
Geographic Information System (GIS) application on urban forest development in Bandung City

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Abstract

Bandung as the capital city of West Java has been facing with massive land conversion leading to reduce of green open space, which in fact affect to the quality of environment. This study will examine current urban forest policy-Bandung City Regulation No. 25/2009 and Spatial Plan of Bandung City, spatial distribution of urban forest, and also to develop method to prioritize location for urban forest design in Bandung using GIS. Method used in this study was overlay of several parameters; altitude, slope, land cover, climate, population density, and the distance of the protocol road. Parameters measured were analyzed using AHP. Based on Landsat 8 analysis, the factual urban forest areas only cover 338.94 hectares (less than 10% area of Bandung), and thus it is necessary to locate the appropriate location for a well-designed urban forest development. Result shows that there was three scores indicating the rank prioritization as the 652.65 hectares for the first rank, 7336.65 hectares for the second rank and lastly 8,733.61 hectares. It is concluded that the first priority to be developed for urban forest in Bandung was Mandalajati, Cibiru, and Ujung Berung that fall within the first rank.

Keywords: Bandung city; development; GIS; urban forest

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1. Introduction

Bandung is the largest metropolitan city in West Java with a vision "Realization of Bandung Excellence, Comfortable, and Prosperity". Bandung has an area of about 16,729.65 ha [1] with a population of 2,483,977 from 30 districts [2]. With a crowded population, the demand for land is becoming more increase, land conversion leading to reduce of green open space. As a result of land conversion that include the destruction of forests, land, and the land has a wide impact through deterioration of biodiversity, flooding, landslides, drought and degradation of land water [3]. With the reduction in vegetation, there will be an increase amount of CO₂ that is causing the earth's surface temperature increase and climate change. One of the causes of climate change is due to the increasing number of the content of greenhouse gases in the atmosphere. Greenhouse gases (GHG) in the atmosphere, among others, CO₂, CH₄, CFCs and N₂O [4].

One of solution to reduce the level of air pollution is developing urban forest appropriately [5]. Government Regulation No. 63 of 2002 defines the urban forest as a stretch of land that trees grow compact and dense in urban areas both on land and land rights of the state, which is designated as an urban forest by a competent authority. The percentage of forest area of the city at least 10% of urban areas and or adapted to local conditions.

In Law No. 41 In 1999, the urban forest has a function to the benefit of micro climate regulation, aesthetics and water infiltration. At PP 63 2002 explained that: (1) Appointment of location and size of urban forest based on the following considerations: (a) area; (b) the total population; (c) the level of pollution; (d) the physical condition of the city. (2) The forest area of the city in a compact stretch of at least 0.25 (twenty five percent) hectares. (3) Percentage of area cities of at least 10% (ten percent) of urban areas and or adapted to local conditions. The third criterion above is a guideline used as consideration in the appointment of the urban forest. These criteria are used as a determinant of forest sites in the city of Bandung, as already mentioned locations have been designated as forest in the city of Bandung Regulation No. 25 of 2009 and RTRW of Bandung. However, the criteria are not appropriate to the urban forest functions as stated in Law No. 41 of 1999. Many urban parks that function has changed was claimed as an urban forest. Currently, there is no proper method in determining the location of priority for the development of urban forests.

Remote sensing technology is growing through the presence of various satellite systems with various missions and sensor technology. Application of remote sensing satellite has been able to provide data / information on natural resources regularly and periodically. Landsat images is one of the remote sensing satellite images that show fairly broad overview of the area and the data processing system fairly easily understood by a wide range of data users [6]. Therefore, the spatial planning of urban forest development can be done more easily and quickly. Given the function of urban forest, the green space to the urban forest needs to be improved in view of the importance of the urban forest. One solution is to make studies in management development, which aims to direct the potential that already exist in order to be better managed to obtain optimal function of urban forest. Good urban forest development is expected to create a comfortable environment in helping people to move smoothly [7]. This research was conducted to study of forest policies in the city of Bandung, determine the spatial distribution of forest in the city of Bandung, and to develop methods for the location of the urban forest development priorities to support decision making in the planning and development activities, in accordance with the Spatial Plan to realize the vision of the city that superior, comfortable, and prosperous.

2. Method

2.1. Study area

This research was conducted in the city of Bandung on month in December 2014 to August 2015. Data processing was performed at the Laboratory of Environmental Analysis and Spatial Modelling, Department of Forest Resources Conservation and Ecotourism, Faculty of Forestry.

2.2. Tools and materials

The tools used in this study include stationery, digital cameras, GPS, Global Mapper, ArcGIS 9.3 and ERDAS Imagine 9.1, V.11 Expert Choice Software and computer / laptop. While the materials used in this research is interview
guide, Landsat 8 (Path 122 Row 65), ASTER GDEM imagery, RBI Bandung Maps, Spatial Plan of Bandung City Map, and literature.

2.3. Research procedure

- **Study library**
  This method aims to obtain secondary data that can be used in completing the research data. The literature study was obtained from various sources, such as book reports, theses, journals, internet and other documents related to the title of this research.

- **Observation field**
  The aim of this field observation is to determine the condition of the field, which determine the initial site conditions and other physical condition. Data taken divided into two aspects: the ecological and social aspects (Table 1).

- **Interview**
  Interviews were conducted with forest managers in the city of Bandung related efforts and programs that have been and will be done in the management of urban forests. Interviews were conducted with an integrated interview.

<table>
<thead>
<tr>
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<th>Primary Data</th>
<th>Secondary Data</th>
<th>Source</th>
<th>Method</th>
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<td>Narrative</td>
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<tr>
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<td>Land Price Index</td>
<td>✓</td>
<td></td>
<td>Navigation Net</td>
<td>Interpretation Map</td>
</tr>
</tbody>
</table>

2.4. Data analysis of physical aspects

- **Altitude mapping and slopes**
  The study was conducted by performing image analysis process ASTER GDEM to obtain data on altitude and slope from ASTER GDEM image analysis process is done by using ArcGIS 9.3 software. Spatial data is the data that gave the slope information of land that has a slope of a percent of the unit value (%) based on the degree of slope angle degrees (°). Slope with a value of 100% = 45° angle of inclination. Spatial data can be constructed with a slope process slope analysis on the data DEM (Digital Elevation Modeling), then the data is grouped by the steepness of a regional classification (classification slopes).

- **Analysis of land cover**
  Land cover data was obtained from the analysis of satellite imagery interpretation (Landsat 8) by using ERDAS Imagine 9.3 and ARGIS 9.1 software. Determination and manufacture of land cover classes based on the interpretation of color pixels Landsat 8. From this analysis will be known locations vegetated and non-vegetated. For the location of the vegetation, then matched with field survey data to determine which trees and non-tree. Then
analyzed with Supervised Classification. The land cover analysis aims to determine the locations that can later be used as the location for the construction of the urban forest.

- **Processing band 10 for surface temperature estimation**

  Band 10 processing on Landsat 8 is made to produce a map of the surface temperature distribution. Estimated value of the surface temperature is done by using ERDAS Imagine 9.1 software, the process is done by creating a model on the menu ERDAS Imagine Model Maker 9.1 is already available for converting pixel values in Landsat 8 band 10. DN (Digital Number) are things that need to be considered in conversion into radiance value with formula [8]:

\[
L_A = M_L Q_{cal} + A_L
\]  
(1)

Where:

- \(L_A\) = Radiance spectral TOA (watts/m² Sradian μm)
- \(M_L\) = \((\text{Radiance}_\text{mult}_\text{bandx}), x = \text{band number}\)
- \(A_L\) = \((\text{Radiance}_\text{add}_\text{bandx}), x = \text{band number}\)
- \(Q_{cal}\) = Quatized and calibrated standard product pixel values (Digital number)

The surface temperature obtained after the conversion process Radian Spectral (Spectral Radiance) into temperature with formula [8]:

\[
T = \frac{K_2}{\ln\left(\frac{K_1}{L_A}+1\right)}
\]  
(2)

Where:

- \(T\) = At-satellite brightness temperature (K)
- \(L_A\) = TOA spectral radiance (Watts/(m² * sradian * μm))
- \(K_1\) = Band-specific thermal conversion constant from the metadata (K1_CONSTANT_BAND_x, where x is the thermal band number)
- \(K_2\) = Band-specific thermal conversion constant from the metadata (K2_CONSTANT_BAND_x, where x is the thermal band number)

2.5. **Data analysis in social aspect**

On the social aspects of the data obtained came from BPS Bandung. Data taken from the population data (demographic data of the population). Population density data was taken because population density regarded as the source of the activities that will produces of pollution and need an urban forest as the absorbent.

2.6. **Data analysis in management aspect**

In the aspect of management conducted interviews with forest managers in the city of Bandung, plans and programs related to forest management in the city of Bandung. The data obtained will be analyzed descriptively. For policy data, obtained through the study of relevant literature Bandung City Regulation on Urban Forest and Spatial Planning of Bandung. Policy analysis done by the policy narrative. A narrative description of the policy is a story that has a beginning, middle, and end in describing certain events that affect policy changes [9].

2.7. **Data analysis in economic aspect**

In the economic aspect, the captured data related to land price index in Bandung. Data on land price index is obtained by the estimated distance of the main streets of Bandung, assuming closer to the protocol road, then the price of land will be more expensive, and further to the protocol road the price of land will be cheaper. The data of distance from the protocol road was taken from Navigation Net. This assumption also supported by the results of the study related modeling land prices urban areas with the Kriging methods (geo-statistics approach), that the increase land prices Bandung city in an urban center is greater than by rising prices land in the suburbs [10].
2.8. Prioritizing location of urban forest

Method for determining the location for the construction of urban forest is done by scoring. Each parameter / sub-factors used (slope, elevation, land use, population density, temperature, and the land price index) classified then given a different value. Factors to be parameter in determining the priority of the city forest sites were analyzed using AHP (Analytical Hierarchy Process). The principle of assessment in comparing in pairs AHP is a factor of the level of interest with other factors that are at a level based on certain considerations. These considerations can be based on consideration of the literature as well as the fact that encountered in the field [9]. The comparison of the results to be obtained a total score. Those values are divided into three classes of priorities, priority 1, priority 2 and priority 3 (Table 2).

Table 2. Hose priority location of urban forest.

<table>
<thead>
<tr>
<th>Priority Classes</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st priority</td>
<td>High priority</td>
</tr>
<tr>
<td>2nd priority</td>
<td>Medium priority</td>
</tr>
<tr>
<td>3rd priority</td>
<td>Low priority</td>
</tr>
</tbody>
</table>

3. Results and Discussion

3.1. Review of urban forest policy in Bandung City

- Bandung Perda No. 25 of 2009
  Designation location and size of the urban forest needs to be protected and preserved, adapted to the Spatial Plan of Bandung, among others (Article 6): a. Tegalega garden area: 190,011 m²; b. Maluku garden area: 24,023 m²; c. Cilaki garden area: 32,860 m²; d. Zoo area: 140,000 m²; e. Traffic Park area: 32,000 m²; f. Ex TPA Pasir Impun area: 44,600 m²; g. Ex TPA Cicabe area: 41,803 m²; h. Scout Park area: 12,845 m²; i. Forest neighbourhood PINDAD City area: 370,000 m²; j. Most areas Punclut controlled / owned by the Local Government and the displaced; k. Abandoned land belonging to the Government and people in the northern Bandung and Bandung. l. In every area of development as set / accordance with the spatial plan and RDTR.

- Spatial Plan of Bandung Year 2011-2031
  Public green space developed by the city and spread across the city, including (Article 46 2nd paragraph): a. park environment unit; b. park along the border of the roads, highways, railways, rivers and irrigation and SUTT; c. burial areas; and d. urban forest. RTH developed urban forest in Babakan Siliwangi area of 3.1 (three point one) hectare (Article 46 6th paragraph).

- Evaluation of Urban Forest Policy (Regulation No.25 / 2009 & Spatial Plan)
  Under PP 63 of 2002 on the urban forest, land rights can be requested for establishment as an urban forest must meet the following criteria:

  a. located in the urban areas of a district / municipality or province to Jakarta Special Capital Region;
  b. a green open space dominated by trees;
  c. have an area that is at least 0.25 (twenty five percent) hectares and is able to establish or improve the microclimate, aesthetics, and function as a water catchment.

  Those criteria above was used to determine the distribution of urban forest. However, when seen from the function of urban forests, urban forest distribution based RTRWK Bandung is more appropriate than the Bandung Regulation No. 25 of 2009. In the study [11], shows that the urban forest based Bandung Regulation No.25 of 2009 consisted of eight forest sites the city is used as a means of sport and recreation / public holidays and 1 location is where the armaments industry so closed to the public. Considering related to the function of the urban forest, some parks are designated as urban forest based regulation is not in accordance with the urban forest functions, such as a children's playground, stage, concert venues, football field, etc.
3.2. Distribution of urban forest in Bandung

Avoid hyphenation at the end of a line. Symbols denoting vectors and matrices should be indicated in bold type. Scalar variable names should normally be expressed using italics. Weights and measures should be expressed in SI units. All non-standard abbreviations or symbols must be defined when first mentioned, or a glossary provided.

3.3. Priorities location of urban forest development in Bandung

Urban forest development priorities in this research includes three factors, biophysical, economic, and social. Biophysical factors include altitude, slope, temperature, and land cover. Economic factors was land price index, and social factors was population density. All of the factors was divided into 5 classes, and the range was appropriated based on the condition of Bandung City (Table 3).

- **Altitude**
  The altitude map obtained from the analysis of ASTER GDEM satellite imagery using ArcGIS software. Altitude classification consist of 5 classes (600-700, 701-800, 801-900, 901-1000, and 1001-1100) m asl. Based on the analysis, there was a strong correlation meaning that the higher area will more recommended to be developed into an urban forest. It’s because trees can reduce soil erosion [12].

- **Slope**
  Slope maps was derived from analysis of ASTER GDEM satellite imagery using ArcGIS software. Slope classification consist of 5 classes (0-8, 8-15, 15-25, 25-40, and> 40) %. Based on the analysis there was a strong
correlation meaning that steeper area will more recommended to be developed into an urban forest. It’s because trees can form an affective barrier as well as limiting landslide run-out distances [12].

Fig. 2. Distribution of urban forest in Bandung City (factual).

- **Temperature**
  Temperature maps obtained from the analysis using 10 bands on Landsat 8 was made to produce a map of the surface temperature distribution. Estimated value of the surface temperature was done by using ERDAS Imagine 9.1 software. Classification of temperature consist of 5 classes (18-20, 21-23, 24-26, 27-29, and> 30) °C. Based on the analysis, there was a strong correlation meaning that the higher temperature (heat) area will more recommended to be developed into an urban forest. It’s because planting trees in city is one way to reduce energy use and thereby reduce carbon dioxide emission [13].

- **Land cover**
  Land cover map derived from the analysis of Landsat 8 by using ArcGIS 9.3 software. Land cover classification consist of 5 classes (wooded areas, dry land farming / composite agriculture, shrub / grassland, open land, farming wetland / land up). Based on the analysis there was a strong correlation meaning that the coverer area will be easier to be developed into an urban forest.

- **Population density**
  Population density map obtained from the secondary data from Statistics Indonesia (BPS) of Bandung City, which is processed by software ARGIS 9.1. Population density classification consist of 5 classes (<7173; 7173-14,346;
14,347-21,520; 21,521-28,695; and > 28,694) people. Based on the analysis there was a strong correlation meaning that the crowded area will be recommended to be developed into an urban forest.

- **Distance from protocol road**
  The road map obtained from the Navigation Net which is then processed by software ARGIS 9.1. Classification distance of the protocol consist of 5 classes (<1.0 km; 1.0-1.5 km; 1.5-2.0 km; 2.0-2.5 km; and > 2.5 km). Based on the analysis, there was a strong correlation meaning the assumption that the closer a location of the protocol, it will be more expensive and the farther a location of the protocol it will be more affordable land prices. With the cheaper price of land, the more priority to be developed into an urban forest.

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### 3.4. Overlay Results

The factors above a parameter in determining the priority of the urban forest sites were analyzed using AHP (Analytical Hierarchy Process). AHP is a decision support tool that can be used to solve complex problems. This method uses multi-level hierarchical structure of objectives, criteria, sub-criteria and alternatives. This comparison is used to get the weight of the importance of decision criteria, and measures the relative performance of the alternative any individual decision criteria [14]. Data obtained using pairwise comparisons from 5 expert in urban forest from Bogor Agricultural University and Bandung Institute of Technology. The data was analyzed using software Expert Choice.

Based on the weighting analysis using AHP, can be formulated following equation:

\[
Total \ Score = 0.441 \ (0.133 \times \text{altitude score} + 0.322 \times \text{slope score} + 0.258 \times \text{land cover score} + 0.287 \times \text{temperature score}) \\
+ 0.334 \ (1.00 \times \text{population density score} + 1.00 \times \text{land price index score}) \\
or \\
Total \ score = 0.059 \times \text{altitude score} + 0.142 \times \text{slope score} + 0.114 \times \text{land cover score} + 0.127 \times \text{temperature score} + 0.334 \times \text{population density score} + 0.225 \times \text{land price index score}
\]

From the overlay, the highest and lowest values were classified into three classes (Table 2), priority 1 (high), priority 2 (medium), and priority 3 (low). From the result, there was an information that the districts that received the highest area of priority 1 (high) is Cibiru, Mandalajati, and Ujung Berung (Fig. 3). Therefore, the districts are recommended as locations that will be developed into an urban forest in Bandung.

From the overlay, the urban forest priority class 1 (high) and land cover, there was an information that the biggest area was composite agriculture of 427. 59 Ha (Fig. 4). The area is in the RTRW of Bandung is an area of protection of the area below it, indicating that the area was important to maintained the function, so that it can be developed into an urban forest. While the overlay map (Urban forest distribution and priority map) shows that the location of the urban forest in Bandung majority are in the priority 2 (medium) and 3 (low), it means the location of urban forest in Bandung are not appropriate yet but the function of urban forest must be maintained (Fig. 5).
Table 3. Factor and sub-factor prioritization of urban forest location.

<table>
<thead>
<tr>
<th>Factors</th>
<th>Sub-factors</th>
<th>Verifier</th>
<th>Description</th>
<th>Score</th>
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<tbody>
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<td>4</td>
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<tr>
<td></td>
<td></td>
<td>15-25 %</td>
<td>Rather Steep</td>
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<td></td>
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<td>8-15 %</td>
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<td></td>
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<td>2.0-2.5 km</td>
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<td>4</td>
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</table>
Factors | Sub-factors | Verifier | Description | Score
---|---|---|---|---
1.5-2.0 km | Medium | 3
1.0-1.5 km | Low | 2
<1.0 km | Very Low | 1

4. Conclusion

Forest Policy in Bandung city related to the urban forest consists of Bandung City Regulation No. 25 of 2009 and RTRWK Bandung. Based on Perda No. 25/2009 urban forest consist of Taman Tegalega, Taman Maluku, Taman Cilaki, Kebun Binatang Bandung, Taman Lalu Lintas, EKS TPA Pasir Impun, EKS TPA Cicabe, PT. PINDAD, and Taman Pramuka. Whereas, the RTRW of Bandung City only mentioned the urban forest just Babakan Siliwangi with an area 3.1 Ha. In accordance with the functions of urban forests, RTRWK more appropriate than the Regulation No. 25 of 2009. Based on Landsat 8 analysis, the factual urban forest areas only cover 338.94 hectares. As the result of the analysis was less than 10% as it is stated in the stipulation. To meet the local government regulation, there is a need to develop method to determine priority of location that can be categorized into urban forest. Urban forest development priorities includes three factors, biophysical, economic, and social. Biophysical factors include altitude, slope, temperature, and land cover. Economic factors was land price index, and social factors was population density. The factors above a parameter in determining the priority of the urban forest sites were analyzed using AHP (Analytical Hierarchy Process). From the result, the districts must be developed into an urban forest in Bandung was Mandalajati, Cibiru, and Ujung Berung.
Acknowledgements

We thank to Bogor Agricultural University. Head of Department Natural Resources Management and Environmental, Bogor Agricultural University. BAPEDDA of Bandung City, Landscaping Services of Bandung City from the data. Muhammad Juan Ardha and Akbar Ramadhan for helping collecting data field.

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