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To cite this article: R Hermawan et al 2018 IOP Conf. Ser.: Earth Environ. Sci. 203 012021

View the article online for updates and enhancements.
Arrangement of blocks and vegetation of urban forest based on land cover and soil properties to increase the functions of recreation, soil and water conservation in Pondok Labu, South Jakarta

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Abstract. Urban forest constitutes a part of an urban ecosystem which has multifunctions. The urban forest of Pondok Labu has ever undergone erosion and landslide which reduced its function. The objective of this research was to study the arrangement of the Pondok Labu Urban Forest based on land cover and soil properties. The collection and processing of data comprised among others the general condition of the area, classification of vegetation density based on NDVI, measurement of leaf area index using technique of hemispherical photograph and software Hemiview 2.1, measurement of throughfall, vegetation analysis and soil erodibility. Afterwards, the determination of the block position and function, and vegetation arrangement were conducted by descriptive and qualitative analysis. There were two blocks developed, i.e.: intensive block and non-intensive block. The intensive block was plotted in the land which has not undergone landslide as visitor activity center. Non-intensive block is a rehabilitation block on the post landslide area. Arrangement of the vegetation is adjusted with the site condition and vegetation function. The edge parts function as shading plants, wind break and noise reduction. The middle part contains plants producing flowers and fruits. The inner part contains plants producing fruits to attract birds.

1. Introduction
Urban area is an ecosystem which contains the physical, biotic and social components which interact among each other. One of the biotic components which has an important function in an ecosystem is vegetation. In a biogeochemical cycle, vegetation constitutes a kind of nerve knot of an ecosystem balance. Vegetation is passed through by chemical element cycle and functions as a synthesizer in a photosynthesis process, in addition, it also acquires a physiological and ecological ability to improve the quality of an environment [1].

Vegetation which either grows naturally or being planted, constitutes a component of urban green open space [2]. One of the types of urban green open space is an urban forest which is an area with a minimum size of 0.25 ha in urban land or around urban area grown by trees and their associates, which has the shapes of a strip, scattered plots or clustered plots, with canopy structures resembling natural forests, so they can serve as wildlife habitats, creating a comfortable, beautiful and a healthy environment [2,3]. The existing urban forests are expected to maintain or even improve urban environmental quality and create many other benefits, such as creating beauty, controlling air pollution, serving as facilities for recreation and social interaction, and providing soil and water conservation services [1,2,4,5].

Government Regulation of the Republic of Indonesia Number 63 Year 2002 article 8 (3) [2] explained that urban forest should be established minimally 10 % of the urban area or be adjusted with
the local condition. One of the urban forests which has been established is the Urban Forest at Pondok Labu, South Jakarta. Based on the Spatial Plan of Jakarta during 2011-2030, the Urban Forest at Pondok Labu is situated in a zone, which is allocated for a park residential area, so that the urban forest is expected to provide convenience for people residing in the surrounding areas, as well as providing benefits in the form of recreation, and soil and water conservation.

In the year 2016, Urban Forest Pondok Labu underwent erosion and landslide which gave impacts on 75 households [6]. These phenomena occurred due probably to urban forest function which was not maximal yet in soil and water conservation. Afterwards, this condition also caused disturbance on other functions. For recovery or even for improving the various functions of the urban forest, there is a need for rearrangement of the urban forest which is based on the land cover condition and soil properties. The two factors are supposed probably to affect the control of soil erosion and landslide [7].

The objectives of this research were to analyze the arrangement and lay out of the Urban Forest Pondok Labu on the basis of land cover and soil properties. The benefit of this research was providing inputs for the management of the Urban Forest at Pondok Labu, South Jakarta for developing blocks and arrangement of vegetation.

2. Method

2.1. Time and location of the research

This research was conducted during March – April 2017. The research location was in the Urban Forest of Pondok Labu, Jalan Pinang II Dalam RT 04 RW 02 Kelurahan Pondok Labu, Subdistrict of Cilandak, South Jakarta.

2.2. Materials and equipments

Materials and equipment used in this research included: (1) for tree density classification: Software ArcGIS 10.3, Google Earth imagery, SExi-FS 2.1, imagery of Landsat 8 ETM+ with the acquisition date 20th June 2013 path/row 122/64; for determination of the leaf area index (LAI): Digital Single-Lens Reflex (DSLR) camera, lens fisheye, and tripod, software hemiview 2.1; (2) for vegetation analysis: Garmin Global Positioning System (GPS) Map 64S, measurement tape, stakes, walking stick, corel draw X6; (3) for a throughfall measurement: manual ombrometer and measuring glasses; (4) for determination of soil properties: Munsell Soil Color Charts, soil sample rings, soil auger, plastic pocket of 20 cm x 40 cm, knife, wooden hammer, porcelain, smooth fine cloth, plastic sieve, plastic basin, bottle, scissor, adhesive tape, water, label paper.

2.3. Data collection and processing

2.3.1. Utilization of urban forest. Data and information on urban forest utilization up to the time of research were obtained by interview with the management of the urban forest and direct field observation. The obtained data were arrangement and utilization of the urban forest up to the time of research.

2.3.2. Classification of tree density. Determination of vegetation density classification used data from satellite imagery Landsat 8 ETM+ with acquisition date 20th June 2013 path/row 122/64, and Google Earth year 2013. This stage was initiated with data collection of imagery of Landsat 8 ETM+ path/row 122/64, combination of band Red Green Blue/RGB (6,5,4), Google Earth imagery, and Indonesia Earth Configuration (IEC) map of year 2013. Data were processed by uniting band 5 (Near Infrared) and band 4 (Red) and cropping the imagery in accordance with the boundary of research location. Afterwards, NDVI (Normalized Difference Vegetation Index) were calculated using band 5 and band 4, and vegetation density classes were determined by reclassification into three levels of
vegetation density, namely low, moderate and high density. After this, map of vegetation densities of Urban Forest Pondok Labu was made.

Determination of vegetation density classification used formula of NDVI [8] namely as in equation (1).

\[
\text{NDVI} = \frac{\text{NIR} - \text{RED}}{\text{NIR} + \text{RED}}
\]

where:
NIR: spectral reflectance in infrared band
RED: spectral reflectance in red band

Vegetation density was classified into three levels of density, namely low, moderate and high, whereas the interval for these density levels were calculated on the basis of the formula as equation (2).

\[
IC = \frac{x_t - x_r}{k}
\]

where:
IC: Interval class
xt: the highest value of NDVI
xr: the lowest value of NDVI
k: Number of classes

2.3.3. Measurement of LAI. Measurement of LAI was conducted by recording the picture of crown cover using hemispherical photograph technique by placing five points, at the middle and at the corner, at observation sample plots with the size of 20 m x 20 m, which was conducted in the morning or under cloudy condition. DSLR camera and tripod were positioned at a height of ± 1 m parallel 180° above ground surface. Fisheye lens was installed in the DSLR camera, being directed to the north to record the picture of a crown cover by directing the camera to face the sky [9].

Pictures of a crown cover were analyzed using the Hemiview 2.1. software. Analysis was conducted by the threshold method in the picture of a crown cover by manually maximizing contrast between foliage and the sky, by increasing and decreasing the level of threshold until a match was found between the imagery of classification result and the original imagery, so that clear boundary was obtained between part which was covered by canopy and the open part [9]. Average value of LAI of each plot was calculated using formula as in equation (3).

\[
\text{Average value of LAI} = \frac{L_i}{N}
\]

where:
Li: LAI value of i\(^{th}\) point
N: Number of points of camera placement in a plot

2.3.4. Vegetation analysis. Vegetation analysis was conducted by using nested quadrat plots, which were placed at low, moderate and high vegetation density. The size of the plot consisted of: 2 m x 2 m for observation on seedlings, 5 m x 5 m for observation on saplings, 10 m x 10 m for observation on poles, 20 m x 20 m for observation on trees. Results of vegetation analysis were in the form of density, and importance value indexes at stages of seedling, sapling, pole and tree [10]. Data collection for constructing profile diagram of urban forest was conducted by using the same plot.

2.3.5. Measurement of throughfall. Measurement of throughfall from the crown was conducted by placing manual ombrometer made from a plastic bottle with a diameter of 8 cm and a height of 23.5 cm, installed at a height of 1 m above ground surface [11]. Measurement was conducted every
morning after occurrence of rainfall event [11]. Measurements was conducted in each representative area of each level of vegetation density.

Calculation of throughfall in each daily rainfall event was conducted with the equation (4) [11].

\[
T_f = \left( \frac{V_t}{L_t} \right) \times 10
\]  

(4)

where:

\( T_f \): Throughfall (mm)

\( V_t \): Volume of water collected in the ombrometer (cm\(^3\))

\( L_t \): Size of ombrometer surface area (cm\(^2\))

2.3.6. Soil properties. The observed soil properties were those parameters, which were used to determine soil erodibility included: (1) soil texture with four fractions (coarse sand, fine sand, silt, and clay) by Testing Laboratory of Soil Research Agency, Cimanggu, Bogor using the pipet method; (2) soil texture estimation using finger assessment procedure; (3) determination organic matter content by Testing Laboratory of Soil Research Agency, Cimanggu, Bogor using Walkley and Black method; (4) measurement of soil permeability using soil sample rings which were flowed with water.

Soil erodibility was obtained with the equation (5) [12]:

\[
100 \ K = 1.292 \ [2.1 \ M^{1.14} \ (10^{-4}) \ (12-a) + 3.25 \ (b-2) + 2.5 \ (c-3)]
\]

(5)

where:

\( M \): (% silt + % fine sand) x (% silt + % sand)

\( a \): Percentage of organic matter

\( b \): Code of soil structure

\( c \): Class of soil permeability

\( K \): Soil erodibility

Afterwards, the obtained \( K \) values were categorized into classes of soil erodibility by the United States Department of Agriculture (USDA) [7] as shown in table 1.

| Class | \( K \) value | Category      |
|-------|--------------|--------------|
| 1     | 0.00 – 0.10  | Very low     |
| 2     | 0.11 – 0.21  | Low          |
| 3     | 0.22 – 0.32  | Moderate     |
| 4     | 0.33 – 0.44  | Rather high  |
| 5     | 0.45 – 0.55  | High         |
| 6     | 0.56 – 0.64  | Very high    |

2.4. Data analysis
Data analysis were conducted descriptively and quantitatively in the form of a table and histogram presentation. To examine the relation between LAI and the magnitude of throughfall, a linear regression was used. Afterwards, for arranging the block development, there were descriptive and qualitative analysis based on the type of the urban forest [1,2,3], the use of the area up to the time of research, and the value of soil erodibility. Development of vegetation was based on descriptive and qualitative analysis by considering density, species and arrangement of plants.

3. Results and discussion

3.1. Classification and density of vegetation
Value of NDVI indicates the density level of a crown cover [13]. NDVI values with a range between 0.1 and 0.7 [14]. The positive value of NDVI indicates a dense vegetation cover, whereas negative values of NDVI indicates sparse vegetation cover or land cover in the form of the water body. Urban Forest Pondok Labu possessed NDVI values in the range between 0.12 - 0.35 which indicate varying density of vegetation as illustrated in table 2.

| NDVI value | Density level |
|------------|---------------|
| 0.12       | Low           |
| 0.20       | Moderate      |
| 0.35       | High          |

Vegetation densities could be grouped into nine classes, i.e.: low 1, low 2, low 3, moderate 1, moderate 2, moderate 3, high 1, high 2, and high 3. Density of low 1 and low 3 were in the form of open areas (bare land) and building. Map of vegetation densities of Urban Forest Pondok Labu is presented in figure 1.

Figure 1. Map of vegetation densities of Urban Forest Pondok Labu.

3.2. Leaf area index
Leaf area index (LAI) is a comparison between the total leaf area and crown projection area. LAI indicates the density level of trees or stand, and constitutes an accumulation of openness of crown, leaves and number of branches [15]. One of the dominant tree species composing Urban Forest Pondok Labu is jackfruit (*Artocarpus heterophyllus*), which has a round crown, sympodial stem and plagiotropic axis [16]. Results of LAI measurement in various levels of vegetation density is presented in table 3, while several illustrations of crown photograph of representative of each vegetation density in the Urban Forest of Pondok Labu is illustrated in figure 2a, 2b and 2c.
Table 3. Results of LAI calculation for each level of vegetation density.

| Level of Vegetation Density | LAI  |
|----------------------------|------|
| Low 2                     | 1.05 |
| Moderate 1                | 1.38 |
| Moderate 2                | 1.54 |
| Moderate 3                | 1.33 |
| High 1                    | 1.86 |
| High 2                    | 2.27 |
| High 3                    | 2.01 |

Figure 2. Crown photograph: (a) Low density, LAI = 1.05; (b) Moderate density, LAI = 1.38; (c) High density, LAI = 2.05.

3.3. Vegetation composition

Results of vegetation analysis indicates that in the Urban Forest of Pondok Labu there were seven dominant plant species at the various growth stages, i.e.: West Indian cherry, lead tree, caqui, jackfruit, big leaf-mahogany, Spanish cherry, and buni with densities and important value indexes as illustrated in table 4. The importance Value Index (IVI) shows the level of dominance of a species within the community. The higher the IVI of a species, the greater is the dominance level of the species within the community [17].

Table 4. Results of vegetation analysis for each density level.

| Level of vegetation density | Growth stage | Dominant species          | Density (individuals/ha) | Importance value index |
|-----------------------------|--------------|---------------------------|--------------------------|------------------------|
| Low                         | Seedling     | -                         | -                        | -                      |
|                             | Sapling      | -                         | -                        | -                      |
|                             | Pole         | *Muntingia calabura*      | 400                      | 69.44                  |
|                             | Tree         | *Leucaena leucocephala*   | 100                      | 66.91                  |
| Moderate                    | Seedling     | -                         | -                        | -                      |
|                             | Sapling      | *Manilkara kauki*         | 6000                     | 86.07                  |
|                             | Pole         | *Artocarpus heterophyllus*| 800                      | 41.05                  |
|                             | Tree         | *Artocarpus heterophyllus*| 300                      | 85.22                  |
| High                        | Seedling     | -                         | -                        | -                      |
|                             | Sapling      | *Swietenia macrophylla*   | 5000                     | 42.98                  |
|                             | Tiang        | *Mimusops elengi*         | 3800                     | 61.15                  |
|                             | Pohon        | *Antidesma bunius*        | 200                      | 32.29                  |

Based on table 4, the pole stage density at high vegetation density shows much higher value as compared with those of other vegetation density level. Besides that, all vegetation density levels did not have complete growth stages, particularly seedlings.
Urban Forest Pondok Labu possessed strata C and D. Strata C were composed of forest crown cover with a tree height between 4 – 20 m, exhibiting considerable variation of tree heights, possessing many branches, and a dense tree crown. Strata D were composed of trees with heights of 0 – 4 m [18]. Stratification of Urban Forest Pondok Labu is illustrated in table 5. The largest crown cover was obtained from the tree species of lead tree (*Leucaena leucocephala*), jackfruit (*A. heterophyllus*), and buni (*Antidesma bunius*).

Table 5. Strata of Urban Forest Pondok Labu.

| Growth stage | Low density | Moderate density | High density | Strata |
|--------------|-------------|------------------|--------------|--------|
| Sapling      | 1.5 – 4     | 1.5 – 4          | 1.5 – 4      | D      |
| Pole         | 4 – 9       | 6 – 8.6          | 5.5 – 8      | C      |
| Tree         | 10 – 12     | 7.5 – 16         | 6 – 13.5     | C      |

3.4. Throughfall

Throughfall is a portion of precipitation which reach soil surface after passing through the tree crown. The denser the crown of a stand, the lesser will be the throughfall [19]. Research results show that the highest throughfall was obtained at density of low 2 because the crown cover at this density level was the lowest as compared with other densities of the crown cover. Besides that, plant species which was dominant at a density of low 2 was the lead tree (*L. leucocephala*). The crown of the lead tree possessed a model of a tree architecture *Troll*, which possessed sympodial stems, axis with plagiotropic direction with a crown which is spread spontaneously [20]. These phenomena were related with the fact that rainfall which fell on the lead tree was easier to pass through. The lowest throughfall was obtained at a density of high 2 because the crown cover was denser as compared with other crown cover densities.

The amount of throughfall is affected by the density of the crown cover as shown by the phenomenon that the higher the value of LAI, the smaller the throughfall. This is shown by the regression between LAI and throughfall, namely \( y = -3.7127x + 15.62 \), with determination coefficient \( R^2 = 0.8874 \). This shows that LAI influence throughfall as far as 88.74% while there were 11.26% of other factors which affect the throughfall. Factors which affect throughfall are the density of the stem and the leaves of plants, plant species, and rainfall duration [21]. Wind constitutes another factor which affect throughfall because its existence could retard the rain water which pass through the plant crown. Graph showing relation between LAI and throughfall is presented in figure 3.

![Graph showing relation between LAI and throughfall.](image)

3.5. Soil erodibility

Soil erodibility is the level of ease that a soil can undergo erosion [7]. Factors which influence erodibility are texture, structure, organic matter and permeability. Results of erodibility determination in each vegetation density level are illustrated in table 6.
Table 6.  Erodibility (K) at each density level.

| Level of vegetation density | M^a | a^b | b^c | c^d | K^e | Category       |
|-----------------------------|-----|-----|-----|-----|-----|----------------|
| Low                         | 2009| 2.09| 2.00| 1.00| 0.09| Very low       |
| Moderate                    | 4224| 0.89| 2.00| 3.00| 0.41| Rather high    |
| High                        | 3185| 2.92| 2.00| 4.00| 0.28| Moderate       |

^a% silt + % fine sand); ^bPercentage of organic matter; ^cCode of soil structure; ^dsoil permeability class; ^esoil erodibility

3.6.  Directives for development of Urban Forest Pondok Labu

3.6.1.  Arrangement of blocks of urban forest. Urban Forest Pondok Labu is situated in the residential areas and the parking lots, so that the suitable type of urban forest is the residential type [2]. The main function of the urban forest type is to be a supporting system for the surrounding residential areas to create cool, fresh, scenic and convenient environment, which will also suppress air pollution and noise [1, 2, 22, 23, 24]. Besides that, considering the physical condition of the area, the existence of Urban Forest Pondok Labu has an important function to control erosion and sedimentation for the surrounding areas, or in other words, with the existence of urban forests, the community residing there are ensured to be safe and will not be exposed to impacts of erosion and landslide. Utilization of Urban Forest Pondok Labu at present has not considered the site carrying capacity, and recreation activities which are commonly conducted.

On the basis of the history of landslide, physical condition of the area and recreation used by the people, Urban Forest Pondok Labu is arranged into two blocks, i.e.: the intensive block and the non-intensive block. The intensive block occupies a large area with its main function for recreation and jogging. Non-intensive block is the rehabilitation block, which is situated in the post landslide area, and there is no utilization in this area, and the area is well protected with a high density of trees. Map of intensive and non-intensive block is illustrated in figure 4.

![Map of blocks](image)

**Figure 4.** Map of blocks for the development of Urban Forest Pondok Labu.
3.6.2. **Arrangement of vegetation.** Plant species which will be selected to be developed in the intensive block should be in compliance with the block function, as well as fulfilling the edaphic and climatic ecological requirement for the site. Tree species developed in these blocks have the following criteria: (1) crown shape and color of the leaves have a high aesthetic value; (2) the species should not shed too many leaves, not thorny, and not producing fruits hazardous to our health [2, 4, 25, 26].

Intensive blocks were composed of moderate and low density vegetation. In accordance to the function of urban forest for soil and water conservation, and based on the previous analysis which indicates that the denser the vegetation cover, the smaller the throughfall (reducing the chance of erosion) therefore, there is a necessity for enrichment planting in areas with low and moderate density. A low erodibility value did not ensure prevention from erosion, but still there should be efforts to increase the crown cover. A tree crown is able to intercept rainfall, therefore, the water is absorbed by the crown and will evaporate as water loss [27].

The activity of vegetation arrangement in the intensive block is to maintain the existing plant species and adding new plant species and a number plants to increase the block function. To create maximal benefits for several functions [3], the crown of the urban forest should have a minimum of two layers. Placement of the plants is in conformity with environmental condition and the function of the plant. The function of the edge of the plant is to be shade plants, wind break and noise reduction. The middle part contains plants producing fruits and flowers. The inner part contains plants producing fruits to attract birds. The placement of plants in the site is adjusted with the condition and shape of the site, environment, species and the function of the plant [28]. Species of the vegetation and their function are presented in table 7, organized as illustrated in figure 5.

Table 7. Plant species and their function in intensive block [29, 30].

| Local name   | Scientific name          | Function                                                      |
|--------------|--------------------------|---------------------------------------------------------------|
| Fern tree    | *Filicium decipiens*     | Shade plant, slope retainer for landslide prevention          |
| Big leaf-mahogany | *Swietenia macrophylla* | Shade plant, wind break                                       |
| Spanish cherry | *Mimusops elengi*       | Shade plant, smell repellent, absorption and adsorption of Pb |
| Ylang-ylang  | *Cananga odorata*        | Shade plant, flower producer, smell repellent                 |
| Pride of India | *Lagerstroemia speciose* | Shade plant, ornamental flower plant                           |
| Lead tree    | *Leucaena leucocephala*  | Plant for inviting birds, slope retainer for landslide prevention |
| Jackfruit tree | *Artocarpus heterophyllus* | Fruit plant                                                   |
| West Indian cherry | *Muntingia calabura*    | Fruit producing plants, bird attracting species               |
| Caqui        | *Manilkara kauki*        | Shade plant, fruit producing plants                            |
| Santol       | *Sandoricum koetjape*    | Fruit producing plants                                        |
Figure 5. Recommended profile of the urban forest.

A non-intensive block is situated in the post landslide area. This area is a rehabilitation area which is intended as a protection area due to its high vulnerability to erosion and landslide. Plant species being used in this block should have tap roots which are deep, strong and are suitable to be placed in cliff areas which are prone to landslide [31], and usually are dicotyls plants [32]. Apus bamboo (*Gigantochloa apus*) is also suitable for this kind of area because it has very dense fibrous roots and a strong rhizome which enable it to form strong bamboo clump, and grows rapidly and easy to adapt [33].

Existing vegetation in post landslide areas consists of cassava (*Manihot esculenta*), chili (*Capsicum annum*), star fruit seedlings (*Averrhoa carambola*), and guava seedlings (*Psidium guajava*). Because of sparse vegetation cover and domination of seedlings and seasonal crops, the function of the area was not enough for soil and water conservation.

To increase the soil and water conservation function in the post landslide area, there should be planting which combine medium ground cover plants (shrub) and tall ground cover plants (protection tree) [7]. The function of vegetation is displayed in table 8, organized as displayed in figure 6.

Table 8. Plant species in a non-intensive block [7, 33].

| Local name       | Scientific name      | Habitus   | Function                              |
|------------------|----------------------|-----------|---------------------------------------|
| Tembelekan       | *Lantana camara*     | Herb      | Terrace reinforcement                 |
| Bandotan         | *Ageratum conyzoides*| Herb      | Terrace reinforcement                 |
| Gempur batu      | *Borreria hispida*   | Undergrowth plant | Terrace reinforcement |
| Apus bamboo      | *Gigantochloa apus*  | Clump     | Protection of cliff or riverside cliff |
| Fern tree        | *Filicium decipiens* | Tree      | Hedgerow, cliff protection            |
| Lead tree        | *Leucaena leucocephala* | Tree      | Cliff protection                      |
4. Conclusion

The Urban Forest of Pondok Labu is developed and categorized into a residential type which has function to support the surrounding areas, and also to provide recreation benefits, soil and water conservation services. This urban forest is arranged into two blocks, namely intensive block and non-intensive block. Intensive block occupies a large area and is used for recreation and jogging. On the other hand, a non-intensive block is situated in the post landslide area, and this block is intended for rehabilitation. Vegetation arrangement in intensive block is conducted to maintain the existing plant species and add new plant species and plant individuals to increase its function. On the other hand, for the non-intensive block there is a combination of ground cover plants and protection plants.

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