45th Anniversary Architecture of Hasanuddin University

Proceeding

international seminar on

green

architecture & environment

"Toward Green Compact Cities"

Architecture Department
Engineering Faculty
Hasanuddin University

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INTERNATIONAL SEMINAR
ON GREEN ARCHITECTURE AND ENVIRONMENT: TOWARDS GREEN COMPACT CITIES

Makassar - Tuesday, October 14, 2008

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ISBN :
978-979-15469-4-2

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CONTENT

MITIGATION OF URBAN HEAT ISLANDS IN CITIES

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Abstract. A heat island is an area of land whose ambient temperature is higher than the land surrounding it. Many studies have shown a direct correlation between the density of population in a city and the intensity of the heat island effects. Higher urban temperatures increase the demand for electricity for cooling and air conditioning in warm conditions leads to an increase in the production of carbon dioxide and other pollutants in the atmosphere. These pollutants in turn contributed to the increasing global temperatures resulting in the 'greenhouse effect'. In this paper we proposed the proto-typical designs which help to illustrate the concepts of landscapes that can be applied to counteract the urban heat in parking lots and urban parks. Mitigation of such urban heat islands by landscapes can contribute to the sustainability of the city.

Keywords: *urban heat island, urban warming, trees, landscapes.*

1. URBAN HEAT ISLAND

Warmer air temperature in cities as compared to air temperatures in the surrounding rural areas is the principal diagnostic feature of urban heat island. Alterations of urban surface by the people may result in a diverse microclimates whose aggregate effect is reflected by the heat island (Landsberg 1981). Buildings, paving, vegetations, and other physical elements of the urban fabric are the active thermal interfaces between the atmosphere and land surface. Their composition and structure within the urban canopy layer, which extends from the ground to about roof level, largely determine the thermal behavior of different sites within a city (Goward 1981). Thus, urban heat islands can be detected at various ranges of scales, from the micro-scale of a shopping center parking lot to the mezzo-scale of an urbanized region.

The horizontal structure of a hypothetical urban heat island is characterized by a 'cliff' (Figure1.0) that follows the city's perimeter and is steepest along the windward boundary (Oke 1982). This sharp temperature gradient leads to the pulses of cool air flowing into the city at night. Intra-urban heat islands and cool islands reflect a localized effect of differences in building density and surface cover. Temperatures in mid-latitude parks can be 1° to 3°C cooler than outside, and their influence can extend to several hundred meters beyond the park boundary (Oke 1989).

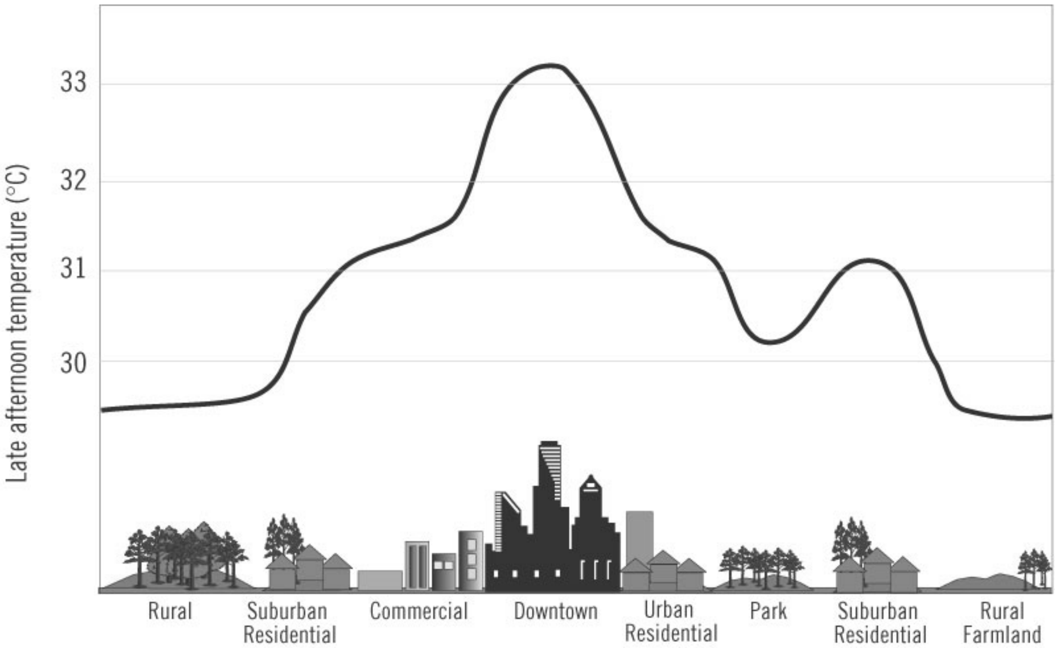

Fig 1. Urban Heat Island Profile

Differences in urban and rural temperatures are usually greatest (3° to 8°C) in the early morning near the city core. However, the daytime temperatures are often warmest outside the core in a zone within a lower buildings or more exposed pavement (Tuller 1973).

Analysis of a temporal difference shows that the intensity of urban heat island is greatest at night, primarily due to differences in urban-rural cooling (Oke 1982). At sunset, rural areas begin to cool rapidly while urban areas remain warm and then cool at a slower rate. Different urban-rural cooling rates at sunset produce maximum heat island intensities of three or five hours later. At sunrise, urban areas begin to warm relatively slowly, sometimes producing urban 'cool islands' during the morning.

2. EFFECTS OF URBAN HEAT ISLAND

Urban temperatures have been increasing in cities around the world. Comparisons of temperature data from paired urban and rural weather stations suggest that the recent warming trends are due to the urban heat island effect rather than a change in regional weather. For example, the data from thirty-one California cities show a warming rate of 0.4°C per decade since 1965 (Akbari et al. 1992). Additionally, scientists project a greenhouse warming rate at about 0.3°C per decade, which could exacerbate urban heat island effects.

Urban heat island can contribute to global warming because warmer temperatures resulting in greater demands for cooling. Coal-burning power plants release about 0.45 kilograms of carbon per kilowatt-hour every time the electricity is generated. Therefore, mitigating urban heat islands can indirectly reduce the carbon dioxide emissions at any power plants with the concentrations of atmospheric CO_2. Large-scale plantings of urban trees and the use of light-colored surfaces can conserve about 2 percent of the total U.S. carbon production (Akbari et al. 1992).

Concentrations of urban smog are increasing at an escalating rate in ambient temperature. One study found that the incidence of smoggy days can increase by 1 percent for each degree Celsius increase in temperature (Akbari et al. 1992). Because of many large cities have smog problems where its concentrations are sensitive to small increase in temperature, thus any attempt to control urban heat islands is one mean of improving air quality. Urban heat island can have a numerous other adverse effects on the physical and psychological well-being of city dwellers. Heat-aggravated illness and death are related to increased cardiovascular diseases that weaken resistance to heat. Unnaturally high heat loads can directly and indirectly reduce life expectancy (Weihe 1986).

3. MITIGATION OF URBAN HEAT ISLANDS

The thermal behavior of cities is largely a by-product of urban morphology or, more specific, the composition and three-dimensional structures of materials that constitute the urban canopy layer. Mitigation of urban heat islands by landscapes can contribute to the sustainability of the city. Since most electrical utilities experience peak demands during summer as a result of air-conditioning loads. This section reviews the mitigation potential and problems associated with vegetations that are commonly manipulated during the development process.

The energy-saving potential of trees and other landscape vegetation has been documented (Meier 1991). Vegetation can mitigate urban heat islands directly by shading heat-absorbing surfaces, and indirectly through evapotranspirational (ET) cooling. Meier (1991) reported that vegetation consistently lowered the wall surface temperature by about seventeen degrees Celsius and reduced the usage of air-conditioning costs by 25 to 80 percent. In most circumstances, the impact of one or several trees on ambient temperatures and cooling load are small compared to the shading effect. Cool air produced in the tree crown is dissipated by the much larger volume of air moving through the tree. However, large numbers of trees and expansive green spaces can reduce local air temperatures by one to five degrees Celsius, and the advection of this cool air can lower the demand for air conditioning (Oke 1989). Trees in urban environments can experience drought stress due to limited soil moisture and large heat gains from absorbed and reflected radiation (Oke 1989). Theoretically, for stressed plants ET cooling is least during midday to late afternoon when water vapor deficits are greatest and stomata are closed. Therefore, actual ET cooling effects may be less than projected. The relative importance of ET cooling has been disputed by Lowry (1988), who calculated an ET cooling rate of 0.3°C per hour and a sensible heating rate of 0.1°C per hour along the ten meters of street canyon containing six mature trees.

Although the potential for planting trees in cities is great and the considerable mitigation of urban heat-island effects is possible, however, there are problems associated with tree planning. Firstly, trees can be serious liability if they are becoming a public hazard, interfering with above ground or below ground utilities; hence it requires an excessive maintenance. Secondly, trees can have an adversely affect on the urban climate by blocking solar access in winter, by trapping pollutants within the urban canopy layer and by increasing aerodynamic roughness, therefore it reduced country-city air flow and caused a convective heat loss. Thirdly, trees can be relatively expensive to plant and slow to provide a return on investment. Fourthly, increased tree planting can increase the amount of pollen that affects allergy sufferers, the usage of water supplies, and the amount of solid waste that goes into landfills. However, these problems can be minimized through careful planning, wise selection of species, and better designs that can use the hydrologic, ecologic, atmospheric, restorative, and aesthetic benefits that vegetation can provide.

4. DESIGN EXAMPLES

These examples exemplify the usage of vegetation in situations that are typical of parking lots, and urban parks. Each design addresses objectives as defined for street canyons and stated for hot-climate cities. The concepts are as follows:

- Promote summertime cooling and conservation of air-conditioning energy by reducing irradiance and increasing heat loss through latent heat flux, convection, and long-wave radiation.
- Allow for the dispersion of air pollutants by promoting down and cross-canyon circulation and mixing with air moving above the city.
- Provide for a solar access during the winter by increasing irradiance.
- Shelter pedestrians from extreme winds, turbulence, and downdrafts near buildings.

4.1. Parking Lots

Parking lots are ubiquitous features of commercial strips and at shopping malls that surround the urban core. Issues of visibility, safety, screening, and access are central to traditional parking-lot design. In Figure 2, the proposed design incorporates these concerns as well as the needs for shade, buffering, and water harvesting (Beatty 1990). Trees are aligned in north-south rows to shade as much as possible the pavement during the summer. Broad-spreading tree crowns increase the amount of shade. Ample growing space and soil moisture enhance the survival of trees, growth, and evapo-transpirational (ET) cooling effects. Trees are pruned at a high level for safe visibility and truck clearance. Pruning also promotes sub-canopy circulation for cooling and pollution dispersion. Rainfall runoff drains into buffer plantings along the perimeter, where it is detained. These buffer plantings exhibit structural diversity, with a variety of species in several strata.

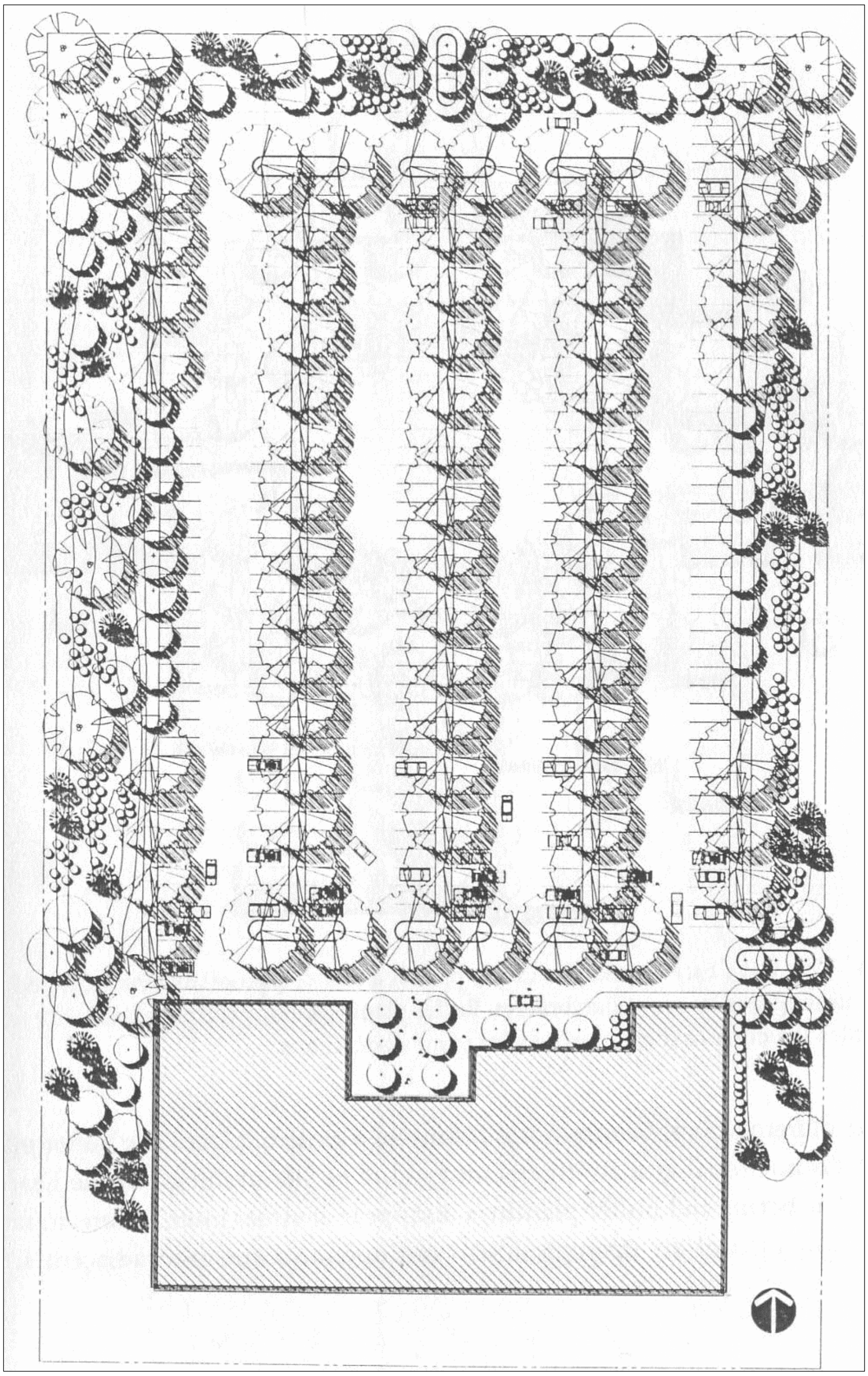

Fig 2. Trees in the parking lots are arranged in north-south rows to provide maximum shade on pavement during summer.

4.2. Urban Parks

Parks can be an important source of fresh cool air within the city. The park in Figure 3 is designed to increase a nocturnal cooling and the advection of cool air into the warmer surrounding neighborhood. Transpiring turf shades at the ground and it cools the air. Although trees in turf can increase the ET cooling effect, nevertheless they also can reduce radiant heat loss to the sky and convection/advection. Multilayered plantings of drought-tolerance species create a buffer along berms that define the park perimeter. The use of native-looking plants in forms that reflect the structure of native plant communities promotes a sense of place. The buffer plantings are multifunctional and important symbol of naturalness in the heart of the city. The berms and buffer plantings disappear at street intersections to facilitate the flow of cool air through downwind openings and into adjacent street canyons.

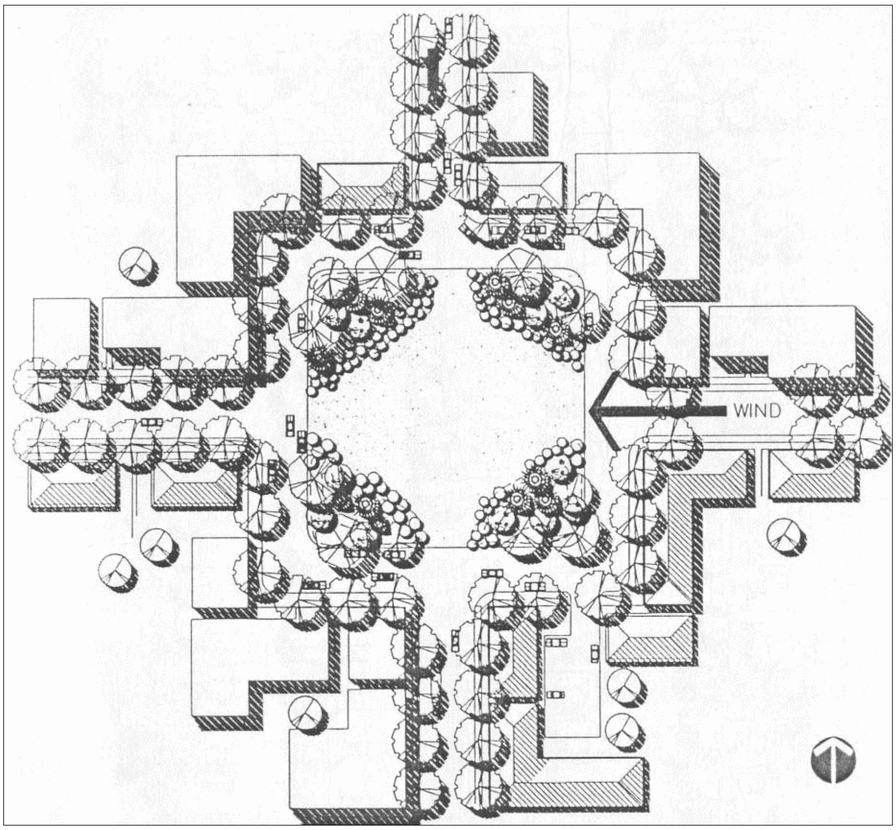

Fig 3. Buffer plantings along the urban park boundary reflect the complex structure of the region's native plant association. Open turf area in this urban park is a source of cool air that is carried into the surrounding area by prevailing breezes

5. CONCLUSION

Heat island increases the discomfort both outdoors and indoors. The stress is imposed by the high temperatures that may lead to sickness. During summer season the demand for electricity increases in hot-climates cities and urban heat island magnifies this demand as more energy are used for indoor cooling. As energy consumption is a major source of greenhouse gases, the concentration of greenhouse gases increases with the intense usage of energy which leads to climate change. Prototypical designs illustrate the concepts of landscapes can be applied to counteract urban heat island in parking lots and urban park. Mitigation of urban heat islands by landscapes can contribute to the sustainability of the city.

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