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The urban heat island in a coastal Mediterranean city: The case study of Kyrenia, Cyprus

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ABSTRACT

As a result of rapid urbanization worldwide, the vegetation areas, grasslands, and forests were replaced with construction and buildings. It is known that roads, pavements, concrete surfaces and walls all absorb sunlight during daytime and reflect heat as heat waves at night. It is clear that green areas have a significant role in urban life. Most of the research conducted in this field has shown that green areas mitigate the urban heat island, improve air quality, decrease noise and manage stormwater within the cities. Green spaces, green roofs, green walls, street trees, and water sources all have a positive impact on urban temperatures. Unfortunately, due to the rapid expansion in urbanization activities in Kyrenia, northern Cyprus, urban green spaces are decreasing at an alarming rate. Therefore, two different experimental works have been applied within the region; the first of these studies has been conducted on Ziya Rızkı Avenue. In this first study, temperature differences of shading with and without trees were measured. Additionally, the second study focused on the temperature differences between urban and rural areas. In the second research, urban and rural spaces were measured concurrently over a period of one month. It was proved by both studies that green spaces mitigate urban temperatures. Therefore, research results should be taken into consideration and architects, urban designers and planners should pay attention to green areas, street trees, parks, green roofs, and vertical green system establishments.

1. Introduction

Today, half of the global population live in metropolitan areas (Taleghani, 2018). Approximately three billion people now live in urban areas around the world. According to the United Nations, by 2030, 83% of the world population will be living in cities (Mentens et al., 2006). After the industrial revolution, urban areas rapidly expanded and significant changes emerged within their environments. The modern cities replaced vegetation areas with asphalt, concrete, cement, walls, and pavements. This has had negative impact on the local urban climate and has contributed to global warming. In particular, the temperature in central parts of cities is higher than the surrounding areas (Alexandri and Jones, 2008).

The rapid growth of cities and the concentration of the population has effect on the climate change. Consequently, efforts are being concentrated on adapting urban areas to the climatic conditions caused by global warming. In general, urban areas under the influence of urban heat islands experience an increase temperature in comparison to their surrounding areas. On the other hand, the impact of climate changes is more significant on urban microclimates than rural areas. Within this scope, the urban heat island effect is very important issue in terms of human life quality and public health (Zinzi and Agnoli, 2012). Heat waves are a natural occurrence which are negatively impacting social life and increasing human mortality in urban areas. The largest cooling effects of the cities are created by parks, street trees, vegetative roofs, and green walls (Akbari et al., 1997). Green roofs also have numerous benefits for urban climates. The green roofs have a positive effect on air pollution, air quality improvement, storm water management,

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biodiversity, and noise reduction. Particularly during the summer, they have a positive impact by decreasing buildings' energy consumption (Susca et al., 2011). Urban morphology, soil materials, anthropogenic emissions and vegetation have an influence on the environmental performance at a micro scale and the intensity of the urban heat island effect can vary as a result of meteorological, location and urban characteristics (Tumini and Rubio-Bellido, 2016).

It is also known that the most abundant anthropogenic greenhouse gas concentration is carbon dioxide (CO_2), which is increasing globally. The anthropogenic emissions are originating from road traffic and local heating with natural gas, oil or coal impact. Nowadays, more than 70% of the energy related to global greenhouse gases is attributed to cities. It is expected that by 2030, this will increase to 76% due to artificial surfaces, fossil fuel combustion and traffic volume (Kar et al., 2018). Therefore, the problem of mitigating CO_2 concentration in urban areas is considerable. Urban green spaces have a significant role in the local carbon cycle. Urban green areas, particularly trees, can positively affect air quality. Green plants remove the CO_2 by storing carbon through photosynthesis. Furthermore, green areas have a recreational role in urban areas as their positive social and psychological effects improve citizen's quality of life. In urban areas, parks and green areas are of strategic importance for life quality. Urban residents' experience of green areas and urban park may reduce stress. Additionally, urban green areas can better contribute to reducing external noise from road traffic (Pace et al., 2018). In other words, it is undeniable that the world is becoming warmer. The temperature increase has coincided with the industrial revolution and burning of fossil fuels. One of the products of burning fossil fuels is the release of carbon dioxide. Carbone dioxide is one of the atmospheric gases that ensure that terrestrial energy does not escape into space. Resultantly, higher temperatures are caused due to the greenhouse effect. Human activities related to the burning of fossil fuels have increased the carbon dioxide levels in the atmosphere by 32% since 1750. It is expected that carbon dioxide emissions due to fossil fuel burning will continue to increase (Rowe, 2011).

A study conducted in United States focused on the positive effect of green areas, using metropolitan areas and high dense constructed areas. The high temperature was monitored in four different metropolitan areas. The study has proved a temperature difference of 2°C. There were differences between the most and least vegetated areas, as well as those with vegetation and man-made building materials. As a result of the analyses, the study has proven that vegetated surface had light impact than other surfaces (Susca et al., 2011).

Another similar research has been carried out in Cyprus in previous years. Within this research the daily meteorological data from 1983-2010 have been used to prove that the urban heat island effect exists in Nicosia, Cyprus. Daily temperature values have been analysed for three decades, namely 1983-1990, 1991-2000 and 2000-2010. Meteorological stations in both urban and rural areas have been used. The study has proven an increase in intensity by 6.8 °C for 1983-1990, 6.2 °C for 1991-2000 and 3.5 °C for 2001-2010. The study has also examined the urban heat island seasonally in terms of winter and summer periods. The analysis proves that heat waves phenomenon occurs in cold months when the wind was less. Daily analysis for a period of one year displayed that the intensity of the heat waves was sense day time (Theophilou and Serghides, 2014).

Northern part of Cyprus has had a fast urbanization process since the late 1980's. Urban environments are increasing; on the other hand, rural and natural environments are lessening day by day in northern part of Cyprus. Kyrenia is one of the cities that are experiencing rapid and mostly an unsustainable urbanization process. As a result of this situation, physical, environmental and natural conditions are changing in Kyrenia. Therefore, this study has been conducted to demonstrate that street tree shade mitigates the urban air temperature. Additionally, within this research another study has been conducted to prove that the city of Kyrenia has a higher temperature than its surrounding areas.

2. Material and methods

2.1. Study area

Cyprus is an island situated in the Eastern Mediterranean region and is under the Mediterranean climate zone. Winters are generally mild, and summers are dry. Average daytime temperatures during winter range between 12-15 °C. The average maximum temperature in coastal regions is around 32 °C in summer. The maximum temperature often reaches 40 °C in the inland regions. The wet season occurs between November and March, with most of the rain falling between December and February. Rainfall is generally associated with the movement of moist maritime flows to the North, particularly occurring over higher elevations. The arid summer characteristics of the region have significant implications in several socio-economic sectors. In the last few decades, Cyprus has been experiencing the worst water shortage on record (Giannakopoulos et al., 2010). The island covers a total of 9,251 km^2. Cyprus has a semi-arid climate and rainfall is the only source of fresh water on the island (Darilmaz, 2017).The island has two mountain ranges, one of which is the Troodos Massif in the southwest region of the island with an elevation of 1,951 meters, and the other is the Pentadaktylos range situated along the northern coast at an elevation of 1,000 meters. These two mountain ranges provide the island with high topographical variability. The autumn and spring seasons are relatively short. October, April and May are characterized by variability and rapid changes in precipitation and temperature. The Troodos Massif and Kyrenia mountain ranges have important roles in defining the weather on the island. In winter, snow falls for several weeks at a considerable depth on the high northern slopes. The Kyrenia range and lowlands rarely experience snowfall. Meteorological data indicates a general increase in overall temperature. There has been a slight decrease in precipitation with a corresponding increase in drought (Griggs et al., 2014). Kyrenia is largely characterised by a hot and humid climate due to its geographic location (Fig. 1). The humidity is relatively high in Kyrenia because the mountains are close to the urban areas. The region also experiences cooler winds and increased rainfall (Ozay, 2005).

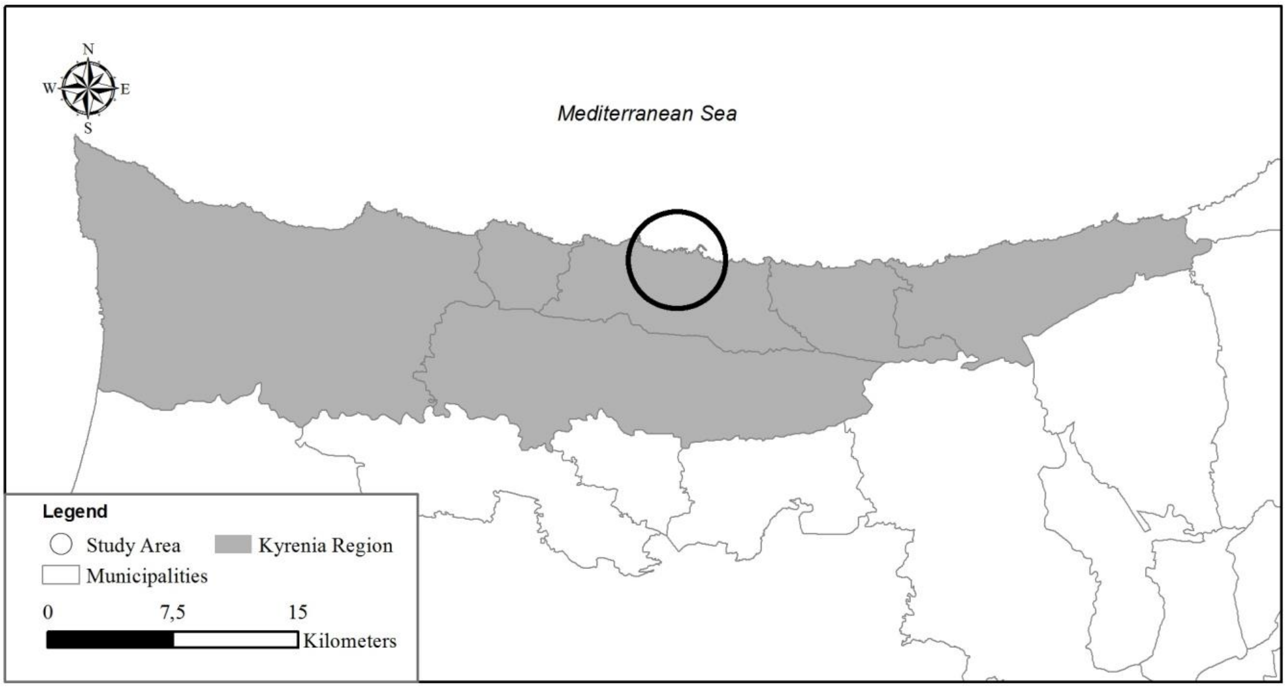

Fig. 1: Study area Kyrenia city in Cyprus

Kyrenia district general vegetation is olive, citrus and almond trees. Kyrenia coastal zone covered with maquis and pine forest (Fuller et al., 2016). Kyrenia district population is 69,163 and Kyrenia Municipality population is 33,207. Monthly maximum and minimum air temperatures in selected stations were measured in 2009 January 19.7– 5.1, August 37.8– 23.4, in 2010 January 23.5-6.0, August 38.8– 24.1 in 2011 January 19.2– 9.8, August 37.0 – 23.9, in 2012 January 19.6– 4.1, August 38.3– 23.1, in 2013 January 19.9– 2.3, August 39.0– 22.4 decree Celsius. Kyrenia precipitation were measured in 2009 January 85.5, in 2010 January 133.2, in 2011 January 177.8, in 2012 January 162.8, in 2013 January 91.4 millimetres (DPÖ, 2013).

2.2. Data collection

The research conducted in the city of Kyrenia was performed using a temperature data logger. The particular model of data logger used was an Elitech RC-5 USB. A total number of four temperature data loggers were used.

This temperature data logger has product features which include a smart and compact design, portability, integrated USB interface, and direct connectivity to a computer. It is suitable for temperature recording in a variety of small spaces. It has a multi-functional LCD display, with a recording capacity of 32,000 points. The temperature range is between -30 ^{0}C and +70 ^{0}C with an accuracy of ± 0.5 ^{0}C (Fig. 2).

2.3. Methodology

Two different research studies were conducted in Kyrenia. The first study was administered to collect temperature data in densely urbanized area of Kyrenia in order to find out if there is any effect of green space on urban temperatures. Kyrenia is an attractive city located in the North of Cyprus that is popular with international tourists throughout the year. Kyrenia is at the centre of Kyrenia district which has numerous public offices and private business. For this reason, Kyrenia district residents visit the city centre to take care of their formal affairs, such as government offices, banks, etc. (Fig. 3).

Fig. 2: Elitech RC-5 temperature data logger

In first study experiment has been conducted at Ziya Rizki Avenue. This avenue is a very active street, which has many businesses, banks, shops and public offices. Data loggers were used in mature tree holding part of the city and also used further along the street which did not have any tree plantations with two replicates (Fig. 4).

Most of the shops on this avenue require shading during the summer period. The study applied on this avenue used two thermometers to measure the differences between the tree shading side and the grey shading side.

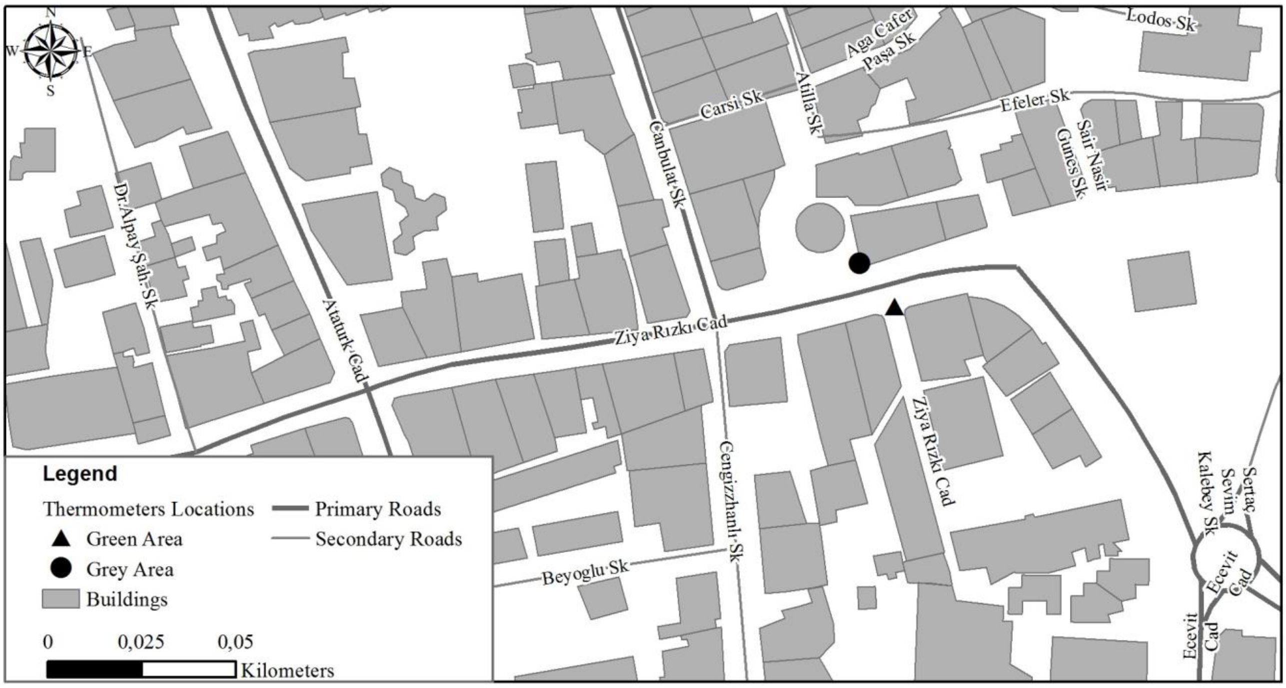

Fig. 3: Ziya Rızkı Avenue, Kyrenia

Fig. 4: A street view of Ziya Rızkı Avenue Kyrenia, Cyprus

The two thermometers were hung under a tree and under the grey shading at the same altitudes of 17 metre. The thermometers were programmed to measure the temperature every ten minutes and they were started at the same time. The temperature measurement process lasted one week from the 20th to 27th September in 2017. The thermometers started to measure at 11:45 am on the 20th September 2017 until 10:25 am on the 27th September 2017. Each thermometer collected 1,001 data points with a total of 2,002. All the data have been transferred to computer and a comparison has been made.

The second study was applied to determine the temperature differences between rural areas and urban areas. A total of four temperature data loggers were used in this study; two thermometers in urban areas and the other two in rural areas. The locations were selected based on their altitudes. The altitude of one of the locations was 13 meters, while the other was 34 meters. At both altitudes, the thermometers were hung under trees in an urban area and a rural area. The thermometers were programmed to measure the temperature every fifteen minutes and all thermometers started recording at the same time.

The measurement process lasted for one month between 18th October and 20th November in 2017. The data have been transferred to computer and a comparison has been made. In the urban area at an altitude of 13 meters on Atilla Street, the thermometers were placed under trees. This street is also known as Old Kyrenia, characterised by narrow streets and two storey buildings. This street has less greenery than other parts of the city because this residential area is very old, and the buildings were constructed in stone. The houses of this street have no patios or gardens (Fig. 5). For the comparison of temperature difference with Atilla Street as the urban area, Bülbüller Street was chosen as the less urbanised area with an altitude of 13 meters.

Fig. 5: Attila Street, Kyrenia, Cyprus

In addition, as part of the second study, a comparison of temperature difference was made between Mücahitler Avenue as the urban area and Şehit Süleyman Recep Avenue as the less urbanised area, at the altitude of 34 meters. These four locations of the second study that are used for measuring the temperature differences between an urban area and a less urbanised environment with two having an altitude of 13 meters and another two having an altitude of 34 meters are displayed below (Fig. 6).

3. Results and discussion

3.1. Green shade area and grey area temperatures

During the week, it was recorded that the daily temperature on Ziya Rızkı Avenue on the side with the large trees was less than the side without trees. The differences were approximately six degrees Celsius during the daytime. However, at night, the temperatures of both sides of the street were the same degree. On the chart, the blue line indicates the temperature of the grey area. The temperature difference is clearly observed. During daytime, the tree shade temperature is less than the grey shade. The shops that do not have tree shade are therefore required to use some form of sunshade (Fig. 7).

3.2. Urban and rural area temperatures

In this part of the research comparison of different temperatures of urban and rural sites has been evaluated. The data clearly shows that the old town is warmer at night-time than the rural areas (Fig. 8).

On the other hand, during the daytime, the rural area is warmer than the urban area because the sunlight directly affects the ground and surrounding area. In the urban area during the daytime, the sunlight is unable to directly reach the ground with the result that the temperature is lower than the rural area. In the narrow street, the buildings create shade for each other. The real temperature differences occurred during the night-time periods. During the daytime, Atilla Street absorbs sunlight, which is reflected at night as heat waves. Additionally, Atilla Street does not have any form of green vegetation. For this reason, there is no evapotranspiration on Atilla Street during the day. The narrow street is completely covered by construction materials, walls, asphalt, stones and pavements and there are also many vehicles and air-conditioning units.

These are the real factors that increase the air temperature. In the rural area, Bülbüller Street is wider than Atilla Street. All houses have patios and gardens. This street has more green vegetation than Atilla Street and there is more evapotranspiration than Atilla Street. There are less construction materials than Atilla Street, which means that less sunlight is absorbed during the day. There are gaps between each of the houses, which enable greater air circulation than Atilla Street.

The sky view factor can occur more than Atilla Street during the night-time. All these reasons lead to a decrease in the air temperature than at the same altitude on Atilla Street. At the altitude of 34 meters, a comparison was made between Mücahitler Avenue as the urban area and Şehit Süleyman Recep Avenue as the rural area. The temperature differences are clearly seen on the chart below. The blue line shows the rural area temperature. During the daytime, the temperature in the rural area is higher than the urban area (Fig. 9).

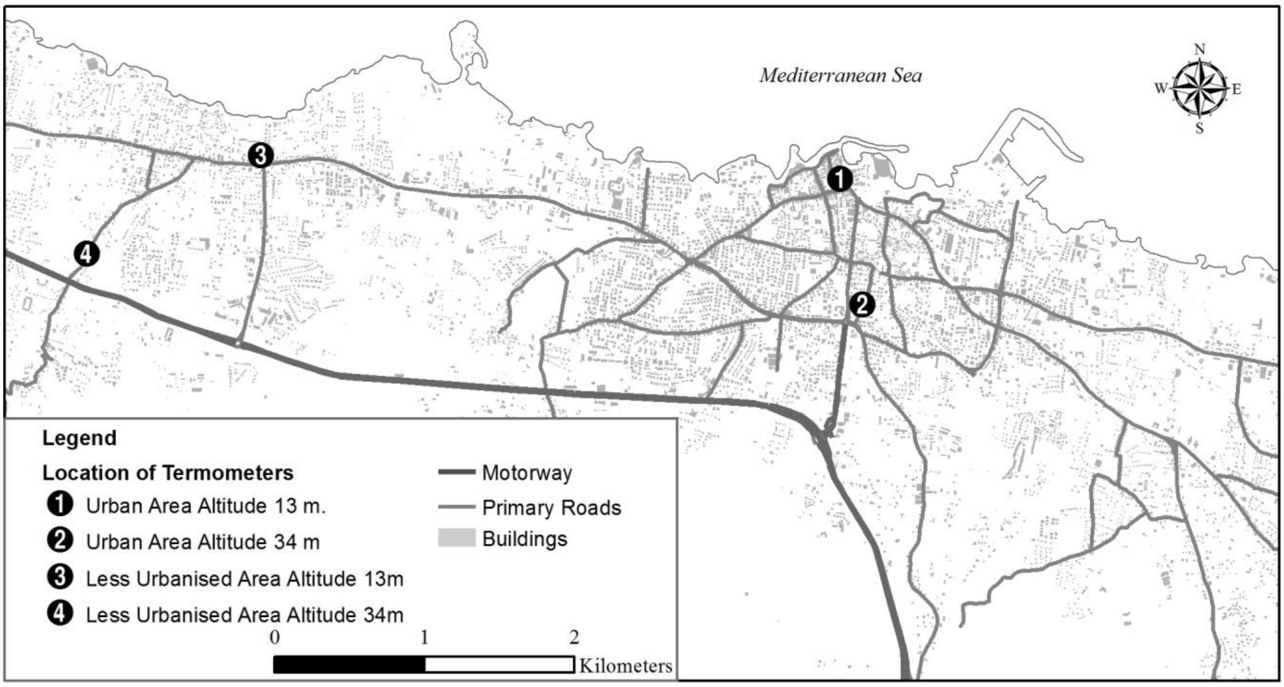

Fig. 6: Rural and urban area of Kyrenia on maps marked numbers

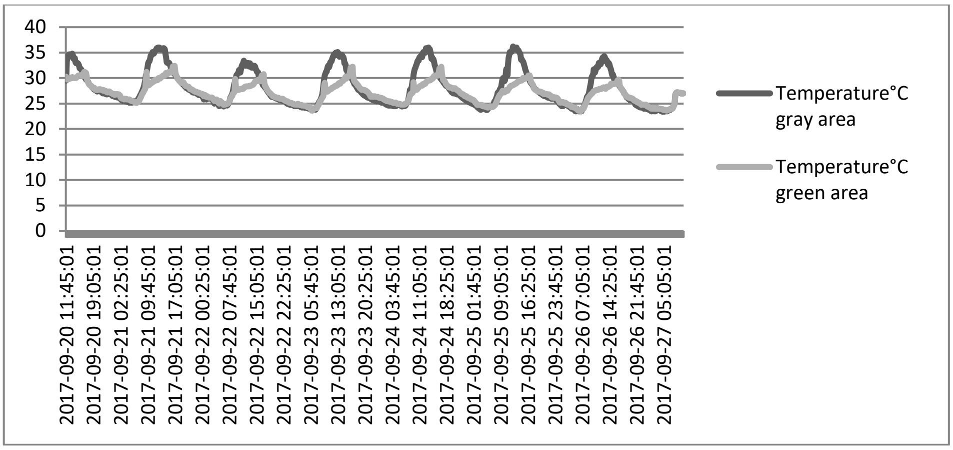

Fig. 7: Tree shade and grey shade temperatures on chart

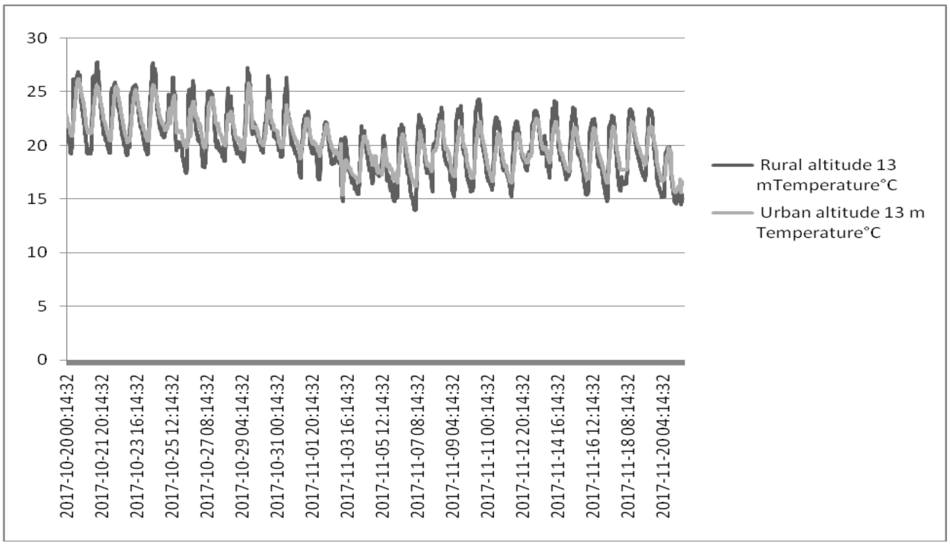

Fig. 8: Rural and urban area temperature difference at an altitude of 13m

Generally, in Cyprus, rural areas have more green vegetation than urban areas. This causes high evapotranspiration and high humidity related to the temperature. There are less construction materials and paved surfaces than the urban areas. During night-time, the clear sky factor leads to radiation loss. This causes a decrease in the rural area temperature during the night-time. In urban areas, there are more construction materials consisting of asphalt, pavements and walls. Furthermore, urban areas have more vehicles and air conditioning units that are related with the increased number of buildings. These kinds of materials increase the anthropogenic heat during night-time periods.

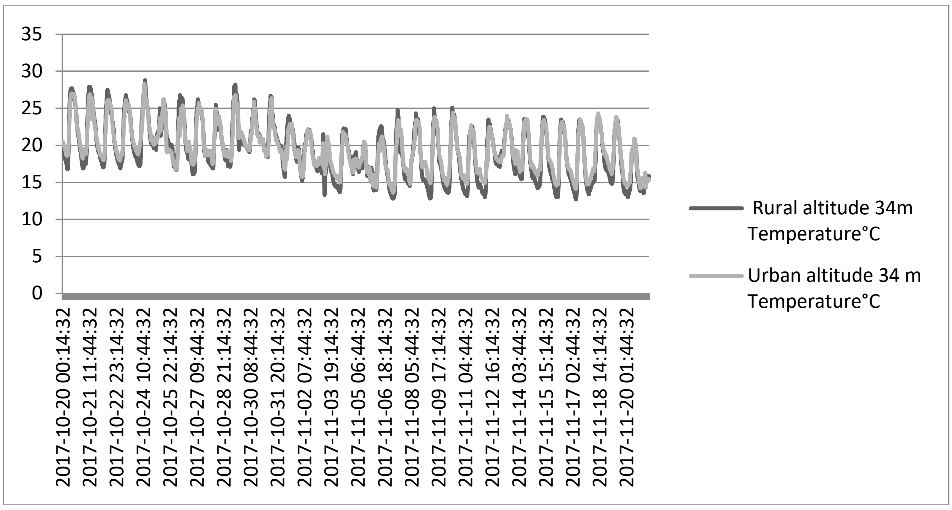

Fig. 9: Less urbanised and urban area temperature difference at an altitude of 34m

Two different types of study applied in Kyrenia. The first study shows and proves that mature urban trees canopy reduces the air temperature and mitigate the urban heat island in Ziya Rızkı Avenue. The second study also proves that densely urbanised areas night temperature higher than surrounding urban areas. Non-urbanised area has more tree and vegetation area and thus night temperature is less than the urban area. Both of the studies were comparable, and the results matched with Bowler et al. (2010).

4. Conclusion

In recent decades, Kyrenia, North Cyprus has experienced a rapid urbanization resulting in the loss of olive trees, lemon trees, pine trees and vegetation areas. Most of the olive trees and lemon trees have been replaced with concrete. Old houses have been destroyed and ten-storey buildings have been constructed in their place. Consequently, the population of Kyrenia has risen proportionally. In line with the increased population, the number of vehicles has risen due to the increase in CO2 emissions. In combination, these factors have had negative effects on the climate of Kyrenia. The tree shade and without tree shade air temperature measurements prove that tree shade has a significant impact on the pavement and pedestrians during the daytime. Also, urban and rural area air temperature measurements have demonstrated that during the night-time, urban areas have higher temperatures than rural area. Furthermore, summertime air-conditioning usage is greater than in the rural areas, which is also a contributory factor to the elevated CO2 emission levels. All these factors are gradually decreasing the quality of life of Kyrenia residents. Therefore, urban planners and landscape architects should study together to provide more shade for urban environments. District governors and local municipalities must pay attention to increase open green areas. Government officials or volunteers must plant trees such as olive, carob, pine, cypress and almond. These kinds of trees are drought tolerant and they are suitable for Mediterranean climate. Together with tree plantings shade areas will increase and they will be mitigating the heat affects eventually. Also, carbon will be captured in plant biomass and carbon dioxide concentration will be decreasing.

Compliance with ethical standards

Conflict of interest

The authors declare that they have no conflict of interest.

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