IJMSIT

International Journal of
Multidisciplinary Studies and
Innovative Technologies

Volume : 2
Number: 2
Year: 2018
Pages: 76-85

The effect of the temperature of the surface of vegetation to the temperature of an urban area.

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Abstract: Urban areas have less vegetation than their surrounding natural environments. Differences between these types of areas affects climate, energy use, and habitats in the cities. In urban areas, dark surfaces and reduced vegetation affects the warmth of air over urban areas, and as a result leading to the creation of urban heat islands. Urban vegetation can have a substantial effect on urban air temperature and as a result can reduce the energy consumption arising from cooling and smog. To estimate the impact of light-colored surfaces and urban vegetation (trees, grass, shrubs and groundcover) on meteorology and air quality of a city, it is essential to accurately characterize various urban surfaces. The characterization of the areas with various vegetation cover has significant importance in understanding the temperature of urban areas. Plants are essential in a dense urban environment not only because of their aesthetic value, but also for their cooling effect during hot time periods, which has a direct effect to the local microclimate of an area. The benefits obtained from plants to the urban environment can either be direct or indirect. For example, trees have an ability to trap sunlight before it warms the ground, they also have an ability to cool their surroundings through evapotranspiration. Not only that but trees can also act as wind barriers by reducing the wind speed of their neighboring surroundings, they can protect buildings from cold winter breezes and they can offer reasonable benefits through reducing the costs of air-conditioning through lowering air temperature and improving the urban air quality by reducing air pollution.

Some trees cope better with high urban temperatures than others. The resolution of the presented urban surface temperature data for the first time allows to determine mean canopy temperatures of individual vegetation belonging to different species.

Leaf temperature is the outcome of the energy balance at leaf level, which depends on a series of anatomical, physical and biological phenomena. The resulting leaf temperature, foliage temperature has important consequences for the plant itself, but also for the environment surrounding the plant. Landscape planners have recognized the link between greenspace provision in the urban environment and environmental quality for a long time.

There is a growing need of analytical work on the beneficial impacts of urban greenspace on micro-climates and as well as biodiversity. Previous studies have shown that land uses have their own distinctive surface cover.

This study contributes a method and tools for analyzing, understanding, planning, and managing urban environments. It is important especially when considering the ever increasing interest of having green infrastructural planning. The study has been conducted in Erzurum though the application of a thermal camera.

Keywords: *Temperature, Surface cover, Vegetation, Thermal camera, Erzurum*

1- INTRODUCTION

A report released by The United Nations, Department of Economic and Social Affairs in 2012 indicated that 52% (3.6 billion) of the world's population inhabit in urban areas. This number is expected to increase to 6.3 billion by 2050. With the rapid population growth, urbanization causes changes in the natural land coverage and as a result causing an ecological imbalance. Understanding and predicting the population changes is a major challenge that will impact the interactions between nature and society (Bettencourt et al. 2007). From the beginning of 20th century, urbanization has become an important contributor for global warming (Lv 2011). Heat stress in the urban areas is expected to worsen due to increasing urbanization (Kovats and Hajat 2008) not only that but climate change is also the biggest global health threat of the 21st century (Göklany, 2009).

Surface Temperature Index (STI) is of prime importance to the study of urban climatology (Vooght and Oke, 2003, Becker and Li, 1995). Increased air temperatures can be expected to be particularly problematic in urban areas, where temperatures already tend to be a few degrees warmer than the surrounding countrysides. This difference in temperature between urban and rural areas has been called the 'Urban Heat Island effect'(UHI) (Jaafar et al., 2011). Numerous studies found that urbanization increases the surrounding air and surface temperatures, which consequently intensify the UHI effect (Yilmaz et al. 2009; Chen et al.2016; Voogt and Oke, 2003, Tam et al 2015; Kaloustian and Diab 2015). The thermal environment in urban areas is characterized by the heat island phenomenon affected energy demand, human health, and environmental conditions (Van, 2005). A decrease in the intensity of UHI may be achieved by increasing the albedo of urban surface materials (Santamouris et al., 2011,Chang et al. 2007; Taha, 1997; Jongtanom et al., 2011) and increasing urban vegetation cover (Akbari et al., 2001, Chen et al., 2012,Shashua-Bar and Hoffman, 2003). While other factors affect UHIs, surface change is the predominant influence (Memon et al., 2008). Surface temperature is also significantly affected by the configuration of green space, especially its patch density. Composition and configuration of green space could largely explain the variance of Land Surface Temperature (LST) (Li et al. 2012; 2013).

Urban greening has been proposed as one approach to mitigate the human health consequences of increased temperatures resulting from climate change (Georgi and Zafiriadis, 2006; Oliveira et al., 2011; Susca et al, 2011.) Trees, shrubs and groundcovers are essential components of urban green infrastructure. An adaptation strategy that has been proposed is to 'green' urban areas, essentially by increasing the abundance and cover of vegetation (Givoni, 1991).

Most studies investigated the air temperature within parks and beneath trees and are broadly supportive that green sites can be cooler than non-green sites (Bowler et al. 2010; Taha et al., 1988; Avissar, 1996). Foristance, in a study which was done in Beijing, China found out that the percentage cover of green spaces determined the land surface temperature of an area. LST decreased approximately by 0.86°C with an increase of 10% green space (Li et al., 2012). In other studies, it was found out that "urban parks cooling effects" average 0.94°C during the day and 1.15°C in the night (Bowler et al. 2010) with large variations ranging from 1 to 7°C (Chang et al. 2007). Analysis of temperature trends for the last 100 years in several large U.S. cities indicate that, since 1940, temperatures in urban areas have increased by about 0.5 – 3.08 ^{0}C (Akbari et al.,2001)

Complex processes are involved in determining the cooling effect of vegetation on daytime air and surface temperature. The vegetation cools the environment through evaporative cooling, shading effects, and its thermal and optical properties (Dimoudi and Nikolopoulou, 2003). Compared to impervious surfaces, which generally have high thermal storage capacity and thermal conductivity, vegetation has low thermal storage and admittance (Oke, 1988; Spronken-Smith and Oke, 1999) and is therefore likely to emit less thermal radiation to the environment. However, the cooling impact of plants on air and surface temperature may vary with environmental factors and plant specific thermal and optical characteristics. Schwarz et al., (2012) and Chen et al. (2012) showed that there is an existence of a positive correlation between the air temperature measurements based on the ground and the surface temperatures which are measured from thermal sensors. Urban heat island studies which are based on temperatures derived from the sensors mounted on satellites such as Landsat are commonly used for assessing the intensity of the surface heat island i.e. Surface Urban Heat Island (SUHI) (Quattrochi & Luvall, 1999; Soer, 1980). The analysis of thermal infrared data from satellite sensors provides with the necessary information on the thermal differences between vegetated areas, built up areas and the non-vegetated areas through the provision of simultaneous observations and a dense grid of the data throughout a city.

It is possible to do surveying of vegetation cover with infrared satellites, however, satellite imagery do not have a resolution that is high enough to be used to differentiate the plant species. According to an experimental study which was done by Lin and Lin (2010), it was found out that the cooling efficiency of urban parks is highly influenced by the color of the leaves and the density of the vegetation.

Differences in foliage temperature between plant species can be significant in a mixed deciduous forest (Leuzinger and Körner, 2007). In a study which was done in Switzerland through the use of a construction crane and a high resolution thermal camera, at an air temperature of 25 C, coniferous trees (Picea abies, Pinus sylverstris and Larix decidua) and deciduous broad-leaved trees with exceptionally high transpiration (Quercus petraea) or vey open, low density canopies (Prunus avium) revealed average canopy temperatures of close to air temperature (0.3 – 2.7 K above ambient) and the maximum amplitude with a given crown got up to 6 – 9K. in comparison, broad leaved deciduous species with dense canopies (Fagus sylvatica, Carpinus betulus and Tilia platyphyllos) were found to be 4.5 – 5K warmer than air temperature and showed within canopy temperature amplitudes of 10-12K (Leuzinger and Körner, 2007).

Researchers have also found out that coniferous forests have a lower albedo as compared to deciduous forests. This is due to the reason that conifers trap more radiation due to the rough leaf and canopy structure (Oke, 1988).

In a study done in Athens (Greece), air temperature measurements under vegetation canopy trees in suburban streets and reference points were done under light wind conditions in five different streets in the city of Athens during a short hot weather period in the year 2007. The study found out that the average cooling effect at 14:00 hours ranged between 0.5 to 1.6 C and at 17:00 hours it ranged between 0.4 to 2.2 C. with the highest cooling effect being found to be 2.2 C (Pauleit, 2003).

Increasing urban vegetation, particularly street trees, may help alleviate higher temperatures as street trees play an important role in providing shade Aguial et al., (2014). The potentials for exotic and native street trees have been compared to help to reduce surface temperatures in urban climates. The surface temperature of asphalt surrounding (or adjacent to) 6 species of street trees (3 exotic and 3 native) at 8 sites each have been recorded using a FLIR Infrared camera on hot and normal temperature days. Surfaces under native trees have exhibited lower temperatures as compared to exotic trees (lower by 2 C). However, very little data exists on urban tree temperatures despite its current and potential economic value in both aesthetical and microclimatic terms.

According to a study done by Leuzinger et al. (2010) by scanning the crown temperatures of 10 common species of trees which are regularly planted in parts of the Central European city of Basel – Switzerland through the use of a helicopter and a high resolution thermal camera, the histogram of the composite image revealed a peak of 18 C for water, 26 C for vegetation, 37 C for streets and a less noticeable one of 45 C for roofs. According to the study, at an ambient temperature of 25 C, the tree crown temperatures lied between 24 C (Aesculus hippocastanum trees found in a park) and 29 C (Acer platanoides) trees which were located in the street. The study also found out that the trees in the parks were cooler (26 C) as compared to the trees which were surrounded by sealed grounds (27 C). In the study, the only coniferous trees whose temperatures didn't vary according to the location that they were found was Pinus sylvestris. They also had a foliage temperature which was close to the air temperature. However, it was generally found that the trees which had small leaves had lower temperatures than the ones with broader ones.

The presence of shades of trees in urban areas plays a great role towards the reduction of the cost of air conditioning buildings and lowering the air temperature of an area. In turn, this improves the air quality of urban areas by reducing pollution. The cost-saving-related benefits realized from trees vary from one climate to another and they can be up to $200 per tree while the cost of planting and maintaining them may range from $10 to $500 per tree (Akbari et al., 2001). It has been estimated that, about 20% of the national cooling demand can be eluded through the carrying out of heat island measures which would make up to 40 TWh/year saving worth of over $4B per year through cooling electricity savings alone (Akbari et al., 2001). When the benefits of smog reduction have been considered, the total savings could increase to more than $10B per annum.

According to a study done by Feyisa et al. (2004), air temperatures of 60 plots found in 9 parks for 15 days were measured through the use of Landsat EYM+ thermal infrared. During the study, the data was used to examine the cooling effect of vegetation of 21 parks on a larger spatial scale. In order to examine the relationship between the characteristics of the vegetation and observed temperatures, linear mixed-effects models were used. The study found out that the Eucalyptus sp. had a reasonable higher cooling effect as compared to other groups of species ($P < 0.05$) and species with the least effect on temperature were Grevillea and Cupressus. The study revealed a positive relationship between the NDVI and area of parks ($P < 0.01$) and the cooling effect of parks on their surroundings (Park Cooling Intensity, PCI) on a larger spatial scale.

In relation to the location, size, density and trees, the green areas in urban areas play a great role in influencing the temperature of the urban areas. They reduce the temperatures in summer periods and increase the winter temperatures through trapping solar energy and as a result creating a balance.

Green areas are also very important in terms of organic integrity and in improving human comfort for the ecosystem. In order to determine the effects of the green areas in the environment areas, a case study of in Erzurum, has been chosen. Images from thermal cameras have been used in the study. The purpose of this study is to provide a basic data set on species-specific tree crown temperatures of urban trees. Additionally, some surface temperatures of non-plant surfaces are shown. Tree crown temperatures have been compared to trees growing in parks and the ones surrounded by sealed grounds.

2- MATERIALS AND METHOD

This study has been done in the city of Erzurum (Figure 1). Turkey where there are approximately 100 different tree species and subspecies planted in the city (Yılmaz and Irmak, 2004). The species which could be adequately be replicated have been chosen for the study ***Cerastium tomentosum*** *L.*, ***Thuja occidentalis L., Petunia x hybrida, Pinus sylvestris L. Tagates erecta).***

Optris® PI-450 (Optris, Berlin, Germany) longwave infrared camera with manual focus used for this study. The spectral range is 7.5 – 13 µm and a resolution of 382 x 288 pixels, with a temperature range of -20 – 900 °C (accuracy: ±2 °C, resolution of 0.1 °C, thermal sensitivity: 40 mK) (Table 1). The whole kit weights 380 g (Smigaj 2015)

Table 1 Specifications of Optris® PI-450 thermal sensor (Smigaj 2015).

Detector	FPA, uncooled (25 µm x 25 µm)
Lens (FOV)	38° x 29° FOV / f = 15 mm
Optical resolution	382 x 288 pixels
Spectral range	7.5 – 13 µm
Thermal sensitivity	40 mK
Temperature range	-20 – 900 °C
Accuracy	±2 °C
Resolution	0.1 °C
Total weight	320 g

The northwestern part of the city covering a number of parks has been systematically overflown in a helicopter with the thermal camera pointing directly downwards.

Figure 1. Study area

Cerastium tomentosum L. (*Snow-in-Summer*) is a herbaceous flowering plant and a member of the *Caryophyllaceae* family. It is a low, spreading perennial native to South and East of Europe. The leaves are silvery-grey, whilst the flowers are star-like, white about 15 mm across. *C. tomentosum* flowers in summer, but may also bloom at other times of the year. It has proven popular as a cultivated ornamental and can be found in gardens the world over (Yücel, 2004).

Petunia* x *hybrida *(Petunia)* is ornamental plant in the family *Solanaceae,* subfamily *Petunioideae.* Petunias are also gaining popularity in the landscape design. An annual, most of the varieties seen in gardens are hybrids (Yücel, 2004).

Thuja occidentalis **L.**, *(Northern white-cedar)* is an evergreen coniferous tree, in the cypress family *Cupressaceae*, which is native to eastern Canada and much of the north, central and upper Northeastern United States, but widely cultivated as an ornamental plant. *Thuja occidentalis* 'Smaragd', *Thuja occidentalis* 'Pyramidalis' and Thuja occidentalis 'Aurea' species often used in landscape design in cold climate regions (Güngör et al., 2002; Yücel, 2012).

Pinus sylvestris **L.** *(Scots pine)* is a Eurasia specie of pine with short blue/green leaves and orange/red bark, which can be found in in a ranging area including Europe, Siberia, Anatolia, and other places. It can grow at the sea level on the northern parts of its range, while it can be also found at the mountains at 1,200–2,600 metres altitude. This plant is the most durable and widely used conifers in Erzurum (Güngör et al., 2002; Yilmaz and Irmak, 2012; Yücel, 2012).

Tagetes erecta **L.** *(Aztec marigold)* is specie of the genus *Tagetes* native to Mexico and Central America. It is grown annually and it has a height between 30 and 100 cm. It is used for medicinal, ceremonial and decorative purposes. The Aztec plant is cultivated and also found in the wild. The plant is widely cultivated for commercial purposes with many cultivators using it as an ornamental plant and for the cut-flower trade (Yücel, 2004).

Lawn surfaces: The measured area of the surfaces of the lawn were found to be containing a mixture of grass species of cool climates. The ratios of the grass species which were found to be occupying the lawn were as follows; *Lolium perenne* 'Ovation' (25%), *Lolium perenne* 'Paltinum' (20%), *Poa protensis* (10%), *Festuca rubra* 'Rubra' (30%), *Festuca rubra* 'Commutata' (15%).

Pavement: Putting into mortar pieces of broken marble paving results that have been created are in contrasting green space around it with white color.

3- FINDINGS

The study area has been divided into three areas. The area on the left has ***Thuja occidentalis L., Petunia x hybrida, Tagates erecta.*** The measurements have been done on the surface of the grass as it has been shown on Figure 2.

Figure 2. The image on the right shows the thermal image of the study area

The measurements which were made on the points which belonged to the ***Thuja occidentalis L.*** Plant showed that the highest surface temperature was 8.85 ^{0}C while the lowest temperature was found to be 8.56^{0}C. The mean temperature was found to be 8.69 ^{0}C as it has been shown in Figure 3.

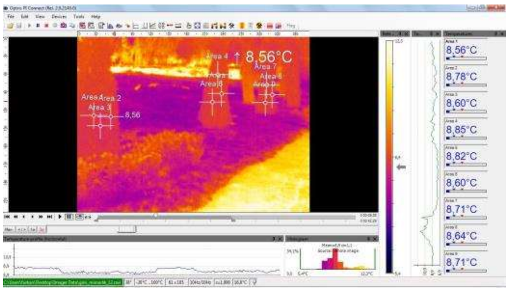

Figure 3: The temperature data of the ***Thuja occidentalis L***. plant is shown on the right hand side of the study area

According to the measurements which were done, the grass of the study area, the highest temperature as found to be 8.09^{0}C while the lowest temperature was found to be 7.57^{0}C. The mean temperature of the grass was found to be 7.75^{0}C as shown by Figure 4.

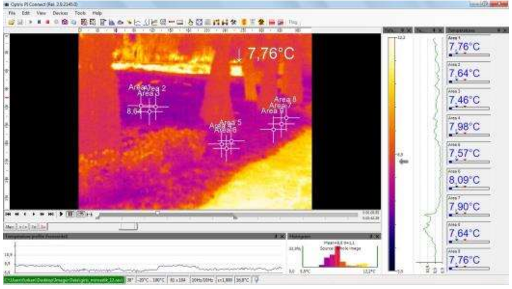

Figure 4. Points used in the measurement of the temperature of the grass

The Petunia* x *hybrida and Tagates erecta, plants have been organized in a disordered manner. According to the temperatures which have been obtained from different points belonging to the plants the highest temperature was found to be 8.96 ^{0}C while the lowest temperature was found to be 8.56^{0}C. The average temperature was found to be 8.76^{0}C as shown in Figure 5.

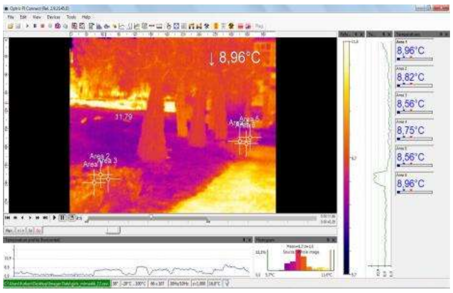

Figure 5. Temperature values belonging to ***Petunia* x *hybrida, Tagates erecta,. Plant species***

During the measurement of the study area, covered by ***Thuja occidentalis* L.** (Area 1,2,3,4), ***Petunia* x *hybrida, Tagates erecta***, (Area 5,6,7), grass surface (Area 8,9), pavement (Area 10, 11), the highest temperature was found to be 11.83 ^{0}C while the pavement was found to be having 6.94^{0}C in average. The lowest temperature was measured on the surface of the grass. The ***Thuja*** plant was found to have a minimum temperature of 8.23^{0}C, a maximum temperature of 9.13^{0}C and a mean of 8.67^{0}C as shown in Figure 6, Table 1 and Figure 7.

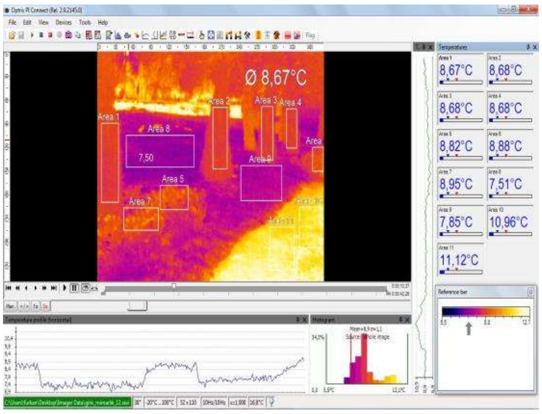

Figure 6. Spatial data of the study area

Table 1. The measurements obtained from left of the study area

		Min (^{0}C)	Max (^{0}C)	Mean (^{0}C)
***Thuja occidentalis* L.**	1.Area	8,2	9,15	8,67
	2.Area	8,31	9,18	8,68
	3.Area	8,16	9,15	8,68
	4.Area	8,27	9,04	8,68
Petunia* x *hybrida,Tagates erecta.	5.Area	7,65	10,12	8,82
	6.Area	8,31	9,65	8,88
	7.Area	7,64	10,26	8,95
Grass Surface	8.Area	6,94	8,38	7,51
	9.Area	7,27	8,53	7,85
Pavement	10.Area	10,3	11,68	10,96
	11.Area	10,26	11,83	11,12

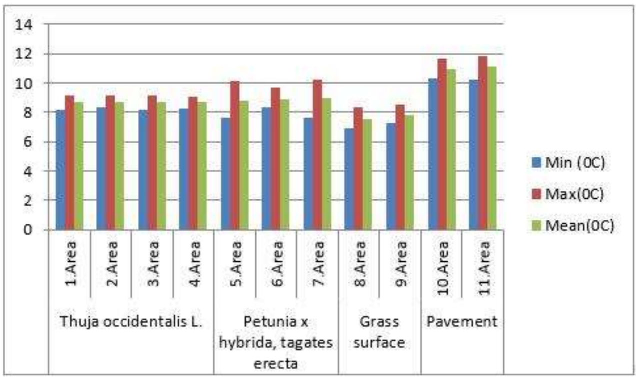

Figure 7. The measurements obtained from left of the study area

***Pinus sylvestris* L.,** measurements have been taken from the middle of the field (Figure 8)

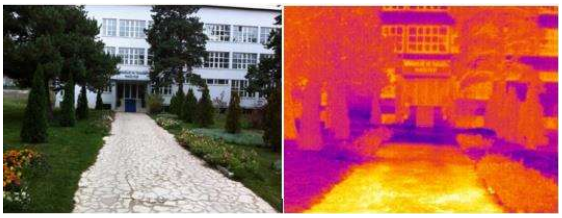

Figure 8. The part which belongs to the middle of the study area

According to different measurements obtained from points belonging to the ***Pinus sylvestris*** plant, the highest temperature was found to be 9.29 ^{0}C while the lowest temperature was 8.89^{0}C and the mean temperature was found to be 9.09^{0}C as shown in Figure 9.

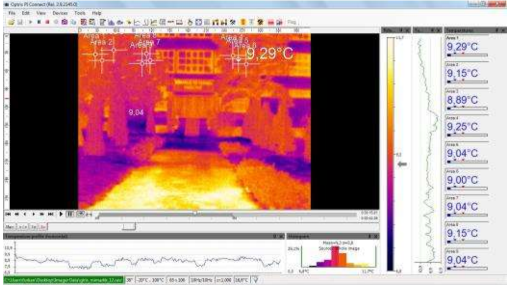

Figure 9. Temperatures measurements of the ***Pinus slyvestris*** plant

During the measurement of the points on the pavement of the study area, the high temperature was found to be 10.73^{0}C while the lowest temperature was found to be 8.51^{0}C and the mean temperature was 10.34^{0}C as it has been shown in Figure 10.

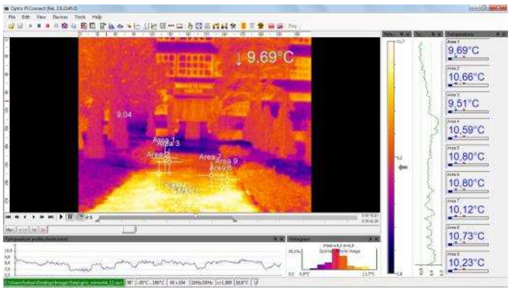

Figure 10. Measurements belonging to the pavement in front of the study area

During the measurement of the values of the study area (***Pinus slyvestris*** (Area 1,2,3,4), ***Petunia* x *hybrida, Tagates erecta***, (Area 5,6,7) and the pavement (Area 8,9)) the highest temperature value was found to be 11.04^{0}C while for the pavement was found to be 9.07^{0}C. The ***Petunia* x *hybrida and Tagates erecta***. Plant species were found to be having the lowest average temperature. The average temperature of the ***Pinus slyvestris*** was found to have a minimum of 8.72^{0}C, a maximum temperature of 10.12^{0}C and a mean of 9.32^{0}C as shown in Table 11, Table 2 and Figure 11.

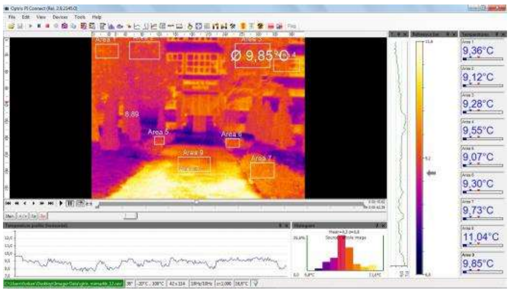

Figure 11. Temperatures measured in front of the study area

Table 2. Measurements of the left side of the study area

		Min (^{0}C)	Max(^{0}C)	Mean(^{0}C)
Pinus slyvestris	Area 1	8,93	10,05	9,36
	Area 2	8,64	9,9	9,12
	Area 3	8,53	10,05	9,28
	Area 4	8,78	10,48	9,55
Petunia* x *hybrida, Tagates erecta	Area 5	8,64	9,58	9,07
	Area 6	8,56	9,72	9,3
	Area 7	9,07	10,19	9,73
Pavement	Area 8	10,16	12,25	11,04
	Area 9	9,00	10,73	9,85

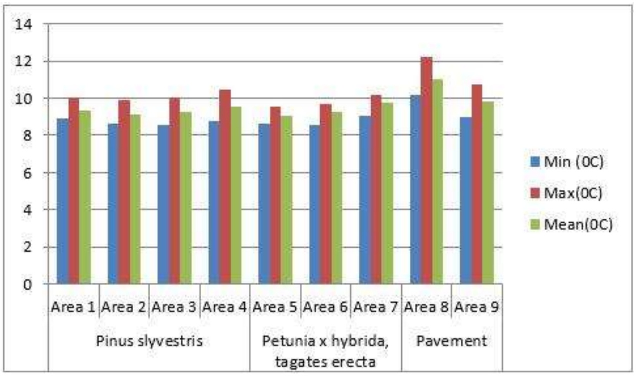

Figure 12. Measurements of the left side of the study area

The measurements of the ***Petunia* x *hybrida, Tagates erecta*, *Thuja occidentalis L. and Cerastium tomentosum L*** plants have been measured from the right hand side of the study area as shown in Figure 13.

Figure 13: The measured area is on the right hand side of the study area

According to the measurements which have been made on the points selected from the area covered by the Thuja occidentalis L. plants, the highest temperature obtained was found to be 9.51^{0}C while the lowest temperature was found to be 8.96^{0}C and the mean temperature was found to be 9.28^{0}C as it has been shown in Figure 14.

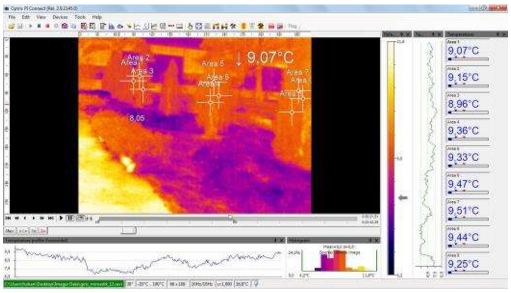

Figure 14: The temperature measurements obtained from measuring the ***Thuja occidentalis L.*** plants are on the right hand side of the study area

According to the different measurements obtained from the different points located on the ***Petunia x hybrida, Tagates erecta,*** plants, the highest surface temperature was found to be 9.58^{0}C while the lowest was found to be 9.07^{0}C and the mean was found to be 9.33^{0}C as it has been shown on Figure 15.

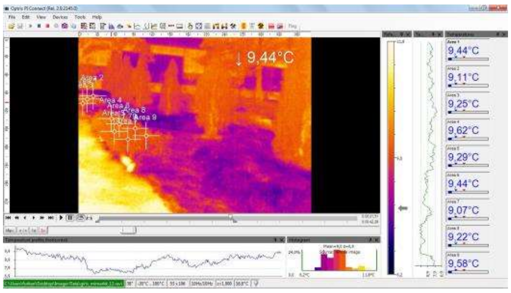

Figure 15: The temperature measurements obtained from measuring the ***Petunia* x *hybrid, Tagates erecta*** plants are on the right hand side of the study area.

According to the different measurements obtained from the different points located on the ***Cerastium tomentosum L,*** plants, the highest surface temperature was found to be 8,23^{0}C while the lowest was found to be 7.46^{0}C and the mean was found to be 7.77^{0}C as it has been shown on Figure 16.

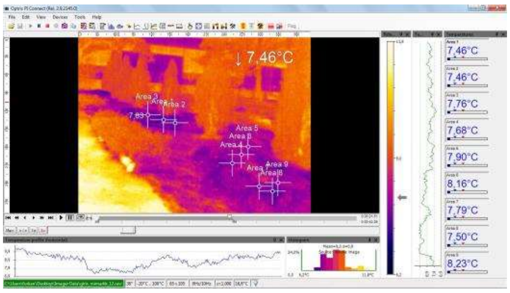

Figure 16: The temperature measurements obtained from measuring the ***Cerastium tomentosum*** plants are on the right hand side of the study area.

During the measurement of the area of study (***Thuja occidentalis* L** (Area 1,2,3,4), ***Petunia* x *hybrida, Tagates erecta***, (Area 5,6,7), ***Pinus slyvestris*** (Area 8.9) plants, ***Cerastium tomentosum*** (Area 10,11,12) and the pavement (Area 13)), the highest temperature has been found to be 11.83^{0}C with the lowest while 7.16^{0}C was the mean. The lowest temperature was measured on the ***Cerastium tomentosum*** plants. The ***Thuja occidentalis* L** plants were found to have an average low temperature of 8,750C, an average maximum temperature of 9,91 ^{0}C and an average temperature of 9,16 ^{0}C as it has been shown in Figure 17, Table 3 and Figure 18.

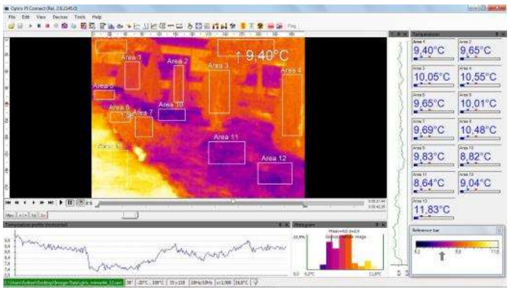

Figure 17. The temperature measurements from are on the right hand side of the study area.

Table 3: The temperature data obtained from the right hand side of the study area.

		Min (^{0}C)	Max(^{0} C)	Mean(^{0} C)
***Thuja occidentalis* L.**	Area 1	8,53	9,4	8,95
	Area 2	8,97	9,65	8,97
	Area 3	8,93	10,05	9,32
	Area 4	8,6	10,55	9,42
Petunia* x *hybrida, Tagates erecta	Area 5	7,57	9,65	9,12
	Area 6	9,07	10,01	9,53
	Area 7	8,49	9,69	9,22
Pinus slyvestris	Area 8	8,71	10,48	9,4
	Area 9	8,67	9,83	9,23
Cerastium tomentosum	Area 10	7,16	8,82	7,61
	Area 11	7,27	8,67	7,87
	Area 12	7,09	9,04	7,9
Pavement	Area 13	9,54	11,83	10,98

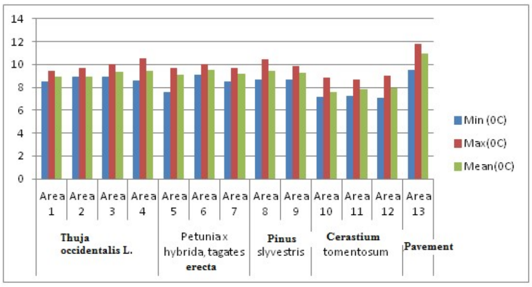

Figure 18. Measurements of the left side of the study area

4- RESULTS

After a complete measurement of the study area, it was found out that the temperature of thuja was 8,91 ^{0}C, petunya is 9,17^{0}C, grass surface is 7,68^{0}C, pavement is 10,95^{0}C, pinus is 9,31^{0}C and cerastium is 7,79^{0}C as it has been shown in Figure 19.

Modern urban areas have typically darker surfaces and less vegetation than their surroundings. These differences affect climate, energy use, and habitability of cities. This is consistent with the hypothesis that green cover may be effective in reducing temperature. However, the surrounding natural and semi natural landscape types facilitate the green cooling effect. These findings are valuable for landscape and urban planning.

The areas which were covered by grass surfaced and the *Cerastium tomentosum* plant were found to have low temperature values. This can be explained by the presence of more leaf surface area in these areas. Leaf Area Index (LAI) is used to express the number of leaves per unit area of the ground (m^{2}). LAI affects processes such as photosynthesis, interception, evapotranspiration and many others (Waring, 1983; Bonan, 1993; Jose ve Gillespie, 1997; Kara et al., 2011).

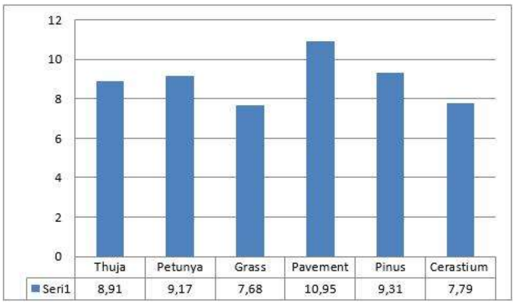

Figure 19. Measurements of the study area

The increase of the number of leaves per surface increases the amount of photosynthesis, transpiration and other related biological processes. The required temperature for vegetation transpiration is obtained from the vegetation's surroundings and a result of the occurrence of transpiration, the surfaces which are close to the vegetation are cooled.

In the study, the temperature of areas with less leaf area, areas where the ground is visible, the areas made up of ***Petunia x hybrida*** and ***Tagates erecta*** flower beds were found to be having higher temperatures than the surfaces covered by grams and ***Cerastrium tomentosum*** as a result of the differences in the leaf surface. In the same way, for the ***Thuja occidentalis*** plant, when compared to the ***Pinus sylvestris*** plant, it appeared to be cooler; this can be explained by the variability of the leaf surface areas.

The pavements which are made up of marble particles, attracted attention as being the hottest surfaces as a result of being quite light in color and having the ability of reflecting sun rays. Open areas which are directly hit by run rays and the surfaces of lively materials have different abilities of holding and radiating heat.

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