2.5A LARGE TREES AS A BARRIER BETWEEN SOLAR RADIATION AND SEALED SURFACES: THEIR CAPACITY TO AMELIORATE URBAN HEAT IF THEY ARE PLANTED STRATEGICALLY TO SHADE PAVEMENT

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ABSTRACT

The urban heat island is in part caused by sun-exposed pavement absorbing radiation, releasing it overnight, hence keeping neighbourhoods warmer than if the surface was vegetated or shaded. Mature large-growing road-side trees overlap streets, shading large proportions pavement, intercepting radiation before it reaches sealed surfaces.

In a preliminary study road surface temperatures were measured in locations of various degrees of shading. Results revealed that even after a full night of cooling exposed sites are still significantly warmer than shaded sites. In order to achieve aerial coverage and avoid tedious manual mapping of trees, high resolution satellite images were used to map vegetation patterns across the city. The resulting vegetation maps were combined with coarser thermal infrared data to examine the influence of vegetation on temperatures.

Even a single block of high vegetation cover in the middle of an otherwise highly sealed downtown area, such as the City Hall block in Huntington, caused a clear depression in surface temperatures at the available satellite resolutions. Large buildings and parking lots in otherwise vegetated residential neighbourhoods on the other hand form clearly detectable hotspots.

Mostly due to budget problems, the City of Huntington is currently in the process of removing all large growing trees along the city's right of way. Results of this study provide strong arguments against this practice. The applied technique to identify cool and hot spots could be adapted by city planners in order to ameliorate the environmental quality in cities, and to identify gaps in urban forests.[1]

1. INTRODUCTION

The urban heat island (UHI, Arnfield, 2003) is in part caused by heat production from cars, heating and air conditioning of buildings, industrial processes, and urban structures that may slow winds and hence prevent heat exchange. However, another main component of the extra heat in cities comes from dry sealed surfaces. Sun-exposed pavement absorbs radiation throughout the day, charging up on heat like a battery, and then releasing it overnight. This release of sensible heat keeps the neighbourhoods warmer than if the surface was vegetated or shaded. Parks with increases surfaces of vegetation have been found to have a cooling effect (Oke, 1989).

Urban trees have many benefits for the environment such as carbon sequestration, air pollutant removal, vehicle emission reduction, and reduced energy consumption (e.g. Nowak et al., 2002, 2006; Nowak and Crane, 2002; Dwyer et al., 2003; Scott et al., 1999). Many cities have started tree planting programs in order to improve environmental conditions and alleviate the urban heat island effect (e.g. Chicago, New York: Rosenzweig et al., 2006).

Although existing literature recognizes the cooling effect of trees in urban areas (Oke, 1989, Laverne and Lewis, 1996, Rosenzweig et al., 2006), one benefit that has not been discussed in the literature so far is that of mature large-growing trees that are planted along road sides. These trees overlap streets to a degree where a large proportion of the pavement is shaded, intercepting radiation before it reaches sealed surfaces. Trees absorb the energy, converting it into latent heat and chemical energy (evapotranspiration and photosynthesis) instead, preventing the warming.

Huntington, West Virginia, used to be famous for its accumulation of large trees lining the streets. However, due to financial problems the city has changed the way trees are handled today. Dead limbs are no longer pruned; instead the entire tree is cut down. Currently more than 700 large trees are currently tagged for removal. It is no longer legal to replant large growing tree types, allowed are small trees such as Bradford pears, cherry, and crabapple.

In this study the influence of vegetation and trees in particular was studied at two scales: pavement temperatures were examined in locations of various shading levels (microclimate) and high resolution satellite images were combined with coarser thermal infrared data to examine the influence of vegetation on temperatures at a local scale in Huntington.

2. FIELD MICROCLIMATE STUDY

In a preliminary study pavement temperature was examined as a function of sun exposure during a hot spell in July 2005. For this purpose canopy width and tree height of all road-side trees along 12 city blocks were measured and mapped along with all paved surfaces of the study area. A three dimensional surface of canopy height was created and shading was simulated in half hour increments across a July day (GIS). Twenty locations of various levels of cumulative shade across the day were visited on hot clear days in the afternoon, around sunset, and again the next morning before sunrise. Surface and air temperatures were measured on site. Regression analysis was then conducted to examine the relationship between shade proportion and pavement temperature.

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The most striking result was that before sunrise on mornings after hot summer days surface temperatures in exposed locations were still two degrees warmer than in shaded sites (Walz, 2006). A comparison of air and surface temperature also showed that far into the night shaded locations have cooler surfaces than the air that moves above, acting like a cooling element. The situation was reversed, more extreme, and lasted through sunrise for sun-exposed pavement.

3. TREE MAPPING BY REMOTE SENSING

While the above pilot project allowed the study of particular surface types and a look under the tree canopy it was limited in aerial coverage. Only point measurements were taken and tree mapping was tedious and therefore limited to small areas. Tree cover also keeps changing rapidly in Huntington because of the City's effort to remove large trees. Other surface types, such as roofs, tree top, and even other yard vegetation, could not be included due to access limitations, although these areas will have an influence on the local climate. To get around these problems the study was expanded to include satellite information.

Land cover in cities is generally highly fragmented with small patches of vegetation interspersed with buildings, roads, parking lots, and other features. Coarse scale satellite information does not pick up these details (Lo et al., 1997). In this study high resolution satellite images (4 and 1 meter cell sizes) were used to map vegetation in a city.

In order to identify vegetation the Normalized Difference Vegetation Index (NDVI) was calculated and the threshold value between vegetated and non-vegetated areas was determined visually (approximately 0.2). A new procedure to map canopy that overlaps with roads was tested using two sets of images (Figure 1). The first was taken in early spring when only the lawns were green but canopies still bare, the second originated in early summer when canopies were fully developed. The difference in spatial distribution of high NDVI values between the two seasons indicates the location of tree canopies over sealed surfaces.

A close match was achieved between the outcome of this technique and the manually mapped tree canopies of the initial 12-block study area. This new method of determining tree cover over roads and vegetation in general simplifies canopy mapping. Large areas in cities can be processed in this manner.

Color IR

NDVI: vegetation shown green

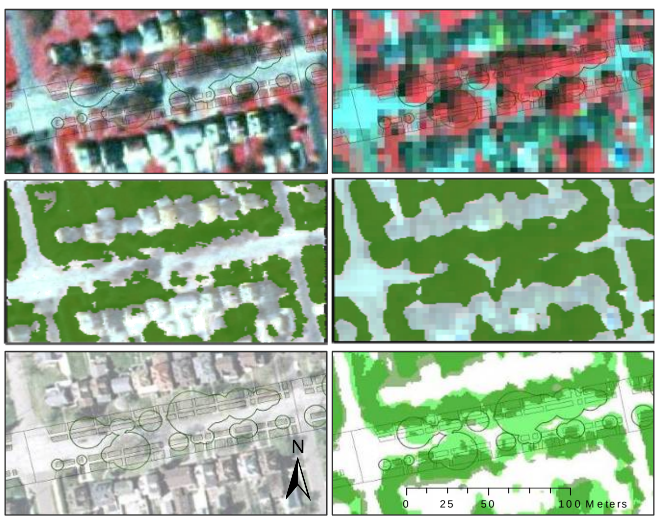

Figure 1. Tree canopy mapping over sealed surfaces using high resolution satellite images and NDVI. Left: March (green lawns, trees bare), right: May (full canopy); bottom right: vector data from field measurements of trees, lawns (dark green grid), canopy over sealed surface (light green).

4. LOCAL THERMAL ANALYSIS

Thermal infrared (TIR) satellite information does not exist in resolutions as high as those used above. The question is whether or not the available resolution is sufficient to distinguish certain hot spots due to vegetation differences in highly fragmented cities. In order to find an answer, thermal information was extracted from Landsat Thematic Mapper images from the hot spells in July 2005. The digital numbers of the thermal infrared channel were converted to degrees Celsius. Vegetation proportions were regressed against temperature.

Not surprisingly vegetation proportion is inversely related to surface temperatures. Trees however have the capacity to extend the vegetation cover over areas where there would otherwise be pavement. Even a single block of high vegetation cover in the middle of an otherwise highly sealed downtown area, such as the City Hall block in Huntington, West Virginia, caused a clear depression in the surface temperatures at the available satellite resolutions. Large buildings and parking lots in otherwise vegetated residential neighbourhoods on the other hand form clearly detectable hotspots (Figure 2).

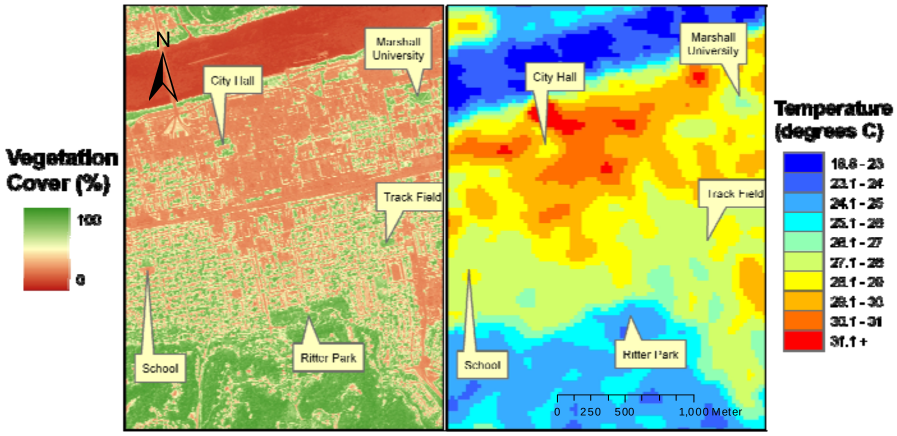

Figure 2. Comparison of vegetation and thermal patterns: fractional vegetation cover (left) derived from NDVI values of an Ikonos image from May 2005 and temperature (right) as derived from the TIR channel of a Landsat TM image from July 2005. Single city blocks that do not match the vegetation pattern of their surrounding show distinguishable hot or cool islands.

4. CONCLUSIONS

Mostly due to budget problems, the City of Huntington is currently in the process of removing all large growing trees along the city's right of way. Results of this study provide strong arguments against this practice. The technique of combining high resolution satellite data with relatively coarse thermal information to identify cool and hot spots in cities could be adapted by city planners in order to ameliorate the environmental quality in cities, and to identify gaps in urban forests.

Trees have the capacity to extend vegetation cover over areas where there would otherwise be pavement. Even a single block of high vegetation cover in the middle of an otherwise highly sealed downtown area, such as the City Hall block in Huntington, can cause a clear depression in surface temperatures at the available satellite resolutions. Large buildings and parking lots in otherwise vegetated residential neighbourhoods on the other hand form clearly detectable hotspots.

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