.009	Acept H_0	No Trend
	Jul	90	22,653	28,072	24,990	1203	+1342	0.1797	0.007	Acept H_0	No Trend
	Aug	90	21,867	28,377	24,944	1384	+2475	0.0133	0.014	Reject H_0	Increasing
	Sep	90	18,168	25,063	21,397	1257	+0397	0.6911	0.002	Acept H_0	No Trend
	Oct	90	11,994	21,236	17,003	1602	+2112	0.0347	0.014	Reject H_0	Increasing
	Nov	90	8426	16,191	12,629	1249	+1624	0.1043	0.009	Acept H_0	No Trend
	Dec	90	5130	17,319	9434	1834	+3966	<0.0001	0.020	Reject H_0	Increasing
	Jan	90	2334	8863	5937	1411	+1603	0.1089	0.009	Acept H_0	No Trend
	Feb	90	1772	11,534	6348	1873	+0091	0.9278	0.001	Acept H_0	No Trend
	Mar	90	4469	12,494	8477	1628	−0760	0.4474	−0.004	Acept H_0	No Trend
	Apr	90	8941	15,000	11,523	1351	−2164	0.0304	−0.012	Reject H_0	Decreasing
	May	90	12,150	23,806	16,286	1789	−0488	0.6256	−0.003	Acept H_0	No Trend
CLUSTER 3	*Jun*	90	17,600	26,366	21,043	1680	−2792	0.0052	−0.019	Reject H_0	Decreasing
	Jul	90	21,438	27,319	23,977	1414	−3109	0.0019	−0.019	Reject H_0	Decreasing
	Aug	90	20,041	27,225	23,831	1536	−1446	0.1481	−0.010	Acept H_0	No Trend
	Sep	90	16,359	24,116	20,002	1549	−2684	0.0073	−0.018	Reject H_0	Decreasing
	Oct	90	9984	19,688	15,367	1676	−0272	0.7857	−0.002	Acept H_0	No Trend
	Nov	90	6209	15,256	10,856	1323	−1046	0.2958	−0.006	Acept H_0	No Trend
	Dec	90	3278	15,797	7606	1954	+1209	0.2265	0.007	Acept H_0	No Trend
	Jan	90	5711	11,658	9245	1241	+4635	<0.0001	0.022	Reject H_0	Increasing
	Feb	90	5819	13,209	9529	1458	+2171	0.0299	0.014	Reject H_0	Increasing
	Mar	90	7775	15,515	11,356	1328	+2872	0.0041	0.012	Reject H_0	Increasing
	Apr	90	11,349	16,062	14,071	1080	+2708	0.0068	0.012	Reject H_0	Increasing
	May	90	15,240	25,240	18,347	1532	+4259	<0.0001	0.024	Reject H_0	Increasing
CLUSTER 4	*Jun*	90	19,636	27,694	22,721	1404	+3416	0.0006	0.019	Reject H_0	Increasing
	Jul	90	22,979	28,604	25,561	1217	+3478	0.0005	0.019	Reject H_0	Increasing
	Aug	90	22,832	28,762	25,649	1351	+4085	<0.0001	0.024	Reject H_0	Increasing
	Sep	90	19,138	25,513	22,406	1163	+1499	0.1340	0.007	Acept H_0	No Trend
	Oct	90	13,213	21,604	18,263	1509	+2642	0.0082	0.017	Reject H_0	Increasing
	Nov	90	9809	17,026	14,039	1181	+1973	0.0485	0.010	Reject H_0	Increasing
	Dec	90	6962	18,294	10,895	1724	+4133	<0.0001	0.020	Reject H_0	Increasing

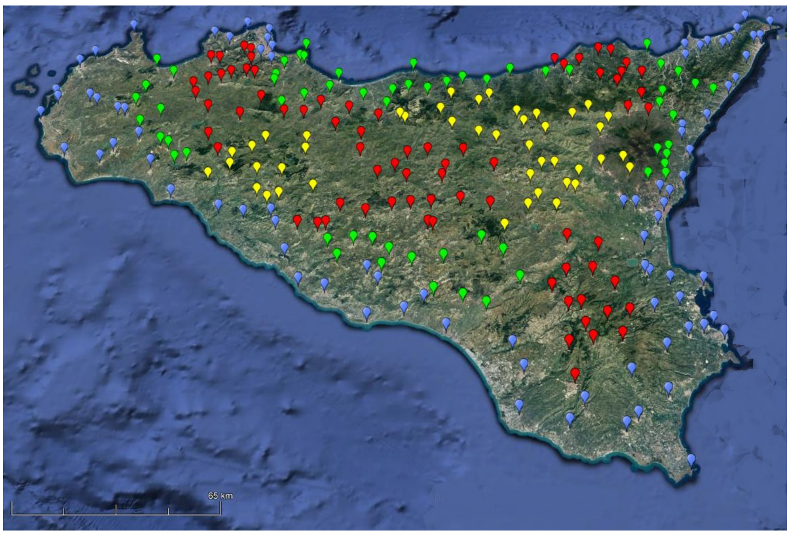

Figure 2. Spatial distribution of the Clusters. In detail in BLUE Cluster 1, in RED Cluster 2, in YELLOW Cluster 3, in GREEN Cluster 4.

Clusters Descriptions

- Cluster 1: The results of the MKT highlight the significant presence of growing trends, regardless of the months of the year, with the exception of November. The null hypothesis H_0 is rejected, which means accepting the alternative hypothesis HA, or that there is a significant trend in the analyzed series. The sign of Z_S indicates an increasing trend. From Sen's slope, it is possible to identify the months that experienced the highest rate of temperature increase. August and May are those that undergo the highest increase, exceeding 1.9 °C. Significant is the month of January where the increase approaches 1.7 °C. The months of June and July show an increase close to 1.6 °C. Another significant month with an increase of 1.5 °C is December. The increases for the months of October, February, April and March instead oscillate between 1.3 °C and 1.0 °C. The months of November, in which no trend was identified; vice versa, September underwent the lowest increase, about 0.7 °C.
- Cluster 2: A double behavior is evident, six months show increasing trends while during the other six months no significant trend has been observed, having accepted the null hypothesis H_0. From the Sen's slope it is clear that the months of January and December are those that have undergone the greatest increase in temperature, respectively 2.0 °C and 1.8 °C. The month of May shows an increase of 1.6 °C, while the increase in August, October, February oscillates between 1.3 °C and 1.2 °C. The remaining six months show no obvious trends; their increase does not exceed 0.8 °C.
- Cluster 3: Based on the results of MKT and in accordance with the sign of Z_S, there are decreasing trends in temperatures in the months of April, September, June and July; for the remaining months no trend was observed as the null hypothesis H_0 is accepted. The Sen slope shows a significant decrease in temperature in the months of June and July with −1.7 °C. September follows with −1.6 °C and April with −1.1 °C. In the remaining months, although there are no significant trends, there was a decrease between −0.2 °C and −0.9 °C, while in the months of January and December there were increases of +0.8 °C and +0.7 °C, respectively.
- Cluster 4: Growing trends are well highlighted by the results of the MKT and in accordance with the sign of Z_S, regardless of the months of the year, with the exception of September in which the null hypothesis H_0 is accepted. From the Sen's slope the highest temperature increase is found in the months of May and August, respectively 2.2 °C and 2.1 °C. Particularly significant is the increase in the months of January and December, 2.0 °C and 1.8 °C respectively. In the months of June and July there is an increase of 1.7 °C. As for the months of February, March, April, October, the increase oscillates between 1.0 °C and 1.5 °C. The month of November, followed by the month of September in which no significant trend is observed, shows increases of 0.9 °C and 0.6 °C, respectively.

Figure 3 is reported the monthly temperature increases from 1925 to 2015 for each Cluster; the light bar indicates the absence of a significant trend. Below Table 2 is showed that the temperature variation rates for the analyzed time interval. For each cluster, the series of average monthly temperatures from 1925 to 2015 are reported (Figures 4–7).

Table 2. Rates of variation of temperature trends in (°C).

Month	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Jan	+1.68	+2.02	+0.85	+2.02
Feb	+1.24	+1.19	+0.07	+1.22
Mar	+1.01	+0.85	−0.38	+1.08
Apr	+1.12	+0.76	−1.12	+1.12
May	+1.92	+1.59	−0.31	+2.16
Jun	+1.59	+0.77	−1.73	+1.75
Jul	+1.56	+0.66	−1.75	+1.70
Aug	+1.93	+1.29	−0.88	+2.15
Sep	+0.74	+0.18	−1.65	+0.62
Oct	+1.34	+1.26	−0.21	+1.49
Nov	+0.75	+0.84	−0.55	+0.92
Dec	+1.51	+1.80	+0.67	+1.82

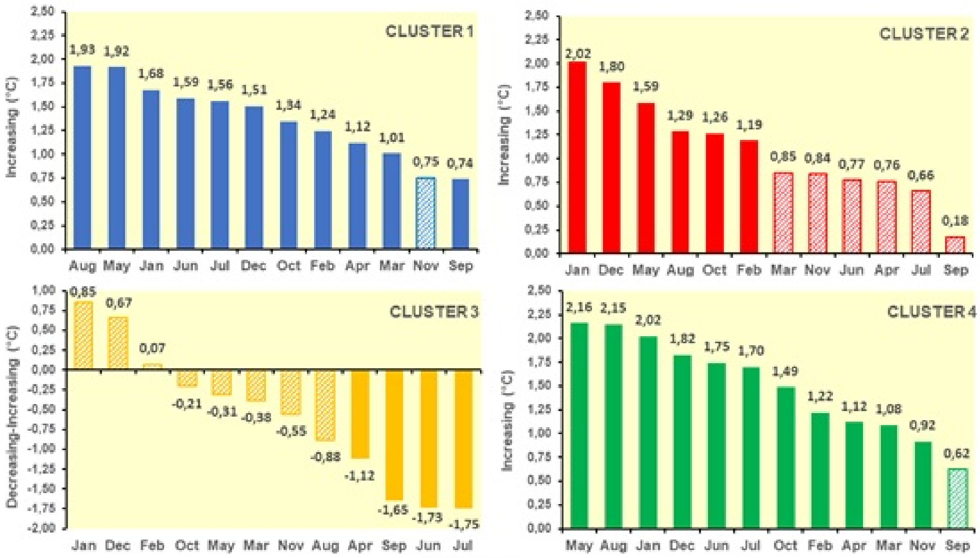

Figure 3. Monthly temperature increases from 1925 to 2015, for each Cluster: the light bar indicates the absence of significant trends.

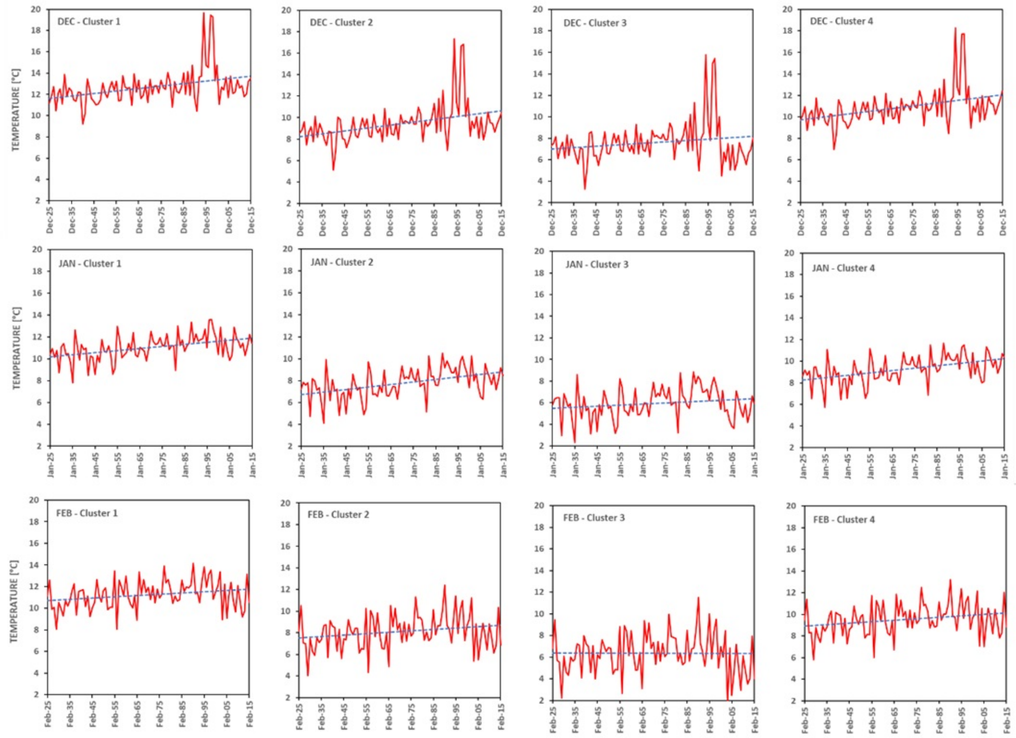

Figure 4. Trend of average monthly temperatures from 1925 to 2015 for each Cluster (quarter Dec–Jan–Feb).

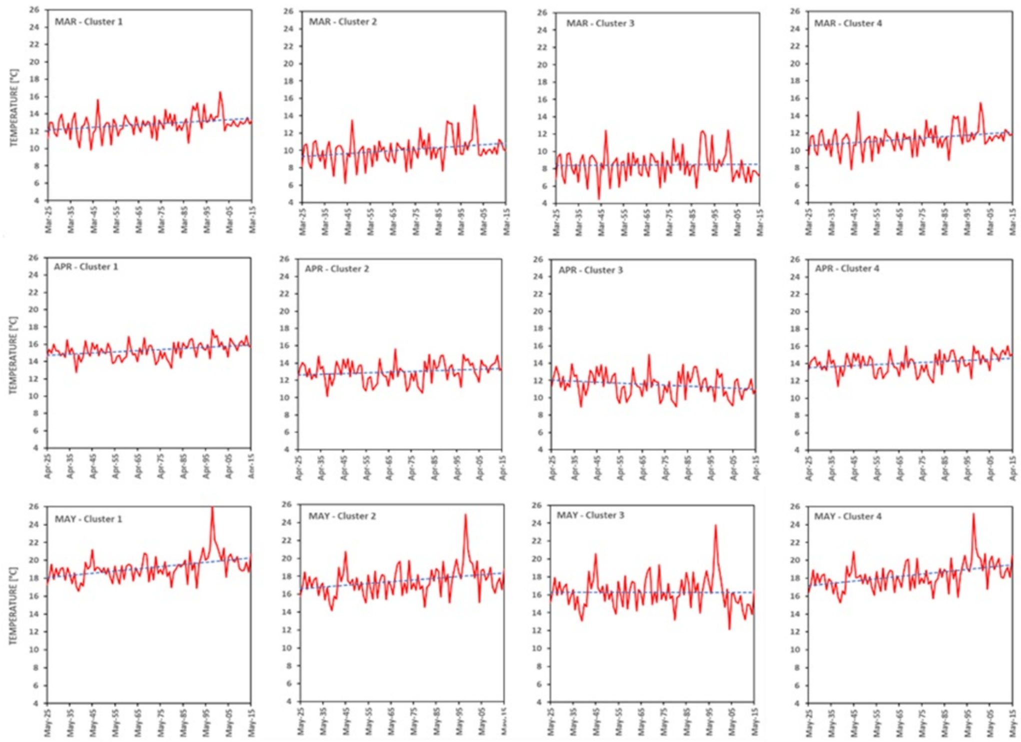

Figure 5. Trend of average monthly temperatures from 1925 to 2015 for each Cluster (quarter Mar–Apr–May).

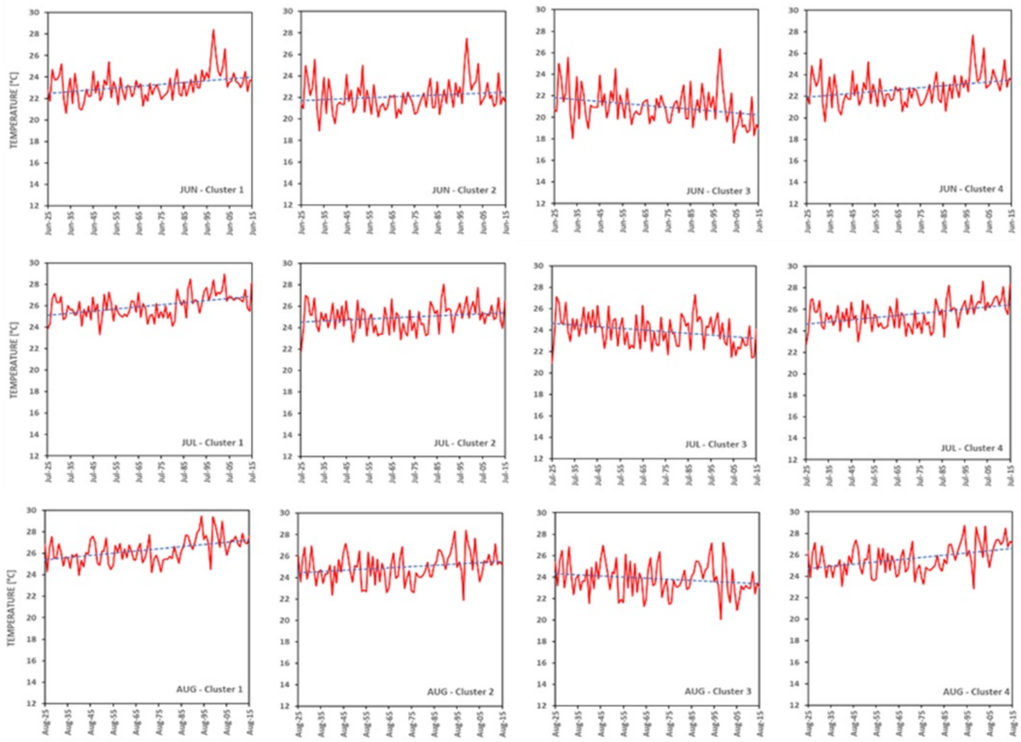

Figure 6. Trend of average monthly temperatures from 1925 to 2015 for each Cluster (quarter Jun–Jul–Aug).

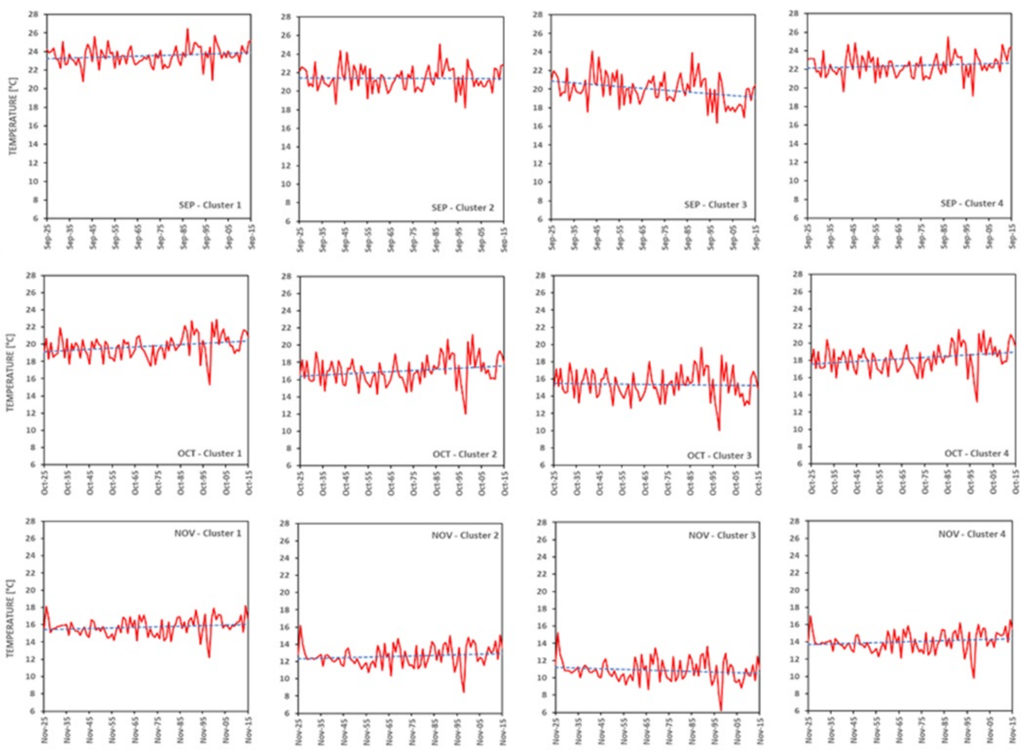

Figure 7. Trend of average monthly temperatures from 1925 to 2015 for each Cluster (quarter Sep–Oct–Nov).

4. Discussion

From the results obtained, it was possible to clarify the temperature trends in each cluster; their rate of change, from 1925 to 2015, was also quantified. By comparing the trends and the rate of variation of the temperatures in the clusters, a non-negligible climatic variability can be deduced. In detail, as regards clusters 1, 2, and 4, the trends that characterize a specific month show a significant and unexpected increase in temperature during the winter season. Evidently, in the Sicilian region there is a mutation in the winter season that is attributable to the climatic changes in progress rather than to territorial factors. If these trends maintain an increasing monotonous character, in the short term there could be a loss of crops and vegetation; an increase in temperature during the winter season would induce alterations in the vegetative rest.

This would significantly contribute to the desertification process the island is facing [46–48]. Additionally, in the spring period there are growing trends with a significant increase, negatively affecting the conditions of the soil; indeed, an increase in temperature causes greater evapotranspiration and consequently an increase in rainfall during those periods of the year not suitable for the accumulation of water [49–51]. Significant, but expected, is the trend towards an increase in temperatures that occurs during the summer, exacerbating the phenomenon of drought [52,53]. The autumn period is also characterized by growing trends but with a smaller increase; especially in the months of September and November, clusters 1, 2, and 4 undergo a low temperature increase.

As far as cluster 3 is concerned, there is a counter-trend; in the summer period there is a decrease in temperatures. In detail, there is a significant downward trend in temperatures during the months of June, July, September and April, while statistically significant trends are not present for the remaining months.

5. Conclusions

In the Sicilian region, the rise in temperatures and the increase in extreme events, such as recurrent and intense droughts, can generate repercussions both on human health, especially for the most vulnerable members of the population, and for the entire agricultural sector. From the analysis conducted, it emerges that the ongoing climate change introduces elements of instability and uncertainty.

It has been shown that in addition to the well-known summer season, which is particularly dry and with high temperatures which the island is subjected to, there is also a winter with rising temperatures and an increasingly warm spring. The winter season, from 1925 to 2015, experienced an increase of 2.0 °C, in much of the region. If this trend maintains a growing monotonous character, in the coming decades there will be a constant loss of fertile soil for the agricultural sector in many areas of the region.

All this would have serious socio-economic repercussions, considering that a large part of the region's economy is based on the agricultural sector, followed by serious environmental implications that would negatively affect the ecological sustainability of the region.

It is known that the effects of all those activities carried out on a global scale, aimed at reducing temperature values, will be visible in the long term; in the meantime, mitigation and adaptation actions must be directed towards the areas most exposed to the consequences of the climate variability present on the island. Future developments will be aimed at estimating the climatic variations expected for the next decades, as well as at adaptation and mitigation strategies of the areas most exposed to climate risks.

Information on the climate of the past, together with that deriving from the analysis of current trends, are and will continue to be of fundamental importance for developing future scenarios for the implementation of adaptation and protection plans for man and nature.

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