Altitude and Canopy Cover Effects on Air Temperature in a Mountainous Region of Ionian Islands, Greece

ATHANASIOS KAMOUTSIS¹, KOSTAS CHRONOPOULOS²* and ARISTIDIS MATSOUKIS¹

¹Department of Crop Science, School of Agricultural Production, Infrastructure and Environment, Iera Odos 75, Agricultural University of Athens, Athens, 11855 Greece.
²Department of Biotechnology, School of Food, Biotechnology and Development, Iera Odos 75, Agricultural University of Athens, Athens, 11855 Greece.

Abstract
Topography and canopy play a decisive role on air temperature (T) conditions in forested areas. Air temperature is a crucial factor in decision making process for the development of these areas. To our knowledge, there is no information regarding the effect of topography along with fractional canopy cover (Pc) on thermal conditions of a vulnerable mountainous forested region of Greece, Mount (Mt) Aenos on the island of Cephalonia, Ionian Islands, Greece. Therefore, the purpose of our work is the investigation of the aforementioned parameters, especially the effect of altitude (alt) and Pc on T of Mt Aenos. Mean values for maximum air temperature (Tx) and Pc were estimated for twelve sites at various alts in Mt Aenos during the period May-October of three consecutive years (2011-2013). The analysis of the results showed that Tx was related to alt and Pc. Altitude has a greater effect on T in relation to Pc. When examining the same or similar alts, an increase of Pc up to 51% resulted in a significant decrease of Tx (p<0.05) up to 3.6°C. Our findings could be taken into account in planning the construction of hiking trails for recreational activities in Mt Aenos, and, in general, in mountainous forest areas of special importance.
Introduction

Air temperature (T), one of the most important climatic parameters of mountain terrain in tourism industry, is considered as a key driver for many physical processes that influence the distribution of vegetation. Topography contributes greatly to the prevailing T conditions. Altitude (alt), in particular, seems to have a more distinguished influence on thermal environment in relation to other parameters, such as slope and aspect. In general, it is known that an increase of alt causes a decrease of T and this change is considered as a basis for the understanding of the distribution of forests over the mountainous terrain.

Canopy cover (Pc), a key for the determination of vegetation structure, strongly influences the thermal environment. Specifically, higher T values were confirmed in more open canopies and by extension in forest clearings than in less open canopy locations. This can explain to a great extent the positive influence of forest cover on microclimatic conditions, since many forest areas are considered as attractive destinations for recreational and walking activities.

The recreational behavior of people is influenced by weather factors. Favorable thermal conditions that prevail in mountains are considered as a fundamental factor in decision-making related to various recreational activities of visitors, for example, hiking, walking and camping, during their vacation. However, is not always possible to determine the weather conditions, due to difficulties of installation and maintenance of meteorological instruments, especially at the high alts of the mountainous regions. Therefore, it is necessary to estimate the meteorological parameters, in particular T, by using appropriate models which include input variables related to local topography and vegetation.

There has been no information, to our knowledge, on how topography in combination with canopy cover affect the T conditions of high alt forested areas of southeastern Europe, Greece in particular. This study aims to investigate the role of alt and Pc on T conditions in an area of great ecological importance, Mount (Mt) Aenos in Cephalonia, Ionian Islands, Greece.

Materials and Methods

Study region and measurement sites

The research was carried out in Mt Aenos (including both the National Park and its greater area) on the island of Cephalonia (Municipality of Cephalonia, Regional unit of Cephalonia, Periphery of Ionian islands) in Greece, during three successive years (2011-2013), from May to October, which is the high tourist season. Mount Aenos (northwestern-southeastern orientation), the tallest mountain in the Ionian Islands group, is located on the southeastern part of Cephalonia island, forming an elongated mountain range with many peaks at alts above

<table>
<thead>
<tr>
<th>Site</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Altitude (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>38° 07’ 38.3” N</td>
<td>020° 37’ 26.0” E</td>
<td>250</td>
</tr>
<tr>
<td>C2</td>
<td>38° 09’ 26.7” N</td>
<td>020° 40’ 06.3” E</td>
<td>758</td>
</tr>
<tr>
<td>C3</td>
<td>38° 11’ 28.5” N</td>
<td>020° 35’ 50.5” E</td>
<td>775</td>
</tr>
<tr>
<td>C4</td>
<td>38° 11’ 38.9” N</td>
<td>020° 36’ 55.0” E</td>
<td>816</td>
</tr>
<tr>
<td>C5</td>
<td>38° 08’ 22.8” N</td>
<td>020° 41’ 52.4” E</td>
<td>827</td>
</tr>
<tr>
<td>C6</td>
<td>38° 08’ 12.3” N</td>
<td>020° 41’ 56.9” E</td>
<td>1037</td>
</tr>
<tr>
<td>C7</td>
<td>38° 09’ 38.3” N</td>
<td>020° 37’ 25.0” E</td>
<td>1100</td>
</tr>
<tr>
<td>C8</td>
<td>38° 07’ 30.3” N</td>
<td>020° 42’ 14.6” E</td>
<td>1100</td>
</tr>
<tr>
<td>C9</td>
<td>38° 11’ 13.4” N</td>
<td>020° 36’ 56.0” E</td>
<td>1107</td>
</tr>
<tr>
<td>C10</td>
<td>38° 09’ 14.9” N</td>
<td>020° 38’ 30.0” E</td>
<td>1300</td>
</tr>
<tr>
<td>C11</td>
<td>38° 07’ 37.3” N</td>
<td>020° 41’ 50.1” E</td>
<td>1300</td>
</tr>
<tr>
<td>C12</td>
<td>38° 07’ 49.6” N</td>
<td>020° 41’ 11.8” E</td>
<td>1400</td>
</tr>
</tbody>
</table>
The National Park of Mt Aenos covers an area of 28,620 km$^2$ and includes two main regions around the summits of Megas Soros and Roudi at alts of 1,627 m and 1,125 m, respectively. The areas of the aforementioned National Park are covered mainly by forests of Abies cephalonica Loudon (Cephalonian fir). There is a rich flora of endemic plant species, many of which are characterized as rare and endangered. It is important to note that the National Park of Mt Aenos is considered as an attractive destination for tourists from all over the world, especially during the hot season.

Twelve sites were selected in the greater area of the National Park of Mt Aenos (Table 1) based mainly on the differences in alt and canopy cover. All sites with alt above 750 m are located within the vegetation zone of Cephalonian fir, while the C1 site at the altitude is covered mainly by sparse and low individuals of Quercus sp. The latitude, longitude and alt of each site were evaluated using a mobile Global Positioning System (Garmin eTrex Vista) and cross-checked against 1:65,000 topographic maps while the aspect was based on the estimation of azimuth.

Instrumentation, Data Collection and Processing

Air temperature data were recorded continually every 10 minutes by sensors with data loggers (Hobo Pro v2 U23-001, Onset Computer Corporation, USA, accuracy ± 0.2 °C over 0 °C to 50 °C). Each sensor was located in each measurement site, during May-October of 2011-2013, in order to evaluate the prevailing thermal conditions in the study region. In order to assure the reliable operation of the instruments both appropriate checks in the laboratory and in situ tests were carried out in agreement with the methods of other studies.

It is pointed out that in the warm Mediterranean environments, visitors are looking for locations with cool thermal conditions during the summer, from 11:00 to 17:00 h, during which the daily maximum air temperature ($T_x$) is reached. Also, the investigation of parameters that improve the thermal conditions is a basic prerequisite for increasing the number of visitors to a National Park and in particular to Mt. Aenos. Thus, in our research, from the initial $T$ data, daily $T_x$ was taken into account for the calculation of mean $T_x$ values for each site for the whole period examined.
For the estimation of \( P_c \) as an indicator of horizon limitation (%) in the fisheye view of the canopy, images were collected using a CoolPix 4500 Nikon digital camera (maximum resolution 4.0 megapixel, 4x zoom, Nikon Corporation, Japan) with Nikon FC-E8 lens (0.21x zoom). This camera was placed directly upwards and aligned on a tripod at the level where each sensor with data logger was installed. In total, nine sampling images were taken at each measuring point, the first one right at each measurement site and the rest eight images around it, in a radius of 50 m and at equal distances between successive images (Fig. 1a). For the estimation of the horizon limitation the images (Fig. 1b) were analyzed using the Rayman software. This software detected the amount of the visible sky indicating thus the shading levels of various vegetated areas.\(^{27}\) The \( P_c \) value for each site was calculated as an average value of the nine images.

**Statistical Analysis**

As a first step, for the detection of possible relationships between \( T_x \), \( \text{alt} \), \( P_c \) and aspect, a linear correlation (Pearson’s) analysis\(^{28}\) was applied including all the sites examined during the study period. From this analysis, significant correlations were confirmed between \( \text{alt} \) and \( T_x \) as well as between \( P_c \) and \( T_x \) (\( p<0.05 \)) with no significance (\( p>0.05 \)) in the rest of the cases.

Thus, this first statistical approach led to the conduction of a multiple linear regression analysis,\(^{29}\) with \( T_x \) as the dependent variable and \( \text{alt} \) and \( P_c \) as the independent variables.

In addition, the two-sample t test for correlated data\(^{29,30}\) was used for the detection of possible differences of \( T_x \) of the whole examined period between sites with same or similar \( \text{alt} \) and different \( P_c \). Statistics were applied using IBM SPSS Statistics 23 and MS Excel 2010 with results to be considered significant at \( p \leq 0.05 \).

**Results and Discussion**

The results of the application of the multiple regression analysis (Table 2) revealed a negative significant relationship between \( T_x \) and each of the examined independent variables (\( \text{alt} \), \( P_c \)).

The higher absolute value of the regression coefficient \( b_1 \) compared with \( b_2 \) indicates, in general, a greater effect of \( \text{alt} \) on the prevailing \( T_x \) conditions than \( P_c \). The negative effect of \( \text{alt} \) on \( T \) has been meticulously confirmed in previous studies carried out in mountainous terrain.\(^{1,4,6,31}\)

Regarding the cases of different \( P_c \) between two sites of similar or same \( \text{alt} \), it seems that \( P_c \) plays a decisive negative role on their thermal conditions. Indicatively, at the sites C4 and C5 which were located at similar \( \text{alts} \) (816 m and 827 m, respectively, Table 1), \( T_x \) values of 22.2 \(^\circ\)C and 25.8 \(^\circ\)C were recorded, respectively. These values, with their difference (-3.6 \(^\circ\)C) being significant (\( p<0.05 \)), could be attributed mainly to the respective values of \( P_c \) which were 90% and 39% (Fig. 2). When examining higher \( \text{alts} \), a similar pattern was noticed. Specifically, at C7 and C9 sites (1100 m and 1107m, respectively) \( T_x \) values of 20.9 \(^\circ\)C (89% \( P_c \)) and 23.6 \(^\circ\)C (40% \( P_c \)) were recorded, respectively. In other words, an increase of \( P_c \) by 49.0% resulted in a respective significant decrease (\( p<0.05 \)) of \( T_x \) by 2.7 \(^\circ\)C (Fig. 2). As for the \( \text{alt} \) of 1300 m (C10 and C11 sites), an increase of \( P_c \) by 11.0% led to a respective significant decrease (\( p<0.05 \)) of \( T_x \) by 1.0 \(^\circ\)C (Fig. 2).

| Table 2. Multiple linear correlation parameters for the mean maximum temperature (\( T_x \)) in relation to the altitude (\( \text{alt} \)) and canopy cover (\( P_c \)) in the study region of Mount Aenos, Cephalonia, Greece during the period 2011-2013 \[ T_x = b_1 \cdot \text{alt} + b_2 \cdot P_c \] |
| --- | --- | --- | --- | --- |
| \( b_1 \) | SE(\( b_1 \)) | \( b_2 \) | SE(\( b_2 \)) | \( R^2 \) |
| -0.74 \( *** \) | 0.01 | -0.42 \( *** \) | 0.01 | 0.96 |

\( b_1 \), \( b_2 \): regression coefficients, SE(\( b_1 \)) and SE(\( b_2 \)): standard errors of \( b_1 \) and \( b_2 \), respectively.  
\( *** \): significance at \( p \leq 0.001 \), \( R^2 \): coefficient of determination.
Therefore, for same or similar als (alt difference up to 11 m), it was demonstrated that a P_c increase ranging from 11% to 51% resulted in distinctly more favorable thermal conditions.

The positive role of forest vegetation on T conditions, especially during the period of April to October, has been reported in the study of Renaud and Rebetez. According to the results of this research, the T_x values were lower below the canopy of deciduous, conifer and mixed forests in comparison with those of open fields. In general, the forest cover effects on T have been examined in many cases of mountain terrain.

In green spaces such as in National Parks, a visitor can enjoy locations with different microclimatic conditions. Sunny open-field and shaded closed-canopy sites are used by the visitors for their recreation and walking activities. However, at the aforementioned shaded sites, lower T values prevailed than in more open sites, which is why shaded sites are preferred by visitors during the summer period.

At the lowest alt site (C1), T_x showed its highest value (28.8 °C) during the examined period. This could be attributed to the combined effect of alt and vegetation composition. It is noted that C1, located outside the Cephalonian fir tree zone, is covered by low and sparse shrubs of Quercus sp. The above site is characterized as the most open and sunny site owing to the lowest canopy cover (33%), leading to the warmest conditions and therefore to the most unfavorable thermal environment.

Regardless of alt, the assessment of high P_c locations can become the basis for the design of recreational sites, especially in the protected forested areas. In the same way, the P_c of the adjacent locations should be taken into account for the construction of hiking trails. The open locations with low values of P_c could be improved by adding plants of the same endemic plant species, thus leading to the shading of the hiking trails. Therefore, favorable thermal conditions can be created during

Fig. 2: Mean maximum temperature (T_x) from May to October and canopy cover (P_c) at the sites (C1-C12) of Mount Aenos in Cephalonia, Greece, during the period 2011-2013.
the summer, particularly during the hot hours of the day.

Conclusions

The analysis of the results of the present study revealed negatively significant relationships of air temperature with altitude and canopy cover during the May-October period. Furthermore, altitude showed a greater effect on the prevailing air temperature conditions rather than canopy cover. However, in cases of sites with same or similar altitude, the canopy cover determined the prevailing temperature conditions to a high degree.

In our study, an increase of canopy cover up to 51\% resulted in a significant decrease of air temperature up to 3.6 °C in locations with the same or similar altitude. Thus, at more closed canopy locations, more favorable conditions are created in comparison with less closed canopy locations. This information can be crucial in planning the construction of hiking trails in mountainous forest areas of special importance, such as the National Park of Mount Aenos in Cephalonia Island, Greece.

References

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34. Ferrez J., Davison A.C., Rebetez M. Extreme temperature analysis under forest cover compared to an open field. Agric For Meteorol. 2011; 151(7): 992-1001.