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Ability of Trees in Reducing Air Temperature

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ABSTRACT

The trees presence in the Green Open Space of City is able to reduce the city air temperature. Trees can provide coolness to the hot city (heat island) due to the reflection of solar heat from buildings, asphalt and steel. Urban temperature heat has 30-10oC higher air temperatures than rural. The trees can reduce urban temperatures because they can intercept, reflect, absorb and transmit the sunlight. The ability of trees to change the air temperature under the canopy is influenced by morphological characteristics. There are 31 green open spaces in Malang city that having 75 tree species, which have different morphology and ability of interception, absorption and transmission of solar radiation. Morphological data of the trees (tree height, stem diameter, canopy width, thick canopy, leaf color, characters of the trees and leaves, branching structure, canopy shape and density of the canopy) was obtained by observing the mature trees (> 10 years), which grow solitary at the Poerwodadi Botanical Garden in Pasuruan, East Java. Microclimate was observed using Thermo-hygrometer (delta air temperature and humidity under the canopy), Anemometer (wind velocity), luxmeter (light intensity). Increased ability of the trees to absorb solar radiation followed by their abilities to reduce the air temperature under the canopy (0.4 -3.8 OC). There are 45% of tree species (38 tree species) in green open space in Malang city, which have the ability to reduce the air temperature to 2 ° C under the canopy.

Key words: Green Open Space, Morphology of trees, Reduce air temperature.

INTRODUCTION

As element of the Green Open Space, trees play their roles as reducer of air pollution, oxygen producer, and shade, reducer of air temperature, atmospheric refiner, and improving quality of urban environment. It suggested that the artificial landscape elements at the urban that comprise of building construction and the paved roads have high air temperature at the daytime and low air temperature on vegetation [1], also supported that vegetations have better effect in controlling the increased air temperature due to the existence of artificial elements made by human [2, 3].

Trees are able to provide coolness to the hot city (heat island) due to the reflection of solar heat from buildings, asphalt and steel. Urban temperature heat has 30-10oC higher air temperatures than rural. The trees plantation at the specific area will reduce the atmospheric temperature in the related area [4]. The trees can influence the urban temperatures because they can intercept, reflect, absorb and transmit the sunlight. Besides that, the branching pattern and the tree shapes have also more influential in changing air temperature under the canopy. Trees could change the urban temperature. Leaves could intercept, reflect, absorb, and transmit the sunlight. Their effectiveness depends on the species, such as, shady, leafy, more branches and twigs. Each species has specific characteristic, color, texture, and size [5,6]. A part of light shed on the leaves will be reflected and transmitted, and quantity of the reflected and transmitted light depends on characteristic of the leaves. While the sunlight falls through the spaces between leaves from a given leaf layer will go through the lower layer and quantity of the sunlight depends on the leaf position. The passing-through sunlight from a layer will falls on the leaf surface below, in which it will be partly transmitted, whereas the sunlight that falls through the spaces between leaves will go through the lowest layer, therefore it will influence air temperature under the canopy.

The limiting presence of Green Open Space in City and the increasing air temperature in urban area require proper selection of suitable trees, which are able to reduce air temperature under the canopy that will implicate the reducing air temperature in urban area. There are 33 Green Open Spaces in Malang city, East Java, which have different shape and structure. Diverse vegetations have significant influence on the ease of such Green Open Space as well as the trees domination, which have diverse morphological characteristic. Feeling at ease and comfortable is an implication of 4 microclimate elements, which includes air temperature, humidity, wind velocity, and solar radiation intensity within the Green Open Spaces. Therefore, further research is

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required to obtain suitable trees, which are able to reduce air temperature under the canopy optimally, based on morphological characteristic of the trees.

MATERIALS AND METHODS

The research was conducted at Purwodadi Botanical Garden from August to December 2010, by selecting 75 trees, which are considered mature, > 10 years old, and grow solitary. The tree selection was based on result of the survey at 33 Green Open Spaces in Malang city, East Java.

Method of the research was direct observation on the field. The observed parameter on the field was morphology of the trees, which were categorized into tree height, thickness of the canopy, and height of the tree branching that was measured using clinometers type Suunto PM 5. The canopy shapes were divided into six main categories, such as, fastigate columnar, spreading,rounded, pyramidal, and weeping through direct observation. The canopy width was measured using rollmeter. It was conducted in order to obtain the canopy diameter by determining 2 points of the wider shade of the outer canopy at 12.00 a.m. The stem diameter was measured using rollmeter as height as DBH (Diameter at Breast Height) of the tree stem. The measurement was taken 140-145 cm from the soil surface. The canopy density was obtained by estimating the canopy shade width/unshady ground area x 100%. Characteristic of the trees (evergreen and decidious) was obtained through direct observation on the field and information from textbooks, internet, and Purwodadi Botanical Garden. The branching patterns and types included (monopodial, sympodial and dichotomy). Color of the leaves was obtained by taking samples of the observed leaves using RHS (Royal Horticulture Society) colour chart. Texture of the leaves was obtained through direct observation on the field by observing the leaf size and the leaf structure was obtained through direct observation on the field by observing the leaf structure.

The microclimate included ability of the trees to transmit the sunlight using lightmeter type LX-101A, observation under the canopy and outside the canopy conducted at 12.00 a.m. during maximum irradiation. After obtaining the sunlight intensity, percentage of the absorbed and intercepted light will be gained. The absorption value is calculated using equation : [(intensity outside the canopy – intensity inside the canopy) / intensity outside the canopy x 100%]. Equation to find out the transmission value is : (100 – Absorption). Air temperature and humidity are obtained by measuring air temperature/humidity under the canopy and for outside the canopy, it used thermohygrometer (thermometer and hygrometer – TA218c and wind velocity is obtained by applying direct measurement on the field using Anemometer Vane Probe (Lutron AM-4201), observation was based on the wind direction where the wind come from and behind the trees.

Relationship between morphological characteristics of the trees (tree height, branching height of the tree, the canopy thickness, canopy width, and density of the canopy) and the microclimate (air temperature, humidity, absorption, transmission) was analyzed by regression.

RESULTS AND DISCUSSION

Based on result of observation on 75 trees (Table 2) at the Green Open Space in Malang City, 25.33% of them are originated from Indonesia and 74,67% are originated from abroad in the form of rounded canopy for about 48% and 81% of trees have canopy density for about 50 – 80%. 47% of the tree height is categorized medium (9-18 m), and 40% of the trees have branching height > 4 m and 40% tree species with the canopy width > 9 m. 76% of them are evergreen plants that having sympodial branching (53.33%). Leaf texture, leaf structure, and more colorful leaves, which are planted at the Green Open Spaces in Malang are trees that having leaf texture of 6 – 8 cm in size, folium compositum and the leaf color of Strong Yellowish Green 143 A.

Relationship between morphological characteristics of trees and reduced air temperature under the canopy (Figure 1) showed that the higher branching from the soil surface, the lower ability of the trees in reducing air temperature, while the air temperature delta will be increased along with the increasing thickness of the canopy, density and width of the canopy, as well as low closeness value. The higher branching from the soil surface, air temperatures under and outside the canopy is almost similar on the average, due to the air flows under the canopy, therefore, the heat energy of the air from higher pressure will transfer to the lowest one.

The absorptive capacity of the solar radiation is influenced by the branching height, canopy thickness, canopy width, and canopy density (Figure 2), in which the increasing height of the branch from the soil surface is followed by the reducing absorptive capacity of solar radiation, increasing the canopy width, canopy thickness, and canopy density. Meanwhile, ability of the trees in transmitting solar radiation is reduced by the increasing of the branch height from the soil surface, canopy thickness, canopy width, and canopy density (Figure 3).

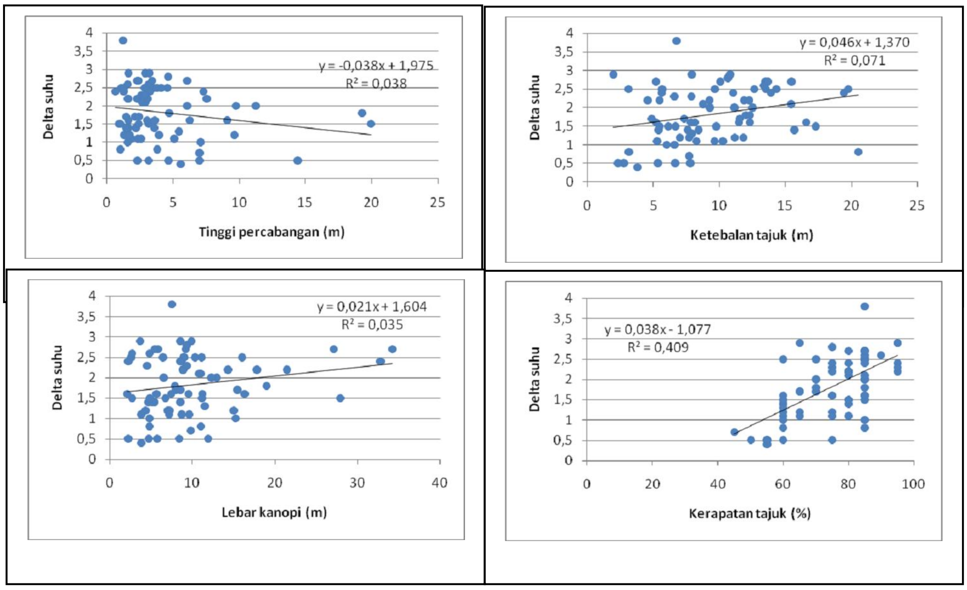

Figure 1. Relationship between the Branching Height, Canopy Thickness, Canopy Width, and Canopy Density of the Trees and the Air temperature Delta.

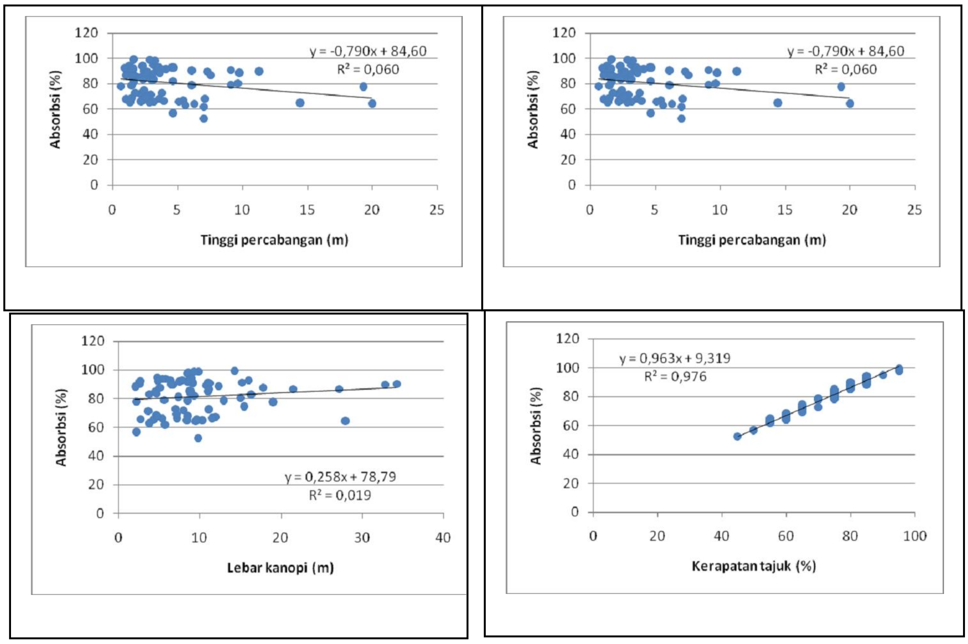

Figure 2. Relationship between the Branching Height, Canopy Thickness, Canopy Width, and Canopy Density of the Trees and the Absorption.

The branching height from the soil surface and the canopy thickness do not influence the wind velocity. This is due to the height of the branching from the soil surface of the observed trees is > 6 m on the average as well as the wind velocity.

Table 1. R^2 value for relationship between morphology and microclimate

R^2 Value	Δ Air temperature	Absorption	Transmission	Δ Wind
Canopy width	0,035	0,019	0,019	
Branching height	0,038	0,06	0,06	0,001
Canopy thickness	0,071	0,045	0,045	0,002
Canopy density	0,409	0,976	0,976	

Note : Δ air temperature = air temperature outside the canopy-air temperature under the canopy Δ wind = wind flow outside the canopy-wind flow under the canopy

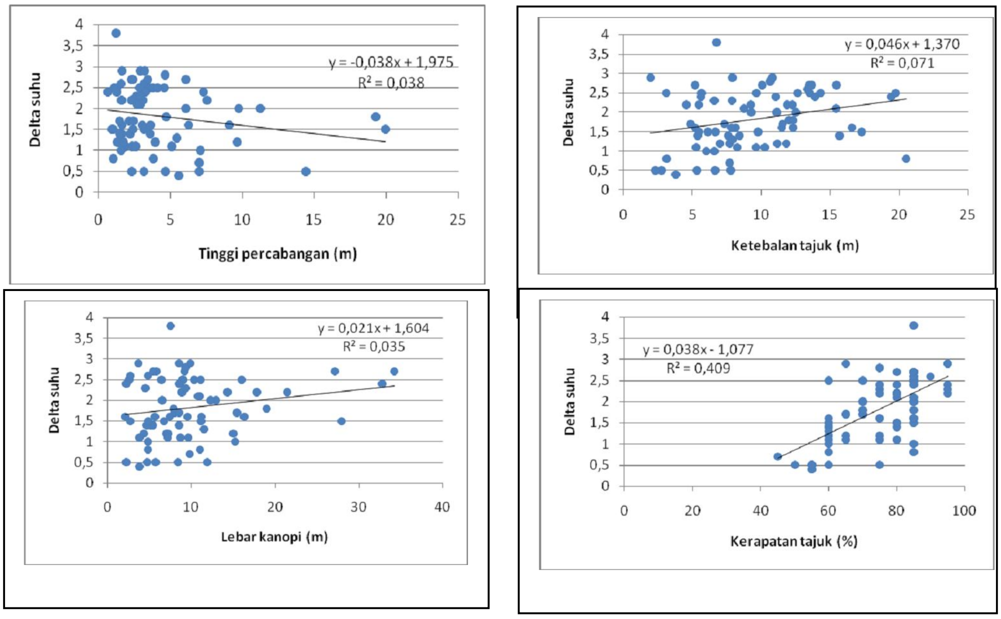

Figure 3. Relationship between the Branching Height, Canopy Thickness, Canopy Width, and Canopy Density of the Trees Canopy and the Transmission.

Based on result of the observation, it showed close relationship between the canopy density and absorption as well as the transmission. In fact, relationship between illumination transmission analysis is very complex with broader variation of the structures/diverse shapes of the canopy, both horizontally and vertically. This is related to the difference in attributes of the plants, which are concerning with the illumination transmission, such as, size, shape, and orientation of the leaf, canopy width, and the plant height [7]. Ability of the trees in shading and screening the radiation is the best, depends on shape and thickness of the canopy [6]. Out of 75 trees, 38 species of them have absorptive value of 85% and transmission for about 15% (Table 3), for example, Akasia (*Acacia auriculiformis)*, alpukat *Persea Americana* , angsana *Pterocarpus indicus* , belimbing *Averrhoa carambola*, beringin *Ficus benjamina* , beringin karet *Ficus elastic*, bintaro *Cerbera odoliam*, bisbul *Diospyros blancoi*, bunga sikat botol *Callistemon citrinus*, bungur *Lagerstroemia thorelii* , duku *Phylanthus acidus* , genitu *Chrysophyllum cainito* , glodokan local *Polyalthea longifolia pendula*, glodokan tiang *Polyalthea longifolia* , johar *Cassia fistula L.* , juwet *Euginia cuminii* , kantil *Michelia alba* , kayu manis *Cinnamomun verum*, kelengkeng *Cocos nucifera* L, kemiri *Aleurites moluccana* , kenari *Canarium sp*, kepel *Stelechocarpus burahol* , kiara payung *Fillicium decipiens*, kluwih *Artocarpus camansi*, kupu-kupu *Bauhinia blackeana*, mahoni *Swietenia mahagoni*, mangga *Mangifera indica* L, matoa *Pometia pinnata* J, mengkudu *Morinda citrifolia* L., nam-nam *Cynometra cauliflora* L., nangka *Artocarpus integra*, petai *Parkia speciosa* , rambutan *Nephelium lappaceum* L., saputangan *Maniltoa brawneodes* sawo kecik *Manilkara kauki*, sukun *Artocarpus altilis*, tabebuia *Tabebuia rosea* , tanjung *Mimusop elengi*, trembesi *Albizia saman* which could reduce air temperature under the canopy for about 2 – 3.8^{o}C (Table 4). Most of the trees, on the average, have medium size and fine texture for the leaves, so that they have grid between the leaves. Intensity of the solar radiation that passes through grids between leaves will be reduced on each canopy layer. The denser the canopy, the lower solar radiation that can be transmitted, therefore, it can reduce the air temperature under the canopy.

Conclusions

Morphology of the trees, which is able to absorb and transmit is the canopy density (R^2=0.98), while the branching height, canopy thickness, and canopy width have negative correlation with the ability to absorb and transmit.

Based on observation, out of 75 trees, 38 of them have absorptive value of 85% and transmission for about 15%, for example, Akasia (*Acacia auriculiformis)*, alpukat *Persea Americana* , angsana *Pterocarpus indicus* , belimbing *Averrhoa carambola*, beringin *Ficus benjamina* , beringin karet *Ficus elastic*, bintaro *Cerbera odoliam*, bisbul *Diospyros blancoi*, bunga sikat botol *Callistemon citrinus*, bungur *Lagerstroemia thorelii* , duku *Phylanthus acidus* , genitu *Chrysophyllum cainito* , glodokan local *Polyalthea longifolia pendula*, glodokan tiang *Polyalthea longifolia* , johar *Cassia fistula L.* , juwet *Euginia cuminii* , kantil *Michelia alba* , kayu manis *Cinnamomun verum*, kelengkeng *Cocos nucifera* L, kemiri *Aleurites moluccana* , kenari *Canarium sp*, kepel *Stelechocarpus burahol* , kiara payung *Fillicium decipiens*, kluwih *Artocarpus camansi*, kupu-kupu *Bauhinia blackeana*, mahoni *Swietenia mahagoni*, mangga *Mangifera indica* L, matoa *Pometia pinnata* J, mengkudu *Morinda citrifolia* L., nam-nam *Cynometra cauliflora* L., nangka *Artocarpus integra*, petai *Parkia speciosa* , rambutan *Nephelium lappaceum* L., saputangan *Maniltoa brawneodes* sawo kecik *Manilkara kauki*, sukun *Artocarpus altilis*, tabebuia *Tabebuia rosea* , tanjung *Mimusop elengi*, trembesi *Albizia saman* which could reduce air temperature under the canopy about 2 – 3.8^{o}C.

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