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Precipitation and Potential Evapotranspiration Temporal Variability and Their Relationship in Two Forest Ecosystems in Greece

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Abstract: The assessment of drought conditions is important in forestry because it affects forest growth and species diversity. In this study, temporal variability and trends of precipitation (P), potential evapotranspiration (PET), and their relationship (P/PET) were examined in two selected forest ecosystems that present different climatic conditions and vegetation types due to their location and hypsometric zone. The study area includes the forests of Pertouli and Taxiarchis, which are managed by the Aristotle University Forest Administration and Management Fund. The Pertouli is a coniferous forest in Central Greece with a maximum elevation of 2073 m a.s.l, and Taxiarchis is a broadleaved forest in Northern Greece with a maximum elevation of 1200 m a.s.l. To accomplish the goals of the current research, long–term (1974–2016) monthly precipitation and air temperature data from two mountainous meteorological were collected and processed. The PET was estimated using a parametric model based on simplified formulation of the Penman–Monteith equation rather than the commonly used Thornthwaite approach. Seasonal and annual precipitation, potential evapotranspiration (PET), and their ratio (P/PET) values were subjected to Mann–Kendall tests to assess the possible upward or downward trends, and Sen's slope method was used to estimate the trends magnitude. The results indicated that the examined climatic variables vary greatly between seasons. In general, negative trends were detected for the precipitation time series of Pertouli, whereas positive trends were found in Taxiarchis; both were statistically insignificant. In contrast, statistically significant positive trends were reported for PET in both forest ecosystems. These circumstances led to different drought conditions between the two forests due to the differences of their elevation. Regarding Pertouli, drought trend analysis indicated downward trends for annual, winter, spring, and summer values, whereas autumn showed a slight upward trend. In addition, the average magnitude trend per decade was approximately −2.5%, −3.5%, +4.8%, −0.8%, and +3.3% for annual, winter, autumn, spring, and summer seasons, respectively. On the contrary, the drought trend and the associated magnitude per decade for the Taxiarchis forest were found to be as follows: annual (+2.2%), winter (+6.2%), autumn (+9.2%), spring (+1.0%), and summer (−5.0%). The performed statistical test showed that the reported trend was statistically insignificant at a 5% significance level. These results may be a useful tool as a forest management practice and can enhance the adaptation and resilience of forest ecosystems to climate change.

Keywords: precipitation; evapotranspiration; drought; Mann–Kendall; trend analysis

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1. Introduction

Global warming has increasingly raised the concerns of both governments and the scientific community in recent decades. The Mediterranean basin has been identified as one of the most sensitive regions to climate change, with future warming potentially exceeding the global average [1,2]. According to the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report, the Mediterranean is facing the possibility of experiencing warmer and drier conditions in the near future [3]. Therefore, most countries in the southeastern Mediterranean region are likely to address water scarcity issues [4–6]. It is widely acknowledged that the ongoing changing patterns of precipitation and temperature have revealed an increased frequency of drought and the growing impact of aridity severity [7–9]. The aforementioned climatic conditions have profound effects on streamflow [10,11], lake levels [12], crop production [13], desertification [14], and forest growth [5,15,16].

There is a fundamental difference in terminology between aridity and drought, as noted by the World Meteorological Organization (WMO) [17]. Aridity is a long–term (climatic) phenomenon and concerns a period of at least 30 years. It is usually defined by low–average precipitation, available water, or humidity, and is a permanent climatic feature. Drought, by comparison, is a short–term (meteorological) phenomenon, which can vary from year to year. Assessing and monitoring the drought and aridity conditions prevailing in a certain area is a key element in climate research and provide important information for sustainable ecosystem management.

Numerous indices have been proposed to quantify the degree of dryness in a particular location [18,19]. The most common indicators are defined by the ratio of precipitation (P) to potential evapotranspiration (PET). Thereby, the indices express the water availability concept in a single number. The Thornthwaite method is the easiest way of calculating PET in data–scarce areas [20]. However, PET is preferably estimated, in terms of accuracy, using the Penman formula [21].

There has been a large amount of research on the trends and fluctuations of precipitation in Europe and the Mediterranean regions. Regarding annual precipitation in Europe, a positive trend in the north and a negative trend in the south have been noticed throughout the last century [22]. These findings revealed a remarkable negative tendency in eastern Mediterranean, whereas a positive trend was detected in central and northern Europe [23]. Similar results have been demonstrated for western Europe, indicating a downward trend in annual precipitation, prolongation of the dry period, and increase in the number of rainy days [24]. Moreover, the negative trend of annual precipitation was found to be statistically significant (95% confidence level) for the majority of Mediterranean regions, except north Africa, southern Italy, and western Iberian Peninsula, where a slight positive trend was recorded [25]. Concerning the Greek territory, a decrease in precipitation was recorded at the end of the 19th century, followed by a positive trend in the first three decades of the 20th century, then a smaller fluctuation, before returning to a decreasing trend [26–28]. In terms of PET tendency, fewer studies have been undertaken compared to those examining precipitation [29]. In Greece, trend analysis of weekly time series of PET shows an increasing trend in spring, and particularly in summer, no trend in winter (almost stable), and downward trends in winter; annual trends are also increasing [30]. Finally, in a survey conducted by Myronidis and Theophanous [31], the trend analysis of the P/PET ratio in the South Aegean shows insignificant negative trends, indicating that drought phenomena have slightly intensified [32].

Valuable Mediterranean–type ecosystems, which have remarkable forest species biodiversity, will be highly influenced by drought conditions. Moreover, the uneven precipitation and temperature distribution makes the assessment of climate tendency and variability a necessity for dealing with water scarcity problems. This is particularly important considering that dry conditions will continue to dominate and intensify in the forthcoming period [33,34]. Additionally, the spatial and temporal trends of precipitation and temperature conditions have been identified as the main factor affecting tree growth [16,35,36]. Thus, it is crucial to evaluate trends in the climatic variables in mountainous forested areas. Seasonal patterns can be identified and recorded to improve forest and water management. To the best of the author's knowledge, there are limited studies in Greece analyzing the seasonal trend of precipitation (P) and potential evapotranspiration (PET) based on long–term time series from mountainous meteorological stations [5,37,38]. In addition, these studies examine a short period of meteorological records. This is due to the difficulties of installation and maintenance of meteorological instruments, especially at the high elevations of the mountainous regions. In most cases, studies of the Greek territory take into account stations, including those in the network of The Hellenic National Meteorologic Service, which are usually installed at elevations less than 100 m a.s.l. Thus, the results cannot be exploited for high–elevation forestland and for areas with complex terrain.

The object of this study was to investigate temporal variability and detect trends in drought conditions in two different types of forest ecosystems using long–term time series meteorological data from mountainous meteorological stations. For this purpose, the P/PET ratio was used as a proxy indicator for the evaluation of drought conditions at different timescales (annual/seasonal). The Mann–Kendal and Sen's slope methods were applied in order to evaluate the significance and magnitude of the tendency, and to identify the time of abrupt changes.

2. Materials and Methods

2.1. Study Area

The study was conducted in two selected forest ecosystems in Greece with different forest types (broadleaved, coniferous) and climatic conditions (Figure 1). These are the university forests of Taxiarchis and Pertouli. The management rights of these two forests have been assigned to the Aristotle University of Thessaloniki since 1934 for research and educational purposes.

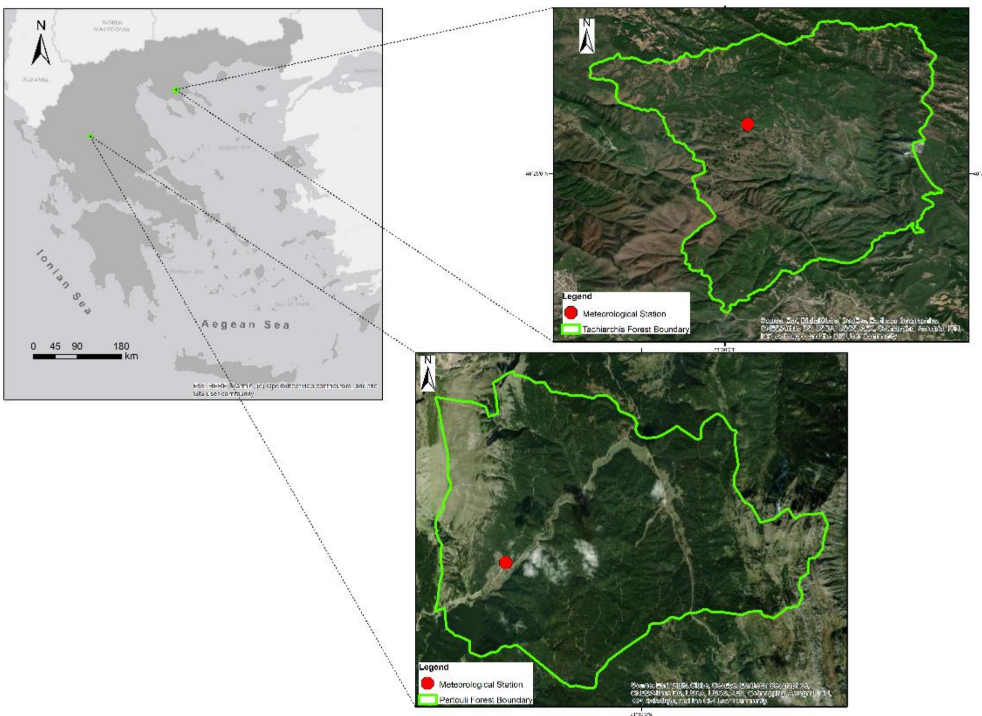

Figure 1. Location map of the selected forest ecosystems.

The Pertouli University Forest is located in the mountainous range of Pindus (Trikala Prefecture, Central Greece) and covers an area of 3290 ha. It consists mainly of pure fir stands (*Abies borisii regis*) and the elevation ranges between 1100 and 2073 m above sea level (a.s.l). The climate is transitional, Mediterranean–Mid–European, with cold, rainy winters and warm, dry summers. The average annual precipitation is 1542.2 mm and the average mean annual air temperature is 8.9 °C according to the existing meteorological station (1180 m a.s.l), which has operated since 1961 and is located at latitude 39°32′35.8″ and longitude 21°28′8.5″. Specifically, the total precipitation was found to be 525.7 mm in winter, 432.6 mm in autumn, 337.9 mm in spring, and 128.1 mm in summer. The average air temperature was found to be 0.8 °C in winter, 9.9 °C in autumn, 7.7 °C in spring, and

17.9 °C in summer. Furthermore, the region is a member of the European environmental protection network, Natura 2000, and is particularly designated as a Site of Community Importance (SCI) with the code GR1440002, namely: *"Kerketio Oros (Koziakas)"*.

The Taxiarchis University Forest is located in the mountainous range of Cholomontas (Chalkidiki Prefecture, Northern Greece) and covers an area of approximately 5800 ha. The area is a coppice oak forest (*Quercus frainetto Ten.*) and the elevation ranges from 320 to 1200 m a.s.l. The climate is characterized as sub–humid Mediterranean, expressed by short periods of drought, hot summers, and mild winters. A meteorological station (860 m a.s.l) has operated in the area since 1974, and is located at latitude 40°25′54.7″ and longitude 23°30′20.1″. According to the station long–term data the average annual precipitation is 808.3 mm and the average mean annual air temperature is 11.5 °C. Precipitation and temperature data show significant seasonal variations. Specifically, the total precipitation was found to be 242.9 mm in winter, 206.7 mm in autumn, 196.4 mm in spring, and 162.3 mm in summer. The average air temperature was found to be 2.7 °C in winter, 12.3 °C in autumn, 10.3 °C in spring, and 20.7 °C in summer. The area is also a part of the Natura 2000 network, including the SCI site with code GR1270001 known as *"Oros Cholomontas"*.

Monthly precipitation and temperature data, for the common operating period (1974–2016) of the two meteorological stations, were collected and processed. These stations are operated by the Aristotle University Forest Administration and Management Fund. The data series are complete without missing values. Moreover, the equipment and observation techniques were common and remained consistent throughout the examined period. The stations' data were checked for homogeneity on a monthly time step using the double mass method and two parametric statistical tests (Student's t–test and chi–squared test), as detailed by WMO [39]. The results verified that the data are homogeneous and can be further processed.

2.2. Potential Evapotranspiration (PET)

In the current approach, a parsimonious regional parametric evapotranspiration model (PET) based on a simplification of the Penman–Monteith formula [29,30] was applied, as proposed by Tegos et al. [40,41]:

$$PET = \frac{\alpha R_a + b}{1 - cT} \tag{1}$$

where R_a (kJ m^{-2}) is the extraterrestrial shortwave radiation calculated without measurements and T (°C) is the air temperature. The model has three additional parameters a (kg kJ^{-1}), b (kg m^{-2}), and c (°C) that should be inferred from either measurement or modeled calibration. The a, b, and c factors were set equal to 0.0000976, 0.83, and 0.02, respectively, in the case of the Pertouli area. Respectively, in the case of Taxiarchis, the values of 0.0000485, −0.19, and 0.03 was given for the parameters a, b, and c.

It should be noted that the aforementioned parameterizations have some physical similarities with the original Penman–Monteith approach. This is because the overall energy term (incoming minus outgoing solar radiation) is represented by αR_a, the missing aerodynamic term is represented by b, and $(1–cT)$ is a rough approximation of the formula's denominator term. This approach is characterized as a radiation–based method because it uses two explanatory variables: extraterrestrial radiation, R_a; and temperature, T. The model variables are highly connected with location characteristics and can be predicted from global spatial interpolation maps [42].

2.3. Trend Analysis

The non–parametric Mann–Kendall (M–K) test was applied in order to analyze the aridity tendency in the study areas and investigate the statistical significance of the tracked trends at the 95% confidence level. This is the most commonly used trend analysis test in climatological time series, and better fits non–normally distributed data with extreme and missing values, which are frequently encountered in environmental time series [43]. The M–K test was conducted as proposed by Sneyers [44] in order to investigate both annual and seasonal trends, and to detect the turning point using the data series at different timescales. Therefore, for each x_i (i = 1 . . . , n) of the time series, the number n_i of lower elements x_j ($x_j < x_i$) preceding it ($j < i$) was calculated, and the test statistic t was given by:

$$t = \sum_i n_i \tag{2}$$

In the absence of any trend (null hypothesis), t is asymptotically normal and independent from the distribution function of the data:

$$u(t) = \frac{(t - \overline{t})}{\sqrt{\mathrm{var}(t)}} \tag{3}$$

and has a standard normal distribution, with t and var(t) given by:

$$t = \frac{n(n-1)}{4} \tag{4}$$

$$\mathrm{var}(t) = \frac{n(n-1)(2n+5)}{72} \tag{5}$$

Therefore, the null hypothesis can be rejected for high values of $|u(t)|$, with the probability α_1 of rejecting the null hypothesis when it is derived by a standard normal distribution table:

$$\alpha_1 = P(|u| > |u(t)|) \tag{6}$$

The Mann–Kendall test in its sequential form was also utilized for a progressive study of the series. This consists of applying the test to all of the series, beginning with the first term and concluding with the ith term (and the reverse).

In the absence of a trend, the graphical depiction of the direct (u_t) and backward ($u_{t'}$) series created curves that overlapped multiple times. Nevertheless, in the case of a significant trend (5% level $|u_t| > 1.96$), the intersection of the curves made it possible to approximately detect the time of occurrence [44].

Although the M–K test is a useful nonparametric test for temporal trend, it is premised on the assumption that observations are independent. This is due to the fact that a positive or negative autocorrelation may led to overestimation or underestimation of the trend's significance. Thus, before applying the M–K test, all datasets have to be checked for the presence of autocorrelation. Herein, the lag–1 autocorrelation coefficient (r_1) at a 5% significance level was calculated.

Additionally, trend magnitudes were calculated using the Theil–Sen technique (TSA) [45,46]. This method is based on slope and is often referred to as Sen's slope. It is preferred to linear regression because it minimizes the influence of outliers on the slope [47].

3. Results

The precipitation and potential evapotranspiration present great inter–annual and intra–annual variability in the selected forest ecosystems of the study areas. The lag–1 autocorrelation coefficient was computed for the examined variables and it was found that the r_1 value does not exceed the confidence interval bounds. Thus, the latter variables are considered to be serially independent and therefore the M–K test can be applied.

Trend analysis of the annual and seasonal precipitations indicated negative trends in Pertouli, except during autumn, whereas positive trends were identified in Taxiarchis in each examined period. However, these trends were found to be statistically insignificant (at the 0.05 significance level). The trend magnitudes were −12.7, −15.8, +11.6, −3.6, and −2.9 mm per decade for annual, winter, autumn, spring, and summer precipitation, respectively, of the Pertouli station. In contrast, the positive trends in Taxiarchis were found to be 45.9, 16.8, 27.2, 1.4, and 0.9 mm for annual, winter, autumn, spring, and summer precipitations, respectively. The graphical representations of the M–K test for the precipitation time series of the Pertouli and Taxiarchis forests are shown in Figures 2 and 3, respectively.

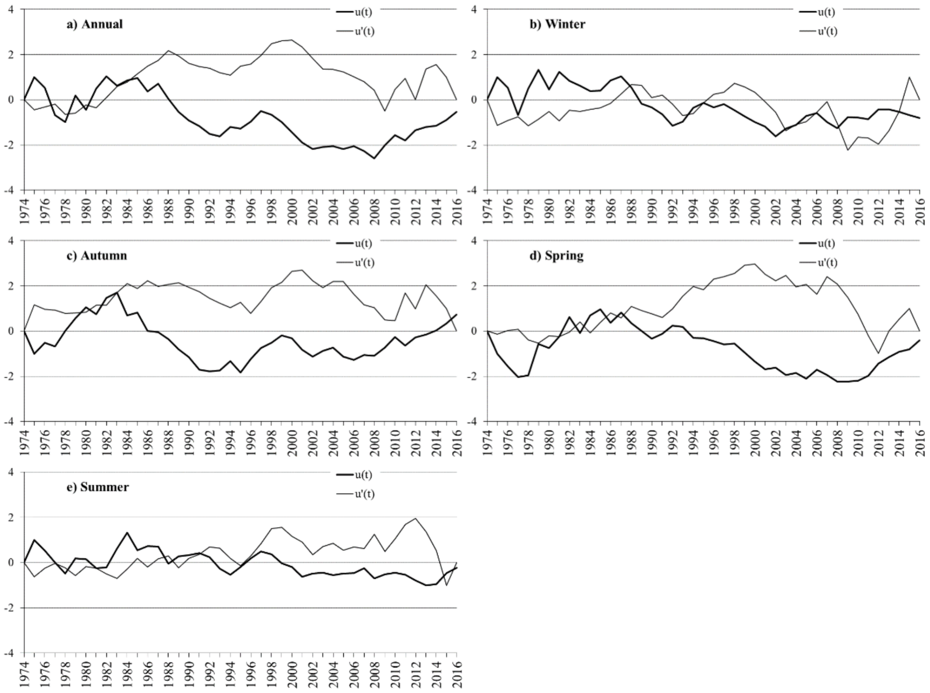

Figure 2. Graphical representation of the series $u_{(t)}$ and the retrograde series $u'_{(t)}$ of the sequential version of the Mann–Kendall test for (**a**) annual, (**b**) winter, (**c**) autumn, (**d**) spring, and (**e**) summer precipitations in the University Forest of Pertouli.

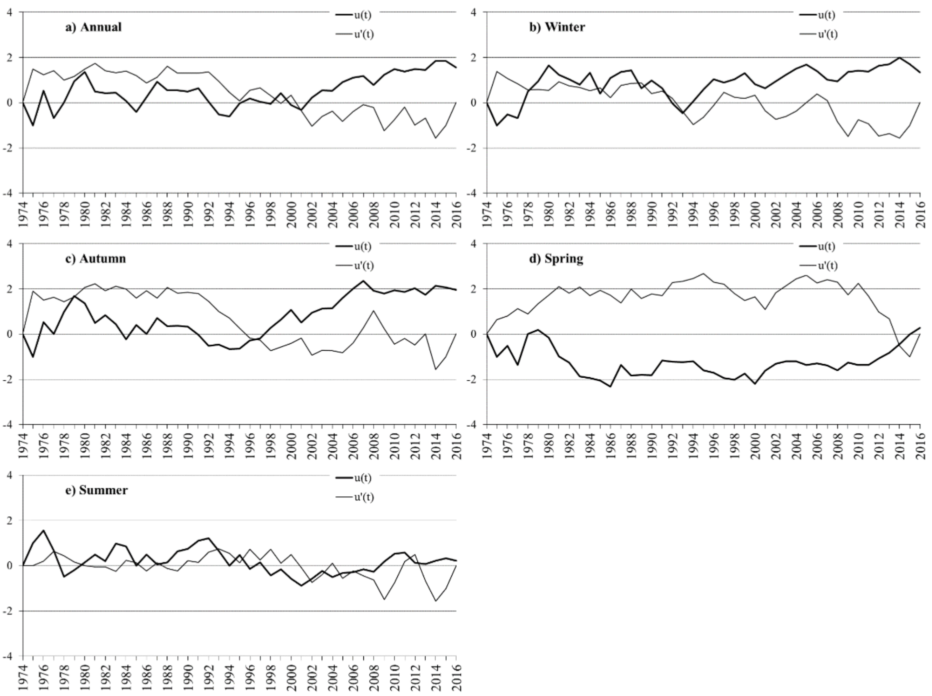

Figure 3. Graphical representation of the series $u_{(t)}$ and the retrograde series $u'_{(t)}$ of the sequential version of the Mann–Kendall test for (**a**) annual, (**b**) winter, (**c**) autumn, (**d**) spring, and (**e**) summer precipitations in the University Forest of Taxiarchis.

Regarding the potential evapotranspiration (PET), upward trends were detected in Pertouli. These trends were found to be statistically significant (at the 0.05 significance level), except in winter and autumn. The timing of this abrupt change was identified as 1992 for the annual and summer time series, and 1997 for summer. Moreover, the increase per decade was 6.8 mm (annual), 0.3 mm (winter), 0.8 mm (autumn), 1.7 mm (spring), and 3.9 mm (summer). The same pattern was also found in Taxiarchis. The trend analysis shows statistically significant trends (at the 0.05 significance level) in all seasons. The abrupt change was identified in 1997 for the annual and summer precipitation, 1996 for winter, 2005 for autumn, and 1999 for spring. The graphs representing the results of the M–K test for the potential evapotranspiration (PET) in the study areas are shown in Figures 4 and 5. Furthermore, the magnitude of the increase in PET in Taxiarchis was higher than that in Pertouli; specifically, it was estimated to be 24.2, 1.3, 2.4, 2.5, and 17.8 mm per decade for annual, winter, autumn, spring, and summer precipitations, respectively. Subsequently, in order to track the effect of precipitation (P) and potential evapotranspiration (PET) on drought conditions, the same analysis was performed for the P/PET ratio.

The results of annual and seasonal ratio P/PET estimation indicate that excess water is available (P > PET) in most cases, with the exception of summer and the annual values in the Taxiarchis forest. This is typical for mountainous areas with complex topography, and uneven precipitation and temperature regime [5,36]. The analytical results of the average P/PET values for the reference period (1974–2016) are presented in Table 1.

Table 1. Analysis of the P/PET ratio for the selected forest ecosystems.

Study Area	Annual	Winter	Autumn	Spring	Summer
Pertouli	1.6	7.5	2.7	1.3	0.3
Taxiarchis	0.9	2.6	1.2	1.0	0.4

Seasonal variability shows winter as the most humid season in the two forest ecosystems, followed by autumn and spring. The variation in P/PET values in the two forests ecosystems can be justified by the difference in their elevation.

Results of the graphical representation of the M–K test for the Pertouli forest are illustrated in Figure 6. It is shown that an insignificant downward trend was exhibited for annual, winter, spring, and summer drought conditions, whereas autumn showed a slight upward trend.

The results from the application of the M–K test based on the data of Taxiarchis forest are presented in Figure 7. In contrast to the Pertouli forest, insignificant positive trends were noted in all seasons, except summer, where a slight downward trend was found. The timing of the abrupt change related to drought was not a consideration for either forest, because the upward and downward trends were not found to be statistically significant [32].

Additionally, concerning the output of the Sen's slope estimation, the magnitude of the trends was determined. In Pertouli, the magnitudes of the P/PET values were equal to -0.04, -0.236, +0.13, -0.013, and -0.01 per decade for annual, winter, autumn, spring, and summer, respectively. On the contrary, the magnitudes of the P/PET values per decade were +0.02 for annual, +0.15 in winter, +0.11 in autumn, +0.01 in spring, and +0.02 in summer for the Taxiarchis forest. These trends are considered negligible, because the increase was found to be greater than 5% per decade compared to the corresponding average AI value for winter and autumn. Moreover, a shift in the climate zone classification did not occur in any of the seasons. The detailed results from the implemented method, showing the percentage of influence on the average annual and seasonal AI, are presented in Table 2.

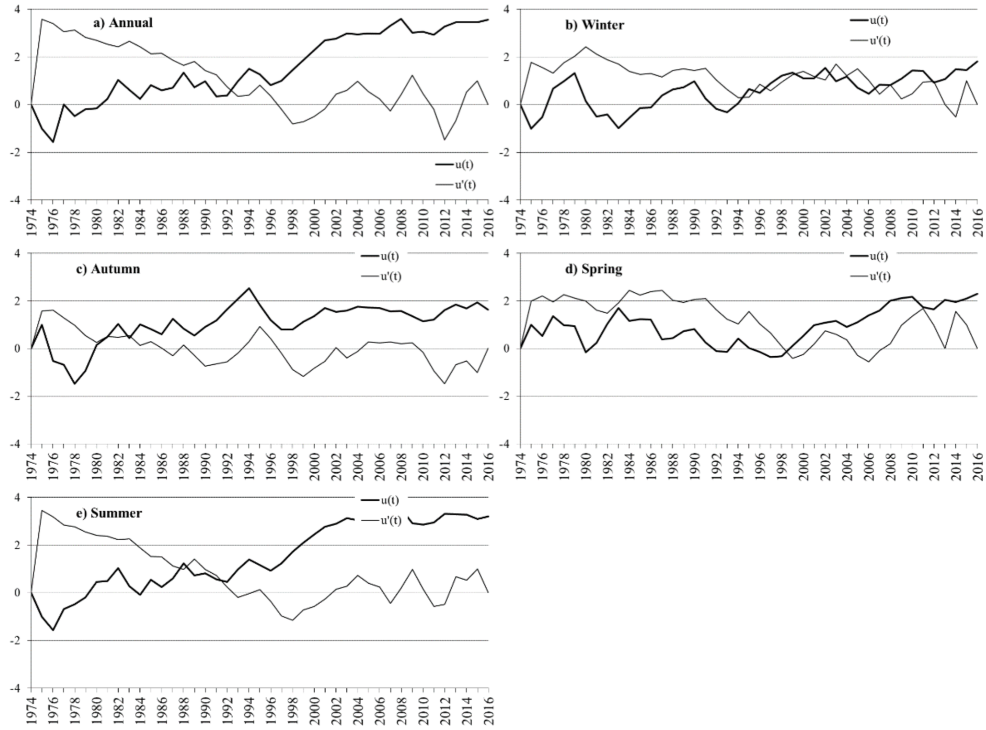

Figure 4. Graphical representation of the series $u_{(t)}$ and the retrograde series $u_{'(t)}$ of the sequential version of the Mann–Kendall test for (**a**) annual, (**b**) winter, (**c**) autumn, (**d**) spring, and (**e**) summer PET in the University Forest of Pertouli.

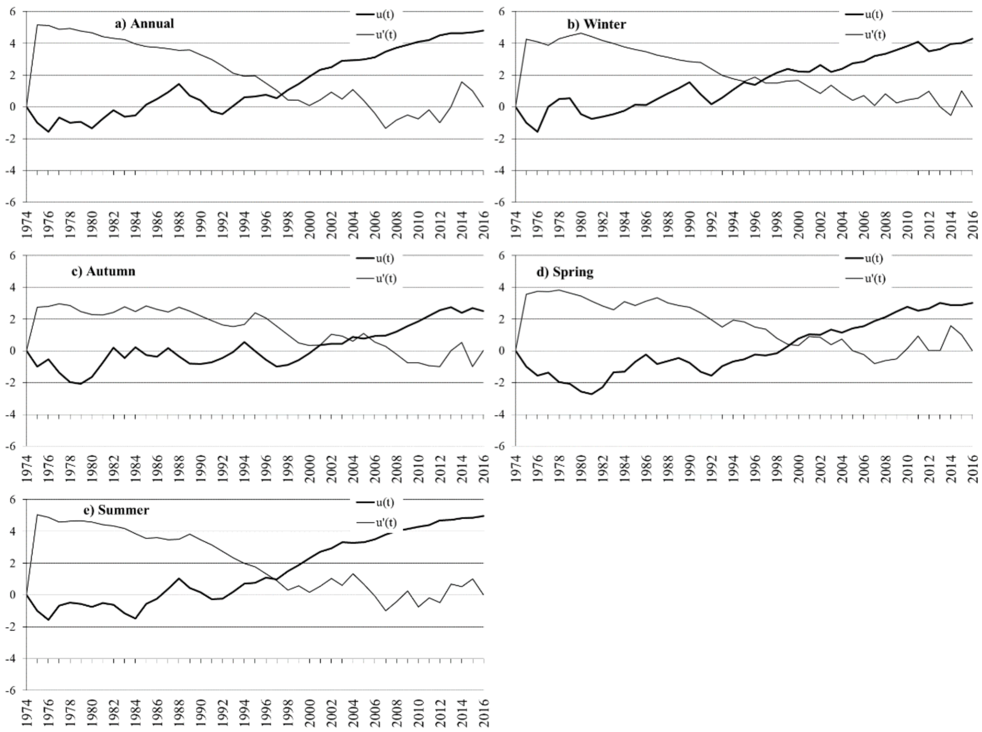

Figure 5. Graphical representation of the series $u_{(t)}$ and the retrograde series $u_{'(t)}$ of the sequential version of the Mann–Kendall test for (**a**) annual, (**b**) winter, (**c**) autumn, (**d**) spring, and (**e**) summer PET in the University Forest of Taxiarchis.

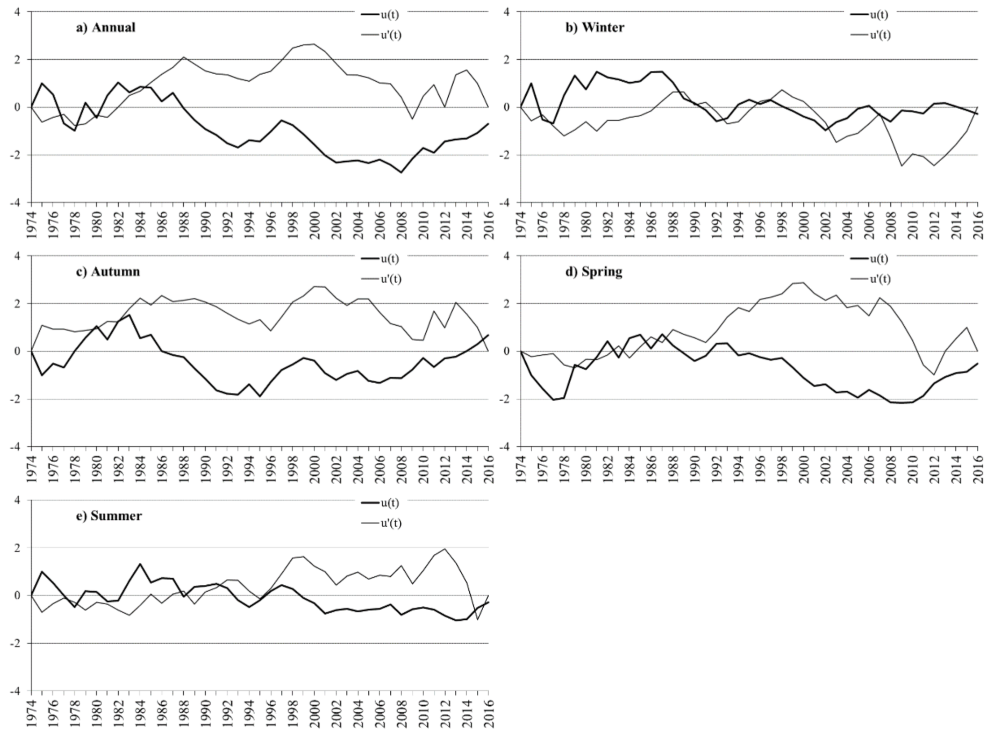

Figure 6. Graphical representation of the series $u_{(t)}$ and the retrograde series $u_{'(t)}$ of the sequential version of the Mann–Kendall test for (**a**) annual, (**b**) winter, (**c**) autumn, (**d**) spring, and (**e**) summer P/PET in the University Forest of Pertouli.

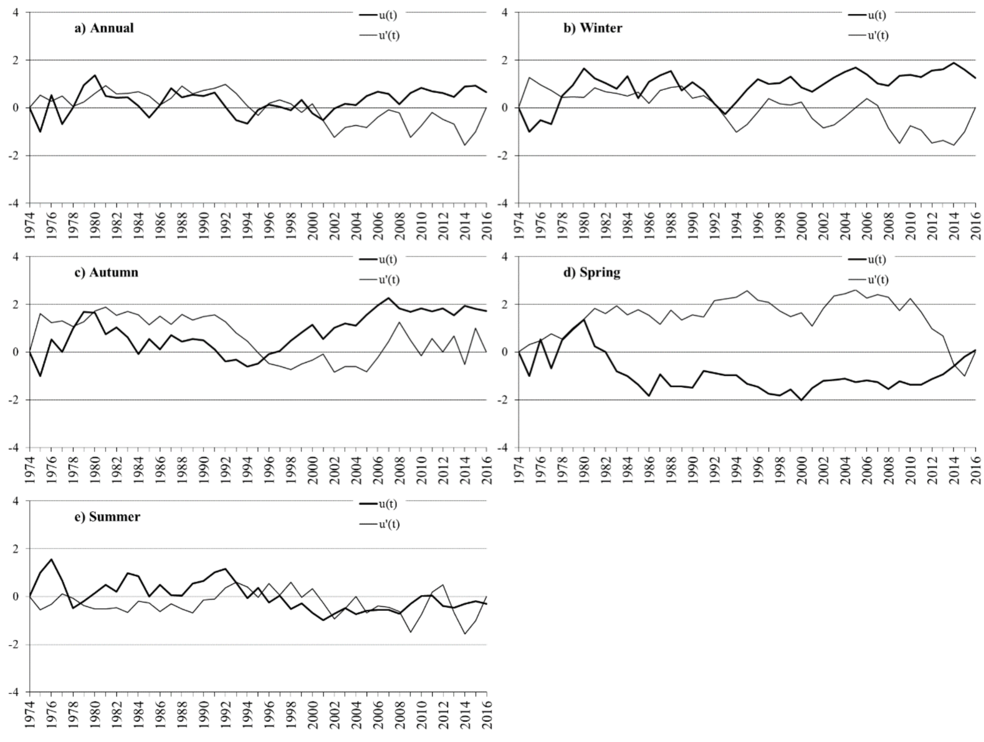

Figure 7. Graphical representation of the series $u_{(t)}$ and the retrograde series $u_{'(t)}$ of the sequential version of the Mann–Kendall test for (**a**) annual, (**b**) winter, (**c**) autumn, (**d**) spring, and (**e**) summer P/PET in the University Forest of Taxiarchis.

Table 2. Sen slope β values and trend magnitude (%) per decade for the P/PET ratio.

	Pertouli		Taxiarchis	
Temporal Coverage	**Slope β**	**% Magnitude per Decade**	**Slope β**	**% Magnitude per Decade**
Annual	−0.004	−2.5	0.002	+2.2
Winter	−0.026	−3.5	0.016	+6.2
Autumn	0.013	+4.8	0.011	+9.2
Spring	−0.001	−0.8	0.001	+1.0
Summer	−0.001	+3.3	−0.002	−5.0

4. Discussion

In recent decades, concerns have increased about climate variability and changes. Therefore, in the context of climate crisis, the tendency in climatic variables has been examined in many studies. However, in the majority of these cases, data from lowland meteorological stations have been analyzed. In forest research, the usage of these meteorological data does not fulfill the conditions for studying the weather and climate conditions in mountainous areas of forest growth.

Reviewing the results of related studies in Europe and Greece revealed both similarities and differences. Caloiero et al. [23] evaluated the tendency of precipitation in continental Europe and the Mediterranean basin for the period 1901–2009 using gridded reanalysis data. The results for annual precipitation demonstrated a negative trend of about −20 mm per decade in eastern Mediterranean (including Greece), −16 mm per decade in North Africa, and a positive trend (+20 mm per decade) in central and north Europe. Moreover, focusing on the results of the aforementioned study [23] for the seasonal precipitation in the Mediterranean, the magnitudes of the negative trends were approximately −10, −6, −4, and −2 mm per decade for winter, autumn, spring, and summer, respectively. Additionally, Philandras et al. [25] highlighted statistically significant negative trends in the Mediterranean region concerning annual precipitation data from stations for the period 1951–2010. Specifically, the magnitude of the trend was found to be 36.1 mm per decade for West Mediterranean, 30.1 mm per decade for central Mediterranean, and 15 mm per decade in east Mediterranean. The results of these two studies [23,25] showed a relative convergence. Several authors mentioned that the reported trends are related to the teleconnection pattern, which has been extensively described in the literature [47,48]. In comparison with our results, it seems that Pertouli station followed the general negative trend in the Mediterranean region, except during winter, whereas Taxiarchis showed an increase in all seasons. Nevertheless, the percentage decrease in precipitation is negligible because the study area is considered one of the rainiest regions in Greece.

Precipitation in Greece has undergone significant changes over the last century, as represented in a national study taking into account stations with different conditions [5]. An average increase of about 4% was reported by comparing the periods 1900–1929 and 1930–1960. On the contrary, a considerable decrease (−15%) was found between the periods 1961–1997 and 1900–1929 [5]. Moreover, in the previous referenced work [5], the findings indicated that the respective average changes in PET were negligible. Furthermore, another study [49] showed a decreasing trend in PET in annual and warm periods (1979–1999) based on data from low–elevation stations. However, in the present study, the trends in PET were found to be statistically significant (95% confidence level). Despite the differences in PET among the examined forest ecosystems, the variability and fluctuation of drought are considered to be almost stable at different timescales. A more recent study [30] analyzed meteorological and hydrological variables from 17 stations located across Greece during 1961–2006. The results generally indicated statistically significant downward trends for seasonal and hydrological year precipitation. Regarding PET, negative trends were found only in winter.

The assessment of aridity and drought is challenging and may have a profound effect in forest ecosystems. A large–scale survey conducted for the entire Greek territory mentioned a progressive shift from the humid aridity class, which previously characterized the wider area of Greece, towards the sub–humid and semi–arid class, especially in southeastern Greece [50]. It should be noted, however, that for a number of areas, mostly located in the western coastal region, the AI class (humid) remains unchanged [5]. In addition, the drought conditions were evaluated and a tool was presented for water resource management [36] and recently linked to drinking water availability [32].

Although aridity is important in forests, custom modification of the basic indices has been undertaken [51,52]. It has also been stated that the climate variability affects forest growth, species adjustability [16], and shifts in the tree line [53]. Nevertheless, trends in AI values and drought in mountainous ecosystems have not been extensively examined.

5. Conclusions

In the present study, the precipitation and potential evapotranspiration, and their relationship, were analyzed in two forest ecosystems with different climate conditions and forest types. Variability and trend analysis of these parameters was performed at seasonal and annual timescales using the M–K and Sen's slope statistical tests. Potential evapotranspiration (PET) is a key parameter in the hydrological cycle and, related to precipitation, has been used as a proxy indicator of drought. In contrast to several studies that commonly used Thornthwaite's PET method, a parametric model for PET based on a simplified formulation of the Penman–Monteith equation was applied in the proposed approach.

The results indicated that humid conditions prevail in both forest areas and that dry conditions occur in summer. The examined parameters present significant variability between seasons, following the Mediterranean climate pattern. The trend analysis showed that the reported upward and downward trends in AI are, in general, statistically insignificant, and the magnitude of the trend is considered negligible.

Southern Europe will be significantly affected by climate changes due to an increase in temperature, a decrease in precipitation, and more frequent extreme weather events. These changes will have an impact on vegetation phenology and the flowering season, in addition to the growth rate and productivity of forest ecosystems. Forest species will face increased competition, whereas those species more resistant to dry–thermal conditions will survive. These conditions are expected to impact the regeneration potential and diversity of forests. The monitoring of precipitation and potential evapotranspiration is recommended for forest ecosystems to contribute to adaptive and resilient forest management in the context of climate change.

A target of future research can be the evaluation of different evapotranspiration methods in forest environments, because PET is considered the most important component of the hydrologic cycle. Moreover, the drought conditions under future climate conditions and different emission scenarios can be evaluated with the use of high–resolution regional climate models (RCMs). The evaluation of the aridity index (AI) and investigating variability by dividing the time series into two climatic periods in the two forests is a particularly interesting subject of study.

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