# EVALUATION OF URBAN FOREST FOR REDUCING AIR POLLUTION
# A CASE STUDY IN YOGYAKARTA CITY, INDONESIA

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THESIS

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**DISCLAIMER**

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Ardiyan Widagdo

# EVALUATION OF URBAN FOREST FOR REDUCING AIR POLLUTION A CASE STUDY IN YOGYAKARTA CITY, INDONESIA

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## Abstract

*Development of city has a tendency to minimize the green open spaces. Urban forest is sum of all woody and associated vegetation in and around dense human settlements. The Data obtained from local Government of Yogyakarta City, (Environment Agency) mention that the city of Yogyakarta only has a urban forest area 260,000 $m^2$ or 26 Ha (0.80%) from total area of Yogyakarta City. Urban forest is a way that can be used to reduce levels of air pollution in the city. The purpose of this research is to evaluate the effectiveness of spatial distribution of urban forest for reducing air pollution in Jogjakarta city and to make recommendations to improve development of urban forest planning in Yogyakarta City. The method use in this research to determine urban forest cover involved an estimation of the area on satellite image with Extraction information segmentation and visual interpretation. The field survey also conduct to measure structural parameters and capability air pollution removal of the Yogyakarta urban forest using UFORE methods (Urban Forest Effect Model).*

*The results of the urban forest cover area in Yogyakarta city in 2005 is 4,447,885.94 $m^2$ (447.79 Ha) or 13.79% with accuracy assessment 94.11%. UFORE analysis method has results number of tree in urban forest of Yogyakarta city is 56,000 trees with 19,880 trees or 35.55% owned by city and 36,092 trees or 64.45% owned by private. The common species trees are Mangifera indica, Mimusops elengi, Pterocarpus indicus, Polyalthia longifolia and Ficus Benjamina. The overall diameter size class distribution is small and too young with 55.82 % of trees less than 15.2cm in diameter, 39.92% between 15.2 and 30 cm, and 4.26 % larger than 30 cm in diameter. The urban forest tree condition has 60.94% of trees are rated as being in excellent or good condition. Air Pollution Removal of Yogyakarta's urban forest are 2,450.1 kg / year for CO, 7,795.9 kg / year for $NO^2$, 24,493.5 Kg / Year for $O^3$, 20,586.0 kg / year for $PM_{10}$, 1,724.4 kg / year for $SO^2$ and total overall in the removal of air pollution amounted to 57,049.9 Kg / year. The effectiveness of air pollution removal from Yogyakarta city is moderate or medium effectiveness with percent air quality improvement 0.10%. Even though the percent air quality improvement from pollution removal by trees may be relatively small, the total effect of trees on air pollution can produce impacts that are significant enough to warrant consideration of tree cover management as a means to improve air quality. Percent air quality improvement estimates are likely conservative and can be increased through programs to increase canopy cover. The tree planting in urban forest still can be used as an effective way in alleviating the air pollution problems in Yogyakarta city.*

*Key words:* ***urban forest, visual interpretation, air pollution, Yogyakarta City***

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Yogyakarta, February 2012

Ardiyan Widagdo

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## Abbreviations

| | |
|---|---|
| Air Pollution | Air pollutant for which acceptable levels of exposure can be determined and for which an ambient air quality standard has been set. Examples include ozone ($O_3$), carbon monoxide (CO), nitrogen dioxide ($NO_2$), sulfur dioxide ($SO_2$), $PM_{10}$ and $PM_{2.5}$.(Source: CA Air Resources Board). |
| BAPPEDA | Local Agency for Planning and Development |
| BLH | Environment Bureau Agency |
| BPS | Central Bureau of Statistics |
| Carbon Sequestration | Amount of carbon removed annually by trees |
| Carbon Storage | Carbon currently held within tree tissue (roots, stems, and branches). |
| D.b.h | Diameter at breast height (approximately 1.3 meters from the ground). |
| GPS | Global Positioning System |
| PPM | Parts Per Million |
| RTRW | Regional Regulation of Spatial Planning |
| Tree | UFORE Model defines a "tree" to be any woody plant with a d.b.h larger than 2.5 centimeters (1 inch). |
| UFORE | Urban Forest Effects Model |
| Urban Forest | The sum of all woody and associated vegetation in and around dense human settlements (Miller 1988) |
| Urban Forest Canopy Cover | The proportion of area occupied by tree canopies when viewed from above (Nowak and McPherson 1993). |
| USDA | United States Department of Agriculture |

# Evaluation of Urban Forest for Reducing Air Pollution A Case Study in Jogjakarta City, Indonesia

## 1. Introduction

### 1.1 Background

Development of city has a tendency to minimize the green open spaces. Urban forest is sum of all woody and associated vegetation in and around dense human settlements (Miller 1988). Regarding Act No. 41 of 1999 on forestry chapter 9, then backed by Government Regulation Number 63 of 2002 concerning the urban forest is still a great line of organizing urban forest. In addition, through Government rule the Republic of Indonesia Minister of Forestry Number: P.71/Menhut-II/2009 on *Guidelines for Implementation of urban forest* mention that urban forest area in a compact one stretch of at least 0.25 (twenty five percent) acres or percentage of the urban forest area at least 10% (ten percent) of urban areas and or adapted to local conditions. The city of Jogjakarta has a local rule governing the existence of the urban forest or green open space (green space) as stipulated in the Regional Regulation No. 2 Year 2010 concerning Spatial Planning Special Region of Yogyakarta in 2009 -2029. The Data obtained from local Government of Yogyakarta City, (Environment Agency) mention that the city of Yogyakarta only has a urban forest area 260,000 $m^2$ or 26 Ha (0.80%) from total area of Yogyakarta City.

Development of Jogjakarta City tends show many aspects environmental degradation caused by pollution. Based on research in 2008 by Regional Environmental Impact Management Agency (Bapedalda) of The Provincial Government of Yogyakarta Special Region, the pollution levels of Carbon Monoxide (CO), is 30,000 microgram per normal cubic meter (ppm) on a average and that above of the standard of index Indonesia (Bapedalda, 2008). The growth of the high number of vehicles will affect air pollution in environment. Based on the data Yogyakarta police, Yogyakarta city in 2007 has 308.246 automobiles. These vehicles may cause adverse effects on the environment and health human. The prediction of growth vehicles in Yogyakarta city every year is 5 to 10 percent every year. Institute for Transportation and Development Policy (ITPD) United States in 2003 declared that the exhaust gas emissions from motor vehicles in the city of Yogyakarta in the form of hydrocarbons already exceeded national ambient air quality standards established by the Government Decree No. 41 of 1999 that is equal to 160 ug / m3 (Thomas, 2008). From these data, it is no wonder if indeed the city of Yogyakarta is said to have high air pollution. Even today, the congestion could not be avoided. With the amount of transport that more and more, and the link that is not changed, there is congestion became one of the consequences that must be accepted.

Urban forest is a way that can be used to reduce levels of air pollution in the city. In addition, urban forest have other functions that can support the realization of good environment, including reducing noise, dust absorbing, heat island, and can be used as a place of recreation. The development of urban forest requires a good planning and management for produce a maximum urban forest functions. Accurate, fast and efficient about the location, distribution and extent of urban forest will greatly assist in development planning in the city. Indonesia Government Regulation no. 63 Year 2002 about Urban Forest, Chapter 21, paragraph (2)" Monitoring and Evalution of Urban Forest do in periodic time". The purpose of this research is to evaluate the effectiveness of spatial distribution of urban forest for reducing air pollution in Jogjakarta city and to make recommendations to improve development of urban forest planning in Yogyakarta City.

## 1.2 Problem Statement

Development of city has a tendency to minimize the green open spaces. Yogyakarta city currently only has urban forest area of the city amounted 0.80 % from area of the Yogyakarta city. Institute for Transportation and Development Policy (ITPD) United States in 2003 declared that the exhaust gas emissions from motor vehicles in the city of Yogyakarta in the form of hydrocarbons already exceeded national ambient air quality standards established by the Government Decree No. 41 of 1999 that is equal to 160 ug / $m^3$. Trees remove air pollutants such as carbon monoxide, nitrogen dioxide, sulfur dioxide, ozone, and particulate matter, which are called 'criteria pollutants'. Trees also absorb carbon dioxide during the photosynthesis process (Center for Urban Forest Research, 2005). UFORE is a tool that can improve inventory efficiency and provide the environmental information necessary to understand urban forest structure and values. With UFORE model, researchers can quantify the structure of the urban forest and the functions of urban ecosystems related to air pollution reducing.

Generally there is a problem with area of forest cover in Yogyakarta City which owned by local government (260,000 $m^2$ or 26 Ha (0.80%)) and high rate of air pollution in the city. In this regard, this research aims to evaluation urban forest in Yogyakarta city related with air pollution reducing. How about spatial distribution of urban forest, size and evaluate the effectiveness of urban Forest to air pollution reducing. The amount of a particular air pollutant removed by trees is influence by canopy cover of urban forest. The canopy cover related to tree cover, health condition of tree, diameter at breast high, and leaf area index. UFORE model is a tool which can improve inventory efficiency and provide the environmental information necessary to understand urban forest structure and values of urban forest. The model is a science-based, peer reviewed computer model (i-Tree) that estimates structural aspects such as species composition and diversity, tree density and overall health, and leaf area, pollution removal and the associated percent improvement in air quality.

### 1.3 Research Objectives

The general research objective is to evaluate of urban forest for reducing air pollution in Yogyakarta city.

There are 2 main objectives in this research:

1. To determine spatial distribution and calculate area of urban forest in Yogyakarta.
2. To evaluate the effectiveness of urban forest for air pollution reducing in Yogyakarta city.

### 1.4 Research Questions

The evaluate urban forest to reducing air pollution with UFORE model need some information from urban forest. The UFORE model is quantifies the hourly amount of pollution removed by the urban forest and associated percent improvement in air quality. Pollution removal is calculated for O3, SO2, NO2, CO, and PM10 based on field data such as tree canopy cover (area), species composition, tree health, leaf area, diameter of tree, pollution concentration, and meteorological data. The canopy covers of urban forest achieved by spatial distribution and size area of urban forest.

There is several research questions need to be address to achieve the two research objectives that are described in Table 1.1.

**Table 1.1 Research Objectives and Research Questions**

| No | Research objectives | Research questions | Indicator |
|---|---|---|---|
| 1. | To determine spatial distribution and calculate area of urban forest in Yogyakarta City | a. How the spatial distribution of urban forest in Yogyakarta city?<br>b. How much area of Urban forest in Yogyakarta city? | Mapping of Spatial Distribution of Urban Forest and area of urban forest in Yogyakarta city |
| 2. | To evaluate urban forest in Yogyakarta city | a. What is Urban forest structure, including species composition, tree cover, tree density, tree health, leaf area?<br>b. How much hourly pollution removal by the urban forest for ozone ($O_3$), sulfur dioxide ($SO_2$), nitrogen dioxide ($NO_2$), carbon monoxide (CO), and particulate matter ($PM_{10}$)? | The Effectiveness of Urban forest related to air pollution reducing using UFORE model (i-Tree). |

**1.5 Data Availability**

Available data used in this research:

**Table 1.2 Data Availability**

| No | Existing Data | Data Resources |
|---|---|---|
| 1 | Quickbird High Resolution Satellite Imagery (2005)<br>• 2.4 m (7 ft 10 in) (5.47 μrad) multispectral at nadir. (2.4 x 2.4 m) | - PSBA Research Center of Gajah Mada University |
| 2 | Land use Map | - Bappeda Kota Yogyakarta |
| 3 | Administrative Map | - Bappeda Kota Yogyakarta |
| 4 | Road Map | - Bappeda Kota Yogyakarta |
| 5 | Air Pollution data | - BLH Kota Yogyakarta |
| 6 | Meteorological Data | - Meteorology Agency (BMG) |

# 2. Literature Review

## 2.1. Urban Forest

### 2.1.1 Urban Forest Definition

Miller (1998) definition of Urban Forest is the sum of all woody and associated vegetation in and around dense human settlements.

Urban forest is a community of trees and associated vegetation that grows in the city and its surrounding land, shaped path, spread, or clustered (accumulate), the structure mimics (like) natural forests, forming habitat possible life for wildlife and create a healthy environment, comfortable atmosphere, cool and aesthetic (Zoeraini, 2005).

The existing urban forest can be shaped, among others; green line (can be a roadside tree, the green line under a high voltage electric wire, the green line at the edge of the railway line, green line on the banks of the river in and out of city ); plant city the plants are laid out in such a way, part or all of human engineering to get a beautiful composition; garden and yard; botanical gardens, zoos and botanical forest; protected forests; grave and cemetery hero (Dahlan 1992).

Lovric (2009) "The terms urban forest and urban forestry is applied in many different situations in a variety of countries: not surprisingly that this has led to imprecise definitions. According to the studies performed on the scientific literature that used the term urban forests, its meaning varied from incorporati 4
single trees, groups of trees, woody vegetation, city parks, green lawns, green space, woodland, across forests and forest ecosystems to all related vegetation and organisms". The compiled of defining urban forest (ry) can see on table 2.1.

It is clear that urban forest can be anything from large peri-urban forest to virtual collection of street and park trees. Whatever the accepted universal definition is, it is going to have to be vague. In-depth research by Brown (2007) suggests the usage of following definitions for the term urban forestry: "…is a specialized branch of forestry and has as its objective the cultivation and management of trees and forests for their present and potential contributions to the physiological, sociological, and economic well-being of urban society. In Lovric, 2009, Jorgensen in 1974 mention that urban forest contributions include the overall ameliorating effect of trees on their environment, as well as their recreational and general amenity value". "The art, science and technology of managing trees and forest resources in and around urban community ecosystems for the physiological, sociological, economic, and aesthetic benefits trees provide society" (*Helms in Lovric, 2009*).

**Table 2.1 Dissemination of Definitions Related to Urban Forests**

| | STRUCTURAL ELEMENTS | | | | LOCATION | | | PURPOSE | | | | PARTICI-PATION | OWNERSHIP | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Trees | Woodlands | Other | Open space | In cities | Around | Rural areas | Recreation | Wood supply | Ornament | Environment | | Public | private |
| **Urban forest(ry)** | ■ | ■ | | | ■ | ■ | | ■ | | ■ | ■ | | ■ | |
| **Urban green(ing)** | ■ | ■ | ■ | ■ | ■ | ■ | | ■ | | ■ | ■ | | ■ | ■ |
| urban greenery | | | ■ | ■ | | | | | | | | | | |
| urban green space | ■ | | ■ | ■ | ■ | ■ | | ■ | | | ■ | | ■ | |
| public green | ■ | | ■ | ■ | ■ | ■ | | ■ | | ■ | ■ | | ■ | |
| **Arboriculture** | ■ | ■ | ■ | | ■ | ■ | | | | ■ | | | ■ | ■ |
| **Urban gardening** | ■ | | ■ | | ■ | ■ | | ■ | ■ | ■ | | ■ | | ■ |
| **Green belt** | | ■ | ■ | ■ | | ■ | | ■ | ■ | ■ | ■ | | ■ | |
| park belt | ■ | ■ | | ■ | | ■ | | ■ | | ■ | | | ■ | |
| agricultural belt | | | ■ | ■ | | ■ | ■ | | ■ | | | ■ | | |
| woodlands belt | | ■ | | ■ | | ■ | | ■ | | | | | | |
| **Greenways** | | | ■ | ■ | | ■ | ■ | ■ | | | ■ | | ■ | ■ |
| **Town forests** | ■ | ■ | ■ | | | | ■ | ■ | | ■ | ■ | | ■ | |
| **Urban agriculture** | ■ | | ■ | | ■ | ■ | ■ | | ■ | | | | ■ | ■ |
| **(Urban) social forestry** | ■ | ■ | ■ | | ■ | ■ | ■ | ■ | | | ■ | ■ | | |
| **Community forest(ry)** | ■ | ■ | ■ | | ■ | ■ | ■ | ■ | | | ■ | ■ | ■ | |

Sources : Lovric, 2009

Indonesia Government Regulation no. 63 Year 2002 on Urban Forest, Article 1, paragraph (2) defines the Forest City, is a stretch of land that grew the trees are compact and dense in the urban areas at both the state land and land rights, defined as urban forest by an officer authorities. Regarding the extent and the percentage is that the vast urban forest in a stretch of at least 0.25 compact (twenty five percent) hectare (article 8 paragraph 2), whereas the percentage of forest area at least 10% (ten percent) of urban areas and / or adapted to local conditions (article 8, paragraph 3).

### 2.1.2 Urban Forest Benefits

Urban forest tree vegetation is a form of partnership that is able to create a micro climate and its location in urban or near the city. Forests in urban areas are not possible in large areas. The form is also not necessarily in the form of blocks, but the urban forest can be built on various land use. Therefore we need criteria to determine the shape and extent of the urban forest. Important criteria that can be used are the environmental criteria. This is related to important benefits in the Form of urban forest which consists of environmental benefits of conservation microclimate, beauty and conservation of flora and wild life (Fandeli, 2004). In general shape the urban forests are:

1. Green lane. Green lane highway in the form of shade, a green line under the wire electricity, on the edge of the railroad, on the banks of the river, on the edge of the freeway.
2. Park City. Park City is defined as plants that are planted and laid out in such a way, in part or all of the results of human engineering, to obtain a certain composition is beautiful.
3. Garden. Other plants are planted in the garden and yard usually of the type that can produce fruit.
4. Botanical Garden, Forest Kingdom, and the Zoo. Botanical gardens, forests and highway zoo can be incorporated into one form of urban forest. Plants can be derived from the local area, as well as from other areas either domestic or foreign.
5. Protected forests, areas with steep slopes should be a region because of landslide-prone forests. Similarly, the coastal areas prone to abrasion of sea water (Dahlan, 1992).

Urban and community forests can strongly influence the physical/biological environment and mitigate many impacts on urban development by moderating climate, conserving energy, carbon dioxide and water, improving air quality, controlling rainfall runoff and flooding, lowering noise levels, harboring wildlife and enhancing the attractiveness of cities. Urban forests can be viewed as a 'living technology' - a key component of the urban infrastructure that helps maintain a healthy environment for urban dwellers (Dwyer et al. 1992). Studies estimate that a typical person's oxygen needs for a year can be produced by two healthy 9.8m (32-foot) tall ash trees (Elmendorf 2004).

**Trees provide multiple benefits such as:**

1. **Engineering benefits:**

   Acoustical control - a screen of dense coniferous trees 30 meters wide can absorb 6-8 decibels; Traffic control - direction for pedestrian or vehicular-safety barriers between pedestrians and vehicles, screen headlight glare from traffic (Faulkner 2004); Pavement performance - 20% shade improves pavement condition by 11% resulting in 60% saving for resurfacing in 30 years (McPherson et al. 1999).

2. **Economic benefits:**

   Consumer behavior - shoppers pay 12 % more for goods in a tree-lined area, property values are an average of 6 % greater in areas with trees (Hastie 2003); Trees pay us back- a cost benefit analysis of 100 trees over 40 years resulted in a net benefit of $244,000 U.S. (McPherson 2005).

3. **Environmental benefits for humans and animals (Hastie, 2003):**

   Wind control - reduce heat loss from buildings; Sun control - hardwood species reduce solar radiation during the summer and 'provide' sunlight during the winter; Precipitation and humidity control – control snow, reduce fog, rain screen, reduce runoff and create a habitat for wildlife.

4. **Architectural benefit (Faulkner, 2004)**:

   Privacy control - space articulators; Screen objectionable views; Gradual unfolding of a view.

5. **Aesthetic benefits (Faulkner, 2004):**

   Softens, complements or enhances architecture by bringing natural elements into urban surroundings; Emphasizes change of seasons; Provides 'play' areas; Add beauty through their shape, texture, color, and fragrance.

6. **Social benefits:**

   Crime reduction - research suggests that appropriate vegetation cover such as mowed grass and high canopy trees reduce crime rate because "vegetation has a mitigating effect on mental fatigue, itself often a precursor of outburst of anger and violence" (Hastie 2003). In Oakville Urban Forest Report 2006, Nowak in 2001 mention that In a different perspective, trees can be seen as a "classic example of a benefit enjoyed by society as a whole coming at a cost only to the individual or agency that planted the tree" (Oakville's Urban Forest, 2006).

## 2.2 Air Pollution

The Pollutants are an air pollutant for which acceptable levels of exposure can be determined and for which an ambient air quality standard has been set. Examples include ozone ($O_3$), carbon monoxide (CO), nitrogen dioxide ($NO_2$), sulfur dioxide ($SO_2$), $PM_{10}$ and $PM_{2.5}$.(Source: CA Air Resources Board). ***Criteria air pollutants*** - referred to as "criteria air contaminants" by Environment Canada- include carbon monoxide (CO), sulphur oxides ($SO_x$), nitrogen oxides ($NO_x$), ozone ($O_3$), and particulate matter ($PM_{10}$ and $PM_{2.5}$).

They have been linked to a negative impact on human health causing headaches, lung, throat and eye irritation respiratory and heart disease and cancer (Kenney 2001). Carbon monoxide (CO) for instance, binds with hemoglobin in humans, which lowers the capability of the blood to carry oxygen; particulate matter (< 5µm diameter) may cause serious health problems because these small particles can pass through upper respiratory tract defense mechanisms and enter lungs (Kenney 2001). Evidence is emerging in other parts of the world that it may be the smaller sized particles less than 2.5 microns in size, that cause most of the health effects. In Great Britain, an estimated 8,100 annual deaths and 10,500 hospital admissions in urban populations are due to the poor air quality (United Kingdom Department of Health 2002).

Yet because it does not affect respiration directly, $CO_2$ is not considered a classic air pollutant. Noting that increasing levels of $CO_2$ cause temperature and water vapor content to rise, Jacobson uses photochemistry to determine that these factors independently feed back to increase ground-level ozone concentrations. This can harm lung function and irritate the respiratory system. Using a high-resolution model that correlates pollution levels to human health, the author finds that each one degree Celsius rise in temperature may increase U.S. annual air pollution deaths by about 1000. About 40 percent of these deaths may result from elevated ground-level ozone concentrations. The rest are likely from particles, which would increase due to $CO_2$-enhanced stability, humidity, and biogenic feedbacks. The author notes that many of these deaths would occur in urban populations subject to smog, as are residents of some areas of California. Extrapolating U.S. deaths to global population yields about 22,000 excess deaths expected worldwide each year (Mark Z. Jacobson, 2008).

Emissions of carbon dioxide ($CO_2$) by 30.6 Giga tones (Gt) is the highest record so far, 5 percent higher than the record year 2008 ie 29.3 Gt. Yet according to IAE, $CO_2$ emissions had dropped in 2009 following the oil crisis in many countries. Based on the comparison of the number of particles, $CO_2$ emissions in 2010 is 450 parts per million (ppm). This figure also increased by 5 percent compared to data released by the year 2000, which was carrying about 430 ppm (Faith Britol, 2011).

Institute for Transportation and Development Policy (ITPD) United States in 2003 declared that the exhaust gas emissions from motor vehicles in the city of Yogyakarta in the form of hydrocarbons already exceeded national ambient air quality standards established by the Government Decree No. 41 of 1999 that is equal to 160 ug / $m^3$ (Thomas, 2008). From these data, it is no wonder if indeed the city of Yogyakarta is said to have high air pollution. Even today, the congestion could not be avoided. With the amount of transport that more and more, and the link that is not changed, there is congestion became one of the consequences that must be accepted (Dwi Novitasari, 2011).

### 2.3 Reducing Air Pollution by Urban Forest

Trees remove air pollutants such as carbon monoxide, nitrogen dioxide, sulfur dioxide, ozone, and particulate matter, which are called 'criteria pollutants'. Trees also absorb carbon dioxide during the photosynthesis process (Center for Urban Forest Research, 2005).

Tree transpiration and tree canopies affect air temperature, radiation absorption and heat storage, wind speed, relative humidity etc. Reduced air temperature due to trees can improve air quality because the emissions of many pollutants and/or ozone-forming chemicals are temperature dependent (Nowak, 1995).

The studies demonstrated that trees play a role in reducing air pollution. Trees remove gaseous air pollution primarily by uptake via leaf stomata, though some gases are removed by the plant surface. Once inside the leaf, gases diffuse into intercellular spaces and may be absorbed by water films to form acids. Trees also remove pollution by intercepting airborne particles. Some particles can be absorbed into the tree, though most particles that are intercepted are retained on the plant surface. The standardized pollution removal rates differ among cities according to the amount of air pollution, length of in-leaf season, precipitation, and other meteorological variables (Nowak, 1995).

Trees can reduce air pollutants in two ways: (1) by direct reduction from the air, and (2) by indirect reduction by avoiding the emission of air pollutants. In direct reduction, trees absorb gaseous pollutants like sulfur dioxide ($SO_2$), nitrogen dioxide ($NO_2$), and ozone ($O_3$) through leaf stomata and also can dissolve water soluble pollutants onto moist leaf surfaces (Nowak,1994a). Tree canopies can also intercept particulate matters in the air (Beckett et al., 1998). Indirectly, trees can reduce the air temperature through direct shading and evapotranspiration in the summer, thus reducing the emission of air pollutants from the process of generating energy for cooling purposes. Also, reduced air temperature can lower the activity of chemical reactions, which produce secondary air pollutants in urban areas (Taha, 1996; Nowak et al., 2000).

People have known that trees can help to reduce air pollutants for a long time. The Roman senate recognized the value of orchards in villas surrounding the city of Rome for maintaining air quality and forbid their conversion to urban housing (Cowell, 1978). In more recent times scientific studies have quantified the amount of air pollutants removed by trees in cities. DeSanto et al. (1976) studied the removal of five major air pollutants, $SO_2$, carbon monoxide (CO), $O_3$, $NO_x$ and particulate matters by street trees in St. Louis area. Dochinger (1980) conducted early studies of the interception of particulates by trees. In these studies, the air pollutants reduction effects of the urban forest were calculated by extrapolating the field measurements of several trees to the whole urban forest. There are, however, problems with this approach. Primary among these problems is that the concentration of air pollutant varies spatially and temporally and the conditions of trees are highly variable within a city. Large samples are needed to account for this variation. Another approach to determine the air pollution reduction effect of trees in urban areas is to integrate the knowledge of meteorology and atmospheric chemistry with tree biology to model air pollution reduction in a certain area and time. This method was used by Nowak (1994a), Nowak and Dwyer (2000) and Scott et al. (1998) to study several American cities. Their studies show that urban forest can contribute significantly to air pollution reduction.

There are some uncertainties and limitations in this modeling method that need to be improved. Scott et al. (1998) gave a detailed discussion of these limitations. The main limitation of this method is that the direct air pollutants reduction by trees is calculated using a ‘‘big leaf’’ model. The air pollutant concentration was assumed as homogenous in whole city, and the trees were assumed as occurring in a homogeneous, connected layer. In reality, the urban building configuration, the local photochemical reaction, and the meteorology condition influences the air pollutants concentration in a city resulting in a somewhat less than homogenous concentration. Also, the trees vary with different heights and crown configurations. So the air pollutants deposition rate estimated using a ‘‘big leaf’’ model is only a rough approximation of the real situation. However, the method is still the best available method and was used in this study.

Growing global concern about climate change and the on-going search for solutions to reduce the impact of "man-made" pollutants has lead to the Kyoto Protocol, signed by Canada in 2003. On April 13, 2005 the former Federal government announced its climate change plan *'Moving Forward on Climate Change: A Plan for Honoring our Kyoto Commitment'* that outlined Canada's commitment to reduce its greenhouse gas emissions to six percent below 1990 levels. The current Federal government is developing climate change policy expected in Fall 2006. "Human activities add greenhouse gases to the atmosphere…..enough to exceed the balancing effects of natural sinks" (Geiger 2005). *Therefore, even small gains in the filtration rate of criteria pollutants by trees can be significant.* The United Nations Framework Convention on Climate Change (UNFCCC) defines "sink" as "any process, activity or mechanism which removes a greenhouse gas, an aerosol or a precursor of a greenhouse gas from the atmosphere." A relatively cost effective way of combating climate change, according to the UNFCCC, can be achieved either by increasing the sink through planting trees or managing forests or by reducing emissions. Separating the *local* vs. *regional* scale of human produced greenhouse gas emissions is critical to understanding the potential influence initiatives such as tree planting can do to help restore the balance of "sink" and "source." This is also very important to keep in mind when assessing the results of the UFORE Model. In other words, while "…trees are highly efficient at reducing air pollution, their contribution to the overall reduction of air pollutants is fairly small, amounting to only about 2 percent of total emitted"(Geiger 2005).

## 2.4 i-Tree (UFORE model)

### 2.4.1 i-Tree Software

i-Tree Eco software is application from of the Urban Forest Effects (UFORE) model. UFORE was developed by US Forest Service Northern Research Station (NRS), the USDA State and Private Forestry's Urban and Community Forestry Program and Northeastern Area, the Davey Tree Expert Company, and SUNY College of Environmental Science and Forestry. Nowak and Crane (1998) said that UFORE is a tool that can improve inventory efficiency and provide the environmental information necessary to understand urban forest structure and values. With UFORE model, researchers can quantify the structure of the urban forest and the functions of urban ecosystems. Analysis of UFORE uses collected field data combine with available external data sources (e.g. weather and air pollution data) to quantify basic tree functions and ecosystem services.

Nowak and Crane (1998) said "The model is a science-based, peer reviewed computer model" (i-Tree 2010b) that estimates structural aspects such as species composition and diversity, tree density and overall health, and leaf area, as well as volatile organic compound emissions, the total amount of carbon stored and sequestered, and pollution removal and the associated percent improvement in air quality. Currently, projects and inventories utilizing the model are referred to as i-Tree Eco projects and inventories; however, the actual computer model used at the time of this study was the UFORE model (i-Tree 2010a).

i-Tree Eco can help managers and researchers to quantify urban forest structure and functions based on standard inputs of field, meteorological, and pollution data (figure 2.1). The model currently calculates the following parameters based on local measurements:

1. Urban forest structure, including species composition, tree cover, tree density, tree health (crown dieback, tree damage), leaf area, leaf biomass, and information on shrubs and ground cover types. The local measurements must determine first. There are many variables that can be collected in the field. For each data type, a decision must be made if these data are important for the analysis. The following are the core variables that are required to analysis functional of air removal of urban forest using field measurement are Tree Species, Diameter breast height, Height of tree, and Tree Health condition. The analysis functional of air removal calculated by using input data from local measurement using the model algorithms into software packing.

   Four files are required as input into the UFORE model:

   a) Land use area
   b) Original land use
   c) Plot information
   d) Tree information (local measurement, such as Tree Species, Number of DBHs recorded, DBH, DBH measurement height, Total height, Height to crown base, Crown width, Percent Canopy Missing, Dieback, CLE – crown light exposure.

**The input of local measurement will be analysis and calculated by UFORE-A: Anatomy of the Urban Forest** -- quantifies urban forest structure (e.g., species composition, tree density, tree health, leaf area, leaf and tree biomass) based on input data. Urban forest structure is the spatial arrangement and characteristics of vegetation in relation to other objects, e.g., buildings, within urban areas (e.g., Nowak 1994a). The number of plots to be inventoried must be determined. As a general rule, the size of plot is 1/10 acre or 0.04 Ha. On each plot, the following general plot data were estimated / recorded for input in this model:

- Percent tree cover
- Actual land use on the plot
- Percent of plot within the land use
- Ground cover: percent of ground covered by following cover types: buildings, cement, tar-blacktop/asphalt, other impervious, soil, pervious rock, duff/mulch, herbaceous (exclusive of grass and shrubs), maintained grass, wild/unmaintained grass, and water.
- Percent shrub cover ( Optional)

For each tree with the center of its stem in the plot, minimum diameter at breast height (d.b.h.) of 2.54 cm, the following information was measured /recorded:

- species
- number of stems
- d.b.h. of each stem (or if greater than six stems, diameter recorded below fork and height of measure recorded)
- tree height
- height to base of live crown
- crown width (average of two perpendicular measurements).
- percent of branch dieback in crown (used to rate tree crown condition):
    - Excellent (< 1)

  - Good (1-10)
  - Fair (11-25)
  - Poor (26-50)
  - Critical (51-75)
  - Dying (76-99)
  - Death (100 -- no leaves)
- Percent of canopy volume devoid of leaves (0-100%)
- Percent of land area beneath entire tree canopy's drip line that is impervious
- Percent of land area beneath canopy drip line that is occupied by shrubs
- Crown Light Exposure: Number of sides of the tree receiving sunlight from above
- Distance to residential building (optional)
- Direction to building (optional
- Street tree: Y if a street tree, N if not. (Optional).

The output from this model is Leaf area, leaf biomass and Species Diversity. Leaf area and leaf biomass of individual trees were calculated using regression equations for deciduous urban species (Nowak 1996). If shading coefficients (percent light intensity intercepted by foliated tree crowns) used in the regression did not exist for an individual species, genus or hardwood averages were used. Leaf area was calculated using the regression equation with the maximum or minimum ratio; leaf area was then scaled back proportionally to reach the original crown volume. Average tree condition was calculated by assigning each condition class a numeric condition rating. A condition rating of 1 indicates no dieback (excellent); a condition rating of 0 indicates a dead tree (100-percent dieback). Each code between excellent and dead was given a rating between 1 and 0 based on the mid-value of the class (e.g., fair = 11-25 percent dieback was given a rating of 0.82 or 82-percent healthy crown.

Estimates of leaf area and leaf biomass were adjusted downward based on crown leaf dieback (tree condition). To adjust for overlapping tree crowns, estimates of tree leaf area and leaf biomass (derived from open-grown tree equations) were scaled back proportional to the amount of crown competition on the plot. A plot competition factor (CF) was calculated as:

$$CF = GA/TA \quad \ldots \quad (1)$$

where GA = projected crown area (m2) of individual trees in the plot and TA = % tree cover × plot size (m2). Leaf area (LAn) of individual trees was calculated as:

$$LAI_n = LA_o \, x \, LAI_n \, / \, LAI_o \quad \ldots \quad (2)$$

where LA0 = leaf area based on open-grown equations; LAI0 = LAI of plot based on open-grown equations; and LAIn = LAI adjusted for plot competition. LAIn varied with CF. For CF < 1 (open grown trees): LAIn = LAI0. For CF > 1 and CF < 2 (mixed open-grown and closed-canopy conditions):

$$LAI_n = LAI_{op} + LAI_{cl} \quad \ldots (3)$$

**Species Diversity**

Species diversity indices (Shannon-Wiener's index) and species richness, i.e., number of species (Barbour et al. 1980), were calculated for living trees for the entire city. The proportion of the tree population that originated from different parts of the country and world was calculated based on the native range of each species.

2. Hourly pollution removal by the urban forest for ozone ($O_3$), sulfur dioxide ($SO_2$), nitrogen dioxide ($NO_2$), carbon monoxide (CO), and particulate matter ($PM_{10}$). The UFORE model uses standard field, air pollution, and meteorological data to quantify urban forest structure and numerous forest-related effects in various U.S. cities (Nowak and Crane, 2000). The hourly pollution removal calculated by **UFORE-D: Dry Deposition of Air Pollution** -- quantifies the hourly amount of pollution removed by the urban forest and associated percent improvement in air

quality throughout a year. Pollution removal is calculated for O3, SO2, NO2, CO, and PM10 based on field, pollution concentration, and meteorological data.

Air pollution reduction calculations Trees with their dense leaves, twigs, and branches, construct a rough aerodynamic surface. Their surface is very effective for direct removal of the air pollutants from the air through the dry deposition process (Beckett et al. 1998). The removal of a particular air pollutant at a given place over certain time period then was calculated as (Nowak, 1994a).

$$Q = F \text{ x } L \text{ x } T \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Q is the amount of a particular air pollutant removed by trees in a certain time, F is the pollutant flux, L is the total canopy cover in that area, and T is the time period. The pollutant flux F is calculated as (Nowak, 1994a)

$$F = Vd \text{ x } C\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Vd is the dry deposition velocity of a certain air pollutants, and C is the concentration of a particular air pollutant in the air. The dry deposition process can be described as (Nowak, 1994a)

$$Vd = \frac{1}{\text{Ra} + \text{Rb} + \text{Rc}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Vd is the dry deposition velocity, Ra the aerodynamic resistance, Rb the quasi-laminar boundary layer, and Rc is the canopy resistance. Ra, Rb, Rc was calculated as (Killus et al., 1984)

$$\text{Ra} = \frac{u(z)}{\text{u2}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

*u* (*z*) is the wind speed at height z; u* is the frictional velocity, and is expressed as the dimensionless $\boldsymbol{\psi}_{\text{m}}$ stability function for momentum.

$$\text{u} *= \frac{ku\,(z-d)}{\ln\left[\frac{z-d}{Zo}\right] - \psi m \left[\frac{z-d}{L}\right] + \psi m \,[\frac{Zo}{L})} \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

where k is the von Karman’s constant (0.4), d the displacement length (8 m) and z0 the roughness length (0.5 m), and L the Monin–Obukhov stability length. L was estimated by classifying local meteorological data into stability classes using Turner classes and then estimating 1=L as a function of stability class and z0 (Zannetti,1990). When L < 0: unstable condition:

$$\psi m = 2\ln[\frac{(1+X)}{2}] + \ln[\frac{(1+x^2)}{2} - 2\tan^{-1}(X) + 0.5 \quad \ldots\ldots\ldots(6)$$

where the dimensionless factor X was calculated as (Dyer and Bradley, 1982)

$$X = (1 - 28\frac{zx^2}{L})^{0.25} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots,,,(7)$$

when L > 0: stable condition

$$\psi m = -17[1 - \exp\left(-0.29\frac{(z-d)}{L}\right)] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(8)$$

$R_b$ was calculated as (Pederson et al., 1995)

$$Rb = \frac{2Sc^{2/3} \times Pr^{-2/3}}{ku*})^{0.25} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots...(9)$$

where k is the von Karman constant, Sc the Schmidt number, and Pr is the Prandtl number.

During the growing season, hourly tree-canopy resistances Rc for O3, SO2, and NO2 are calculated based on a multi-layer canopy deposition models (Baldocchi et al., 1987; Baldocchi, 1988). Hourly inputs to calculate canopy resistance is photosynthetic active radiation (PAR), air temperature, wind speed, u; carbon dioxide concentration, and absolute humidity. For PM10, its deposition velocity was assumed to be 0.0064ms_1 for growing season and 0.0014ms_1 for the leaf-off season, a 50% re suspension rate for PM10 back to the atmosphere was assumed. Monthly and yearly removal of NO2, O3, PM10, and SO2 by trees were calculated using the Urban Forest Effects model (UFORE) developed by the USDA Forest Service, Northeastern Research Station, which incorporated these algorithms into one software package (Nowak and Crane, 2000).

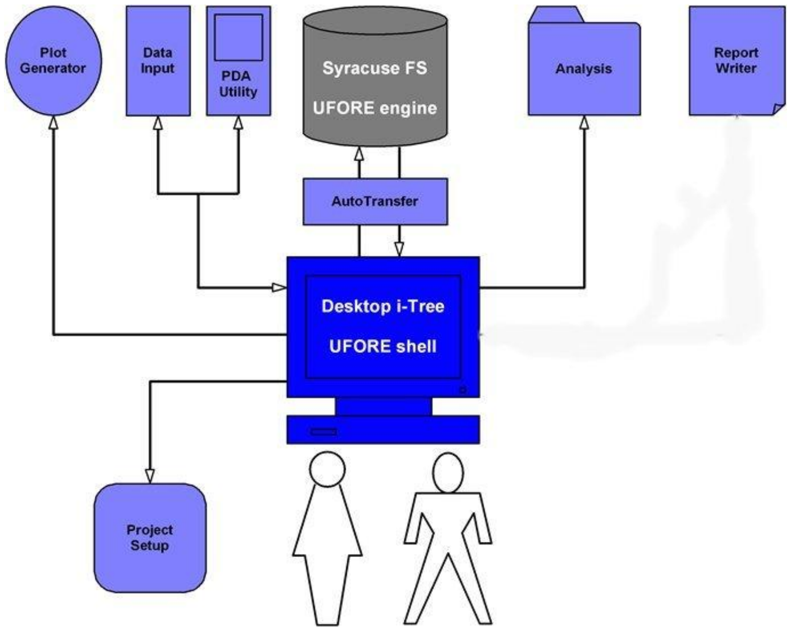



**Figure 2.1 i-Tree (UFORE) Framework**

i-Tree Eco has been used in several cities in the United States (US), including Atlanta, GA, Baltimore, MD, Boston, MA, New York, NY, and Philadelphia, PA (Nowak and Crane 1998), Minneapolis, MN, and San Francisco, CA (Nowak et al. 2008a). The standardized air pollution removal rate calculate by UFORE for around the world can see on table 2.2.

**Table 2.2 Standardized air pollution removal rate a few cities around the world**

| No | City | % tree cover | Number of Trees | Pollution Removal (ton/yr) | Area ($km^2$) |
|---|---|---|---|---|---|
| 1 | Jersey City, New Jersey, U.S.A | 11.5 | 136,000 | 41 | 54.59 |
| 2 | Freehold, New Jersey, U.S.A | 34.4 | 48.000 | 22 | 5 |
| 3 | Calgary, Canada | 7.2 | 11,889,000 | 326 | 789.90 |
| 4 | New York, U.S.A | 20.9 | 5,212,000 | 1,677 | 1,214.4 |
| 5 | Beijing, China | 29 | 2,400,000 | 1,261 | 300 |
| 6 | Torbay, United Kingdom (U.K) | 11.2 | 818,000 | 50 | 62.88 |

Source: D.J Nowak, 2006

### 2.4.2. Advantages of i-Tree

UFORE provides necessary information on the urban forest resource and its ecosystem services to improve urban forest management and garner support for urban forestry programs. Data on urban forest structure and health can aid in establishing appropriate budget levels and workload allocation, while information on tree cover can help define areas where new tree plantings would be more beneficial. Pest information can help detect existing vulnerabilities to insects and pathogens that could devastate the urban forest. The ecosystem service results can be used to determine the value of the resource and support integrating urban forest programs in larger regulatory efforts to improve environmental quality (Nowak, D.J., 2010).

### 2.4.3. Disadvantages and Limitation of i-Tree

Various local information on the city or area of analysis are require d to run the model. International users must enter this data in to a form s o the location information can be entered in the location database (*procedu res under development).*If new species are encountered that are not in the s pecies database, international user must fill out a form with required inform ation on the new species for species entry into the database (*procedures un der development).*Without local improvements (e.g., biomass formulas, growt h rates) the modewill default to US conditions. The model will produce est imates based on local international field data, but default to US equations without the additional desired information. Location information is required unless users want to run the model as if their trees existed in a US city. New species information is required unless the user wants to substitut e an existing species in the data base for the true species (Nowak, D.J., 2010).

## 2.5 Study Area

Yogyakarta city is situated between 110° 24'19 "-110 ° 28'53" East Longitude and between 07° 49'26 "-07 ° 15'24" south latitude, with an area of 32.5 $km^2$ or 1.02% of area of Yogyakarta Special Region. The city of Yogyakarta, located in the plain slopes of Mount Merapi flows have a relatively flat slope (between 0 – 2 %) and are at an average altitude of 114 meters from sea level (mdpl). Some region with an area of 1657 hectares situated at an altitude of less than 100 meters and the rest (1593 acres) located at an altitude between 100-199 mdpl. The Most of the type of soil is regosol.

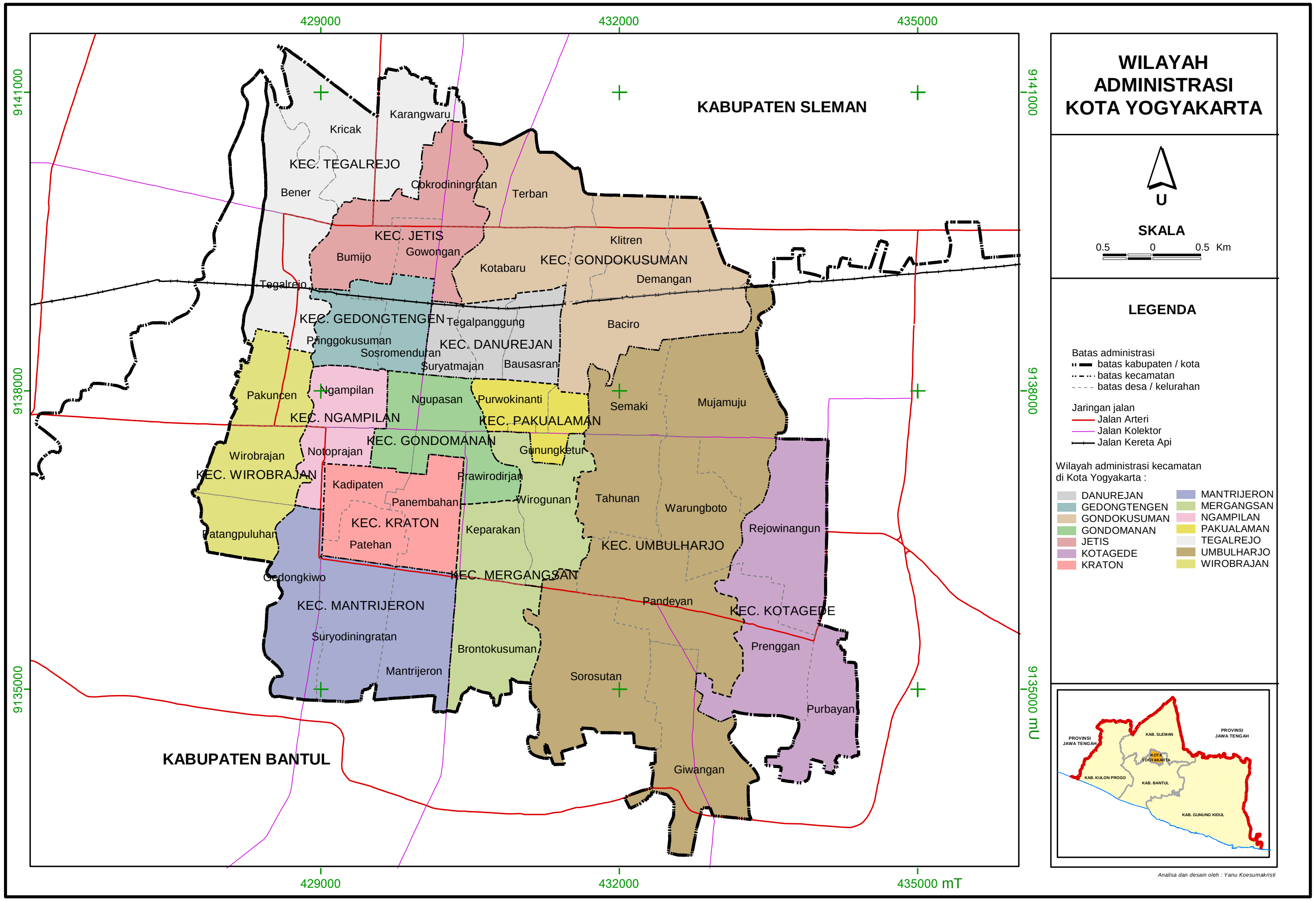
Administratively, the city of Yogyakarta consists of 14 districts and 45 villages with a boundary region (show in Figure 2):

| | |
|---|---|
| North | : Sleman Regency |
| East | : Bantul and Sleman Regency |
| The South | : Bantul Regency |
| West | : Bantul and Sleman Regency |

Based on the results of the 2000 Population Census, the population numbered 397,398 persons Yogyakarta consisting of 194,530 persons (48.95 percent) males and 202 868 people (51.05 percent) women. Total population based on results SUPAS in 2005 were 435 236 people. The average population growth period from 2000-2005 is 1.9 percent. Based on a projection of the 2000 Population Census of 2009 recorded a population of 462,752 people. Composition of population by sex is 48.86 percent male and 51.14 percent female. With a total area of 32.50 $km^2$, the population density of Yogyakarta is 14,239 inhabitants per km2 (BPS Kota Yogyakarta, 2011).

The length of roads throughout the city of Yogyakarta in 2009 reached 265.93 km. The length of road which is under the authority of the state 18.13 km, while 247.80 km are under the authority of the City of Yogyakarta In the year 2009 the number of public transport vehicles carrying four or more wheels as much as 10,388 units. Its composition in 2009 consisted of: 61.08 percent of the general pickup BU, 21.07 percent of trucks, buses 10.65 percent, and the remaining 7.2 percent the tank and special vehicles and trains (BPS Kota Yogyakarta, 2011)

**Figure 2.2 Administrative Map of Yogyakarta City**



# 3 Research Method

The method used in this study to determine urban forest cover involved an estimation of the area on satellite image using remote sensing with extraction method and a field survey conduct to measure structural parameters of the Yogyakarta urban forest using UFORE model.

## 3.1 Satellite Image Acquisition and Analysis

A High Resolution satellite image acquired in 2005 (Quickbird) with a geo reference and image preprocessing to the coordinate system of the study area and a projection of WGS 84 and UTM zone of 49 S was obtained from PSBA Research Center of Gajah Mada University and PUSPIC of Gajah Mada University, Yogyakarta, Indonesia. Quick Bird is a high spatial resolution digital images that can be use to produce relatively accurate cover maps of urban forest in Yogyakarta city. Zhang in 2001 with the research in Germany mention that "for improved land and urban forest planning and management at the neighborhood scale, high-spatial resolution imagery is more valuable and appropriate. The recent advent of relatively low-cost digital high-spatial resolution color-infrared aerial images allows developing urban cover maps with detailed information at the local scale. These maps can be integrated within Geographic Information Systems (GISs) and can provide a wealth of information to managers, planners, and scientists to improve urban vegetation management and understanding of urban ecosystems.

Suitable remotely sensed image data for mapping vegetation cover and properties at different spatial scales (from global to local) are becoming increasingly available. There is an extensive body of work covering the usefulness of these image data and the associated methods for vegetation mapping and monitoring. The availability of data from high spatial resolution sensors such as the IKONOS, QuickBird, GeoEye-1, and WorldView-2 satellite sensors and airborne multispectral, hyperspectral, and light detection and ranging (lidar) sensors has opened up new opportunities for the development of operational mapping and monitoring of small features such as individual tree crowns and narrow riparian zones (Hurtt et al. 2003).

Vegetation mapping and monitoring has benefited significantly from the more readily available high spatial resolution image data, which have proven essential for vegetation and forest inventories at local to regional spatial scales. Higher spatial resolution may not necessarily result in improved mapping accuracies (Harvey and Hill 2001; Wang, Sousa, and Gong 2004). Although increased spatial resolution provides opportunities for detecting small features and for mapping objects of interest in great detail, it also creates a variety of challenges in image analysis due to the variability of reflectance values within features of interest, for example, sunlit and shaded parts within one tree crown (Aplin, Atkinson, and Curran 1999; Cochrane 2000; Goetz et al. 2003; Sawaya et al. 2003). The suitability of high spatial resolution image data for detailed vegetation mapping and monitoring in various environments is supported by the ability to scale-up mapping results derived at high spatial resolutions.

### 3.1.1 Urban Forest Classification

Urban forest classification used extraction information from high spatial resolution image. In this research, there were two methods of extraction information from remote sensing image will be use. Information extraction based on semi-automatic processing by computer, in this method feature extraction from ENVI 4.5 and Information extraction based on visual image interpretation using Arc GIS 9.3. In general, Information extraction methods from remote sensing images can be subdivided into two groups, Information extraction based on visual image interpretation and information extraction based on semi-automatic processing by computer (ITC Educational Textbook Series, 2009)

The ENVI Feature Extraction Module allows you to quickly, easily, and accurately extract features from high resolution imagery. The new, add-on module to ENVI uses object-based image analysis technology for extracting features from readily available pan and multi-spectral imagery and data The ENVI Feature Extraction Module provides significant time savings over traditional feature extraction methods. Segment an image and quickly view the results in a Preview Window to assess the accuracy of the segmentation, rather than waiting for the full image to process. The segmentation scale is quickly adjusted and previewed as many times as needed prior to full image processing. Once accurate parameters have been established, the process can be automatically repeated on a collection of images. ENVI Feature Extraction is a module for extracting information from high-resolution panchromatic or multispectral imagery based on spatial, spectral, and texture characteristics. This technique works well with hyperspectral data, but it is not ideal for panchromatic or multispectral imagery. With high-resolution panchromatic or multispectral imagery, an object-based method offers more flexibility in the types of features to be extracted. An object is a region of interest with spatial, spectral (brightness and color), and/or texture characteristics that define the region (ITT Visual Information Solutions, 2007).

Information extraction based on semi-automatic processing by computer with feature extraction from ENVI 4.5. The following steps were:

1. The Feature Extraction is choosing the highest Scale Level that delineates the urban trees as well as possible. Choosing a high Scale Level causes fewer segments to be defined, and choosing a low Scale Level causes more segments to be defined. A value of 30.0 seems to delineate urban trees boundaries while preserving some detail in their shapes.
2. Feature Extraction proceeds to the Merge step which Merging group similar adjacent segments by re-assembling over-segmented or highly textured results. For this dataset, set the Merge Level to a value of 94.0.
3. Feature Extraction proceeds to the Refine step. The Refine step was an optional; accept the default selection of No Thresholding.
4. Select to compute all available attributes such as spatial, spectral, texture, color space and band ratio. These attributes will be available for the rule-based classification.
5. Select Classify by creating rules and defined rule for classification of urban tree were min band less than 0.500 and band ratio less than 0.0850 (the band ratio attribute is a measure of NDVI).
6. Exporting Classification Results to a Shapefile.

The second method was use Information extraction based on visual image interpretation using Arc GIS 9.3. The extraction based on visual image interpretation was intuitive way which based on ability to relate colours and patterns in an image to real world features. The visual image interpretation used digitize on screen using Arc GIS 9.3 as polygons. There were seven interpretation elements are distinguished: tone/hue, texture, pattern, shape, size, height/elevation and location/association. The interpretation process consists of delineating areas that internally appears similar and the same time different from other areas. Different interpretation units can be described according to the interpretation elements. In this interpretation made up example of an interpretation legend from urban trees (see on figure 3).

| Figure of unit | Tone | Texture | Shape | Height | location |
|---|---|---|---|---|---|
|  Urban tree | Green | Granular | polygon | High | Urban area |

Figure 3 Urban forest classifications.

The result of interpretation was tentative urban forest spatial distribution map. The tentative urban forest spatial distribution will be assessing with accuracy assessment. After trough accuracy assessment, the urban forest spatial distribution will be overlay with administration map, land use map, river basin map and roads network map. The urban forest map overlay with arc GIS 9.3 to land use map, administration boundary map, river map and roads network. The overlay with administration boundary map was important, because from this process, we can know where the district has maximum and minimum urban forest cover area. The all district in Yogyakarta city has influence to the total tree cover in Yogyakarta city where the regulation of Ministry of Forestry P.71 and Indonesia Government Regulation PP. 63 indicate that the minimum of urban forest area in some city is not less than 10% from total area of the city. The second overlay with land use map was wanted to know how the urban forest distribution and area related to each category in land use (Settlement, Agriculture, other land use). The third overlay was river map with buffering 50 meters from edge of river line. The buffering 50 meters based on the Republic Indonesia government regulation

Number 41 Year 1999 on Forestry, article 50 paragraph 3 which reads “Every person is prohibited: cutting trees within a radius or distance up to 50 (fifty) meters from the left and right side of the river. The target of overlay was to know how urban forest distribution, size area and the potential area which can be optimize as urban forest. The last overlay operation was road network with buffering from edge of road networks (5 meters (2.5 meters on each edge) meters and 8 meters (4 meters on each edge of roads). The buffering on the road edge was based on The National Standard of Indonesia (SNI) Number 03-2447-1991 about Pedestrian Specification which mentions that the minimum size of pedestrian in Indonesia is 1.5 meters (class III), 3.0 meters (class II) and 3.0 meters (class I). This process was to know how urban forest distributions especially in pedestrian, urban forest size area and potential area which can be optimize as urban forest.

### 3.1.2 Accuracy Assessment

Accuracy assessment is an important element of land cover mapping that offers a guide to the map quality, reliability, implication to users and insight into the thematic uncertainty (Treitz, 2004). Sample size based on Binomial Probability theory that suggests that the sample size N to be used to assess the accuracy of land use classification map be determined from formula for the binominal probability theory (Jensen, 2008).

$$N = \frac{Z^2 (p) (q)}{E^2} \qquad \text{……………………………………………………………….(1)}$$

Where p is the expected percent accuracy of the entire map, q = 100 – p, E is the allowable error and Z = 2 from the standard normal deviate of 1.96 for the 95% two sided confidence level. The research use expected map accuracies of 85 % and an accepted error of 10%, the sample size for the map would be 51.

$$N = \frac{2^2 (85) (15)}{10^2} = 51 \qquad \text{…………………………………………………….(2)}$$

The 51 points sampling were taken by randomly to the map use Arc GIS and then was check on the field to indentify that the classification was the same with field condition. The amount of the correct point sampling in the field with sample point from map classification will be use to determined the accuracy of the map.

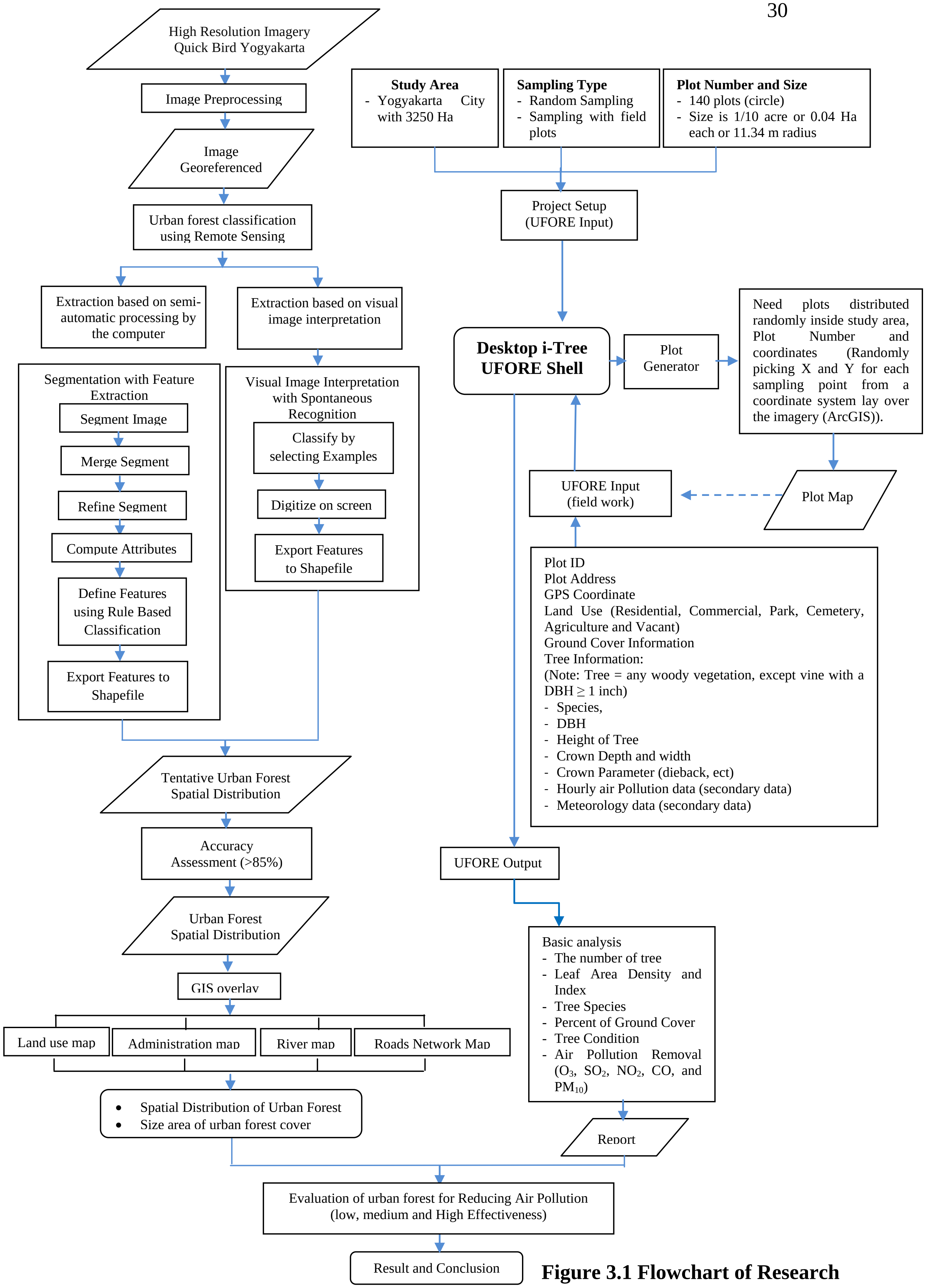
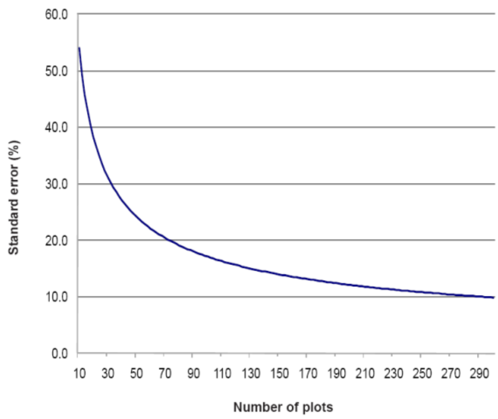



**Figure 3.1 Flowchart of Research Method**

### 3.2. Field Survey and Analysis of i-Tree

All data and field survey were collected following i-Tree Eco tree inventory protocol (i-Tree 2010c). A field survey is conduct in September 2011. Survey of i-Tree was detail investigation survey. The detail investigation survey use density on the field with 1 per 20 hectare and the scale average was 1:25.000 until 1:10.000. The number of plots to be inventoried must be determined. As a general rule, 140 plots (1/10 acre or 0.04 ha each or 11.34 m) in a unstratified random sampling will yield a standard error of about 10 - 15 % for an estimate for the entire city. As the number of plots increases, the standard error decreases and it can be more confident in the estimate for the population. The graph below provides a rough estimate of how the standard error of the total number of trees in a city changes based on the number of plots sampled. Note how for the first 100 plots, the standard error drops more rapidly than for the second 100 plots, although the standard error continues to drop with increased sample size (show in figure 3.2, i-tree manual, 2010).

**Figure 3.2 The Standard Error Changes Based on The Number of Plots Sampled**

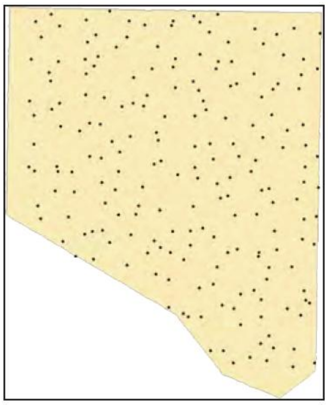



Source: i-Tree Manual, 2010

One hundred and forty (140) sampling plots are located in the entire study area. The total number of plots is decided by referring to the number used by Nowak on Effect of Plot and Sampling Size on Timing and Precision of Urban Forest Assessments (2008, Based on Nowak's experiment on estimates of total number of trees and standard errors from 14 cities analyzed using the UFORE model, some cities in U.S.A have same area with Yogyakarta city such as Freehold, New Jersey (5.0 $km^2$) with 144 plots and the results of error is 10.1 %, Minneapolis (142 $km^2$) with 110 plots and the results of error is 12.5 % and Morgantown (26,2 $km^2$) with 136 plots and the results of error is 9.9 %.

The plots were located on the 2.4 m resolution of Quickbird satellite imagery by randomly picking X and Y for each sampling point from a coordinate system lay over the imagery through Arc GIS (see on Appendix 2 and 3). On the ground, once a plot center is located with the help of the satellite imagery, a circular plot with a radius of 11.3m was set up. The area of each plot is approximately 400 $m^2$. **Randomized grid:** In this method, an evenly spaced grid is laid over the study area. Then, plot points are selected randomly within each cell, which allows for a more even distribution of points throughout your study area with a greater degree of randomness than using a fixed grid. This method would most likely require use of a GIS to complete. One advantage of the randomized grid is that it allows for multiple post-stratification schemes because plots are more evenly distributed (shown figure 3.3).

**Figure 3.3 Randomized Grid**



Source: i-Tree Manual, 2010

The UFORE input from the field work base on the plot map was to collect some data which related to reducing air pollution by tree. The amount of a particular air pollutant removed by trees is influence by canopy cover of urban forest. The canopy cover related to tree cover, health condition of tree, diameter at breast high, and leaf area index.

The survey information which collected from the plots is (Table 3.1 and data sheet on Appendix 1):

1. **Plot ID**: Required for sample inventories
2. **Plot address**
3. **GPS Coordinates**: Optional. GPS coordinates help if revisiting the site is necessary, although GPS accuracy can vary greatly, especially under trees.
4. **Actual land use**: Required for sample inventories. Land use should be determined by the inventory team based on impressions out in the field (i.e., not from land use maps). This field describes how the land is being used, which is not necessarily the same as the ownership of the land. The following land use types are included *Residential (R*, *Multi-family residential (M), Commercial/Industrial (C), Park (P), Cemetery (E), Golf Course (G), Agriculture (A), Vacant (V), Institutional (I* ) and *Transportation (T).*
5. **Percent in each land use**: Required for sample inventories. For plots that include only one land use, this value is 100%. For plots that include two or more land uses, estimate what percentage of the plot each land use occupies. For example, a plot that falls on the property line between a house and a convenience store might be 40% residential and 60% commercial/industrial. Land use differences must be clearly identifiable on the plot with a clear change in human use of the land, not just its cover or ownership.
6. ***Ground cover,*** Required for sample inventories. Within the plot, various materials will cover the ground (trees and shrubs are considered separately; tree stems as a ground cover are ignored). The crew should note the percentage of the plot ground area that is covered by the following materials: *Building (%BLDG, Cement (%CMNT), Tar (%TAR)*: Blacktop/asphalt, *Rock (%ROCK), Bare soil (%SOIL),*

*Duff/mulch (%DUFF/MULCH), Herbs (%HERB/IVY), Grass (%MAIN.GRASS), Unmaintained grass (%UNMAIN.GRASS), Water (%H20).*

7. **Tree ID**: Required. Each tree in a plot requires a unique ID.
8. **Land Use**: Required for sample inventories. Record the land use in which the tree is located
9. **Tree Species,** When, possible tree identification to the species level is made on the site. If a species could not be identified in the field, a sample is collected, labeled and later identified by using an identification key to trees of the Yogyakarta region tree identification or by consulting local arbor culturist.
10. **Status**: The eight possible statuses of a tree are shown below. In an initial inventory of a project area, all trees will be identified as Planted (P), Ingrowth (I), or Unknown (U). In future inventories of the same plot, new trees will be identified as P, I, or U. Trees that were present during a previous inventory should be identified with the other status codes.
11. **Total tree height:** Required. Measure the height to top (alive or dead) of tree. For standing dead trees, downed living trees, or severely leaning trees, height is considered the distance along the main stem from ground to tree top. (Do not include dead trees that are lying on the ground.). The height of each tree is measured by using a SUUNTO clinometer to the nearest 0.1 m.
12. **Height to live top**: This height will be the same as total tree height unless the tree is alive but the top of the crown is dead. This variable cannot be greater than total tree height. Record to the nearest foot or meter.
13. **Height to crown base**: Required. Measure height to base of live crown (to nearest ft or m). The live crown base is the point on the main trunk perpendicular to the lowest live foliage on the last branch that is included in the live crown. The live crown base is determined by the live

foliage and not by the point where a branch intersects with the main bole.

14. **Crown width**: Required. Measure crown width (to nearest ft or m) in two directions: north-south and east-west or as safety considerations or physical obstructions allow. If tree is downed or leaning, take width measurements perpendicular to the tree bole.
15. **Percent canopy missing**: Required. Percent of the crown volume that is not occupied by branches and leaves. Missing canopy should be measured by two people standing at perpendicular angles to the tree.
16. **Crown dieback**: Required. Percent dieback in crown area. This dieback does not include normal, natural branch dieback, i.e., self-pruning due to crown competition or shading in the lower portion of the crown. The percentage of any normal live crown that is missing is estimated as the part of the crown if the tree had grown to its full crown shape. The health condition of trees is classified into seven categories: Excellent, no obvious dead branches inside tree crown; Good, 1–10 % of crown composed of dead branches; Fair, 11–25%; Poor, 26–50; Critical, 51–75%; Dying, 76–99%; Dead, 100%. (Adopted from Nowak et al.,2003).
17. **DBH**: Required. Record the tree's DBH on the uphill side of the tree to the nearest 0.1 inch/cm. The DBH of trees are measured with a DBH tape at a height of 1.35m above the ground for single stem trees. If a tree had multiple stems, the DBH of each stem is measured and recorded. DBH is measured to the nearest 0.1 cm.

**Table 3.1 Information Collected on Sample Plots for the Yogyakarta Urban Forest**

| | |
|---|---|
| Plot information Land use | Land use<br>Tree cover |

Continue

| | |
|---|---|
| Ground cover information (percentage covered by each type) | Buildings<br>Cement surface<br>Other impervious surface material area (e.g. brick)<br>Soil surface<br>Shrub cover<br>Grass cover<br>Herbaceous cover (other than grass)<br>Water surface |
| Tree information | Species<br>DBH<br>Height<br>Height to live crown<br>Crown width<br>Percent of normal live crown that is missing<br>Health condition |

Source: i-Tree Manual, 2010

I-Tree Eco makes use air quality and weather data to analysis the air pollution removal by urban forest. Air quality data use with hourly air pollution data for a complete year in Microsoft Excel format with column names and data as shown in the table 3.2.

**Table 3.2 Air Quality Data**

| Column | Column name | Format | Description |
|---|---|---|---|
| A | Year | Number | The year the data were recorded |
| B | Month | Number | The month the data were recorded (1–12) |
| C | Spname | Text | Name of pollutant; must be CO, $NO_2$, $O_3$, $PM_{10}$, $SO_2$ |
| D | Cityname | Text | The name of the city where the pollution monitor is located |
| E | Addr | Text | The address of the pollution monitor (cannot exceed 5 characters including spaces) |
| F | Units | Number | 1 indicates μg/m$^3$; 7 indicates ppm |
| G | Quantity | Number | The concentration of the pollutant in ppm for CO, $NO_2$, $O_3$, $SO_2$; and in μg/m$^3$ for $PM_{10}$ |
| H | Day | Number | The day the data were recorded (1–31) |
| I | Hour | Number | The hour the data were recorded (1–24) |

Source: i-Tree Manual, 2010

***Weather data***

Hourly weather data are necessary to analyze air pollution removal by the urban forest. All Data from field survey and support data (air quality and weather data) will processing and analyzing using i-Tree Eco V.4.1.0 software.

### 3.3 Evaluation of Urban Forest

The evaluation of urban forest for effectiveness air pollution reducing uses multi criteria evaluation from the result analysis of i-Tree and spatial analysis. The assessment procedure for effectiveness of urban forest can be implemented as follow:

1. Prepare criteria by assigning criterion score, assigning scores per criterion at scale 0-10.

   The factor affecting tree to remove air pollution is:

   a. Tree cover area
   b. Tree Health Condition
   c. Diameter at the breast height
   d. Leaf Area Index

2. The degree of effectiveness was categorized into three classes: Low Effectiveness, Medium effectiveness and High Effectiveness.

# 4. RESULT

## 4.1. Urban Forest Cover Classification

Urban forest cover classification was performed with extraction information from high spatial resolution image. In this research, there are two methods of extraction information from remote sensing image will be use. Information extraction based on semi-automatic processing by computer, in this method feature extraction from ENVI 4.5 and Information extraction based on visual image interpretation using Arc GIS 9.3. The results of information extraction based on semi-automatic by ENVI 4.5 with feature extraction was 4353944.76 $m^2$ (435.40 Ha) which is 13.40 % from total of Yogyakarta city area (shown Figure 4.2). The other result use visual image interpretation with Arc GIS 9.3 is 4,447,885.94 $m^2$ (447.79 Ha) which is 13.79% from total Yogyakarta city area (shown figure 4.1). The result of two method which use in this research were not significant different result, where the different between them only 2.81 %. This result implies that the extraction information of remote sensing with semi-automatic and visual image interpretation was not different. The semi-automatic interpretation is quickly, easily, and accurately extract features from high resolution imagery. But the semi-automatic depends on object-based image analysis technology for extracting features from readily available pan and multi-spectral imagery and data. The extraction based on visual image interpretation is intuitive way which based on ability to relate colours and patterns in an image to real world features.

The visual image interpretation use digitize on screen using Arc GIS 9.3 and the result as polygons. There are seven interpretation elements are distinguished of urban forest (tree): tone/hue, texture, pattern, shape, size, height/elevation and location/association (see on Figure 3).

Distinguishing tree from non-vegetation areas or other vegetation (grass or shrub) was a generally straightforward visual interpretation process when trees can usually be separated from grass or shrub by a combination of tone and texture. When attempting to distinguish tree as a sub-class of woody vegetation there were several persistent conditions that introduce subjectivity into the interpretation. There was no clear spectral division that separates what is a shrub or bush from what is a tree. In general, trees can be distinguished from large bushes by shape and from small bushes by shadows, but these shape and size clues are not always conclusive. The tree shadows cast by the trees obscure edges and can make outlining the exact canopy boundary difficult. This condition is especially vexing for large trees, which cast broad shadows: the edge of the tree is somewhere in the shadow but, depending on the shape / form of the tree, the shadow may be mostly on the ground or mostly on the tree or somewhere in between.

| Figure of unit | Tone | Texture | Shape | Height | Location |
|---|---|---|---|---|---|
|  Urban tree | Green | Granular | polygon | high | Urban area |

Figure 3 urban forest classifications

The Quality of the result of visual image interpretation depends on the experience and skills of the interpreter, appropriates of the images available, and the quality of the guidelines being used.

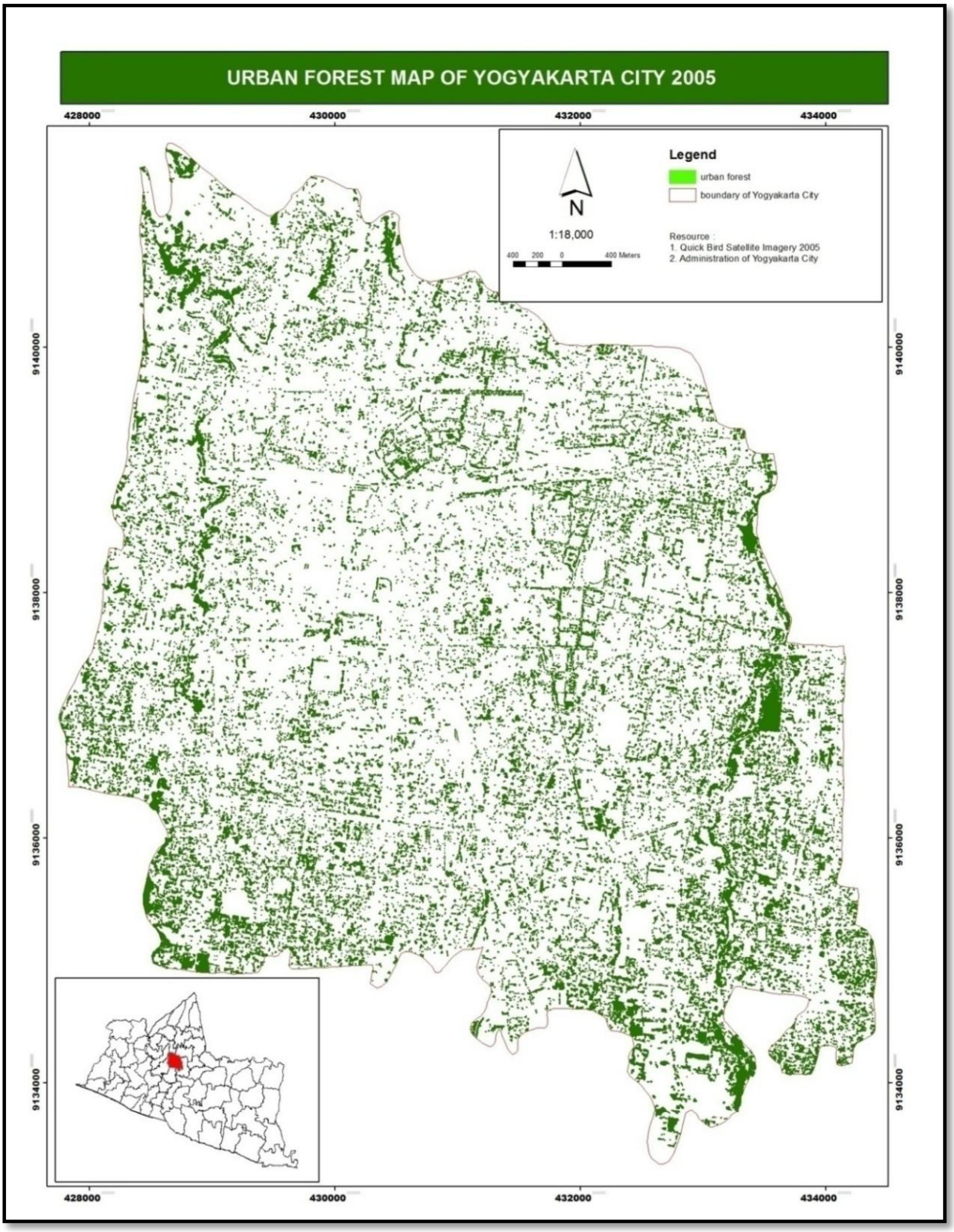



**Figure 4.1 Urban Forest Cover map of Yogyakarta City 2005 based on Visual Image Interpretation**

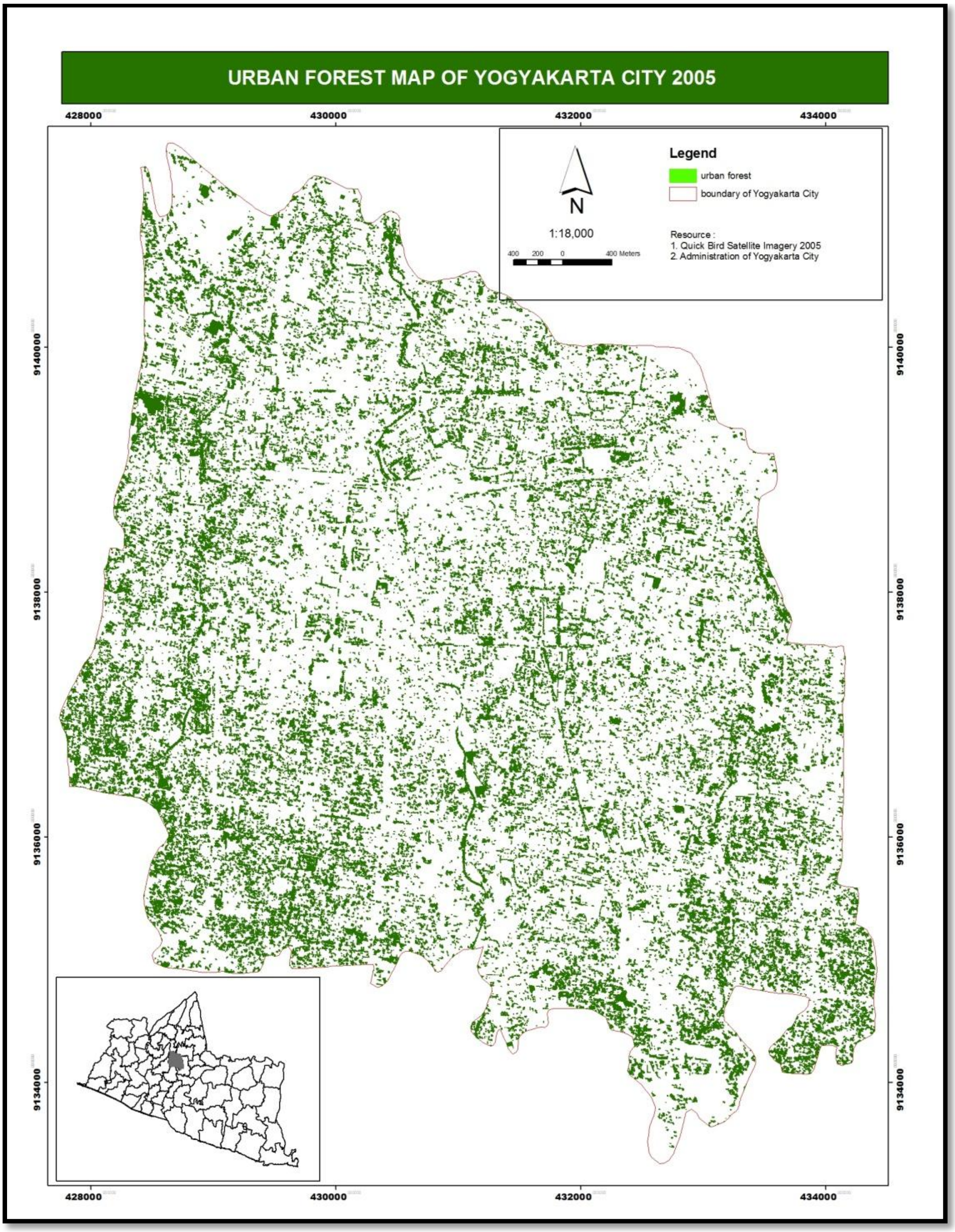



**Figure 4.2 Urban Forest Cover map of Yogyakarta City 2005 based on Semi-automatic extraction (segmentation)**

## 4.2 Accuracy Assessment

Accuracy assessment is an important element of land cover mapping that offers a guide to the map quality, reliability, implication to users and insight into the thematic uncertainty (Treitz, 2004).

Fitzpatrick-lins in Jensen, suggests that the sample size N to be used to assess the accuracy of a land use classification map be determined from the formula for the binomial probability theory:

$$N = \frac{Z^2 (p)(q)}{E^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where p is the expected percent accuracy of the entire map, q = 100 – p, E is the allowable error and Z = 2 from the standard normal deviate of 1.96 for the 95% two sided confidence level. The research use expected map accuracies of 85 % and an accepted error of 10%, the sample size for the map would be 51.

$$N = \frac{2^2 (85)(15)}{10^2} = 51 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

The 51 point sampling was taken by randomly to the map and then was check on the field. The amount of the correct point sampling in the field with sample point from map classification will be use to determine how much the accuracy assessment. The accuracy assessment from two results of urban forest spatial distribution map is 94.11 % from visual image interpretation method and the other result which segmentation process is 84.31 % (show in Table 4.2).

**Table 4.2 Accuracy assessment**

| **Class name** | **Reference / Field Check** | **Sample size on map** | **Number of Correct** | **Overall Accuracy** |
|---|---|---|---|---|
| Urban Forest with (visual image interpretation) | 51 | 51 | 48 | 94.11% |
| Urban Forest with (Semi-automatic interpretation / Segmentation) | 51 | 51 | 43 | 84.31% |

Source: Data Processing, 2011

The result above implies that visual image interpretation have a better result than segmentation process for the accuracy in classification. The visual image interpretation is 94.11 % which implies that the urban forest map agrees with the reference data (truth condition) because higher than expected map accuracies of 85%. The result from segmentation process is below than 85 %. Based on the result from accuracy assessment, the urban forest map that will be use in this research is from visual image interpretation which has better accuracy than segmentation process.

The urban forest map distribution overlay with arc GIS 9.3 to land use map, administration map, river map and roads network map to know how the distribution of urban forest for each categories.

The GIS overlay with administration map of Yogyakarta city show Percentage Distribution of urban forest area where divided according to “Kecamatan” (district) town of Yogyakarta can be seen in figure 4.3.

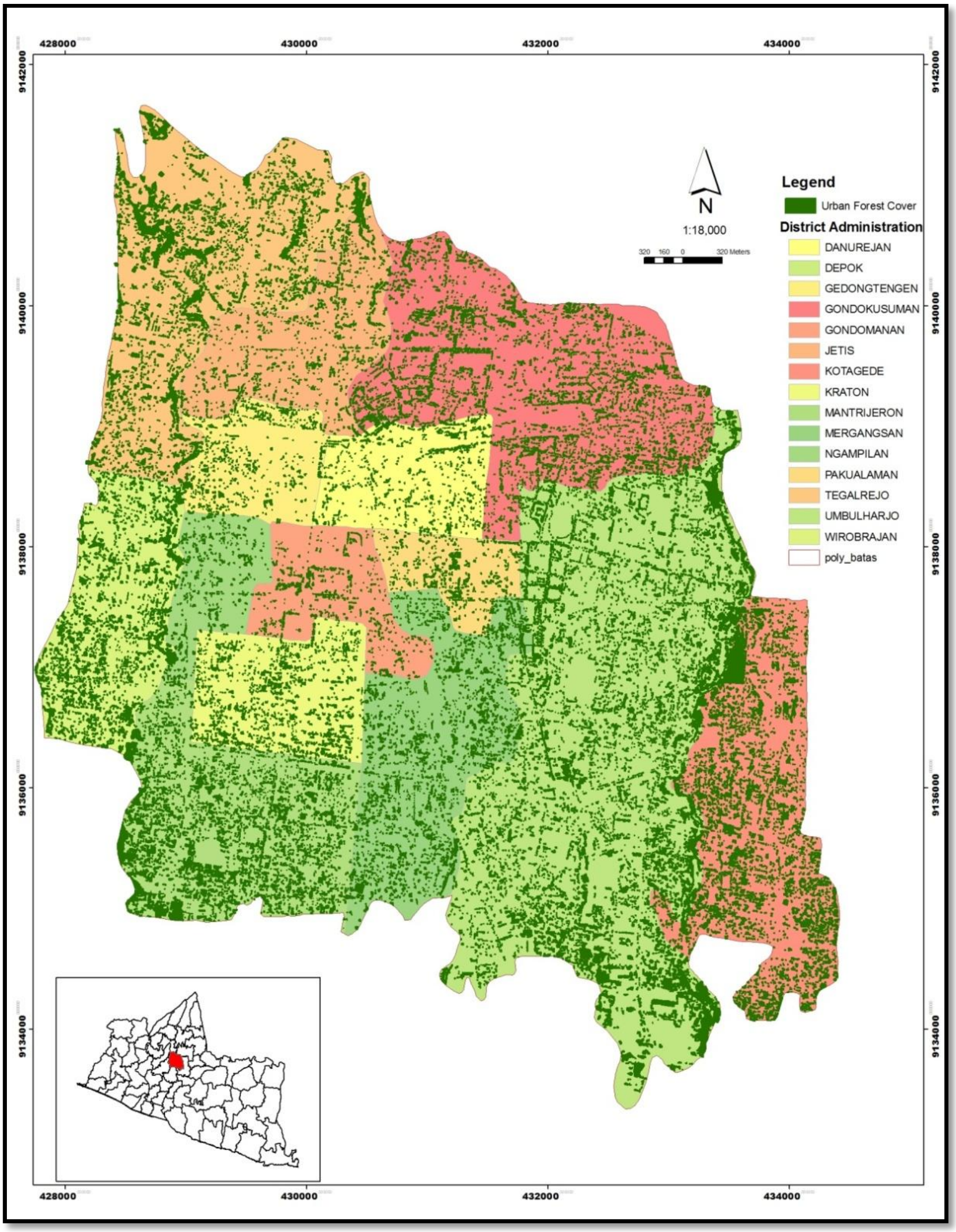



**Figure 4.3 Urban Forest cover map overlay with District Administration Boundary**

From figure 4.3, obtained information that the district has a largest urban forest cover area is Umbulharjo district, with an area of 1,255,800.18 $m^2$ (25.63%) whereas Ngampilan District has the smallest area with 51,268.44 $m^2$ (1.38 %), See on Table 4.3. The result implies that urban forest in Yogyakarta city not so well distributed in all district of Yogyakarta City. Almost all District (10 District) in Yogyakarta city have cover tree less than 10%, and the rest of district have tree cover over 10%. This situation has described that the development in Yogyakarta city has tendency to minimize the green area. With this condition, the local government of Yogyakarta city should have strategy to solve this situation. The tree planting in some district with minimum tree cover can be an effective way in alleviating the lack of urban forest distribution problems in Yogyakarta city. With this strategy, not only extend and increase the tree cover in some district, but also will be influence to the total tree cover in Yogyakarta city where the regulation of Ministry of Forestry P.71 and Indonesia Government Regulation PP. 63 indicate that the minimum of urban forest area in some city is not less than 10% from total area of the city.

**Table 4.3 Area cover of urban forest based on district administration**

| No | District Name | Areas Widht | | |
|---|---|---|---|---|
| | | **m2** | **Ha** | **Percentage** |
| 1 | Gedongteng | 72,415.41 | 7.24 | 1.62 |
| 2 | Danurejan | 78,262.65 | 7.83 | 1.93 |
| 3 | Gondokusuman | 433,670.92 | 43.37 | 9.34 |
| 4 | Gondomanan | 62,895.61 | 6.29 | 1.46 |
| 5 | Jetis | 114,897.57 | 11.49 | 2.97 |
| 6 | Kotagede | 592,346.64 | 59.23 | 12.64 |
| 7 | Kraton | 147,520.27 | 14.75 | 3.83 |
| 8 | Mantrijeron | 526,778.44 | 52.68 | 11.73 |
| 9 | Mergangsan | 264,350.73 | 26.44 | 6.09 |
| 10 | Ngampilan | 51,268.44 | 5.13 | 1.38 |
| 11 | Pakualam | 60,226.73 | 6.02 | 1.54 |
| 12 | Tegalrejo | 494,183.88 | 49.42 | 12.00 |
| 13 | Umbulharjo | 1,255,800.18 | 125.58 | 25.63 |
| 14 | Wirobrajan | 323,268.45 | 32.33 | 7.61 |
| **Total** | | **4,477,885.94** | **447.79** | **100.00** |

Source: Data Processing, 2011

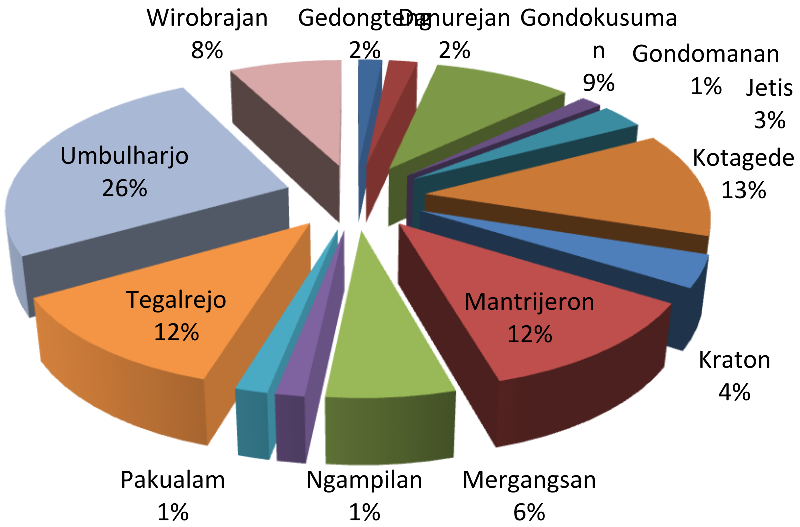



**Figure 4.4 Urban forest cover area based on District Administration**

The urban forest spatial distribution also overlay with land use 2007 from BAPEDDA Yogyakarta Agency and the percentages of result can be show from figure 4. 5. Figure 4.5 shows that the composition of the urban forest cover area in the city of Yogyakarta based on land use map from local Government of Yogyakarta city (BAPPEDA), settlement has a urban forest cover area with the highest area with 3,580,634.69 $m^2$ or 79.96% from total urban forest cover area. And, the smallest area is vacant land only 131,591.48 m2 or 2.86% (shown on table 4.4).

**Table 4.4 Area cover of urban forest based on Land Use Map (BAPPEDA)**

| No | Land Use | Area Widht | | |
|---|---|---|---|---|
| | | (m2) | Ha | Percentage |
| 1 | Agriculture | 765,659.77 | 76.57 | 17.10 |
| 2 | Settlement | 3,580,634.69 | 358.06 | 79.96 |
| 3 | Vacant Land | 131,591.48 | 13.16 | 2.94 |
| **Total** | | **4,477,885.94** | **447.79** | **100.00** |

Source: Data Processing, 2011

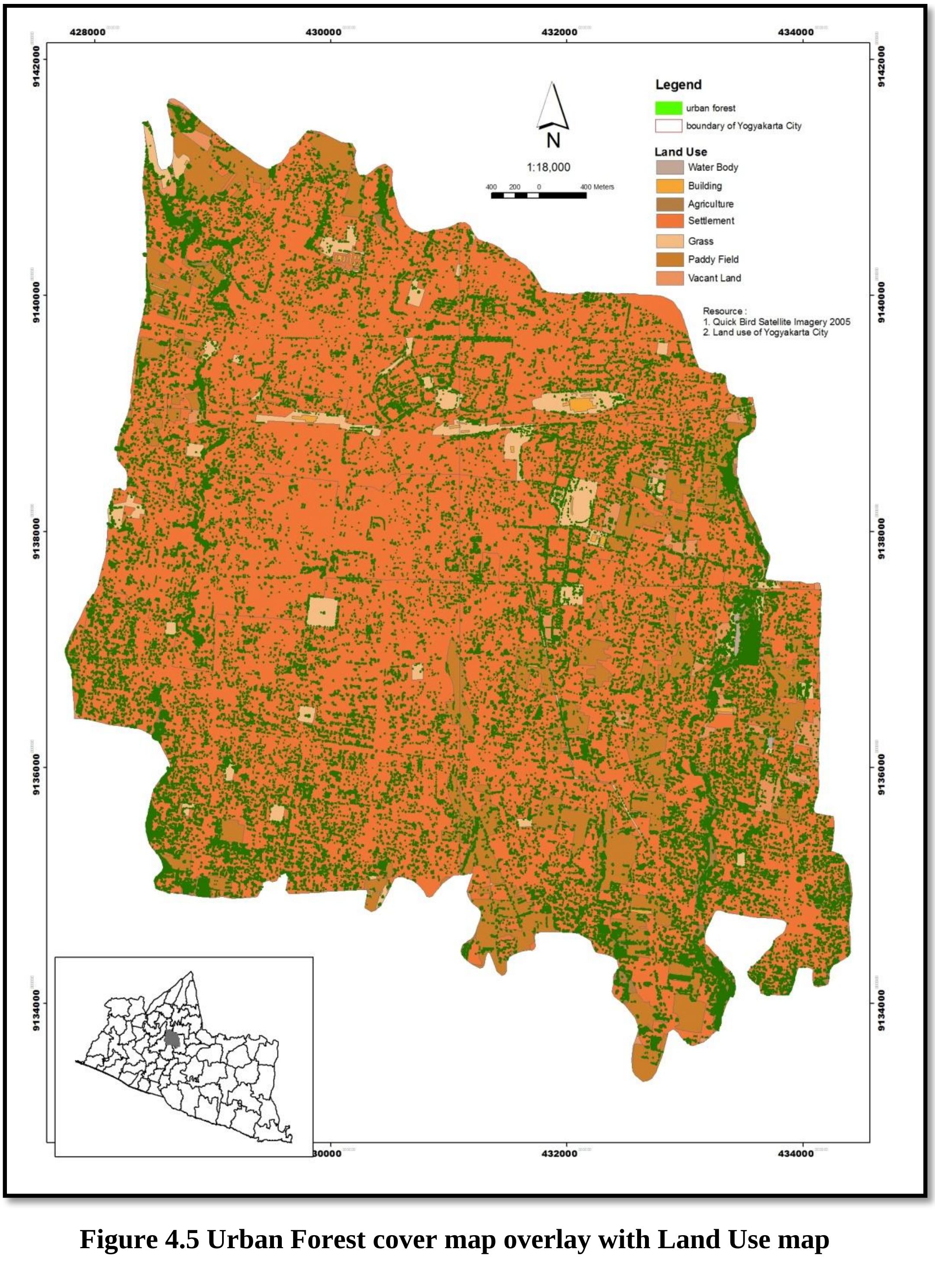



**Figure 4.5 Urban Forest cover map overlay with Land Use map**

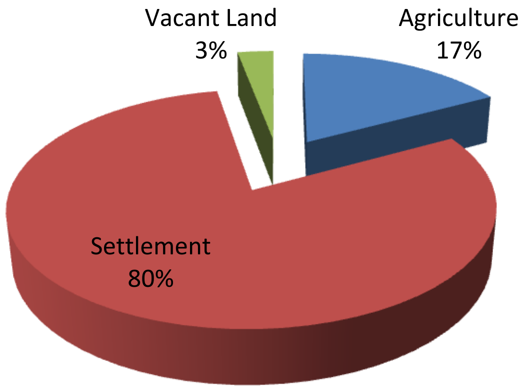



**Figure 4.6 Urban Forest cover area based on Land Use**

. This has implications that urban forest canopy cover in the city of Yogyakarta, mostly located in the settlement or land owned by institutions or individuals. Previous data obtained from authority agency in this case by Environment Agency of Yogyakarta that extensive urban forest which is owned by the municipality of Yogyakarta only 260.000 $m^2$ or 0.8% from Yogyakarta City area. This condition has different with the urban forest cover classification results that show the cover area of urban forest in Yogyakarta city reach 4,447,885.94 $m^2$ (447.79 Ha), or 13.79% of the area of the city of Yogyakarta. But the area is dominated by institutional and individual settlements as much as 79.96%.

Urban forest spatial distribution also overlay with the presence of rivers and roads in Yogyakarta city, in this case by creating a buffer along the river in the equivalent of 50 meters beside left and right of river (Figure 4.7). The buffer along river basin 50 meter is based on the Republic Indonesia government regulation Number 41 Year 1999 on Forestry, article 50 paragraph 3 which reads "Every person is prohibited: cutting trees within a radius or distance up to 50 (fifty) meters from the left and right side of the river (Table 4.5).

**Table 4.5 Areas cover of urban forest with buffer of river and road**

| No | Land Use | Area Widht | |
|---|---|---|---|
| | | (m2) | Ha |
| 1 | River | 998,500.26 | 99.85 |
| 2 | Road (Buffer 5 meters) | 427,005.93 | 42.70 |
| 3 | Road (Buffer 8 meters) | 654,928.45 | 65.49 |

Source: Data Processing, 2011

The table show that the urban forest cover area has located along the river throughout the city of Yogyakarta has a lot of vegetation which is a component of the urban forest with an area of **998,500.26** m$^2$ this indicate that urban forest cover in along river basin only **22.30**% from total urban forest cover area in Yogyakarta city. The government can use advantage or empty space in river basin. The potential area which located in river basin can extend the urban forest cover area reach 4,449,374.63 m2 (444.93 Ha). The matrix can be shown on Figure 4.8.

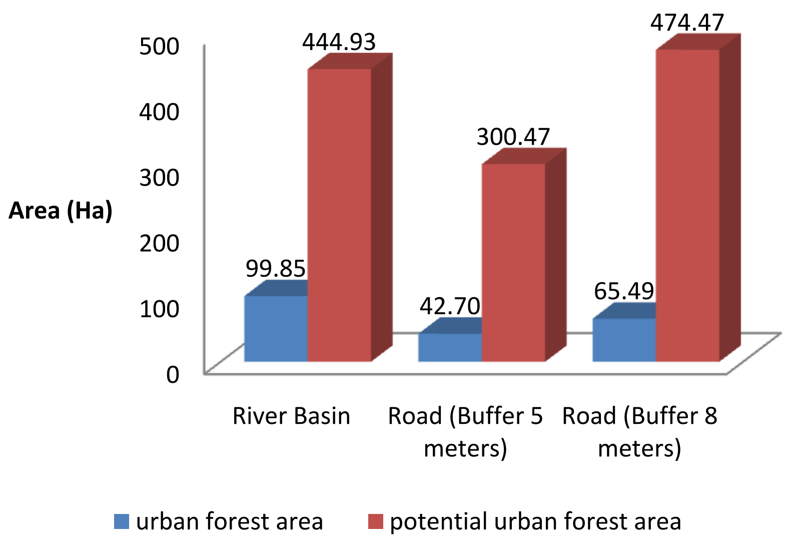



**Figure 4.8 Comparing urban forest cover area on field and potential area**

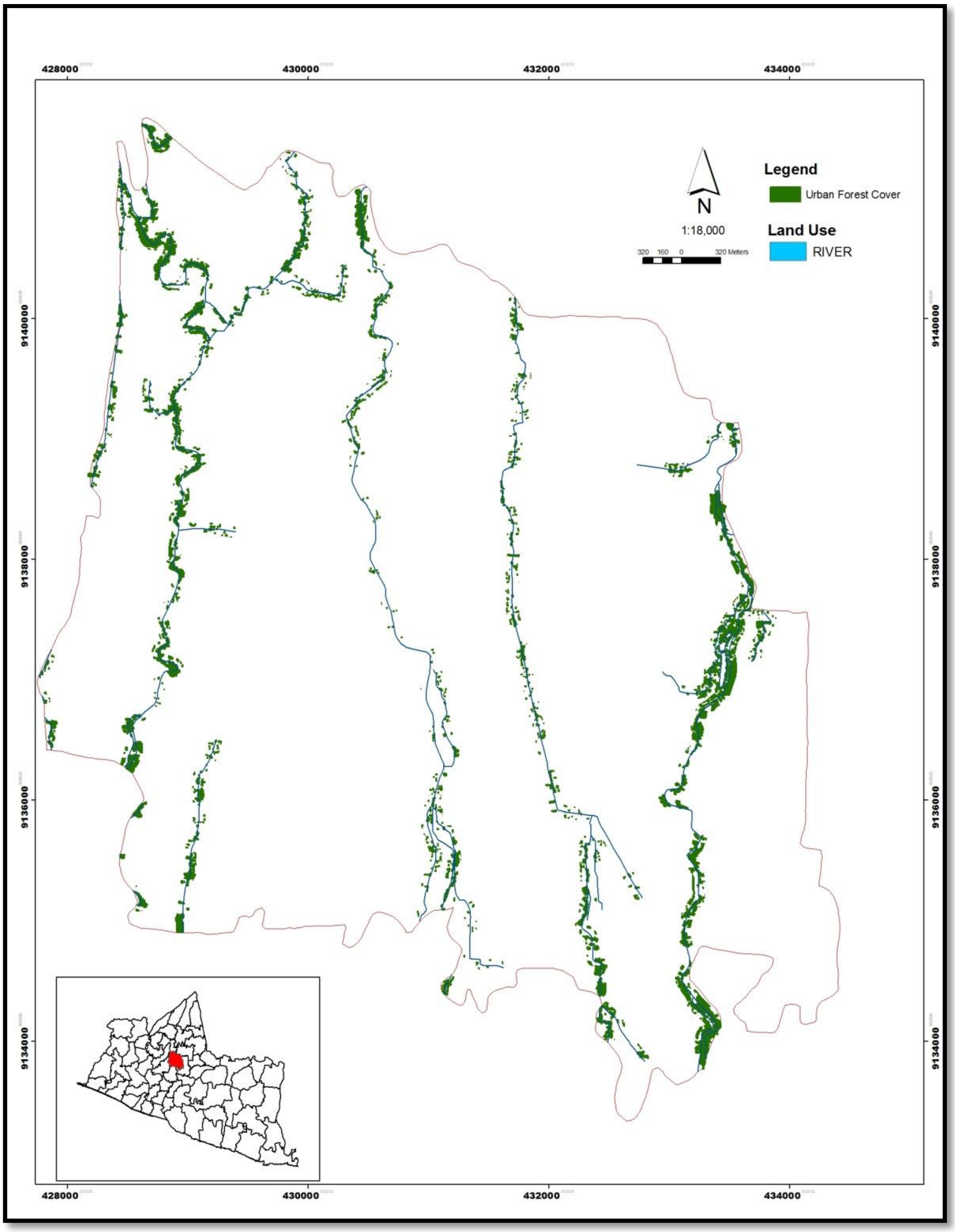



**Figure 4.7 Urban Forest cover map overlay with River map**

The existence of urban forest area is located on the side or along the road is an important aspect in reducing air pollution caused by motor vehicles. Road function is not only for movement of vehicles but also people walking too (walker). Some part of a road is pedestrian area. The pedestrian area is part of public space and one of important component of urban space. Pedestrian area beside the function as movement of walker, in other function is planting of tree for urban forest (Regulation from Yogyakarta Local Government Number 618 in 2007 about Action Plan of Quality Public Development in Yogyakarta City in period 2007 – 2011). In that regulation mention that “The City Beautification program” use pedestrian for replanting tree to increasing area of urban forest in Yogyakarta city. The National Standard of Indonesia (SNI) Number 03-2447-1991 about Pedestrian Specification which mentions that the minimum size of pedestrian in Indonesia is 1.5 meters (class III), 3.0 meters (class II) and 3.0 meters (class I). In Yogyakarta City, based on survey and the result of research by M. Arief Ariwibowo in 2008 mentions that size of pedestrian in Yogyakarta has size between 2 meters until 4 meters (in road class I such as Malioboro and Pakualam). Based on that, this research use buffering size area of road network is 5 meters (2.5 meters for each edge of road) and 8 meters (4 meters for each edge of road). The results can be seen in table 4.5 The city of Yogyakarta has a urban forest located on the edge of the highway as much as 427,005.93 $m^2$ (9.41%) with a distance of 5 meters from the highway, while the 8-meter buffer area having 654,928.45 $m^2$ (14.63%). The local Government of Yogyakarta City will have potential urban forest cover area by utilizing the space that was left or right side of the main road (buffer 5 m) is 3,004,653.92 $m^2$ (300.47 Ha / 9.25 %), it’s mean that urban forest cover area just 14.21 % from potential urban forest cover area. If the potential urban forest cover area with buffer 8 m is 4,744,723.65 $m^2$ (474.47 Ha / 14.60 %), the condition show that urban forest cover just only 13.80 % from potential area of urban forest cover area in the beside roads.


**Figure 4.9 Urban Forest cover map overlay with Road Network map**

### 4.3 Analysis Data of i-Tree Eco

Of the 140 plots initially selected for sampling, only 137 plots (97.86%) were actually sampled (show in **Figure 5 Point Sampling of i-Tree (140 plots) and Appendix 5)**. This Survey of i-Tree was detail investigation survey. The detail investigation survey use density on the field with 1 per 20 hectare and the scale average was 1:25.000 until 1:10.000. Most of the un sampled plots were located on military and institution land where access was denied. From total 137 sample plots all ready done, the results was 63 plots are not vegetation and 77 plots with vegetation. 32 species was found, 27 species has already registered in species database of i-Tree software and 5 species were unregistered (see on Appendix 4). The 5 new species sill entry into i-Tree with standard use of i-Tree Eco, there were limited to the species list provided. The solution is choosing an available species that is similar in character (growth, form and function) to the one not represented in Eco. Therefore, to move the project, it will need to select the allied species, but could note the correct species for updating the project in the future should the species be added to the list.

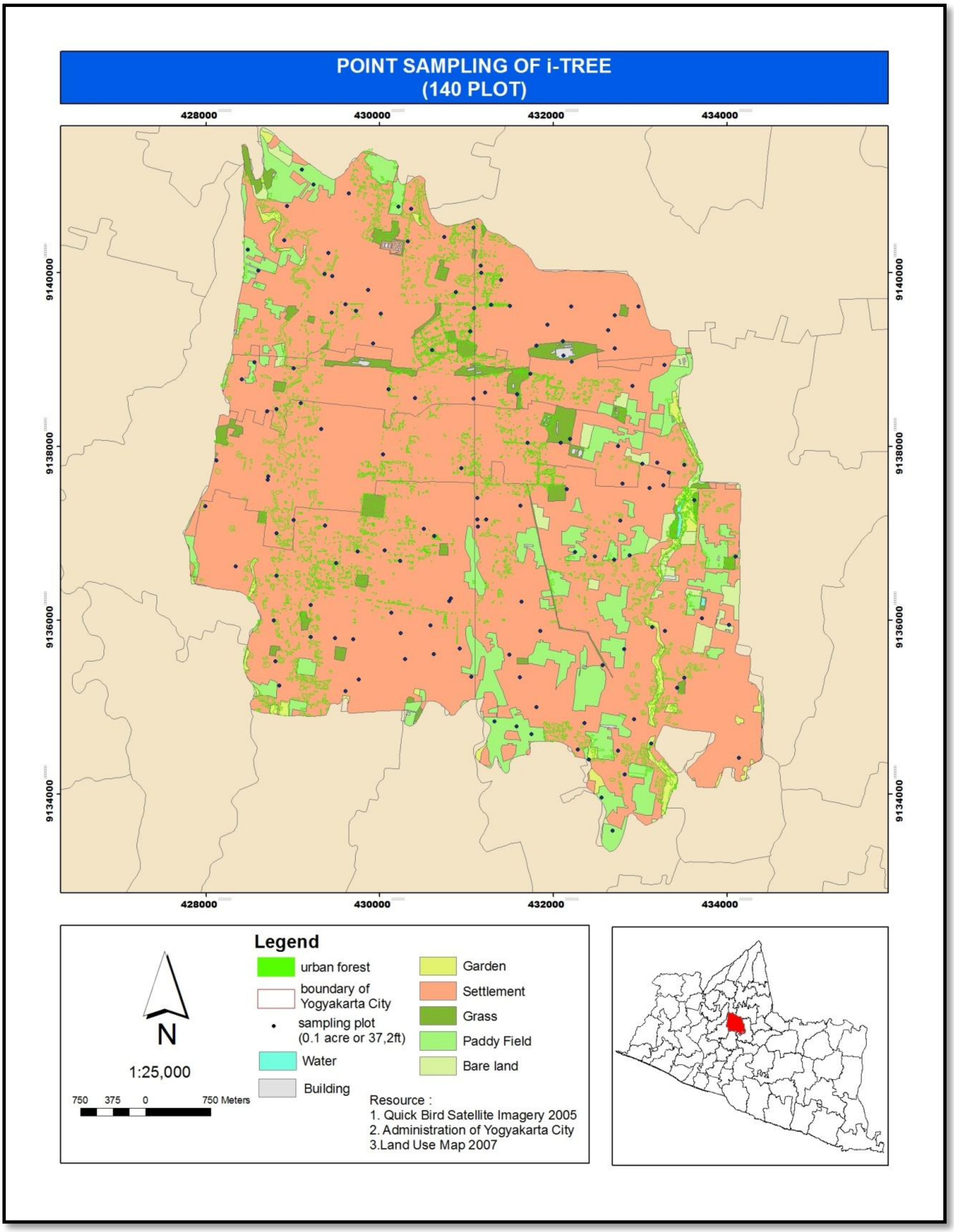



**Figure 5 Point Sampling of i-Tree (140 plots)**

### 4.3.1 The Urban Forest Structure

The extent of community tree canopy cover is one of many possible indicators of urban forest sustainability (Clark, J.R, 1997).

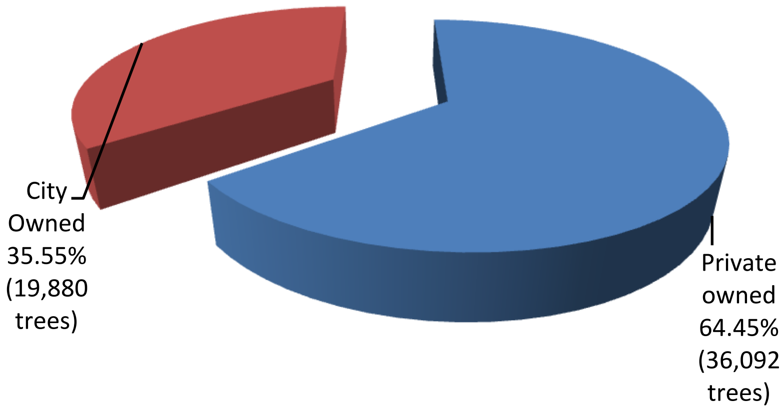



**Figure 5.1 Trees ownership in Yogyakarta City**

The i-Tree analysis shows the urban forest of Yogyakarta city has an estimated 56.000 trees where the count based on American Forests recommendations of an average 40% canopy cover or the equivalent of approximately 50 trees per hectare. Figure 5.1 shows the number and percentage of tree ownership which the significant contribution of trees ownership by private property (64.45% of the city's tree population).The trees which city owned just only 35.55 % with variation institution in Yogyakarta city such as school and government office.

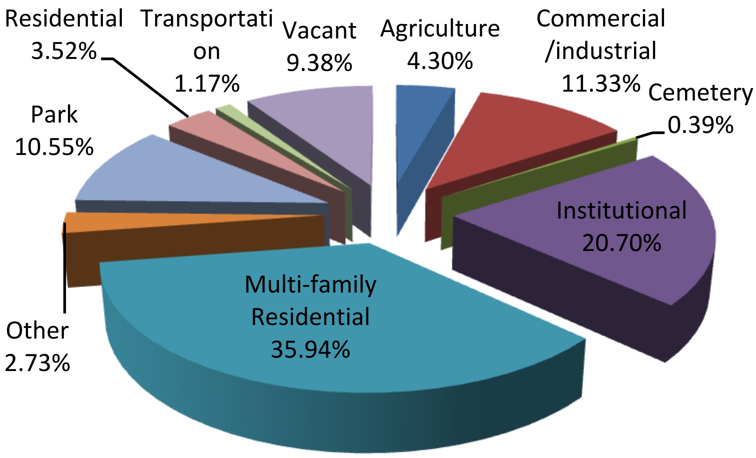



**Figure 5.2 Trees Population by Land Use**

Figure 5.2 shows trees population by land use on Yogyakarta city based on field data estimations and measurement. Overall, the predominate trees population based on land use in Yogyakarta's urban forest is Multi-Family Residential with 35.94 % and the minimum of trees population is cemetery only 0.39 %.

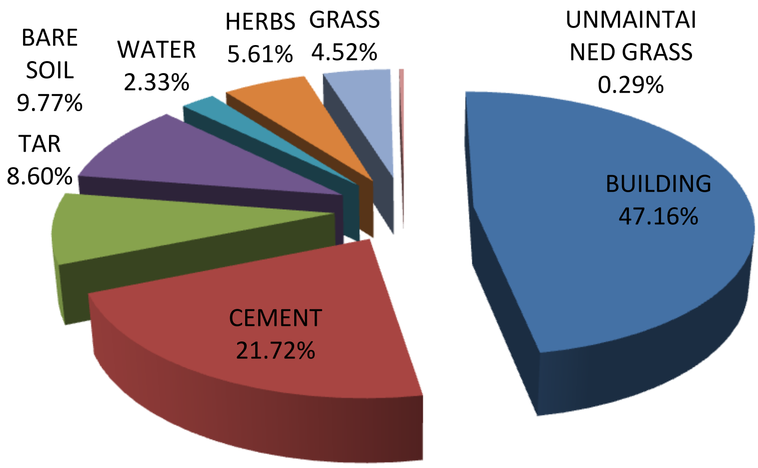



**Figure 5.3 Ground cover distributions**

Figure 5.3 shows ground cover under trees in Yogyakarta. The ground cover distribution is dominated by building with 47%, and cement with 22%. This condition shows that the ground cover below tree in Yogyakarta city is dominated by residential or non vegetation area with 79.96%, while the green cover only around 10%.

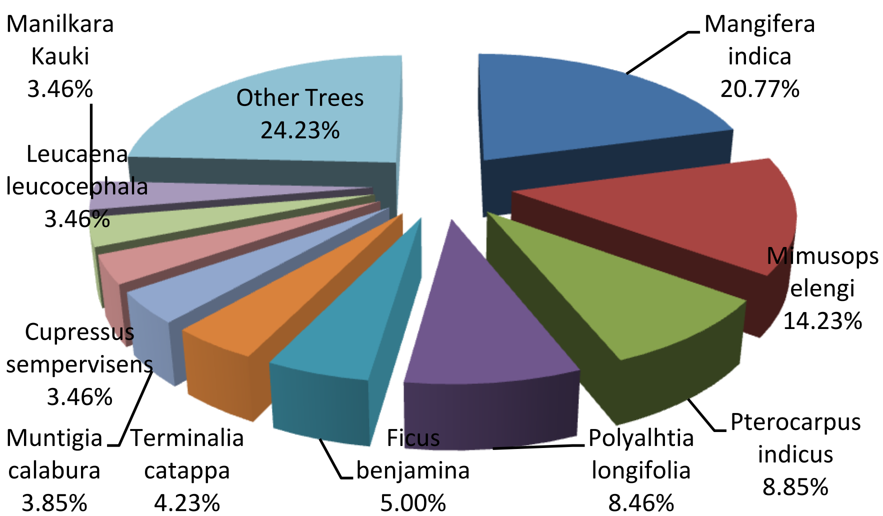



**Figure 5.4 The common species account**

In Total. 33 species were documented in i-Tree field sample. The top five tree species That Dominate in Yogyakarta urban forest are *Mangifera indica, Mimusops elengi, Pterocarpus indicus, Polyalthia longifolia* and *Ficus Benjamina* (Figure 5.4). The number one species is *Mangifera indica* with 20.77%. This species is more commonly found and planted by people in private land. This plant is favored by the public because it is easy in maintenance and preferred because of its fruit. The *Mangifera indica* is the most important species in Yogyakarta with important value 56.44 % and Percent Leaf Area is 35.81%. The “Manggo also the tree with excellent condition (Health of Tree condition) with almost 35.80 % this tree is execellent and 37.70 is Good Condition. *Mimusops elengi* is native tree otherwise known as the "Tanjung" in local language. This species is found in many government institutions and private land and even in schools in the city of Yogyakarta. This tree is the second largest species with a 14.23% and important value is 29.50% with percent Leaf area reach 14.32%. The condition of this tree is 15.40% excellent and 38.50 in Good condition..Sequentially in third, fourth and fifth are *Pterocarpus indicus* with 8.85% *Polyalthia longifolia* with 8.46 % and *Ficus benjamina* with 5%. These three species are more commonly found and planted in the area either side of the road; the third trees are tree shade in beside left and right road and air pollution removal of Yogyakarta city.

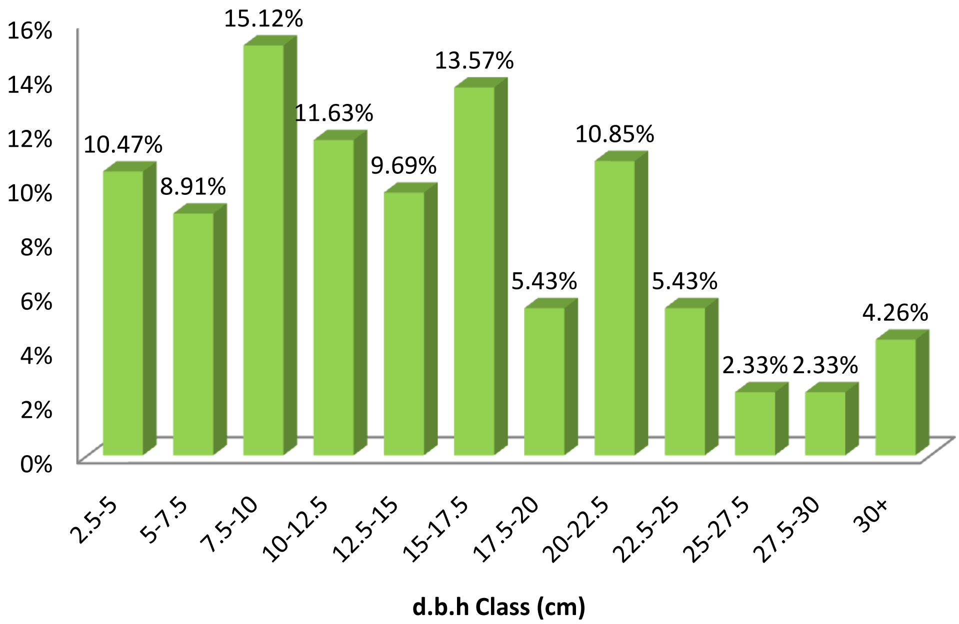



**Figure 5.5 Diameter classes**

Urban forest in Yogyakarta city is composed of a mix diameter class of tree. The average diameter tree is 14.55 cm. Figure 5.5 shows the overall size class distribution of Yogyakarta's urban forest including all trees (planted and naturally regenerated). Diameter size class distribution is a complex indicator for urban forests. Overall, small trees predominate in Yogyakarta's urban forest with 55.82 % of trees are less than 15.2cm in diameter, 39.92% are between 15.2 and 30 cm in diameter and 4.26 % are larger than 30 cm in diameter.

There are many indicators of tree health such as damage to bark or stem, evidence of decay or insect damage, structural characteristics. The rating results from an assessment of:

1. Percent crown dieback (how much deadwood there is in a tree crown)
2. Percent of crown missing (how much of the full tree crown is missing).

Based on these criteria, 60.94% of Yogyakarta's trees are rated as being in excellent or good condition, 35.55% in fair or poor and 3.51% trees in critical or dying condition (Figure 5.6).

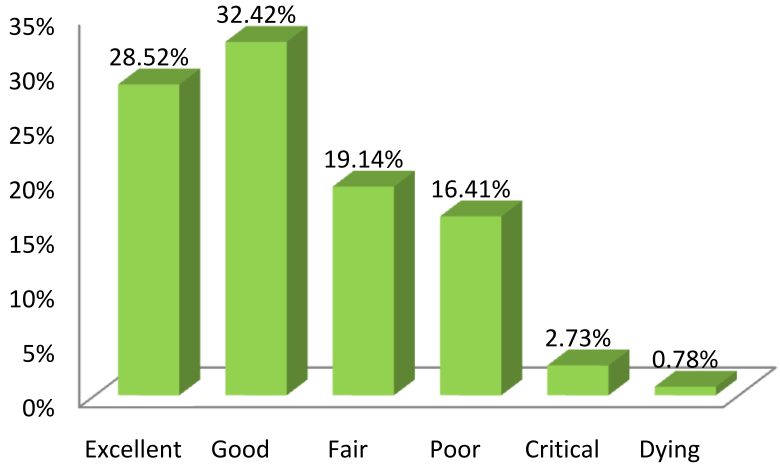



**Figure 5.6 Trees Condition**

The "Manggo is the tree with excellent condition (Health of Tree condition) with almost 35.80 % this tree is excellent and 37.70 is Good Condition. *Mimusops elengi* is native tree otherwise known as the "Tanjung" in local language. This tree is the second largest species with a 14.23% and important value is 29.50% with percent Leaf area reach 14.32%. The condition of this tree is 15.40% excellent and 38.50 in Good conditions. The Poor Condition of Tree is *Pterocarpus indicus* with 36.40% in Poor and 9.10% in critical condition. The condition of tree is important related to reducing air pollution. The healthy tree will have a lower percent crown dieback and lower percent of crown missing. The health crown indicates that the tree will have big leaf area index which the leaf area index is one important component of tree that influence capability of tree to removal air pollution.

The result of Evaluation Urban forest using UFORE model can show on the table 4.6

**Table 4.6 Evaluation Urban Forest Effect using UFORE model**

| No | Feature | Measure |
|---|---|---|
| 1 | Number of trees in Yogyakarta | 56.000 |
| 2 | Number of trees owned by town | 19,880 trees / 35.55% |
| 3 | Number of tree owned by private | 36,092 trees / 64.45% |
| 4 | Top 5 common species tree | *Mangifera indica, Mimusops elengi, Pterocarpus indicus,* |

Continue

| | | |
|---|---|---|
| | | *Polyalthia longifolia* and *Ficus Benjamina* |
| 5 | Average Tree Diameter | 14.55 cm |
| 6 | Leaf Area Index (LAI) | 2.16 |
| 6 | Tree Condition | • 60.94% excellent or good condition<br>• 35.55% fair or poor<br>• 3.51% trees in critical or dying condition |
| 7 | Air Pollution Removal | 2,450.1 kg / year for CO,<br>7,795.9 kg / year for $NO^2$,<br>24,493.5 kg / year for $O^3$<br>20,586.0 kg / year for $PM_{10}$,<br>1,724.4 kg / year for $SO^2$<br>Total removal 57,049.9 Kg / year |

Source: Data Processing, 2011

From table 4.6 shows the number of trees in urban forest of Yogyakarta city has 56,000. It is representative from urban forest cover 13.79%. The number of tree which owned by city only 19,880 trees or 35.55%, it's quite different with trees which owned by private 36,092 or 64.45%. The validation of this value has been granted with the data which achieved from Environment Agency of Yogyakarta city which mention that the number of trees which owned by local government of Yogyakarta is 10.842 trees. The differential between the result of UFORE analysis and the number from authority agency is 54.53 %. The ownership of tree in Yogyakarta city has implies that the situation is complicated. The local government will be face difficulty in developing and managing protection urban forest cover area which is important to maintain leaf area, more big cover area its mean higher the urban forest has capability to remove air pollution.

### 4.3.2 Air Pollution Removal by Urban Trees

The urban forest improves air quality in five main ways by

- absorbing gaseous pollutants (ozone [O3], nitrogen dioxide [NO2]) through leaf surfaces
- intercepting particulate matter (e.g., dust, ash, dirt, pollen, smoke)

- reducing emissions from power generation by reducing energy consumption from
- heating and cooling in sheltered/shaded buildings
- releasing oxygen through photosynthesis
- Transpiring water and shading surfaces, resulting in lower local air temperatures, thereby reducing O3 levels.

Pollution estimator use methods and analyses conducted for this program are based on the Urban Forest Effects (UFORE) model developed by Nowak and Crane (Figure 5.7).

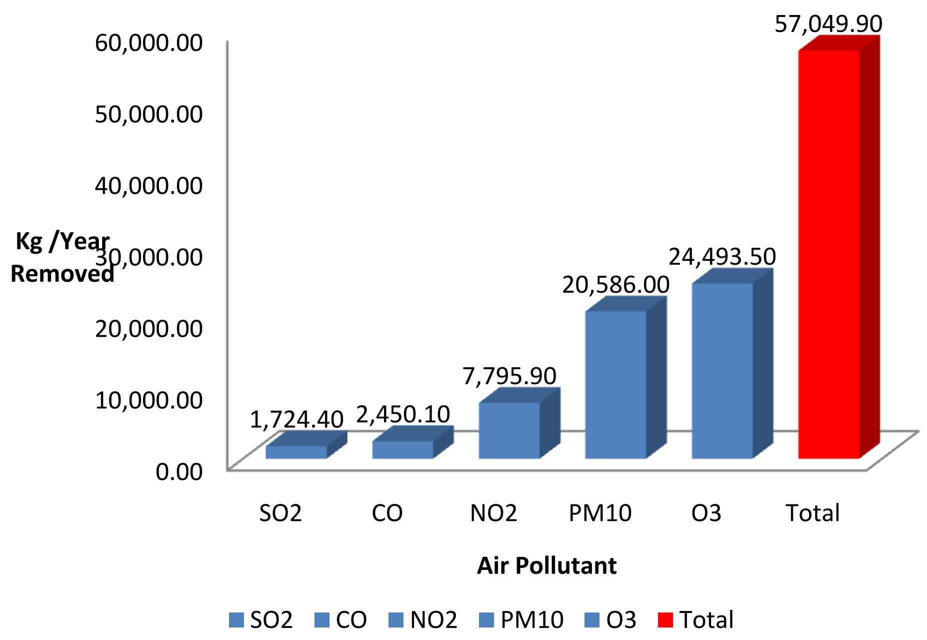



**Figure 5.7 Annual pollution removals (kg)**

In figure 5.3 shows that estimate calculation by using the air pollution calculator. The results obtained for the external flux of the urban forest of Yogyakarta is 0.54669 for CO, 1.73947 for $NO_2$, 5.46517 for $O_3$, 4.59329 for $PM_{10}$, and 0.38477 for $SO^2$. As for Air Pollution Removal amounted to 2,450.1 kg / year for CO, 7,795.9 kg / year for $NO_2$, 24,493.5 Kg / Year for $O_3$, 20,586.0 kg / year for $PM_{10}$, 1,724.4 kg / year for $SO_2$ and total overall in the removal of air pollution amounted to 57,049.9 Kg / year.

The World Bank estimates that 70% of air pollution in big cities comes from the evaporation of fossil fuel and exhaust emissions in motor vehicles. The Emission air pollution based on transportation in Yogyakarta reach 21,061.33 ton/year for CO, 10,238.39 ton/year for $NO_2$, 787.57 for $SO_2$ and 74.37 ton/year for $PM_{10}$ and the total value is 3,2161.66 ton/year. This rate is high because the number of vehicles in Yogyakarta city is 300.000 vehicles with the growth rate reach 5 – 10% each year. The contribution of urban forest in air pollution reduction are 2.45 ton / year for CO, 7.80 ton / year for $NO_2$, 20.59 ton / year for $PM_{10}$, 1.72 ton / year for $SO_2$ and total overall in the removal of air pollution amounted is 32.56 ton / year. The percent air quality improvement from urban forest in Yogyakarta city is 0.001 (0.10%) to reducing air pollution based on transportation.

# 5. Discussion

## 5.1 Spatial Distribution of Urban Forest

Based on the results of urban forest classification is 4,447,885.94 $m^2$ (447.79 Ha) or 13.79 % from total area of Yogyakarta city. The legality aspect from the law has been qualified in accordance with Government regulations Permenhut rule the Republic of Indonesia Minister of Forestry Number: P.71/Menhut-II/2009 and Government Regulation 63 of 2002 which states that the urban forest area in a compact form is at least 0.25 (five twenty percent) Hectare, or percentage of the urban forest area at least 10% (ten percent) from total of urban area and or adapted to local conditions. In this regulation explain that urban forest with minimum area is 0.25 (25%) Ha is the minimum area urban forest in the city but with some additional condition that the trees can growth and creating of micro climate affect. The meaning of compact is the urban forest growing concentrated in an area. The second statements on government regulation mention that percentage of urban forest area at least 10% (ten percent) from total urban or city area. it is mean that the 10% from the total area of urban area or city should be as urban forest (tree cover area). In this regulation, the urban forest is determine by authorize agency (government officer) which have right to declare that some area is determine as urban forest area. The urban forest can be determined by authorize agency in state land or private land. In this case, mostly the urban forest in state land already declared by authorize agency, in other condition urban forest growth in private land not officially determine by authorize agency.  The result of this research show that from 13.79 % urban forest area still have a problem because the ownership status of land where the urban forest is located. Based on field realities, urban forest in the city of Yogyakarta area of 336.94 hectares in which 79.23% came from individual and institutional land (private land), urban forest is not established and managed by the Regional Government of Yogyakarta. This case also adopted in the Indonesia Government Regulation no. 63 Year 2002 on the Urban Forest in Chapter 7 Paragraph 2, namely:

“Chapter 7, paragraph (2) mentions that the private land which define as urban forest area can be give some compensation from the government according to regulation and law”.

Therefore, the local government of Yogyakarta City should formulate new rules or regulations governing the presence in the urban forest in private land. Because the importance of urban forests, especially in efforts to reduce air pollution the local government must protect the urban forest on private lands or private institution. Yogyakarta Regional Government may implement a new policy in this regard Reward and Punishment in which an incentive or ease of administration (reducing taxes, water supply or giving discount for payment of electricity and water for tree maintenance, etc) for individuals or private institution that has provided their land for urban forest planting. This recommendation based on Government Regulation number 63 year 2002 on urban forest mentioned in article 7, paragraph 2, that the right to land designated as the location of urban forests be compensated in accordance with the provisions of laws and regulations applicable.

## 5.2 Evaluation of Urban Forest to Reducing Air Pollution

The evaluation effectiveness of urban forest in reducing air pollution calculates by scoring to factor from tree that affecting of influence tree to removal air pollution. The removal of a particular air pollutant at a given place over certain time period then was calculated as

$$Q = F \times L \times T;$$

Q is the amount of a particular air pollutant removed by trees in a certain time, F is the pollutant flux, L is the total canopy cover in that area, and T is the time period (Nowak, 1994a). Based on the equation, L is the total canopy cover of tree. The factors related to the canopy cover of the tree are tree cover, health condition of tree, diameter at breast high, and leaf area index. This factor will be use to assigning criterion score and the degree of effectiveness is categorized into three classes: Low Effectiveness, Medium effectiveness and High Effectiveness

The urban forest covers area describes the trees remove gaseous air pollution primarily by uptake via leaf stomata, though some gases are removed by the plant surface. The American Forests recommendations of an average 40% canopy cover or the equivalent of approximately 50 trees per hectare. The Ministry Forestry of Indonesia recommendations that urban forest area minimum is 10 % from the total area of the city. Air quality improves with increased percent tree cover and decreased mixing-layer heights. In urban areas with 100% tree cover (i.e., contiguous forest stands), short-term improvements in air quality (one hour) from pollution removal by trees were as high as 15% for ozone, 14% for sulfur dioxide, 13% for particulate matter, 8% for nitrogen dioxide, and 0.05% for carbon monoxide. The scoring tree cover of Urban forest in Yogyakarta city is 3 with 13.79%. The scoring of tree cover sees on table 5.1.

**Table 5.1 Scoring of Tree Cover aspect**

| Tree Cover | Value range | Scoring |
|---|---|---|
| Very low | <5% | 1 |
| Low | 6-10% | 2 |
| Moderate | 11-15% | 3 |
| High | 15-30% | 4 |
| Very High | >30% | 5 |

The tree condition is one of the factor influence tree to reducing air pollution. The urban forest of Yogyakarta city has 60.94% of trees are rated as being in excellent or good condition, 35.55% in fair or poor and 3.51% trees in critical or dying condition. The scoring of tree health condition of urban forest in Yogyakarta City is 4 (good) with 61% (see on table 5.2).

**Table 5.2 Scoring Tree Health Condition**

| Tree Health Condition | Value range | Scoring |
|---|---|---|
| Critical and Dying | ➢ 51 % | 1 |
| Poor | 26 -50 % | 2 |
| Fair | 11-25 % | 3 |
| Good | 1-10% | 4 |
| Excellent | >1% | 5 |

The other result of i-Tree analysis that shows about current size diameter of tree. Large healthy trees greater than 77 cm in diameter remove approximately 70 times more air pollution annually (1.4 kg/yr) than small healthy trees less than 8 cm in diameter (0.02 kg/yr). The structure of the urban forest in Yogyakarta is almost fifty five percent (55.82%) of the trees are still too small or too young to provide considerable air pollution removal. The scoring of diameter of tree in urban forest in Yogyakarta city is 2 (14.55 cm / young tree, see table 5.3).

**Table 5.3 Scoring Diameter of Tree**

| Diameter (d.b.h) | |
|---|---|
| **Value range (cm)** | **Scoring** |
| 0 – 7.6 | 1 |
| 7.7 – 15.2 | 2 |
| 15.3 – 22.9 | 3 |
| 23 - 30 | 4 |
| >30 | 5 |

Leaf area estimates are adjusted according to the physical condition of the tree, that is, the percentage of dead branches (crown dieback). In addition, the leaf area of trees exposed to certain pollutants can be reduced due to the inhibition of leaf formation, the halting of leaf expansion or the acceleration of leaf abscission (ICTA 2002). David J. Nowak mention that Air quality improvement due to pollution removal by trees during daytime of the in-leaf season averaged 0.47% for particulate matter, 0.45% for ozone, 0.43% for sulfur dioxide, 0.30% for nitrogen dioxide, and 0.002% for carbon monoxide (David J. Nowak, 2002). The result analysis of UFORE in Leaf Area Index is 2.16 and the scoring is 3 (table 5.4).

**Table 5.4 Scoring of Leaf Area Index**

| Leaf area index (LAI) | |
|---|---|
| **Value range ($m^2$)** | **Scoring** |
| < 1 | 1 |
| 1.1 – 2.0 | 2 |
| 2.1 – 3.0 | 3 |
| 3.1 – 4.0 | 4 |
| ➢ 4.0 | 5 |

The total accumulation score from each aspect is 12 (table 5.5), which implies that urban forest in Yogyakarta City have moderate or medium effectiveness to reducing air pollution.

**Table 5.5 The degree of Effectiveness**

| The accumulation scoring | The Degree of Effectiveness |
|---|---|
| 0 - 6 | Low |
| 7 -13 | Moderate / Medium |
| 14 -20 | High |

The comparing of pollution removal rates in Yogyakarta city with several cities around the world (Table 5.1). These standardized pollution removal rates differ among cities according to the amount of air pollution, length of in-leaf season, precipitation, and other meteorological variables. Pollution removal values for each pollutant will vary among cities based on the amount of tree cover (increased tree cover leading to greater total removal), pollution concentration (increased concentration leading to greater downward flux and total removal), length of in-leaf season (increased growing season length leading to greater total removal), amount of precipitation (increased precipitation leading to reduced total removal via dry deposition), and other meteorological variables that affect tree transpiration and deposition velocities (factors leading to increased deposition velocities would lead to greater downward flux and total removal). All of these factors combine to affect total pollution removal and the standard pollution removal rate per unit tree cover (Nowak, 2006).

From the table 5.6 show some different standardized in air pollution removal. The comparison between Jersey City, U.S and Yogyakarta city in air pollution removal has different result, which the new jersey have a big number in tree population reach 136,000 trees (11.5%) than Yogyakarta city with 56,000 (13.79%) trees but the pollution removal is less than Yogyakarta city only 41 ton /year rather than 57 ton / year. This different phenomenon can be happen because the standardized pollution removal rates differ among cities according to the amount of air pollution, length of in-leaf season, precipitation, and other meteorological variables. Jersey City could have a large tree number than Yogyakarta city but this not only factor influence the air pollution removal. From the estimation, Yogyakarta City has bigger removal pollution because the city has high rate of pollution concentration, length of in-leaf season (Yogyakarta has tropical climate and this condition support the growing of tree) and tropical Country where the city has high amount of precipitation. Nowak in 2006 has research in some cities in U.S and he conclude that the different standardized pollution removal will vary among cities based on the amount of tree cover (increased tree cover leading to greater total removal), pollution concentration (increased concentration leading to greater downward flux and total removal), length of in-leaf season (increased growing season length leading to greater total removal), amount of precipitation (increased precipitation leading to reduced total removal via dry deposition), and other meteorological variables that affect tree transpiration and deposition velocities (factors leading to increased deposition velocities would lead to greater downward flux and total removal).

**Table 5.6 Standardized air pollution removal rate in Yogyakarta city and a few cities around the world**

| No | City | % tree cover | Number of Trees | Pollution Removal (ton/yr) | Area ($km^2$) |
|---|---|---|---|---|---|
| 1 | Jersey City, New Jersey, U.S.A | 11.5 | 136,000 | 41 | 54.59 |
| 2 | Freehold, New Jersey, U.S.A | 34.4 | 48.000 | 22 | 5 |
| 3 | Calgary, Canada | 7.2 | 11,889,000 | 326 | 789.90 |
| 4 | New York, U.S.A | 20.9 | 5,212,000 | 1,677 | 1,214.4 |
| 5 | Beijing, China | 29 | 2,400,000 | 1,261 | 300 |
| 6 | Torbay, United Kingdom (U.K) | 11.2 | 818,000 | 50 | 62.88 |
| **7** | **Yogyakarta** | **13.79** | **56,000** | **57** | **32.5** |

Source: D.J Nowak, 2006

Pollution removal by urban forest in Yogyakarta city was estimated using the UFORE model and calculate by cover area of urban forest. Pollution removal was greatest for ozone ($O_{3)}$, followed by particulate matter less than 10 microns ($PM_{10}$), nitrogen dioxide ($NO_2$), carbon monoxide (CO) and sulfur dioxide ($SO_2$). Air Pollution Removal amounted to 2,450.1 kg / year for CO, 7,795.9 kg / year for $NO_2$, 24,493.5 Kg / Year for $O_3$, 20,586.0 kg / year for $PM_{10}$, 1,724.4 kg / year for $SO_2$ and total overall in the removal of air pollution amounted to 57,049.9 Kg / year. It is estimated that trees remove 57 tons of air pollution (CO, $NO_2$, $O_3$, $PM_{10}$, $SO_2$) per year. The greatest effect of urban trees on ozone, sulfur dioxide, and nitrogen dioxide is during the daytime of the in-leaf season when trees are transpiring water. Particulate matter removal occurs both day and night and throughout the year as particles are intercepted by leaf and bark surfaces. Carbon monoxide removal also occurs both day and night of the in-leaf season, but at much lower rates than for the other pollutants (D.J Nowak, 2006)

To estimate the relative value of tree benefits on air pollution removal in Yogyakarta City were compared with estimates of average municipal average passenger automobile emissions in Indonesia (BPS, 2005).

- Carbon monoxide (CO) removal with **2.45 ton/yea**r is equivalent to:
  Annual carbon monoxide emissions from **4** automobiles

- Nitrogen dioxide removal ($NO_2$) with **7.8 ton/yea**r is equivalent to:
  Annual nitrogen dioxide emissions from **235** automobiles
- Sulfur dioxide removal ($SO_2$) with **1.72 ton/year** is equivalent to:
  Annual sulfur dioxide emissions from **675** automobiles
- Particulate matter less than 10 micron (PM10) removal with **20.59 ton/year** is equivalent to:
  Annual PM10 emissions from **85,324** automobiles
  *Note: estimates above are partially based on data The Statistic Agency of Indonesia 2005.*

The World Bank estimates that 70% of air pollution in big cities comes from the evaporation of fossil fuel and exhaust emissions in motor vehicles. Pollution emissions or material released can cause health problems and even organ damage. The results of air pollution from transportation sector reached 66.4%, industry 18.9%, residential 11.1% and waste 3.7%. Based on the data Yogyakarta police, Yogyakarta city in 2007 has 308.246 automobiles. The automobile emissions in Yogyakarta city from transportation are 21,061.33 ton/year for CO, 10,238.39 ton/year for $NO_2$, 787.57 for $SO_2$ and 74.37 ton/year for $PM_{10}$ and the total value is 221,718.66 ton/year minus $O_3$. The capability air removal from Yogyakarta city from calculation was 2.45 ton / year for CO, 7.80 ton / year for $NO_2$, 20.59 ton / year for $PM_{10}$, 1.72 ton / year for $SO_2$ and total overall in the removal of air pollution amount is 32.56 ton / year. The percent air quality improvement from urban forest in Yogyakarta city is 0.001 (0.10%) to reducing air pollution based on transportation (see on table 5.7).

**Table 5.7 Estimated percent air quality improvement by Urban Forest of Yogyakarta City**

| No | Air Pollution | Emission Pollution by Car in Yogyakarta (308,246 vehicles) | Pollution Removal by urban forest | Percent air quality improvement (%) |
|---|---|---|---|---|
| 1 | CO | 21061.33 | 2.45 | 0.01 |
| 2 | SO2 | 787.57 | 1.72 | 0.22 |
| 3 | NO2 | 10238.39 | 7.8 | 0.08 |
| 4 | PM10 | 74.37 | 20.59 | 27.69 |
| | **Total** | 32161.66 | 32.56 | 0.10 |

Source: Data Processing, 2011

The comparison of percent air quality improvement between Yogyakarta city and other city in the world (table 5.8) is not significant different. D.J. Nowak in 2006 mention that Percent air quality improvement was typically greatest for particulate matter, ozone, and sulfur dioxide. Air quality improvement increases with increased percent tree cover and decreased mixing-layer heights. In urban areas with 100% tree cover (i.e., contiguous forest stands), average air quality improvements during the daytime of the in leaf season were around two percent for particulate matter, ozone, and sulfur dioxide. In some cities, short term air quality improvements (one hour) in areas with 100% tree cover are estimated to be as high as 16% for ozone and sulfur dioxide, 9% for nitrogen dioxide, 8% for particulate matter, and 0.03% for carbon monoxide.

**Table 5.8 Estimated percent air quality improvement in some cities due to air pollution removal by urban trees**

| city | % tree cover | % air quality improvement | | | |
|---|---|---|---|---|---|
| | | CO | $NO_2$ | $SO_2$ | $PM_{10}$ |
| New York | 16.6 | 0.001 | 0.3 | 0.4 | 0.5 |
| San Diego | 8.6 | 0.001 | 0.2 | 0.3 | 0.3 |
| Tampa, Florida | 9.6 | 0.001 | 0.2 | 0.2 | 0.2 |
| **Yogyakarta** | **13.79** | **0.01** | **0.07** | **0.2** | **0.3** |

Source: D.J Nowak, 2006

Finally, so even though the percent air quality improvement from pollution removal by trees may be relatively small, the total effect of trees on air pollution can produce impacts that are significant enough to warrant consideration of tree cover management as a means to improve air quality. Percent air quality improvement estimates are likely conservative and can be increased through programs to increase canopy cover. The tree planting in urban forest still can be used as an effective way in alleviating the air pollution problems in Yogyakarta city.

## 6. Conclusion and Recommendation

The conclusion that we can take from this research are:

1. Related to research question 1 ” Spatial Distribution of urban forest”
   The urban forest cover area in Yogyakarta city 2005 is 4,447,885.94 $m^2$ (447.79 Ha) or 13.79% with Accuracy Assessment 94.11%.
2. Related to Research Question number 2 “Evaluate urban Forest use UFORE model / i-Tree.
   a. The effectiveness of air pollution removal from Yogyakarta city is moderate or medium effectiveness with percent air quality improvement 0.10%.
   b. The total effect of trees on air pollution can produce impacts that are significant enough to warrant consideration of tree cover management as a means to improve air quality and consequently can help improve human health.

Recommendations for this research are:

1. Urban forest management strategies can do to improve capability of urban forest to reducing air pollution is sustaining, maintaining and protecting exist tree condition (Percent Crown Dieback of tree 1-10%, Diameter at Height Breast (d.b.h) up 30 cm and maximum Leaf Area Index).
2. Developing or improving modeling of the urban forest effect to generate better model which suitable with local condition of tropical countries, because i-Tree or UFORE dominant use for sub tropical countries.

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i-Tree Eco Data Collection Sheet for Inventory Option

| Project Name: | | | | | | Location/Address: | | | | | | | | | | Height | | | Crown Attributes | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tree ID | Date | Crew | X Coord. | Y Coord. | Photo ID | Status (NR) | Tree Species | Land Use | HT DBH | DBH1 | DBH2 | DBH3 | DBH4 | DBH5 | DBH6 | Total Height | Live Top | Crown Base | Width N-S | Width E-W | % Missing | %Die Back | CLE | Tree Site |
| | | | | | | | | | | | | | | | | | | | | | | | | |
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Source: i-Tree Manual, 2010

**Appendix 1. i-Tree Eco Data Collection Sheet for Inventory Option**

**Appendix 2. Plot located on Imagery**


Source: Data Processing, 2011

The plots were located on the 2.4 m resolution of Quickbird satellite imagery by randomly picking X and Y for each sampling point ( Plot No. 64 in Terban District)


Source: Data Processing, 2011

The circular plot with a radius of 11.3m was set up (approximately 400 $m^2$)

**Appendix 3. Plots i-Tree Picture**

Source: Field Work, 2011

Figure1 Plot i-Tree number 10 (in Malioboro Street)

Source: Field Work, 2011

Figure 2 Plot i-Tree Number 51 (Sidobali Street, Mujamuju District)

Source: Field Work, 2011

Figure 3 Plot i-Tree number 103 (Argolubang Street)

Source: Field Wok, 2011

Figure 4. Plot i-Tree number 69 (SMA Santa Maria Yogyakarta)

## Appendix 4. Trees species and Percentage

| No | Species | Percentage |
|---|---|---|
| 1 | Mangifera indica | 20.77% |
| 2 | Mimusops elengi | 14.23% |
| 3 | Pterocarpus indicus | 8.85% |
| 4 | Polyalhtia longifolia | 8.46% |
| 5 | Ficus benjamina | 5.00% |
| 6 | Terminalia catappa | 4.23% |
| 7 | Muntigia calabura | 3.85% |
| 8 | Cupressus sempervisens | 3.46% |
| 9 | Leucaena leucocephala | 3.46% |
| 10 | Manilkara Kauki | 3.46% |
| 11 | Swietenia macrophylla | 3.08% |
| 12 | Nephelium lappaceum | 2.69% |
| 13 | Syzygium queum | 1.92% |
| 14 | Gnetum gnemon | 1.92% |
| 15 | Hibiscus tiliaceus | 1.92% |
| 16 | Tamarindus indica | 1.54% |
| 17 | Artocarpus heterophyllus | 1.54% |
| 18 | Morinda citrifolia | 1.15% |
| 19 | Acasia longifolia | 1.15% |
| 20 | Logerstroemia speciosa | 1.15% |
| 21 | Artocarpus altilis | 0.77% |
| 22 | Persea americana | 0.77% |
| 23 | Araucaria cunninghammi | 0.77% |
| 24 | Hibiscus similis | 0.77% |
| 25 | Pinus merkusii | 0.38% |
| 26 | Albizia falcataria | 0.38% |
| 27 | Fillicium decipiens | 0.38% |
| 28 | Hibiscus macrophylus | 0.38% |
| 29 | Annona muricata | 0.38% |
| 30 | Averhoa carambola | 0.38% |
| 31 | Syzygium cumini | 0.38% |
| 32 | Canarium ovatum | 0.38% |

Source: Data Processing i-Tree, 2011

**Appendix 5. Coordinate of 140 i-Tree Plots**

| ID | ID_NUM | X | Y | address |
|---|---|---|---|---|
| 1 | 1 | 432768 | 9137146 | Warung Boto |
| 2 | 2 | 431079 | 9138550 | Lempuyangan, Bausasran |
| 3 | 3 | 432474 | 9136732 | Glagahsari Street, Warung Boto District |
| 4 | 4 | 431801 | 9139162 | Langensari Street, Klitren District |
| 5 | 5 | 432507 | 9133975 | Malangan, Umbulharjo District |
| 6 | 6 | 430797 | 9136217 | Kampung Keparaan area, Kerapah District |
| 7 | 7 | 432886 | 9134821 | Panggalan, Umbulharjo District |
| 8 | 8 | 431458 | 9134793 | KI Ageng Pemanahan Street, Sorosutan District |
| 9 | 9 | 429099 | 9141188 | Kragilan, Kricak |
| 10 | 10 | 430144 | 9138629 | Sosromenduran Street, Sosromedeuran area |
| 11 | 11 | 431184 | 9137093 | BIntaran Street, Wirogunan District |
| 12 | 12 | 432977 | 9139599 | Laksda Adi Sucipto Street, Klitren District |
| 13 | 13 | 430328 | 9140348 | A. M. Sangaji Street, Terban District |
| 14 | 14 | 431511 | 9135599 | Sorosutan Street, Umbulharjo District |
| 15 | 15 | 432348 | 9134783 | Nitikan Street, Giwangan District |
| 16 | 16 | 431503 | 9139565 | Kotabaru District |
| 17 | 17 | 433123 | 9134577 | Jagalan, Umbulharjo District |
| 18 | 18 | 429482 | 9135793 | Suryodiningratan |
| 19 | 19 | 427993 | 9137312 | Harjuno Street, Wirobrajan District |
| 20 | 20 | 429643 | 9140912 | Warung Waru Lor |
| 21 | 21 | 430918 | 9135673 | Brontokusuman |
| 22 | 22 | 432628 | 9139338 | Pengok, Demangan |
| 23 | 23 | 433135 | 9135918 | Kalangan, Pandeyan |
| 24 | 24 | 429353 | 9137064 | Ngasem Street, Genthong, Kadipaten District |
| 25 | 25 | 430402 | 9138553 | Gemblakan, Tegal panggung |
| 26 | 26 | 433280 | 9138935 | Demangan District |
| 27 | 27 | 432846 | 9138648 | |
| 28 | 28 | 434133 | 9134414 | Purbayan |
| 29 | 29 | 430387 | 9140770 | Karang Waru |
| 30 | 30 | 432813 | 9135669 | Gambiran, Umbulharjo District |
| 31 | 31 | 431620 | 9135371 | Dagaran Street, Sorosutan District |
| 32 | 32 | 428899 | 9140371 | Kricak Kidul, Bener |
| 33 | 33 | 432660 | 9139168 | Bima sakti Street, Demangan District |
| 34 | 34 | 429794 | 9135352 | Jageran Street, Mantrijeron District |
| 35 | 35 | 432791 | 9137994 | Kampung Militan, Mujamuju District |
| 36 | 36 | 431584 | 9138627 | Subagyiono Street, Danukusuman District |
| 37 | 37 | 431176 | 9137409 | Bintara Wetan Street, Wirogunan District |
| 38 | 38 | 432236 | 9134534 | Kranan, Nitikan Umbulharjo District |

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| | | | | |
|---|---|---|---|---|
| 39 | 39 | 428701 | 9138406 | Tegal mulyo, Tegalrejo |
| 40 | 40 | 429604 | 9139636 | Pangeran Dipenegoro, Gowongan District |
| 41 | 41 | 428798 | 9136997 | Wirobrajan |
| 42 | 42 | 432191 | 9138980 | Demangan District |
| 43 | 43 | 430041 | 9136792 | Panembahan, Panembahan |
| 44 | 44 | 430227 | 9135825 | Danunegaran Street, Mantrirejo District |
| 45 | 45 | 433951 | 9135986 | Rejowinagun |
| 46 | 46 | 429450 | 9139957 | Bener area |
| 47 | 47 | 432147 | 9137507 | Tahunan |
| 48 | 48 | 431197 | 9140071 | Cut Di Tiro Street, Terban District |
| 49 | 49 | 431319 | 9134833 | Jotawong, Sorosutan |
| 50 | 50 | 429200 | 9135803 | Suryodiningrat Street, Suryodiningratan District |
| 51 | 51 | 433036 | 9137908 | Sidobali Street, Mujamuju District |
| 52 | 52 | 430272 | 9135545 | Mantrijeron Street, Mantrijeron District |
| 53 | 53 | 430007 | 9139525 | Gowongan Lor III Street, Wilosoprojo District |
| 54 | 54 | 428779 | 9135984 | Gedongkiwo Street, Gedungkiwo District |
| 55 | 55 | 429443 | 9139542 | Damai Street, Tegalrejo |
| 56 | 56 | 428710 | 9137618 | Wirobrajan |
| 57 | 57 | 432794 | 9137572 | Timoho |
| 58 | 58 | 431567 | 9137349 | Pronocitro Street, Wirogunan District |
| 59 | 59 | 432872 | 9136744 | Glagahsari, Warung Boto |
| 60 | 60 | 433502 | 9135334 | Anugerah Street, Kotagede District |
| 61 | 61 | 432690 | 9133575 | Malangan area, Giwangan District |
| 62 | 62 | 431130 | 9137078 | Surokarsari |
| 63 | 63 | 433665 | 9137554 | Gedong Kuning, Rejowinangun District |
| 64 | 64 | 430991 | 9139946 | Terban District |
| 65 | 65 | 428838 | 9135244 | Dukuh Gedongkiwo |
| 66 | 66 | 432452 | 9138042 | Baciro area, Smaki District |
| 67 | 67 | 430819 | 9136253 | Karopan |
| 68 | 68 | 430804 | 9139852 | Terban District |
| 69 | 69 | 430612 | 9136950 | SMA Santa Maria |
| 70 | 70 | 432246 | 9136785 | Batikan |
| 71 | 71 | 432077 | 9138044 | Stadium, Smaki District |
| 72 | 72 | 431118 | 9137160 | Bintaran, Wirohgunan |
| 73 | 73 | 429494 | 9136659 | Taman Sari, Patehan |
| 74 | 74 | 429344 | 9139955 | Bangunrejo area |
| 75 | 75 | 432222 | 9139536 | Urip Sumoharjo Street, Klitren District |
| 76 | 76 | 431630 | 9136214 | Mergansari Kidul, Wirogunan |
| 77 | 77 | 430225 | 9136695 | Mantrigawen Kidul |
| 78 | 78 | 433020 | 9137803 | Timoho Street, Timoho District |
| 79 | 79 | 434094 | 9136734 | Rejowinangun |

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| | | | | |
|---|---|---|---|---|
| 80 | 80 | 428905 | 9138404 | Pringgokusuman |
| 81 | 81 | 431280 | 9139631 | Novotel Hotel, Terban District |
| 82 | 82 | 429719 | 9136890 | Panembahan, Keraton District |
| 83 | 83 | 429008 | 9138899 | Pringgokusuman |
| 84 | 84 | 429236 | 9141014 | Jatimulyo, Kricak |
| 85 | 85 | 429408 | 9140228 | Tegalrejo |
| 86 | 86 | 429604 | 9135185 | Mantrijeron District |
| 87 | 87 | 430696 | 9135902 | Timuran Street, Brontokusuman area |
| 88 | 88 | 431732 | 9134708 | Gurami Street, Nitikan, Umbulharjo District |
| 89 | 89 | 430215 | 9140760 | Karang Waru |
| 90 | 90 | 431927 | 9139402 | Klitren lor |
| 91 | 91 | 428119 | 9137837 | Pakuncen |
| 92 | 92 | 431207 | 9138619 | Lempungan, Bausastran |
| 93 | 93 | 432815 | 9134227 | Pemukti Street, Umbulharjo District |
| 94 | 94 | 433732 | 9136019 | Nyi Ageng Nis Pilahan area, Kotagede District |
| 95 | 95 | 429660 | 9135764 | D.I. Panjaitan Street, Mantrijeron District |
| 96 | 96 | 431054 | 9135350 | Brontokusuman |
| 97 | 97 | 432681 | 9134457 | Imogiri Timur Street, Giwangan District |
| 98 | 98 | 428339 | 9136619 | Bulgisari Street, Patungpuluhan District |
| 99 | 99 | 432565 | 9135484 | Umbulharjo District |
| 100 | 100 | 430622 | 9135600 | Brontokusuman |
| 101 | 101 | 428481 | 9140267 | Bener area |
| 102 | 102 | 431075 | 9140517 | Sagan |
| 103 | 103 | 431737 | 9138854 | Argolubang Street |
| 104 | 104 | 428712 | 9137656 | Gampilan, Ngampilan District |
| 105 | 105 | 433422 | 9135224 | Lapangan Karang, Kotagede District |
| 106 | 106 | 429202 | 9136174 | Pugaran Barat Street, Suryodiningrat District |
| 107 | 107 | 431392 | 9139916 | Purbonegaran Street, Terban District |
| 108 | 108 | 429323 | 9138200 | Ngampilan District |
| 109 | 109 | 429957 | 9138890 | Krasak, Kotabaru District |
| 110 | 110 | 431652 | 9138141 | Smaki Kulon area, Smaki District |
| 111 | 111 | 429723 | 9139558 | Bumiijo, Jetis District |
| 112 | 112 | 430937 | 9137747 | Kepatihan, Pakualam district |
| 113 | 113 | 432105 | 9139215 | Langansari Street, Demangan District |
| 114 | 114 | 433317 | 9137773 | Kenari Street, Mujamuju District |
| 115 | 115 | 430725 | 9140431 | Blimbing Sari Street, Terban District |
| 116 | 116 | 430129 | 9136082 | Ngadinegaran, Mantrijeron District |
| 117 | 117 | 431084 | 9139592 | Kotabaru District |
| 118 | 118 | 428641 | 9140034 | Bener Street, Tegalrejo District |
| 119 | 119 | 429086 | 9138499 | Pringgokusuman |
| 120 | 120 | 429923 | 9139185 | Umbulharjo District |

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| | | | | |
|---|---|---|---|---|
| 121 | 121 | 432698 | 9136696 | Warung Boto District |
| 122 | 122 | 432110 | 9139047 | |
| 123 | 123 | 432847 | 9139534 | Berkuda Street, Demangan District |
| 124 | 124 | 433104 | 9137522 | Kusumanegara Street, Timoho District |
| 125 | 125 | 428408 | 9138773 | |
| 126 | 126 | 428933 | 9140767 | Kricak |
| 127 | 127 | 433373 | 9135964 | Depokan I Street, Kotagede District |
| 128 | 128 | 431798 | 9134998 | Demakan, Tegalrejo |
| 129 | 129 | 428900 | 9137155 | Gendingan Street, Notoprajah District |
| 130 | 130 | 428539 | 9139000 | Sudagaran Street, Tegalrejo District |
| 131 | 131 | 430037 | 9137910 | Malioboro, Ngupasan |
| 132 | 132 | 429864 | 9139799 | Cokrokusuman, Karangwaru |
| 133 | 133 | 430585 | 9137029 | Prawirodirjan area |
| 134 | 134 | 433532 | 9137752 | Mujamuju District |
| 135 | 135 | 428692 | 9139920 | Kotabaru District |
| 136 | 136 | 432386 | 9134410 | Mendungan Street, Giwangan District |
| 137 | 137 | 428692 | 9135537 | Gejuron Street, Gedong Kiwo District |
| 138 | 138 | 431843 | 9135888 | Jetis, Umbulharjo District |
| 139 | 139 | 433259 | 9137552 | Timoho |
| 140 | 140 | 428812 | 9136510 | Suryowijayan Street, Patang puluhan District |

Source: Data Processing, 2011