Vegetation as a climatic component in the design of an urban street

Abstract

The cooling effect of small urban green wooded sites of various geometric configurations in summer is the object of this study. It was studied experimentally at 11 different wooded sites in the Tel-Aviv urban complex during the period July–August 1996. An empirical model is developed in this study for predicting the cooling effect inside the wooded sites. The model is based on the statistical analysis carried out on 714 experimental observations gathered each hour from the 11 sites on calm days, when urban climate is expressed. Two factors were found to explain over 70% of the air temperature variance inside the studied green site, namely, the partial shaded area under the tree canopy and the air temperature of the non-wooded surroundings adjoining the site. The specific cooling effect of the site due to its geometry and tree characteristics, besides the shading, was found to be relatively small, about 0.5 K, out of an average cooling of about 3 K at noon. The cooling effect of the green wooded areas on their immediate surroundings at noon was also analyzed. The findings corroborate earlier studies that the range is noticeable. At small green sites, the cooling effect estimated in this study is perceivable up to about 100 m in the streets branching out from the site. The empirical findings in this study permit development of tools for incorporating the climatic effects of green areas in the urban design. Some policy measures are proposed accordingly, for alleviating the “heat island” effect in the urban environment.

Introduction

As urbanization progresses, the “heat island” problem is aggravated mainly because of the reduced density of the green vegetation in the urban environment [1]. Additions to public green areas usually lag behind the urban development. Private green areas in the courtyards of apartment houses are also declining, due to conversion for parking purposes.

The reduction in the green area densities has an adverse effect on local air temperature. Rosenfeld et al. 2, 3illustrate the case for downtown Los Angeles over the period 1882–1984. With increasing irrigation and orchards, the city of Los Angeles cooled by 2 K until the 1930s. Since then, as asphalt replaced trees, the city warmed by 3 K. The phenomenon is universally typical. In macro, the control measures suggested are mainly vegetation and high-albedo roofs and streets. Rosenfeld et al. [2]study in alleviating the heat-island problem, believe in a three-pronged strategies beyond microclimate below trees: (a) cool roofs, (b) cool pavements, and (c) vegetation for evapotranspiration.

Vegetation surfaces show lower radiative temperatures than other inanimate ones of the same colour. The difference in maximum temperature may exceed 20 K [4]. In the case of large green areas such as parks, vegetation affects the air temperature above it and thus improves the thermal environment of the urban area. Jauregui [5]found that in Chapultepec Park (500 ha) in Mexico City, the effect of the park on air temperature is noticeable at a radius of 2 km, about the same as its width. In a new paper on Tama New Town's Central Park in Japan by Ca et al. [6]found that the influence area of the park (about 35 ha) can extend to a distance of 1 km in the northwest direction when the wind is very strong.

In micro, the effect of vegetation on the thermal environment of its surroundings area is rather small but still significant. In Israel, Givoni [7]found that the cooling effect of Haifa's Biniamin Park (0.5 ha) is noticeable 20 to 150 m outside it. In Japan, Hunjo and Takakura [8], using a numerical model, showed a range of 200 m in the direction of the wind, the width of the green area being 300 to 700 m. The results of their simulations indicate that the range of the effect is a function of the green area scale and the intervals between the green areas. They suggest that smaller green areas with sufficient intervals are preferable for effective cooling of the surroundings to lumped larger green areas.

The cooling effect in small areas is obtained mainly through shading 9, 10. Other factors that inhibit penetration of solar radiation, besides shading, may also play a role in determining the cooling effect of a green site. The geometric configuration may also affect temperature variations, as was found to be the case in non-wooded building structures 11, 12.[1]

In the present project, to allow for geometric variations, the empirical study covered a set of urban green habitats of different sizes, shapes and built-up morphology. Measurements of air temperature, humidity, wind velocity, solar radiation penetration and surface radiant temperature[2] were carried out at the sites during the summer of 1996.

The object of this empirical study was to determine the factors affecting the microclimate inside the green site and its influence on the surrounding areas. On the basis of the statistical findings, an empirical model was developed for predicting the maximum cooling effect inside the site and its range outside the site. The model may be useful in cost–benefit analysis in designing a green area.[3]

Section snippets

Methodology

Statistical analysis of the collected experimental data on air temperature and humidity inside and outside the sites was carried out with the aid of linear regression models. The relationships to be explained are the cooling and humidity effects of the site on its own microclimate and on its immediate surroundings.

Comparison of these effects among different sites is problematic. From the publications cited above it is known that the air temperature inside the site depends on the shading

Sites and observations

The present study was conducted during the summer (July–August) of 1996 on 11 urban green areas with trees, chosen so as to represent a variety of typical areas such as small gardens and courtyards, avenues with and without traffic and “canyon” streets with trees. The sites were located in the so-called Dan complex, consisting of Tel-Aviv proper and the adjoining cities of Givatayim and Ramat-Gan (Fig. 1). This region is characterized by an almost uniform topography and small climatic

Analysis of the cooling effect

The multiple linear regression method was applied in estimating the cooling effect inside the sites. The explanatory variables considered are shading coverage, background (reference) air temperature, and the site specific effect.

The shading coverage plays an important role in predicting the air temperature inside a site in analytical models (e.g., Refs. 7, 10). In a green area with trees, the cooling effect is determined by the amount of canopy shading. Different levels of shading will produce

Thermal effects of green sites on their surrounding areas

The “surrounding area” of a site is defined in this study as the area just outside the entrance to the site (case A) or a street crossing the site (case B). These areas have no green vegetation.
For each site, several outside points of measurement were chosen at 20 m intervals. The air temperature measurements at these points were taken at the same hour between 1430 and 1530 h as at the other sites. The cooling effect was calculated as the difference between the air temperature at each

Summary and conclusions

In this study, we investigated the cooling effect at 11 small urban green sites with trees. The sites studied here have various geometric configurations: two gardens, four avenues, one green square, two courtyards and two streets. The analysis was carried out on measured air temperature data at noon gathered during July–August 1996, in the Tel-Aviv urban complex.

The average air temperature at the surrounding areas outside near the sites was 32.7°C, at 1500 h, with relatively small deviation

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