EFFECTS OF VEGETATION CHARACTERISTICS ON MICROCLIMATE CONDITION IN URBAN AREA

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ABSTRACT

The rise of temperature outdoor has a significant effect on temperature increase inside building, so that it becomes harder to achieve thermal comfort in summer and causes more utilization of air conditioner occurs. Trees should be considered as real means for the improvement of microclimatic conditions in outdoor spaces. Based on those conditions, this research investigates the effects of vegetation characteristics to the urban climate by literature review and simulation of meteorological model MM5.
The results show that vegetation characteristics can influence the thermal performance and microclimate conditions. Evergreen broad leaf forest can reduce temperature of about 3°C and mixture vegetation and water bodies can reduce temperature by more than 5°C. Therefore, vegetation is useful to improve human environment in future.

Keywords: Vegetation, Urban Climate, Temperature, Thermal

I. INTRODUCTION

Urban areas have particular climatic conditions with a higher temperature than exposed country-side. Weak winds and an amount of sunshine vary according to the degree of pollution, urban density, orientation of the streets and the shade provided by buildings. Urban microclimates are complex because of the number and diversity of factors which come into play. Solar radiation, temperature and wind conditions can vary significantly according to density, topography and local surroundings[1,2]. Urban areas are warmer than their rural surroundings. This is known as the 'Urban Heat Island' (UHI). On hot summer days, urban air can be 2-10°F (2-6°C) hotter than the surrounding countryside[3]. It causes climate change; Half of the global warming trend from 1980 to 2002 is caused by Urban Heat Island[4,5].

Climate change can be mitigated by land cover improvement and reduction of anthropogenic heat and the utilization of wind through local wind circulation systems[6]. Modification of land cover in urban areas can cause local air and surface temperatures to rise several degrees higher than temperatures of surrounding rural areas[7]. The proper placement of trees can lower air conditioning loads by 30%[8] .

Buildings surrounded by plants have lower environmental temperature than those of buildings that are distant from plants. Temperature reduction depends on the level of building density[9]

II. URBAN CLIMATE PHENOMENON

Urbanization has negative impacts on the environment mainly by the production of pollution, modification of the physical and chemical properties of the atmosphere and covering of the soil surface. Considered to be a cumulative effect of all these impacts is the UHI. It causes a metropolitan area into hotter than the surrounding area. This occurs when the rate of atmospheric temperature increase from heat stored on roads and building surfaces and released from air conditioning systems, road vehicles and other sources significantly higher than the rate of atmospheric temperature decrease from plants transpiration, river evaporation and other sources. The UHI negative impacts are not only for residents of urban-related environs but also humans and their associated ecosystems located far away from cities. In fact, UHIs have been indirectly related to climate change due to their contribution to the greenhouse effect, so that it causes global warming[1,2].

II. IMPROVE URBAN CLIMATE BY LAND SURFACE MITIGATION

The main contributing factors are changes in land surface characteristics (albedo, thermal capacity, and heat conductivity), replacement of vegetation by asphalt and concrete, and decreased surface moisture available for evapotranspiration. Vegetation intercepts radiation and produces shade, which contributes for reducing urban heat release. The decrease and fragmentation of large vegetated areas such as parks is not only reducing these benefits, but also it inhibits atmospheric cooling due to horizontal air circulation generated by the temperature gradient between vegetated and urbanized areas (i.e. advection). On the other hand, the narrow arrangement of buildings along the city's streets forms urban canyons that inhibit the escape of the reflected radiation from most of the three-dimensional urban surface to space. This radiation is ultimately absorbed by the building walls (i.e. reduced sky view factor) so as enhancing the urban heat release[1,10].

Natural surfaces are often composed of vegetation and moisture-trapping soils, so that they utilize a relatively large proportion of the absorbed radiation in the evapotranspiration process and release water vapor contributed to cool the air in their vicinity. In contrast, built surfaces are composed of a high percentage of non-reflective and water-resistant construction materials contributed to the rising of hot air in atmosphere. There are two main UHI reduction strategies: first, to increase surface reflectivity (i.e. high albedo) for reducing radiation absorption of urban surfaces, reflective surfaces simply results from light colored or white paint on the surface of a given construction material or from cover the construction material surface with a white membrane. The second, to increase vegetation cover mainly in the form of urban forests and parks, in order to maximize the multiple vegetation benefits in controlling the temperature rises[1,10]. Therefore, it is necessary to know the type of vegetation effectively reducing the temperature.

Strategies to lower urban temperatures and achieve related benefits include installing reflective cool roof son residential and commercial buildings; planting trees and vegetation, including green roofs; and using cool paving materials for roads, sidewalks, and parking lots. Widespread implementation across a community can reduce urban temperatures, energy use, air pollution, and heat-related health impacts. Heat island reduction strategies also benefit individual home and building owners directly. Cool roofs and shade trees, for example, can save money on summer time cooling bills[11].

III. IMPACT OF VEGETATION CHARACTERISTICS TO REDUCE URBAN TEMPERATURE

Table 1 show that thermal conditions in urban area (Nagoya) during 27-31 August 2010. It portrays that thermal performances are slightly different in each land surface categories. Generally, vegetation decreases temperature for several degrees and water bodies decrease temperature more than vegetation in urban area. This difference is caused by the physical interaction on the surface, if the sun strikes earth surfaces and heats them up, the surfaces start interacting with the air layer above them and exchange heat and energy. The extent of this exchange is dependent on the physical properties of the surface being irradiated. These properties include thickness, color and roughness, thermal conductivity, specific heat capacity, density, moisture content, and emissivity.

Table 1. Thermal condition average at daytime in Nagoya

Land cover Description	Temperature (°C)	Relative Humidity (%)	Wind Speed (m/s)
Real Condition	30.3	68.9	2.5
Grassland	30.1	69.1	3.1
Mixed Forest	29.4	74.2	2.1
Deciduous BF.	29.5	73.7	2.2
Evergreen BF.	28.7	78.7	1.9

27-31 August 2010; day time (6.00-18.00 JST).

Thermal condition in urban area is over the thermal comfortable levels. Thermal comfort in hot-humid tropic area is temperature: 24oC-26oC, relative humidity: 40-60%, wind velocity: 0,6-1,5 m/sec with the activity of relaxed and a thin dress[12]. The outdoor thermal comfort in cold climate area; temperature is about 18–23°C[13,14].

Table 2. Temperature Daytime in Urban Area

City	Real Condition (°C)	Evergreen BF	Mix Evergreen & Water Bodies (°C)
Tokyo	35.85	32.80	28.85
Nagoya	34.60	32.50	27.65
Gifu	34.15	32.35	28.35

31 August 2010; day time (6.00-18.00 JST).

Decrease of temperatures from existing condition to those on modification land surface during daytime is greater in evergreen BF of around 3°C in Tokyo, 2°C in Nagoya and Gifu. Temperatures of mix vegetation with water bodies are lower than those of real conditions by around 7°C in Tokyo and Gifu (see Table 2). It indicates that the water bodies have significant impact for reducing temperature. They tend to store the heat in warm periods and release it in cold periods. This is because the thermal capacity of water is high, meaning it takes a lot of energy to change the temperature of water. Thus, during the summer, land areas near a large body of water may not heat up as much as areas that are not close to water, because the water itself is absorbing much of the heat energy.

Therefore, the combination vegetation and water bodies around the building have a large effect on temperature, air movement, and humidity. The most obvious use of trees for landscaping is to shade windows, walls, and roofs and to reduce solar heat gain that penetrates to the interior of the building. The area surrounding the building has a direct impact on air temperature. Paved surfaces, especially blacktop, absorb huge amounts of heat from the sun and radiate it back into the surrounding air, by shading these outdoor areas, the air temperature can be kept down. This will result in lower indoor temperatures. If hard surfaces are required, a product called "grasscrete" can be used. It provides a hard surface but allows grass to grow through it to provide a cooler surface. A shaded grass lawn would be the best option to surround the building.

Furthermore, with the combination between vegetation and water elements, the cooling effect of vegetation is enhanced by the process of evapotranspiration. Plants can absorb solar radiation and evaporates water into the air. This maintains lower temperatures that drop toward the ground and move the warmer temperatures up (by convection) and away from the building. In using trees to shade the building, it must be taken into consideration that during the winter, the heat gain from the sun is very beneficial. The ideal situation is to place trees so that they provide shading during the summer, but not during the winter. One way of doing this is by using deciduous trees, those trees that lose their leaves during the winter, so that the desired sunshine in the winter is not blocked by trees.

In addition, several previous studies showed that dense vegetation is effective for reducing temperatures and increasing human comfort. Lower surface temperatures are generally observed in green areas, although higher temperatures have been found on soil and building areas during the daytime. The effect of vegetation on reducing surface temperatures in urban areas is smaller than that in the suburbs. In urban areas of Tokyo, the surface temperature was 1.4–2.7°C in green areas, whilst it was 2.0–3.4°C in buildings and 2.3–4.9°C on the soil. In the countryside, the surface temperature was 2.6–2.8°C in forests, but 3.3–4.2°C in buildings, and 5.1–5.9°C on the soil. At night, lower surface temperatures were measured in green areas in urban environments, but higher surface temperatures were found in forests in the suburbs[15]. In Tama Town, Tokyo; surface temperatures measured on grass fields in parks are much lower than those measured on asphalt and concrete surfaces. Air temperatures measured at 1.2 m above a grassy area are at least 2°C lower than those measured above hard surfaces in commercial and parking areas[16,17].

IV. CONCLUSION

Changes of the vegetation characteristics can influence the thermal performance and microclimate conditions in urban area; temperature decrease about 3°C in evergreen. Mixture of evergreen and water bodies can reduce temperature by more than 5°C. Therefore, combination of vegetation and water elements in a garden, park, and urban forest are useful to improve thermal comfort and microclimate conditions. Vegetations absorb CO_2 and sunlight, artificial ponds can increase evaporation, and mixture of them is effective to increase surface evapotranspiration.

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