Role of Relief and Land Use on Air Temperature Modification in Attica, Greece

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Abstract. The diversity of the terrain, the land uses and the human interventions in the environment cause local differentiation of the air temperature. The change of land uses during the last decades in Attica have created intense thermal pollution, among other environmental problems. In Attica there is a strong spatial air temperature differentiation. The air temperature conditions that are formed spatially in Attica because of relief and land uses were evaluated in this work. The built-up areas, the road network that crosses them and the adjacent structures are positions of high temperature. Conversely, the cultivated areas as well as the areas with forested vegetation create cooler environment conditions.

Key words: Attica, air temperature, land use, relief.

Introduction

Attica is a triangular shape peninsula between 37º39' N and 38º20' N and between 23º07' E and 24º05' E (H.M.G.S., 2021). This peninsula is located in the southern mainland of Greece projecting into the Aegean Sea. It is a historical area in which the city of Athens, the capital of Greece, is located. Athens has been inhabited continuously for more than 3000 years, a fact that makes it the city with the longest history in Europe and one of the oldest historical cities in the world. Athens was one of the most important cities of Ancient Greece during the first Millennium BC and its achievements (5th century BC) laid the foundations of Western Civilization. It has many monuments, but the Parthenon is considered as the most important one (Paparrigopoulos, 1995: 351).

Attica is characterized by a variety of geomorphological features. Thus, its southeastern part is distinguished from its northwestern one. More specifically, southeastern Attica is characterized by hills whose altitude (alt) does not exceed 650 m. However, there are smaller hills that reach an alt of up to 300 m. These hills show north to east and east to west direction. The shape of the relief, as it is well known, is influenced by the precipitation, which creates a smooth low relief with the formation of valleys between hills, due to the erosion of their surface layer.

The relief of northwestern Attica is more intense than that of southeastern Attica, resulting in high mountains with steep slopes. In northwestern Attica there are three mountains, Ymittos (maximum alt of 1026 m), Penteli (maximum alt of 1107 m) and Parnitha (maximum alt of 1413 m), which are surrounded by lower hills arranged in such a way that they form gaps of a much lower alt, through which the communication of the Athens basin with other large population areas takes place (Antoniou, 2010: 304). A large plain area is located between northwestern and southeastern Attica, which has an average alt of 100 m and contains sedimentary materials from the adjacent mountains.

In summary, we can say that the soils of Attica are characterized in their largest percentage (64.3%) as semi-mountainous, in their smallest percentage (5.8%) as mountainous and the rest (29.9%) as lowland (N.S.S.G., 1995: 171). More specifically, the northeastern part of Attica includes large areas in which olive trees and other fruit trees, vines and all kinds of vegetables are grown (H.S.A., 2021: 83). Moreover, there are many pines and firs in the mountainous areas (Nikitiadis, 2019). The diversity of the terrain and the form of the ground cover are key parameters for differentiating the air temperature (T) conditions that prevail in an area.

Methodology

Climatic data of T from thirteen meteorological stations under the supervision of Hellenic National Meteorological Service, National Observatory of Athens and Laboratory of General and Agricultural Meteorology of Agricultural University of Athens, Greece, were used. These stations are located at different positions within the borders of the prefecture of Attica. Published results of research works as well as projects that have been completed in the study area (Attica) were also used.

Results and Discussion

The climate of Attica is characterized as Mediterranean with hot and dry summers and mild rainy winters. The average annual temperature ranges from 16.5 ^{o}C to 19.0 ^{o}C. The highest temperatures are found in the southern coastal areas, while the lowest in the northern inland areas with the exception of the Athens basin, where the average annual temperature exceeds 19.0 ^{o}C due to urbanization (HNMS, 1999; 2021).

Apart from the terrain and other individual parameters, the spatial distribution of T in Attica is affected by the winds, which have an average speed of 5.0 Knots to 7.0 Knots and a main direction north to northeast (HNMS, 2021). The cold season in Attica starts in mid-December and can be extended until mid-March. As we approach the coastal areas T increases, given that the average sea temperature is 3.5 ^{o}C higher than T (Kotini-Zambaka, 1983). In contrast, T decreases as we approach the peaks of the northern mountains.

The cold season coincides with the rainy season of the year. The cloud coverage is small and the sunless days are less than 25 (N.O.A., 2013: 190). Around mid-January the "Alkyonides days" appear which are a series of sunny days (Chronopoulou-Sereli and Flocas, 2010: 573) that interrupt the bad weather of winter.

The warm period of the year begins in the last ten days of May and extends until the first ten days of September. This period is characterized by clear weather, continuous drought and prevalence of north-northeast winds known as Etesians. Air temperature, especially during the warmer months (July and August), is high and can sometimes exceed 40.0 ^{o}C (Chronopoulou-Sereli and Flocas, 2010: 573). However, the sea breeze reduces the maximum temperature in the coastal areas by 2.0 ^{o}C to 3.0 ^{o}C (Philandras et al., 1999: 65-72; Tzanakou and Deligiorgi, 2006: 186-194).

The mountains in Attica that are covered mainly by arboreal vegetation, with pines at lower alts and fir at higher ones, show decreased T values compared to adjacent semi-mountainous and lowland areas (Nikitiadis, 2019: 226). The T conditions in the air layer near the ground of mountains are a result of alt as well as the type and density of tree coverage (Barry, 2008: 531; Kamoutsis et al., 2018: 292-298). More specifically, with the increase of the alt, based on T lapse rate, there is a decrease of T from 0.47 ^{o}C to 0.70 ^{o}C per 100 m, depending on the season and the month of the year (Flocas et al., 1983: 287-295).

Of particular interest is the decrease in T observed during the hot days of the year in tree-covered areas, compared to adjacent uncovered areas. In other words, a decrease in T by 8.0 ^{o}C to 10.0 ^{o}C has been observed in a forest-covered area compared to a neighboring non-tree-covered area. In general, during the 24-hour period, tree-covered areas show an equilibrium tendency by decreasing the maximum T values and increasing the minimum T ones (Chronopoulou-Sereli and Flocas, 2010: 573).

The tree-covered hills in Attica show a similar behavior to the tree-covered mountainous areas. In contrast, hills covered with shrubby or herbaceous vegetation show increased T values during the warm period and decreased T values during the cold period compared to tree-covered areas of the same alt and orientation. These increased T values can be attributed to the unobstructed effect of direct solar radiation and the lack of shading. In contrast, the decreased T values during the winter period are due to the thermal radiation released from the ground, which does not happen in the tree-covered areas because the canopy of the trees prevents the loss of thermal radiation.

Air temperature differences are also attributed to the small-scale topographic configuration of the relief of the plain area of Attica. That is to say, an increase in T from 2.0 to 5.0 oC was observed in the closed and leeward positions compared to the open and upwind positions (Chronopoulou-Sereli and Chronopoulos, 1994a: 77-85). This is attributed to the different radiation and air mass conditions (Seeman, 1979: 125-130; Geiger et al., 2003: 601) formed at these positions due to the terrain.

The plains in Attica are generally productive, as their soil has come from transport and deposition of fine-grained material from the surrounding mountains and hills and the water required for irrigation of crops derives from the underground water supply zones that exist in Attica. The type of crops and the existence or not of irrigation in the lowland agricultural areas of Attica result in different T conditions. Thus, for example, in the largest plain of Attica, Mesogaia, irrigated tree crops showed a decrease in T by 0.8 ^{o}C to 3.1 ^{o}C compared to non-irrigated tree crops. Smaller T differences ranging from 0.5 ^{o}C to 2.2 ^{o}C were detected in irrigated and non-irrigated vineyards (Chronopoulou-Sereli and Chronopoulos, 1994a: 77-85).

The plains in Attica originally had rural and recreational characteristics. In recent decades, however, they have changed use after the major projects that have taken place there, such as the international airport “Eleftherios Venizelos”, “Attiki Odos”, a major ring road with a total length of 70 km, suburban railway and other constructions, which serve the needs of the airport as well as many companies and factories that have been established there.

Conclusion

Although Attica covers 2.9% of the total area of Greece, it has gathered 34.9% of its population (H.S.A., 2021). This means that the villages in Attica have developed into cities and its capital, Athens, has grown in size, resulting in intense thermal pollution, in addition to other environmental problems that have been created.

The problem of thermal pollution is most evident during the hot period of the year. Thus, the built-up areas and the avenues that cross the lowland areas, show an increase in T, which reaches 6.0 ^{o}C, in comparison with the adjacent cultivated areas or areas covered with other forms of vegetation. The participation of the traffic load in the shaping of the T conditions is important (Horbert et al., 1988: 22-29). In other words, there was an increase in T in central avenues that cross the lowlands compared to side roads of less car traffic, which ranged from 1.0 ^{o}C to 4.5 ^{o}C, depending on the wind conditions.

In particular, when there is calm or low wind intensity (0.1 m/sec to 2.0 m/sec), largest T differences between plant-covered areas and non plant-covered ones as well as between boulevards and side roads are observed, due to reduced exchange of air masses. Conversely, when a stronger wind blows (1.1 m/sec to 4.8 m/sec) and the exchange of air masses is more intense, then the T differences decrease and often reach

1.0 ºC to 2.0 ºC. Finally, in wind conditions of even greater intensity (5.5 m/sec to 13.5 m/sec) the T differences are almost zero (Chronopoulou-Sereli and Chronopoulos, 1994b: 50).

Of particular interest is the strong effect of the Etesians that blow in Attica during the warm period of the year, that is, cool air masses which enter Attica and normalize the T extremes created by the terrain and land uses.

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