STUDY ON THE ROLE OF URBAN FOREST TOWARD TEMPERATURE REDUCTION IN RESIDENTIAL AREA

(Peran Hutan Kota Terhadap Penurunan Suhu Udara di Kawasan Perkotaan)

Oleh/by :

Etty Marlina[1], I Nengah Surati Jaya[1] dan Antonius B Wijanarto[3]

[1]Dinas Kehutanan dan Perkebunan, Kabupaten Banyuasin, Provinsi Sumatera Selatan
[2]Laboratory of Forest Resources Inventory, Bogor Agricultural University (IPB)
[3]National Coordinating Agency for Surveys and Mapping (Bakosurtanal)

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ABSTRACT

Nowadays, the quality of urban environment is a challenging problem. Urban development indicated by the increase of population as well as development in all aspects, either positive or negative. But it can degrade the environment quality. This can be indicated by for example, air pollution, which can reduce the oxygen supply and overwhelms the production of carbon dioxide as well as the increase in temperature. From the foregoing problems, the "back to nature" concept is needed to solve environment problem in urban area, by introducing the urban forest. However, constraints in available space exists, therefore, alternative solution can be employed by increasing the effectiveness of existing urban forest. This research aims at analyzing the effectiveness of urban forest in reducing the air temperature based on two parameters: forest structures and forest forms.

***Keywords**: Urban Forest, Temperature Reduction, Forest Structure, Forest Forms, GIS Analysis.*

ABSTRAK

Kualitas lingkungan perkotaan, akhir-akhir ini, merupakan masalah yang menantang. Perkembangan perkotaan selalu mengindikasikan dengan pencemaran udara dan perkembangan di segala bidang, yang berdampak positif maupun negatif. Namun demikian, perkembangan ini dapat menurunkan kualitas lingkungan. Hal ini dapat diindikasikan misalnya polusi udara, yang dapat menurunkan jumlah oksigen dan meningkatkan jumlah karbon dioksida yang juga terindikasikan dengan naiknya suhu udara perkotaan. Dari berbagai masalah lingkungan tersebut, konsep kembali ke alam dibutuhkan untuk mengatasi masalah lingkungan perkotaan, dengan mengenalkan konsep hutan kota. Namun, banyak pembatasan-pembatasan termasuk lahan yang tersedia, sehingga solusi yang dapat meningkatkan efektivitas hutan kota dibutuhkan. Penelitian ini menganalisa efektivitas hutan kota dalam menurunkan suhu udara perkotaan berdasarkan dua parameter: struktur hutan dan bentuk hutan.

***Kata Kunci**: Hutan Kota, Penurunan Suhu Udara, Struktur Hutan, Bentuk Hutan, Analisa SIG.*

INTRODUCTION

Background

Urban area is center of population which facilitates development of social, culture, and economic (Irwan, 2005). Urban development is indicated by the increase of population as well as development in all aspects, for instance office and industry area, super and hyper market, medical and education facilities, also road network. These facilities are provided to support people activities. In the other hand, urban developments also give negative impacts and ultimately, it can impact the degradation of environment quality. Urban environments only progress economically but decline ecologically, whereas ecology stability in urban area as important as economy stability (Dahlan, 1992). This fact is indicated by environment problems in urban area, for instance: air pollution which reduces oxygen supply and overwhelms production of carbon dioxide (CO_2), also rising of air temperature.

Air temperature in urban area is hotter than its surrounding area and it is called "urban heat-island" effect. There is a direct link between urban heat islands and global warming. Firstly, the greenhouse effect could aggravate rising urban temperature significantly. Secondly, heat islands may contribute to the greenhouse effect. According to Herlianto (2007) starting from 1960 to 1969, the average global temperature was 13.9^{o}C and in the period of 2000-2004, it is about 14.6^{o}C and it is projected to raise 1.4-5.8°C by 2100 (**Figure 1**). Jaelani (2006) states that Indonesia is the biggest producer of CO_2 in South East Asia, moreover CO_2 emission in 2010 is estimated will increase five times bigger than CO_2 emission in 1986, i.e. it will reach 469 million ton. In Indonesia, symptoms of global warming have been seen, i.e. the last decade, Indonesia has experienced long dry spells which were occurred in 1982-1983, 1987, and 1991, and this disaster gave negative impacts to people.

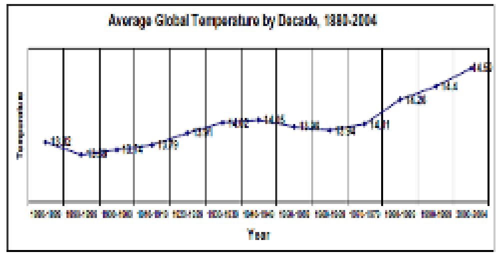

Figure 1. Average Global Temperature by Decade (Brown 2002).

Meanwhile, Bogor as buffer zone for Jakarta tends to have high concentration of air pollution (Lestari, 2005). It is indicated from rapidly growth of vehicles and population. Total vehicles in 2003 were 66.541 units and it increased twice bigger than total vehicle in 2000, then number of population in 2005 reached 855.085 and it increased 1.2 times bigger than population in 2000 (BPS, 2006). In line with the growth of population, landcover change from naturally vegetated area to build up area also increased rapidly, and several types of landcover change tending to increase temperature significantly are: residential, industry, and bare land (Tursilowati, 2005). From the foregoing problems, "back to nature" concept is needed to solve environment problem in urban area. Urban forest was introduced to recover environment and ecological condition, for instance: temperature reduction and other microclimatic effects, removal of air pollutants, emission of volatile organic compounds and tree maintenance emissions, energy effects on buildings reduce air pollution) (Nowak, 2000).

Urban forest research in Bogor city has been conducted by Lestari (2005). She assessed minimum size of urban forest based on oxygen need. Based on this research, minimum size of urban forest to fulfill oxygen need in 2003 was 51,397.706 ha while existing urban forest in 2003 was only 4,214.39 ha, then minimum size of urban forest to fulfill oxygen need in 2020 will be 571,191 ha, and it will be even larger than total large of Bogor City (only 11, 850 ha). The constraint in urban forest development is limitation of space for urban forest. Moreover many conflicting interests relate with land and expensiveness of land value in urban area. Therefore, alternative solution can be employed by increasing the effectiveness of existing urban forest in controlling quality of urban environment.

Urban forest development needs good planning and management in order optimal function and role of urban forest can be achieved. Accurate and efficient information will be very helpful for urban forest development, and Remote Sensing technology is precise tool which can give accurate and efficient information over large area (Jaelani, 2006). In this research, high resolution image is used to classify urban forest type (structure and form) and residential area. Meanwhile, geography information system (GIS) offers facilities to manage spatial data, starting from input data, store and manage data, analyze and manipulate, until produce the expect output. Therefore, in this study GIS is needed to obtain possible location for temperature measurement. Common problems faced in urban forest development, include: the limitations of space for urban forest, many conflict of interests related with landuse, and the expensiveness of land price in urban area. Moreover, urban forests are frequently suffered from land conversion causing urban forest space decrease than ever. To solve the limitation of urban forest space, alternative solution should be employed. The solution is the optimize function and role of existing urban forest, by analyzing relationship between urban forest structures (second-storey and multi-storey) and urban forest forms (linear, clustered, and dispersed) in reducing negative effects from urban activities. From the foregoing problem, it is important to make problem definition on how the difference of urban forest types (structure and form) can give different effectiveness toward air temperature reduction.

The Objective

The objective of this research is to find out the effectiveness of several urban forest types based on their structures and forms toward urban temperature reduction.

Role of GIS and Remote Sensing (RS) in Urban Forest Development and Planning

Urban forest development is much related to spatial condition. Therefore, the effective, efficient and accurate spatial information provided by GIS and RS are highly required. Several study and research had used GIS and RS to derive, store, manage and analyze spatial information. Kali, (2006), used satellite image (Landsat ETM 2002) and GIS to identify the potency and spatial distribution of urban forest development. Landsat ETM was classified image in to several classes based on vegetation type as oxygen supplier. While GIS capabilities are used to develop database management and spatially analyze the supply of oxygen and production of CO_2. Jaelani, (2006), has used IKONOS and geography information system (GIS) to determine urban forest in North Jakarta and Centre Jakarta. Integrating of GIS capabilities, IKONOS image and other secondary data will provide worthwhile information about large and distribution of existing urban forest and potential area for urban forest. Meanwhile, Ginting (2006), developed environment spatial database based on GIS capabilities, satellite image, field data, secondary data, and developed spatial model for urban forest distribution.

METHODS

Study Area

The study area is located in Bogor City, West Java, Indonesia, approximately between 6°30’ 30’’ and 6°41’ 00’’ South Latitude and 106°43’ 30’’ and 106°51’ 00’’ East Longitude (**Figure 2**).

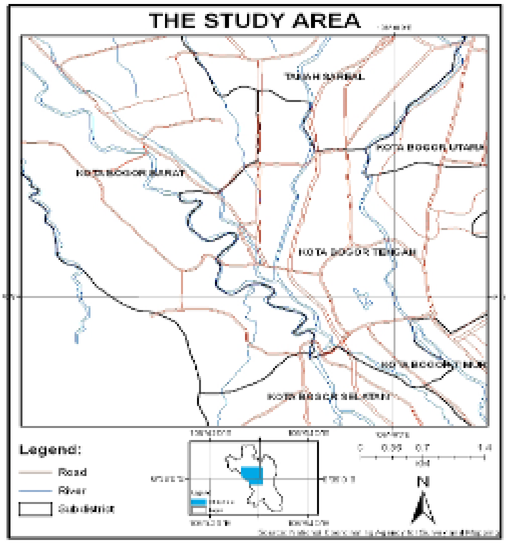

Figure 2. Study Area in Bogor Botanical Garden and its surrounding areas

Image Classification

The first step before selecting location of field measurement was digitizing IKONOS image to produce thematic map. The digitizing process was conducted by using *“digitizing on screen”* technique. There were three types of thematic layer:

1. Urban forest structure (vegetation community composing urban forest): This was classified into two classes: *second-structure urban forest* (vegetation community in urban forest only composed by trees and grasses or other coverage) and *multi-structure urban forest* (vegetation community in urban forest composed by trees, grasses, bushes, and other vegetation covering ground). Based on urban forest structures, there are 139 urban forests classified into two classes, namely: 40 urban forests are multi structures, and 99 urban forests are second structures (**Figure 3**).

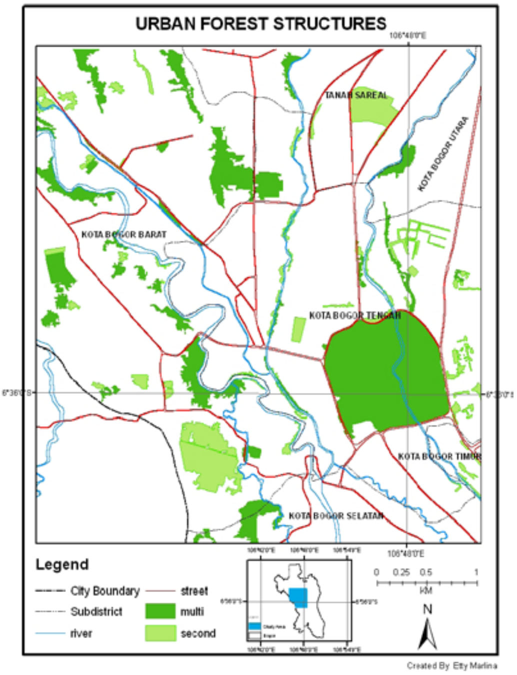

Figure 3. Urban Forest Structures.

2. Urban forest form. There are three type of urban forest form (Irwan, 2005): *Clustered* (urban forest with green community clustered in certain area, minimal trees are 100 trees and each tree is close each other, which are unarranged), *dispersed* (urban forest which does not have certain pattern, green community disperses in small group of vegetation), and *Linear/strip* (this form includes trees and shrubs in street side, trees in riparian areas). Based on this classification, there are 139 urban forests classified in this study, they are: 25 urban forests are clustered forms, 54 urban forests are dispersed forms, and 60 urban forests are lined forms (**Figure 4**).

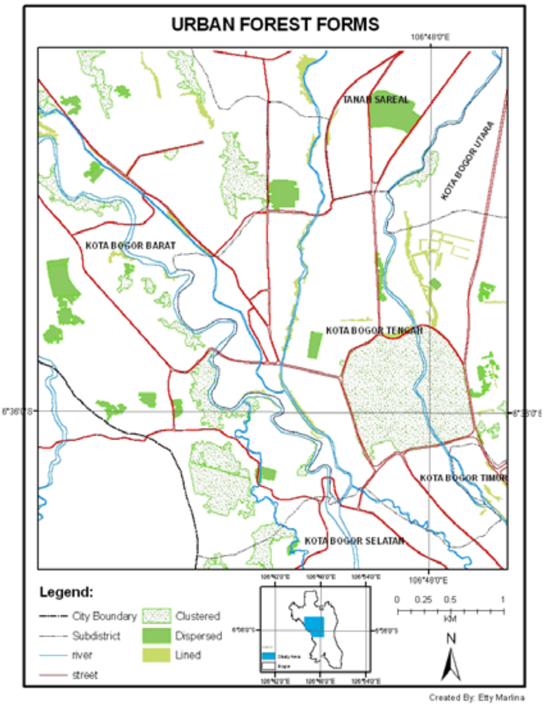

Figure 4. Urban Forest Forms

3. Residential area. This thematic layer was used to determine urban forest types which are next to residential area. Urban forest types should be around 50-70 meter from residential.

After getting classification of urban forest structures, urban forest forms and residential area, the next step was join attribute between urban forest structures map and urban forest forms map to obtain six combinations of urban forest types. **Table 1** describes six combinations of urban forest structures and forms. Thereafter, map of urban forest type was overlaid with residential area thus six types of urban forest next to residential area was derived. These combinations were used to determine possible location for air temperature measurement.

Table 1. Combination of urban forest structures and forms

Structures	Forms		
	Lined (L)	Clustered (C)	Dispersed (D)
Second-storey (S)	LS	CS	DS
Multi-storey (M)	LM	CM	DM

LS = Linear form with second-structure
LM = Linear form with multi-structure
CS = Clustered form with second-structure
CM = Clustered form with multi-structure
DS = Dispersed form with second-structure
DM = Dispersed form with multi-structure

Table 2. Combination of urban forest types and residential area

Urban Forest Types	Residential Area
LS	LSR
LM	LMR
CS	CSR
CM	CMR
DS	DSR
DM	DMR

Note:
LSR = Linear form with second-structure next to residential area
LMR = Linear form with multi-structure next to residential area
CSR = Clustered form with second-structure next to residential area
CMR = Clustered form with multi-structure next to residential area
DSR = Dispersed form with second-structure next to residential area
DMR = Dispersed form with multi-structure next to residential area

Table 3. Combination of urban forest structures and forms

Structures	Forms		
	Lined (L)	Clustered (C)	Dispersed (D)
Second-storey (S)	LS	CS	DS
Multi-storey (M)	LM	CM	DM

Note:

LS = Linear form with second-structure
LM = Linear form with multi-structure
CS = Clustered form with second-structure
CM = Clustered form with multi-structure
DS = Dispersed form with second-structure
DM = Dispersed form with multi-structure

Effectiveness of Urban Forest Types toward Air Temperature Reduction Based on Time of Measurement

Tukey Test: Tukey's method considers all possible pairwise differences of means at the same time. The Tukey method applies simultaneously to the set of all pairwise comparisons.

Trend Analysis: Trend analysis was done to *analyze* and predict the change of temperature toward the change of time measurement and also analyze how these changes influenced by urban forest are. Temperature trend toward the change of time in three points measurement (P1, P2, and P3) was derived from polynomial (non-linear) regression and time of measurement is independent variable (X_1).

Effectiveness of Urban Forest Types toward Air Temperature Reduction Based on Distance

Simple Regression: Simple regression analysis was chosen to analyze the relationship between dependent variable (Y) and one independent variable (X). While, dependent variable in this research is Temperature (C) and independent variable is distance of temperature measurement (m).

RESULTS

Field Data Analysis

In this study, air temperature was chosen as parameter because air temperature is one of weather element which can directly impact human life. The results of temperature average in five urban forest types, namely: linear form with second structure (LS), linear form with multi structure (LM), dispersed form with second structure (DS), clustered form with second structure (CS), and clustered form with multi structure (CM)) are provided in **Table 4**. This table shows that average temperature inside urban forest (P1) is always lower than on perimeter of urban forest (P2) and outside urban forest (P3) in each urban forest type. It also shows that five urban forest types can reduce air temperature.

During temperature measurement, several data were also collected included: number of trees and vegetation species in each urban forest type (Table 5). Each urban forest was found to have different vegetation species. Clustered multi with multi structure urban forest has high biodiversity of vegetation species.

Table 4. Air Temperature average in each urban forest type

No	Urban Forest Types	Temperature			Average
		P1	P2	P3	
1	Lined Second (LS)	26.18462	26.38462	26.98846	26.51923
2	Lined Multi (LM)	26.15385	26.42692	27.40385	26.66154
3	Dispersed Second (DS)	27.01538	27.38846	27.74231	27.38205
4	Clustered Second (CS)	27.40385	28.55769	29.06538	28.34231
5	Clustered Multi (CM)	27.52308	27.77692	30.61154	28.63718

Table 5. Number of trees and vegetation species in each urban forest type

	LM	LS	DS	CM	CS
Number of trees	201	30	35	± 500	450
Number of vegetation species	6	3	4	16	1

Effectiveness of Urban Forest Types toward Air Temperature Reduction Based upon Time of Measurement

The results of air temperature average in five urban forest types are illustrated visually in **Figure 5**. Generally, air temperature in P1 of all urban forest type is lower than air temperature in P2 and P3. Air temperature in P3 of Clustered form with multi structure (CM) urban forest reached 36°C on day time, and it is the highest temperature recorded during this study. At the same time, the temperature in P2 was only 29°C, while in P1 is 28°C. It shows that inconvenient temperature occurred at midday (noon) and it also means clustered form with multi structure (CM) is very effective to reduce air temperature inside urban forest but it is ineffective to affect air temperature in its surrounding area. In clustered form with multi structure urban forest, the difference of air temperature (Δt) between inside urban forest and outside urban forest at midday was very high in amount of 5.76°C

Table 6. Air Temperature Changing (Δt) toward Time Changing in Each Urban Forest Type (C)

Time	Point	Urban Forest				
		LS	LM	CS	CM	DS
Morning	P2-P1	0.17	0.08	0.42	0.62	0.37
	P3-P1	0.80	1.25	2.38	1.48	0.97
Midday	P2-P1	0.12	0.41	2.15	0.28	0.66
	P3-P1	1.16	1.40	2.58	5.76	0.93
Afternoon	P2-P1	0.30	0.25	0.60	0.01	0.09
	P3-P1	0.45	1.10	0.31	1.38	0.38

Note:
P1 = Point inside urban forest
P2 = Point on perimeter
P3 = Point outside urban forest
(-) = Air temperature is increased
(+)= Air temperature is decreased

In clustered form with second structure (CS) urban forest, the difference of air temperature (Δt) between inside urban forest and outside urban forest at midday was about 2.58°C. It also shows inconvenient temperature also occurred during midday (Table 6). While, air temperature in P3 of dispersed form with second structure (DS) urban forest was 31.5°C on 14.00 PM. At the same time, air temperature in P2 and P1 respectively was 29.5°C and 29.4°C.

It shows that air temperature inside and outside DS urban forest do not change significantly, it indicates DS urban forest still influence air temperature on its perimeter and outside urban forest during midday. In line with DS urban forest, air temperature P3 of linear form with second structure (LS) urban forest was 29°C on 14.00 PM. At the same time, air temperature in P2 and P1 respectively was 28.5°C and 28°C. It also shows that air temperature inside and outside LS urban forest do not change significantly, it indicates LS urban forest also influence air temperature on its parameter and **Table 6** and **Figure 7** illustrates that air temperatures in P1 were lower than P2 and P3 in morning time and even in day and afternoon time, air temperatures in P1 of all urban types were still lower than air temperature in P2 and P3. While, air temperatures in P1, P2, and P3 during afternoon time were constant, it shows that air temperatures in P1 on afternoon time were not extreme cool. It also means that urban forest can control air temperature.

Result of Tukey test summarized in **Table 7** shows that air temperatures in morning time are lower than air temperature in day time, but air temperatures in morning time are higher than air temperatures in afternoon time. These results indicate that time changing influence temperature changing, and air temperature reduction in each urban forest type based upon time of measurement summarizes in **Table 7**.

As seen in Figure 6 showing that time changing influences temperature changing in LS, LM, DS, CS, and CM urban forests. This figure also describes that air temperature inside urban forest (P1) is lower than air temperature urban forest perimeter (P2) and outside urban forest (P3). Based on Figure 6a, b, and e, air temperature in three points of LS, LM and DS urban forests tend to increase on 8.00 AM until 12.00 PM and air temperatures start decreasing on 13.00 PM until 20.00 PM. This phenomena show that air temperature start decreasing earlier because when temperature measurement was done, weather condition in LS, LM and DS urban forests were cloudy. While, in CM and CS urban forests, air temperature start increasing on 08.00 AM until 13.00 PM and it start decreasing on 14.00 PM until 20.00 PM.

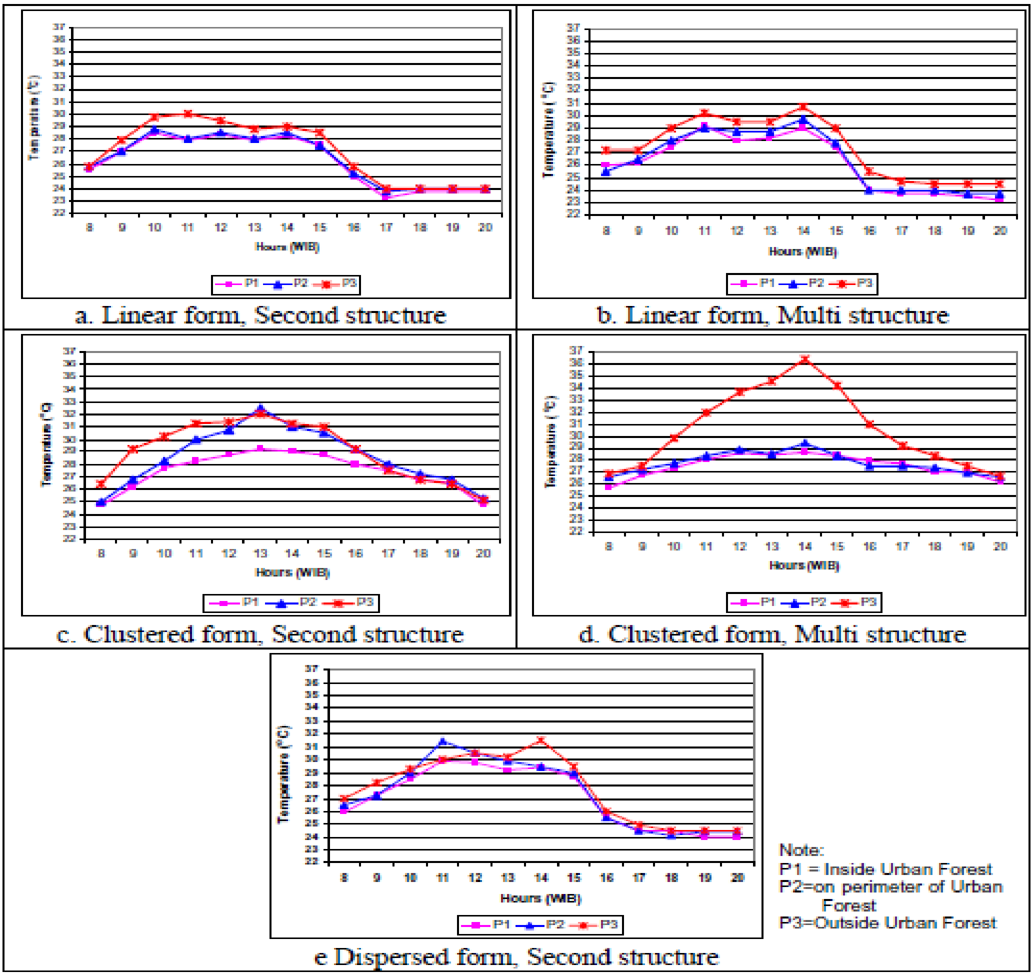

Figure 5. Graphic of Temperature Average in Each Urban Forest Type (LS, LM, DS, CS,CM).

Weather condition in both urban forests were sunny during air temperature measurement. Regarding to analysis of urban forest types toward air temperature reduction based upon time of measurement, dispersed form with second structure (DS) and linear form with second structure urban forests are more effective toward air temperature reduction during day time. Even though, clustered form with multistructured urban forest is very effective in reducing air temperature inside urban forest during day time. Yet, inconvenient temperature is occurred outside urban forest at midday.

Table 7. Air Temperature Reduction in Each Urban Forest Type Based on Time of Measurement

Difference of Time (Δw)	Air Temperature (Δt) (°C)				
	LS	LM	DS	CS	CM
T1- T2	-1.084	0.273	-2.279	-3.193	-3.16
T1- T3	3.172	1.25	3.004	0.18	-0.36
T2- T3	4.257	0.977	5.283	3.373	2.8

Note:
T1 = 08.00 AM – 10.00 AM (morning time)
T2 = 11.00 AM – 15.00 PM (day time)
T3 = 16.00 PM – 20.00 PM (afternoon time)
(-) = Air temperature is increased
(+)= Air temperature is decreased

From temperature trend models in five urban forest types (**Figure 5**) show that time changing influences temperature changing in each urban forest type, and important information derived is temperature in P1 is lower than temperature in P2 and P3. It informs that urban forest can reduce air temperature. While, the mathematical models of polynomial regression are summarized in **Table 8.**

Urban forest can reduce air temperature because due to their evaporation, transpiration and photosynthesis process. Evaporation and transpiretion processes take sensible heat and convert sensible heat into latent heat, while vegetation also absorb sun radiation for photosynthesis process and convert it into food reserves. These processes cause air temperature inside urban forest lower than air temperature in its surrounding. Moreover, trees canopy will protect its surrounding area from extreme sun radiation, wild wind and rain.

Effectiveness of Urban Forest Types toward Air Temperature Based upon Distance

The results of average of air temperature changing based upon distance of measurement are displayed in Figure 6. As shown in Figure 6, starting from 0 meter (inside urban forest) – 50 meter, the changes of air temperature in clustered form with multi structure (CM) urban forest did not change significantly. This is probably caused by Cisadane River which is closed to the perimeter of CM urban forest. It affects reduction of air temperature because the river crossing urban areas have been recorded as contributors to air purification and microclimate features and the water bodies return heat and moisture to the atmosphere through evaporation and conduction (Arroyo & Ja'uregui (2001)). The changes of air temperature in CM urban forest are lowest than other urban forest types on distance ≤ 50 meter and the changes of air temperature in this urban forest start increasing on distance above 50 meter.

The changes of air temperature in clustered form with second structure (CS) urban forest increase significantly starting from 0 meter until 30 meter, and then trend of the change of air temperature was slightly skewed to the normal trend. Air temperature was measured on grassy area, where sun radiation is absorbed by grass and converted into food reserves moreover evaporation and transpiration processes also occurred on grassy area, therefore it affects different air temperature trend in CS urban forest. While, air temperature trend of LS, LM, and DS urban forests more sharply peaked than air temperature trend of CS and CM urban forests. It is caused air temperature of LS, LM and DS urban forests were measured on asphalt. The existence of river, air temperature measured on grassy area and asphalt were several constraints faced in this study, and it was difficult to find ideal locations for this research. Therefore, five selected locations are as ideal as possible location for air temperature measurement. For further analysis, the changes of air temperature models were generated from regression analysis, and then its models are presented in **Figure 7**.

Visual analysis toward Figure 8 shows that the increments of air temperature based upon the increase of distance in each urban forest type are different. The different increment of air temperature shows different effectiveness toward air temperature reduction in each urban forest type. The most effective urban forest type is the smallest increment of air temperature in each increase of distance. In linear form with multi structure (LM) urban forest, air temperature increases 0.0303 (C) in each increase of distance (m) and it is the highest increment of air temperature of all urban forest types. Figure 8 also illustrates that LM urban forest is less significant in influencing air temperature in its surrounding area because its increment of air temperature per meter is high. While, the role of LM urban forest towards air temperature reduction is different from other urban forest types, it is summarized in **Table 8**.

In clustered form with second structure (CS) urban forest, air temperature will increase 0.0277 (C) per meter. As seen in Figure 8, air temperature is sharply peaked in each increase of distance (m). As well as linear form with multi structure (LM) urban forest, this urban forest type also less significant in influencing air temperature in its surrounding area.

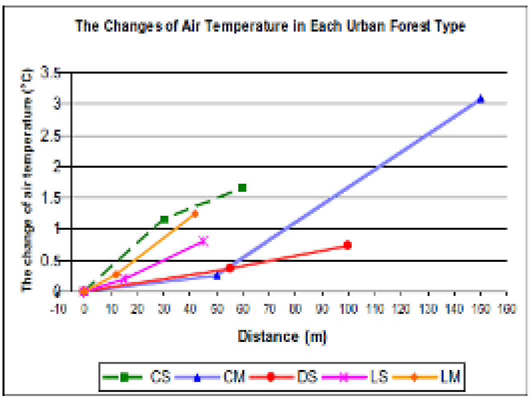

Figure 6. Air Temperature Changing in Each Urban Forest Type Based upon Distance

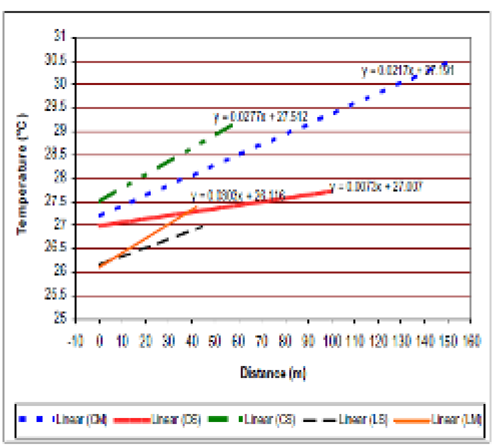

Figure 7. Regression Model in Each Urban Forest Type.

Table 8. Significant Value of Each Pair of Urban Forest Type

	P- Value					
P-Value	Urban Forest Types	LS	LM	DS	CS	CM
	LS	0	0.000	0.883	0.000	0.000
	LM	0.000	0	0.004	0.000	0.002
	DS	0.883	0.004	0	0.000	0.000
	CS	0.000	0.000	0.000	0	0.000
	CM	0.000	0.002	0.000	0.000	0

Note:
Each urban forest type has different role when P-Value < 0.05

While, the role of cluster form with second structure (CS) and linear form with multi structure (LM) urban forests towards air temperature reduction is different from other urban forest types (**Table 8**). In this study, dispersed form with second structure (DS) urban forest is the most effective urban forest type toward air temperature reduction because the existence of dispersed form with second structure (DS) urban forest is able to affect air temperature in its surrounding area. It is indicated by increment of air temperature of this urban forest in amount of 0.0073 (C) per meter and it is the lowest increment of air temperature of all urban forest types.

This means that air temperature in dispersed form with second structure (DS) urban forest will increase 0.0073 (C) in each increase of distance (m), and this is good achievement through existence of dispersed form with second structure (DS) urban forest. This urban forest is more effective toward air temperature reduction because of its dispersed structure, the structure, which disperses and not only concentrates in one location, can affect air temperature in its surrounding area. The role of dispersed form with second structure urban forest towards air temperature reduction is different from other urban forest types, except linear form with second structure (LS) urban forest. As summarized from Table 8, DS and LS urban forests have equal role toward air temperature reduction. This is caused linear form with second structure

(LS) urban forest exists in each cluster of houses continuously.

Thereby, positions of three point of measurement were always next to LS urban forest in different side. The existence of LS urban forest which disperses in each cluster of houses can reduce air temperature in its surrounding area, therefore it has equal role with dispersed form with second structure (DS) urban forest. Further analysis, homogeneity tests of slope and elevation in each urban forest regression model were employed to test effectiveness of urban forest types toward air temperature reduction. The results of this test are shown in **Figure 8**. Homogeneity test is intended to test whether one or more urban forest types have equal effectiveness and role with other urban forest types.

If there are urban forest types having equal role and effectiveness, therefore those urban forest types will only have single regression model. Based on Figure 8, there are five pairs of urban forest types which have equal role and effectiveness, namely: LS & LM urban forests, LS & DS urban forests, LM & DS urban forest, CS & CM urban forests, and LM & CM urban forests. This information is summarized in **Table 9**.

Table 10 informs five pairs of urban forest regression model merging into single regression model, and it means that these pairs have equal role and effecttiveness toward air temperature reduction.

Based on slope and elevation analysis, LS, LM, and DS urban forests have equal role and effectiveness toward air temperature reduction. While, urban forests clustered form with second structure (CS) and clustered form with multi structure (CM) urban forests also can be merged in to one regression model. It means that both urban forests have equal role and effectiveness toward air temperature reduction. Even though, based on analysis in Figure 7, CM urban forest is more effective than CS urban forest.

Table 9: Pairs of urban forest types having equal role

No	Pairs of urban forest types
1	Linear form with second structure (LS) and linear form with multi structure (LM)
2	Linear form with second structure (LS) and dispersed form with second structure (DS)
3	Linear form with multi structure (LM) and dispersed form with second structure (DS)
4	Clustered form with second structure (CS) and clustered form with multi structure (CM)
5	Linear form with multi structure (LM) and clustered form with multi structure (CM)

Table 10. Pairs of urban Forest Types, which have equal role and effectiveness

No	Previous Regression		New Regression
1.	Urban Forest LS: Y= 26.155 + 0.0182x	Urban Forest LM: Y= 26.116 + 0.0303x	Y= 26.136 + 0.0239x
2.	Urban Forest LS: Y= 26.155 + 0.0182x	Urban Forest DS: Y= 27.007 + 0.0073x	Y= 26.623 + 0.0091x
3.	Urban Forest LM: Y= 26.116 + 0.0303x	Urban Forest DS: Y= 27.007 + 0.0073x	Y= 26.643 + 0.011x
4.	Urban Forest CS: Y= 27.512 + 0.0277x	Urban Forest CM: Y= 27.191 + 0.0217x	Y= 27.402 + 0.0225x
5.	Urban Forest LM: Y= 26.116 + 0.0303x	Urban Forest CM: Y= 27.191 + 0.0217x	Y= 26.704 + 0.022x

Thereby, effectiveness of CM urban forest is not significantly different compare with CS urban forest. As shown in **Appendix 1**, regression model LM urban forest also can be merged with CM urban forest. It means LM and CM urban forests have equal role and effectiveness toward air temperature reduction. Although, clustered form with multi structure (CM) urban forest has equal role and effectiveness with LM urban forest, it does not mean that CM urban forest also has equal role and effectiveness with LS and DS urban forests.

Table 11 summarizes the results of regression homogeneity test in order this information is easier to be understood. As shown in this table, urban forests having equal slope and elevation are considered as urban forest having equal role and effectiveness toward air temperature reduction. Based on this study, Dispersed form with second structure (DS) urban forest is the most effective urban forest toward air temperature reduction based upon both time and distance of measurement, and further analysis also show that dispersed form with second structure (DS) urban forest has equal role and effectiveness toward air temperature reduction with linear form with second structure (LS) and linear form with multi structure (LM) urban forests. The priority of urban forest from the most effective urban forest to the less effective urban forest respectively are: dispersed form with second structure urban forest, linear form with second (LS) structure urban forest, linear form with multi structure (LM) structure, clustered form with multi structure (CM) urban forest, clustered form with second structure urban forest (CS).

Table 11. Results of Regression Homogeneity Test

No	Pairs of urban forest	Elevation		Slope	
		Different	Equal	Different	Equal
1.	Linear form with second structure (LS) & Linear form with multi structure (LM)	-	√	-	√
2.	Linear form with second structure (LS) & Dispersed form with second structure (DS)	-	√	-	√
3.	Linear form with second structure (LS) & Clustered form with second structure (CS)	√	-	-	√
4.	Linear form with second structure (LS) & Clustered form with multi structure (CM)	√	-	-	√
5.	Linear form with multi structure (LM) & Dispersed form with second structure (DS)	-	√	-	√
6.	Linear form with multi structure (LM) & Clustered form with second structure (CS)	√	-	-	√
7.	Linear form with multi structure (LM) & Clustered form with multi structure (CM)	-	√	-	√
8.	Dispersed form with second structure (DS) & Clustered form with second structure (CS)	√	-	-	√
9.	Dispersed form with second structure (DS) & Clustered form with multi structure (CM)	√	-	-	√
10.	Clustered form with second structure (CS) & Clustered form with multi structure (CM)	-	√	-	√

The new finding and also the strength of method proposed compare to previous research is this study considers about the change of air temperature toward the increase of distance, and ultimately urban forest which is most effective toward air temperature reduction based upon distance of measurement can be obtained. While, in previous research, air tempera-tures in each increase of distance (m) are not considered.

CONCLUSION

From the foregoing discussion, the following are some conclusions:

1. All of urban forest types are able to reduce air temperature, namely: clustered form with multi structure (CM) urban forest can reduce air temperature in amount of 5.76°C at midday, at the same time clustered form with second structure (CS) urban forest can reduce air temperature in amount of 2.58°C, linear form with multi structure (LM), linear form with second structure (LS), and dispersed form with second structure (DS) urban forests also can reduce air temperature in amount of 1.4°C, 1.16°C, and 0.93°C. Yet, dispersed form with second structure urban forest is most effective urban forest type toward air temperature reduction.
2. Dispersed form with second structure (DS) urban forest, linear form with second structure (LS) urban forest, and linear form with multi structure (LM) have equal role and effectiveness toward air temperature reduction.
3. The most effective urban forest type to the less effective urban forest type toward air temperature reduction are respectively mentioned in the following ranking: dispersed form with second structure (DS) urban forest, linear form with second structure (LS) urban forest, linear form with multi structure (LM) urban forest, clustered form with multi structure (CM) urban forest, clustered form with second structure (CS) urban forest.

REFERENCES

Arroyo & Ja'uregui. 2001. *On the Environmental Role of Urban Lakes in Mexico City*. Kluwer Academic Publishers. Manufactured in The Netherlands.

Brown, L.R. 2002. *Global Temperature Rising.* Earth Policy Institute. [Cited

2007 *July 4]; Available from: http://www.earth-policy.org/ Indicators/ indicator8.htm*

Dahlan, N.E. 1992. *Hutan Kota: untuk pengelolaan dan peningkatan kualitas lingkungan hidup.* Asosiasi Pengusaha Hutan Indonesia (APHI). Jakarta.

Ginting, F. A. 2006. *Pemodelan Spatial Penetuan Agihan Optimal Ruang Terbuka HIjau (RTH) Kota Berdasarkan Basisdata Spatial Lingkungan Kota Memanfaatkan Sistem Informasi Geografi.* Tesis. Fakultas Geografi. Universitas Gadjah Mada. Yogyakarta.

Herlianto, D. 2007. *Akibat Pemanasan Global Suhu Bumi Terus Meningkat.* Media Indonesia. Available: 21 April 2007/No.9601/Tahun XXXVIII.P 11.

Irwan, Z.D. 2005. *Tantangan Lingkungan dan Lansekap Hutan Kota.* Bumi Aksara. Bogor.

Jaelani, A. 2006. *Estimasi Kebutuhan Hutan Kota Menggunakan Citra IKONOS dan Sistem Informasi Geografis (SIG): Studi Kasus di Kota Jakarta Barat, Jakarta Pusat dan Jakarta Utara.* Skripsi. Manajemen Hutan, Fakultas Kehutanan, Institut Pertanian Bogor. Bogor.

Kali, L. 2006. *Prediksi Kebutuhan Hutan Kota Menggunakan Data Penginderaan Jauh dan Sistem Informasi Geografis: Studi Kasus di Kabupaten Belu Provinsi Nusa Tenggara Timur.* Tesis. Program Pasca Sarjana. Institut Pertanian Bogor. Bogor.

Lestari. R.A.E. 2005. *Analisis Spasial Penentuan Luas Minimal Hutan Kota Menggunakan SIG dan Data Penginderaan Jauh: Studi Kasus di Kota Bogor*. Skripsi. Manajemen Hutan, Fakultas Kehutanan. Institut Pertanian Bogor. Bogor.

Nowak, D.J. 2000. *The Effects of Urban Trees on Air Quality*. USDA Forest Service, Northeastern Research Station. Syracuse. New York.

Tursilowati, L. 2005. Pulau Panas Perkotaan Akibat Perubahan Tata Guna dan Penutup Lahan di Bandung dan Bogor. Jurnal of Sains Dirgantara Vol.3 No.1: Page 43 - 64.

Appendix 1. Analysis of Slope and Elevation Regression Model in Each Pair of Urban Forest Type