VEGETATION IN THE URBAN AREA OF TUNIS: A STUDY OF IMPACTS ON TEMPERATURE AND LIGHT *

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Abstract

LANDSAT and ASTER images enabled us to detect increased surface coolness corresponding to urban parks that heat up less than the artificial substrate. Maximum temperature differences reached 7°C diurnally and over 10°C at night. Field measurements showed that these green spaces lower air temperatures by 1 to 2°C during the day and by about 3°C at night. The study showed that the intensity of the urban park effect in Tunis depends on the size of the vegetated area, the volume of plant biomass and irrigation. Vegetation enables streets to cool by 1 to 2°C during daytime sunshine hours in summer. Light measurement showed special lighting effects in vegetated streets that diminish bright light and provide a comfortable visual perception.

Keywords: green space, temperature, cool island, light, Tunis.

Introduction

Urban sprawl to the detriment of natural areas is accompanied by changes in ground surface and thus in energy balance, the phenomenon of urban heat islands (UHIs) being the main outward sign of this (Charfi, 2012). Urban heat increase reinforces the negative effects of climate change, especially during heatwaves. In Britain, Kieron & Tony (2013) estimate that between 8 and 11 extra deaths occur each day for every degree of air temperature rise during summer heatwaves. Tunis, a large city on the southern Mediterranean coast, is subject to extreme heat events in summer, with maxima sometimes in excess of 45°C. Nocturnal UHIs can reach up to 10°C. Such heatwaves are accompanied by increased mortality rates and higher energy consumption for air conditioning. Green spaces in cities have become a solution for attenuating excessive rises in urban temperatures (Choi et al., 2012), since they provide one of the best forms of shelter from summer heat (Robert & Nicole, 2012). Vegetation helps cool the urban thermal environment through evaporation, evapotranspiration and shade. It thus reduces the demand for air conditioning and consequently anthropogenic heat emissions. It also filters the sun’s rays and the intense light at street level (Krout, 2012).

The present study aims to quantify the effects of vegetation on urban-area diurnal and nocturnal temperatures during summer: ground-surface temperatures from satellite images, and air temperatures from measurements made in several streets using a vehicle equipped

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with air-quality survey instruments in Tunis. We have also sought to show the impact of vegetation on light intensity at street level. Two city parks and two vegetation-lined streets were chosen as experimental areas. They were: the Belvédère Zoological Park in the city center, located on a 60m-high hill next to the Medina, with a dense urban environment (except for the northwestern part) and medium-density vegetation; the grounds of the former Essaada presidential palace located in the center of Marsa village, a seaside resort in the northern suburbs of Tunis; and rue de Turquie and Ali Darghouth Street, both in what is known as the ‘European’ quarter of the city.

1. Data and methods

Two kinds of satellite images were used in the present study:

- A LANDSAT ETM+ and ETM image: an ETM+ scene taken at 09:30 UT on August 27, 2007 was used for spatializing brightness temperature. This is extracted from the sixth band with a spatial resolution of 60m, after atmospheric effects were corrected by using the calculator on the following website (http://landsat.gsfc.nasa.gov/atm_corr.) (Barsi et al., 2003).

- An Advanced Spaceborne Thermal Emission and Reflection Radiometer/Thermal Infrared Radiometer (ASTER) image. This enables nocturnal surface temperatures to be characterized with a spatial resolution of 90m. We used a scene taken in clear conditions at 21:26 UT on October 31, 2005. The ASTER-TIR has 5 channels in the thermal infrared range. To extract surface temperature, we used the Multi-Channel Sea-Surface Temperature (MCSST) method developed by Matsunga (1996). The entire set of satellite images mentioned above was geometrically corrected according to the Carthage UTM projection before being submitted to an unsupervised classification.

Five sets of field measurements of air temperature and humidity were used, three of them diurnal and two nocturnal, all made in clear conditions and by the same team of researchers. Two were made in Belvédère Park at 11:05 UT on August 27, 2007 and at 00:35 UT on August 28, 2007, two others in Marsa Park at 0:30 UT and 12:00 UT on August 29, 2008, and the last one in a small urban sector at 16:00 UT on August 28, 2008. Another survey made using a vehicle equipped with measuring devices focused on measuring illuminance (expressed in lux) on two vegetation-lined streets, rue de Turquie and Ali Darghouth. A digital lux meter fitted with a separate cell was used. It was positioned horizontally at a height of 1.6 m, in accordance with the visual field of a moving pedestrian. For easier data representation and interpretation, sidewalks were divided into 1m-by-1m grids and roadways into 2m-by-2m grids, where the grid intersections corresponded to the points of measurement (Krout, 2012).

2. The influence of urban parks on air and surface temperatures in Tunis

2.1. Daytime

On the Landsat image, the Belvédère Park canopy is cooler by 6 to 7°C maximum than surrounding urban surfaces (figure 1). The heterogeneous nature of brightness temperatures might be explained by the number of bare paths inside the park and the state of the plant biomass, which is of medium density and fairly unkempt. For the air, the sample used from August 27, 2007, shows that Belvédère is cooler than the surrounding urbanized areas. The maximum thermal gradient is 1.5°C between P2 at the extreme northern limit of the park and the densely urbanized European quarter (P6, P7). The humidity is relatively higher due to the
amount of evaporative surface area. Green spaces modify the elements of energy balance by favoring latent energy consumed by evaporation. Less heat is thus expended on heating the air. Comparing measurement points P1 and P2, nevertheless, shows that the inner areas of the park are not always as cool as the outer areas, most likely because of topographical positions and shade effects. Point P1 is located at the top of Belvédère hill at an altitude of 50m in open space exposed south-west, whereas Point P2 is a little lower (32m), and remains longer in the shade in the morning, since it is sheltered by lines of buildings (figure 2). The park’s thermal effect diminishes as the distance from the source of coolness increases. After 700m, it no longer operates. Temperatures rise progressively going south-east along Mohamed V Avenue, and humidity diminishes simultaneously.

For Essaada Palace, a weakly matching cool island can also be barely distinguished on the Landsat image with a low gradient of 3°C maximum (figure 3). As the sea is close by and the Palace grounds’ area relatively small, the surface thermal field is homogenous. For comparable weather conditions, our field measurements of air temperatures at 12:00 UT on August 29, 2008 show that Essaada Palace grounds are a cool island (figure 4).
A gradient of 1.9°C was recorded between the edge of the vegetated area (P5) and the residential areas of individual houses (P1). In contrast, the relative humidity gradient is fairly weak, not exceeding 5%. The grounds are only 200m from the shore, thus favoring a relatively homogenous hygrometric environment due to high evaporation rates from the sea. Comparing air and surface temperatures by day and by night shows strong concordance in the case studied here, proving the importance of surface temperature in determining that of the air above.

2.2. Night-time

For Belvédère, the brightness temperatures calculated from the Aster image show a nocturnal cool island, that is more obvious early in the night as the ground radiation from artificial surfaces (figure 5) intensifies. The maximum thermal range between the hottest point and the park canopy is close to that recorded by day (8°C). Mobile vehicle-based measurements of air temperatures made at 00:35 UT under a clear night sky on August 28, 2007 show that Belvédère Park is cooler than its high-density urban surroundings. The greatest thermal difference (between Points P2 and P8) exceeds that recorded by day, at around 2.9°C. The amount of water vapor in the air in and near the park is higher by 12% (figure 6).

![Figure 5. Spatialized brightness temperatures in and around Belvédère Park from an ASTER-TIR scene dated du 10/31/2005 at 21:26 UT.](image)

![Figure 6. Spatialized air temperatures and relative humidity in and around Belvédère Park, 8/28/2007 at 00:35 UT.](image)

In view of the wide meshes of the Aster image grid compared to the size of the Essaada Gardens, brightness temperatures are not shown. At a height of 2m above the ground, the relative denseness of the regularly-watered vegetation has favored the development of the Gardens’ thermo-hygrometric effect comparable to that recorded at Belvédère (figure 7). The measurements made at 0:30 UT on August 29, 2008, show a close fit with the cool island, with 2.8°C between Marsa village center (P1) and the north-west entrance of the Palace (P4). At over 12%, the relative humidity gradient is greater than by day.

3. Impact of roadside vegetation on temperature and light

3.1. Impact of roadside vegetation on temperature

Temperatures were measured at 16:00 on August 28, 2008, in streets of similar width and with mainly the same orientation. The aim was to highlight vegetation effects. We recorded a
maximum gradient of 2.5°C between the hottest point (P3) in rue d’Espagne, oriented east-west, and in the sun when the measurements were made, and the coolest point (P6). The latter was in rue de Hollande, oriented north-south and lined by two dense rows of jacaranda trees whose canopies touch.

The difference drops to 2°C in rue Charles de Gaulle (P4), whose orientation is the same but which has no vegetation and is less shady. Avenue de France (P1) is the broadest, the most exposed to the sun, has the heaviest vehicle traffic, and is therefore the hottest (figure 8).

3.2. Impact of vegetation on light

Light measurements were made on two separate occasions in clear conditions. The first set was made on September 8, 2012, from 10:50 to 12:00 in rue de Turquie, a 20m-wide street oriented north-south. Its western side is bordered by a four-storey building and the eastern side by a one-storey building and a parking lot. The measurements show that light intensity varies according to the density of plant biomass and shade. Brightness values range from 500 lx underneath the ficus trees near the buildings’ façades to 74,100 lx in the middle of the road (figure 9).
The second set of measurements was made the following day between 10:20 and 11:00 in Ali Darghouth Street, 15m in width and oriented east-west. On each side of the street, there is a six-storey building with a high ground floor and two rows of large jacarandas whose canopies touch. Light intensity is considerably less contrasted, with more homogenous values ranging between 1,000 and 58,000 lx. The weakness of the gradient can be explained, on the one hand by the lower density and greater transparency of the jacaranda biomass texture, and on the other hand by the significant shade effect masking about half the light, estimated in the literature at $\approx 1,000$ lx with a clear summer sky (Krout, 2012) (figure 10). The resulting light intensity provides a comfortable visual perception at around 1,000 lx (Nikolopoulou, 2004).

### Conclusion

From the examples analyzed in this study, it can be observed that green spaces in urban areas of Tunis constitute cool islands with lower air temperatures, ranging from 1 to 2°C by day and 2.5 to 3°C at night, and with higher air humidity. Interpreting the measurements of the various parameters is much more difficult when the green spaces are located in a special geographical context, as is the case with Belvédère. The spatial influence of the urban park effect in Tunis depends on the surface area of the vegetalized zone, the volume of the plant biomass, and irrigation. Although Essaada Palace gardens at Marsa are much smaller than Belvédère Park, they have an equal effect on temperature and humidity because they are denser and are watered more. As for streets, dense vegetation can result in a drop of 2°C in comparison with nearby non-vegetalized streets and engender a cool environment with a
comfortable visual perception due to filtering of light. Such filtering depends, however, on biomass density and the form of the plant cover.

References


