Urban forest development at landside of Hang Nadim Batam Airport based on the microclimate and noise study

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Abstract. The landside of Hang Nadim Batam Airport can be adapted to urban forests to reduce emissions, stabilize the microclimate, and reduce noise. The purpose of this research are to study the microclimate and noise around the Hang Nadim Batam Airport, and develop landside based on the condition of the airport urban forest. Research was conducted on April, 8th-15th 2019 based on the density of vegetation. Location determining, characteristics of trees and leaf area index, air temperature and humidity, and noise were used as the methods of this research. The factors that analyzed by this research were NDVI, tree profile diagrams, LAI, air temperature and humidity, thermal humidity, and noise. The result showed that there were 55 trees of 11 species from 6 families. The profile diagram showed the densest vegetation was at point F, one of the points of measurements with dense vegetation category, seen by horizontally and vertically. The highest air temperature and thermal humidity was at point E and the lowest was at point F. The highest humidity was at point F and the lowest was at point E. The highest noise was at rare vegetation and the lowest was at dense vegetation. Landside development needs to look at ecology, technical, and aesthetic.

1. Introduction
Indonesian aviation industry is experiencing rapid growth, it causes high emissions from the aviation sector. Fleet numbers have increased in 2011 by almost every airline according to Mora [1]. The increase followed by high exhaust emissions means that air transportation is a significant contributor to air pollution. The increase in the number of passengers, baggage and aircraft from year to year continues to occur at Hang Nadim Batam Airport [2]. Batam with its rapid increase in the tourism and trade sector, requires having good transportation facilities to support the sector. These means the number of passengers are increasing and flight activity become higher, as well as the emissions.

Air temperature can be affected by land cover and land built up. Land that is built up high will cause an increasing of temperature due to reduce green open space [3]. Land cover that can act as an absorber of long wavelength radiation from the sun can reduce ambient temperature. More buildings than land cover will cause longwave radiation high, resulting in an increasing of temperature. Buildings can help stabilize the microclimate according to its comfort limits [4]. Paying attention to the conditions of the microclimate means making a difference to the changes in ambient air temperature, sufficient air...
humidity, and increase the oxygen levels so that the environment is maintained to be more comfortable for people. Airport conditions with the addition of a fleet cause noise. The noise caused affects the level of hearing quality of humans and other living things can be prevented by placing sound-absorbing material or planting certain types of trees to reduce the impact of noise on the surrounding environment [5].

Airport area consisting of air side and landside is an area that emits quite a lot so that it affects the conditions of the surrounding microclimate [6]. The construction of the airport pays attention to the management and monitoring of the environment includes air quality, energy, noise, water, soil pollution, waste, natural environment, to socio-economic/ cultural/ public health. According to the guidelines for implementing an environmentally friendly airport (eco-airport) regulated in Regulation of the Director General of Civil Aviation Number: SKEP/124/VI/2009 and PP No.40 of 2012 concerning Airport Development and Environmental Conservation which explains that each airport is required to adopt an environmentally friendly airport. The landside is one of the emission areas, needs to be considered for its management to maintain visitor comfort. The design of the landside of Hang Nadim Airport in Batam can be adapted to the urban forest around the airport with the intention of reducing emissions, stabilizing the microclimate, and reducing noise around the landside so as to increase the convenience of airport users. Based on this background, the objectives of this research were to develop urban forests on the landside of Hang Nadim Batam Airport based on microclimate and noise study, and to develop landside area based on airport urban forest.

2. Method

2.1 Study site and materials
The study was conducted at six points around Hang Nadim Batam Airport based on the vegetation density of NDVI values which were divided into three categories, such as sparse vegetation, medium vegetation, and dense vegetation. The tools used were dry and wet thermometers, sound level meters, GPS, camera, tripod, fish eye lens, compass, measuring tape, sewing meters, hypsometers, plant manuals, tallysheets, stationery, ArcGIS 10.5, Erdas Imagine 2014, Google Earth, Hemiview Canopy Analysis, SexI-FS, Corel Draw, and Microsoft Excel. The material were satellite image of Landsat-8 and various species of plants found at the site.

2.2 Procedures
Data collection in the field consisted of image preprocessing to find groups of tree from sparse vegetation to dense vegetation in the field as preliminary data, then checked for suitability in the field. It would be used as a reference for the study before field checked and then grouped into several NDVI classes. Image processing with NDVI (Normalized Vegetation Index) analysis and classification. Vegetation index with quantitative measurements based on digital values from remote sensing data used to determined the density of vegetation in the field [7]. Collecting the research point in the field was done by stratified random sampling method, where the determination of the research point was carried out randomly based on a distance that was considered safe that is about 300 to 600 m from the runaway and representation in each NDVI class in the image that had been done.

Tree characteristics were measured at two points in the airport's landside area and four points in the airport forest area. Tree characteristic data needed were the diameter of the tree, the total height of the tree, branch-free height, width of the canopy, and the position’s coordinates of the tree. The threshold method was determined by researchers manually. The threshold value could be increased or decreased until a match between the image of the classification results with the original image. Therefore a clear boundary was obtained, namely a part was covered by the canopy and other part was open [8]. Photos taken in the morning, evening, or cloudy conditions to avoid the reflection of light by the lens [9]. Data collected in each vegetation category was taken in 20x20 m plot.

Measurement of air temperature and humidity was carried out at 7.00 to 7.30 a.m, 7.30 until 8.00 a.m, 8.00 until 8.30 a.m, and 8.30 to 9.00 a.m, daytime temperatures around 12.00 to 12.30 a.m, 12.30
to 13.00 a.m, 13.00 to 13.30 a.m, and 13.30 to 14.00 a.m, and afternoon temperatures around 16.00 to 16.30 a.m, 16.30 to 17.00 a.m, 17.00 to 17.30 a.m, and 17.30 to 18.00 WIB. Noise measurements was in each plot at the same six points with the measurement of the characteristics of trees, LAI, and temperature and humidity of the air. Measurements were made for ten minutes with data readings every five seconds in the morning, at 7.00 a.m, afternoon at 13.00 p.m, and in the afternoon at 16.00 p.m.

2.3 Data analysis
Tree characteristic data was transformed into a diagram profile shows in vertical and horizontal direction. Retrieval of leaf area index or LAI data was carried out using hemispherical photography method at six research points using Hemiview 2.1 with threshold method.

The results of measurements of temperature and humidity were then used to be able to calculate the value of thermal comfort. Thermal comfort is a state of mind that expresses satisfaction with the thermal environment [10]. The next calculation results determined the criteria for the level of comfort felt by the community. The comfortable category is with a temperature of 21-24°C, the moderately comfortable is with a temperature of 25-27°C, and the uncomfortable category is more than 27°C [11]. Noise measurements was using Lutron SL4012 sound level meters in each plot at the same six points with the measurement of the characteristics of trees, LAI, and temperature and humidity of the air.

3. Results and discussion
According to PP No. 2 of 2004, the Southwest of the airport area is the Duriangkang Protection Forest Zone and also the North of the airport is housing area. Acacia mangium, Alstonia beatricis, Anacardium occidentale, Artocarpus altilis, Calophyllum inophyllum, Calophyllum rigidum, Ficus ampelas, Hura crepitans, Rhodamnia cinerea, Parkia speciosa, Spondias pinnata, and Symplocos fasciculata, and plants from the Arecaceae family are the species that found around the airport. There were 11 species with a total of 55 trees at the six points (Table 2). Point C has the highest number of trees, there are 1 tree and 19 poles in the dense vegetation cover category.

| Point | Cover category         | Density (ind/400m²) |
|-------|------------------------|---------------------|
|       |                        | Trees   | Poles   |
| A     | Medium vegetation      | 5       | 3       |
| B     | Medium vegetation      | 4       | 1       |
| C     | Dense vegetation       | 1       | 19      |
| D     | Sparse vegetation      | 1       | -       |
| E     | Sparse vegetation      | -       | 2       |
| F     | Dense vegetation       | 5       | 14      |
|       | Total                  | 16      | 39      |

The species most frequently found at the sites was Bintangur (Calophyllum spp.), with amount 15 individuals spread over medium and dense vegetation cover categories. Bintangur is a tree that grows and spread evenly, naturally, as well as easily cultivated in dry climates. According to Yuliastrin [12], Batam's unique plant is Bintangur. Anacardium occidentale or cashew, is the second most abundant plant in this research that can grow well in tropical climates and dry climate [13]. Acacia mangium is the third largest type found, with as many as 9 individuals. Acacia mangium can grow fast with good quality and able to tolerate various species of soil and environment [14]. Another species found was Rhodamnia cinerea, a pioneer species.

Profile diagram was taken from the measurement results of tree characteristics. Point A had 8 trees. The profile digram at point A was an area which not covered by the canopy seen horizontally (Figure 1). The width of the canopy in the Calophyllum rigidum reach out the plot. Point B had 5 trees and poles occur canopy stacking in horizontally profile diagram (Figure 2). Point C had 20 trees seen horizontally occurs canopy stacking in the middle (Figure 3). Point D only had a species, thusthis point became the
largest diameter point than others. *Parkia speciosa* had rounded canopy shape (Figure 4). Point E had 2 poles, namely *Spondias pinnata* that has conical crowns (Figure 5). Point F had 19 trees with the highest average height and the most diverse types plot. The species at point F are *Alstonia beatricis, Ficus ampelas, Rhodannia cinerea, Calophyllum inophyllum, Symplocos fasciculata, and Calophyllum rigidum*. Based on profile diagram, almost all forest floor covered by canopy trees (Figure 6).

The results showed that leaf area index (LAI) value at point A-F respectively were 1.247, 0.636 (not shady), 1.260, 0.014, 0.260, and 1.299. Point D was the lowest LAI value, while the highest was point F. The highest air temperature was found at point E (31 °C), while the lowest was at point F (29.5 °C). The highest average humidity was at point F (66%), and the lowest was at point E (59%). According to SNI 03-6572-2001, the relative humidity in the tropics area was around 40-50% [15]. The results of the temperature and humidity were processed into a thermal comfort value or Thermal Humidity Index.
(THI). The highest THI value was at point E, (28.4 °C) while the lowest was at point F (27.5 °C). Daily air temperature included in the heat category on a scale of 29-30 °C and very hot above 31 °C [16]. Asphalt roads, paving blocks, walls, and roofs of buildings are some examples of surfaces that have the potential to increase air temperature through reflection, transmission, and absorption of solar radiation [17]. Noise in each category of vegetation cover rarely was 56.06 dB (A), medium vegetation had a smaller value. It was 49.69 dB (A), while dense vegetation had the smallest noise value, it was 47.44 dB (A). Noise levels in medium and dense vegetation did not indicate more than the required quality standard, it was 50 dB (A).

The results of the average noise measurement in the morning reached 50.39 dB (A), during the day it reached 50.47 dB (A), and in the afternoon reached 52.33 dB (A). The highest noise in the afternoon was 52.33 dB (A). The results can be seen in Figure 7.

![Figure 7. Comparison of noise values.](image)

Based on the analysis of temperature, the analysis of humidity, and the analysis of noise, denser vegetation had higher LAI value than sparse vegetation. Vegetation with dense canopy can reduce the input of light energy to heat the air and the surface under the canopy so that it will be cooler. It can be seen from the higher LAI values that have the lower temperatures (Figure 10a). Relative humidity is influenced by air temperature but does not apply otherwise [18]. Vegetations with high LAI values have higher humidity (Figure 10b). Humidity has an inverse relation with thermal comfort. If LAI on vegetation is sparse then the value shown in thermal comfort will be high (Figure 11a). Noise will have a higher value in the low LAI area but have a lowest value in the high LAI area (Figure 11b). Accordance with Gray and Deneke [19], the effectiveness of noise barriers increases with increasing thickness, height, and density of plants.
Figure 10. Relation between LAI with temperature (a) and humidity (b).

Figure 11. Relation between LAI with thermal humidity (a) and noise (b).

The concept of landside main function planning looks at the characteristics of vegetation in the form of canopy, branching, leaves, flowers, fruit, stems, and roots, as well as layout that can be adapted to current conditions and future development plans. The species at the airport landside should matched first with the characteristics of the tree. The species characteristics and functions at the landside at the parking area and near the cargo (Points E and F) can be seen in Table 2.

Table 2. Species and characteristics of plants at Hang Nadim Batam Airport Landside.

| No | Species               | Familia          | C | B | L | F | Fr | S | R | Function                     |
|----|-----------------------|------------------|---|---|---|---|----|---|---|-------------------------------|
| 1  | Hura crepitans        | Euphorbiaceae    | 6 | 2 | 3,5 | 2,4,5 | 2,7 | 1,4 | 2,4 | 1,4 | Aesthetic, shade             |
| 2  | Parkia speciosa       | Fabaceae         | 8 | 1,4 | 5,7 | 2,4 | 2,3,5 | 1,4 | 1,3 | 1,4 | Aesthetic                    |
| 3  | Cocos nutfera         | Arecalesse       | 9 | 1,4 | 5,5 | 2,3,5 | 1,4 | 1,3 | 1,4 | Aesthetic and noise dampener |
| 4  | Aphananxisi polysytachya | Meliaceae      | 8 | 1,4,6 | 5,5 | 2,4 | 2,4,5 | 1,4 | 1,3 | 1,4 | Shade                        |
| 5  | Saribus rotundifolius | Arecalesse       | 9 | 1,4 | 5,5 | 2,3,5 | 1,4 | 1,3 | 1,4 | Aesthetic and noise dampener |
| 6  | Roystonea regia       | Arecalesse       | 9 | 1,4,5 | 5,5 | 2,3,5 | 1,4 | 1,3 | 1,4 | Aesthetic                    |
| 7  | Spondias pinnata      | Anacardiaceae    | 3 | 2,3,6 | 5,7 | 2,4,5 | 2,3,5 | 1,4 | 1,3 | 1,4 | Shade                        |

Information: C: Canopy, B: Branch, L: Leaf, F: Flower, Fr: Fruit, S: Stem, R: Root; C1: Round, C2: Brolly, C3: Dome, C4: Pagoda, C5: Bell, C6: Columnar, C7: Cube, C8: Irregular, C9: Palm; B1: Orthotropik, B2: plagiotropik, B3: Fragile, B4: Strong, B5: Tenuous, B6: Tight; L1: Big, L2: Small, L3: Deciduous, L4: Evergreen, L5: Aesthetic; F1: Smelly, F2: Notsmelly, F3: Bloomy, F4: No bloom, F5: Fall, F6: No fall, F7: Aesthetic; Fr1: Big, Fr2: Small, Fr3: Briery, Fr4: No briery, Fr5: Fall, Fr6: No Fall, Fr7: Poison, Fr8: No poison; S1: No briery, S2: Briery, S3: No sticky, S4: Sticky; R1: No buttress, R2: Buttress, R3: Develop sideways, R4: Develop Down

The species selection is based on species plants growth, contributions to climate amelioration, aesthetics and shading, and costs maintenance. The development of the airport seen based on the results of the LAI conditions, temperature and humidity, thermal, and noise. Point F had the highest plants (28 y = -0.7617x + 30.816  
R² = 0.9799

y = 4.5291x + 59.565  
R² = 0.9577

y = -0.4268x + 28.319  
R² = 0.8818

y = -7.6161x + 57.051  
R² = 0.9986
m), the densest vegetation, and the highest LAI value is considered appropriate to be developed around the landside. Then the recommended plants that can be planted on the landside can be seen in Table 3.

### Table 3. Landside recommended plant species.

| No | Species            | Familia      | Characteristic | Function                  |
|----|--------------------|--------------|----------------|---------------------------|
| 1. | *Mimusops elengi*  | Sapotaceae   | C1: Round      | Shade and pollutan reductor |
|    |                    |              | B2: Plagiotropik |                           |
|    |                    |              | L3: Evergreen   |                           |
|    |                    |              | F1: Smelly      |                           |
|    |                    |              | Fr1: Big       |                           |
| 2. | *Filicium decipiens* | Sapindaceae | C2: Round      | Dust absorber, pollutan reductor |
|    |                    |              | B1: Orthotropic |                           |
|    |                    |              | L4: Deciduous   |                           |
|    |                    |              | F2: Notsmelly   |                           |
|    |                    |              | Fr2: Small     |                           |
| 3. | *Delonix regia*    | Fabaceae     | C2: Round      | Shade, aesthetic, noise dumper |
|    |                    |              | B1: Orthotropic |                           |
|    |                    |              | L4: Deciduous   |                           |
|    |                    |              | F2: Notsmelly   |                           |
|    |                    |              | Fr2: Small     |                           |
| 4. | *Cananga odorata*  | Annonaceae   | C2: Round      | Aesthetic and noise dumper |
|    |                    |              | B1: Orthotropic |                           |
|    |                    |              | L4: Deciduous   |                           |
|    |                    |              | F2: Notsmelly   |                           |
|    |                    |              | Fr2: Small     |                           |
| 5. | *Erythrina variegata* | Fabaceae    | C2: Round      | Shade |
|    |                    |              | B1: Orthotropic |                           |
|    |                    |              | L4: Deciduous   |                           |
|    |                    |              | F2: Notsmelly   |                           |
|    |                    |              | Fr2: Small     |                           |
| 6. | *Calophyllum inophyllum* | Calophyllaceae | C2: Round      | Wind break |
|    |                    |              | B1: Orthotropic |                           |
|    |                    |              | L4: Deciduous   |                           |
|    |                    |              | F2: Notsmelly   |                           |
|    |                    |              | Fr2: Small     |                           |
| 7. | *Caesalpinia pulcherima* | Fabaceae    | C2: Round      | Aesthetic |
|    |                    |              | B1: Orthotropic |                           |
|    |                    |              | L4: Deciduous   |                           |
|    |                    |              | F2: Notsmelly   |                           |
|    |                    |              | Fr2: Small     |                           |
| 8. | *Syzygium oleana*  | Myrtaceae    | C2: Round      | Aesthetic |
|    |                    |              | B1: Orthotropic |                           |
|    |                    |              | L4: Deciduous   |                           |
|    |                    |              | F2: Notsmelly   |                           |
|    |                    |              | Fr2: Small     |                           |
| 9. | *Lagerstroemia speciosa* | Lythraceae | C2: Round      | Aesthetic shade |
|    |                    |              | B1: Orthotropic |                           |
|    |                    |              | L4: Deciduous   |                           |
|    |                    |              | F2: Notsmelly   |                           |
|    |                    |              | Fr2: Small     |                           |

Shade plants have morphological characteristics of leaves that are rounded, elongated, and single. Stiff leaf meat, fruit should not be too big and leaves should not fall too often. Wood should not easily broken, and can’t be too shady to allow the road to dry out quickly. Roots should not damage the road and not easily disturbed by pests and diseases. Species that can be used as road shade plants according to Sulistiyowati and Yuantika [20] include absorbing CO₂ and lead, producing O₂, broad canopy, branches that are not easily broken, strong roots into the ground so it is not easy to fall if blown by wind. The recommended species are *Acacia mangium*, *Lagerstroemia speciosa*, *Delonix regia*, *Cananga odorata*, *Filicium decipiens*, *Calophyllum inophyllum*, and *Mimusops elengi*. Bintangur is one of the unique biodiversity of Batam [12]. According to the Decree of the Minister of Home Affairs Number 48 of 1989, *Piper sp.* is a mascot species of the Riau Island. The species that can be applied to the landside development design plan (Figure 12).

![Figure 12. Landside development design plan.](image-url)
4. Conclusion
The average of air temperature and air humidity of each point indicated that Hang Nadim Batam Airport was in the heat category with a range of 29-30 °C, THI values at six points indicated the uncomfortable category. Tree profile diagram showed point D was the rarest vegetation and point F was the densest vegetation. The highest air temperature was at point E and the lowest air temperature was at point F. The highest air humidity was at point F and the lowest was at point E. Noise at dense vegetation was smaller than sparse vegetation. There were 9 species with a total of 55 individual stands. Airport landside development that needs to be considered based on the results of research is looking at ecological, technical and aesthetic conditions. Selection the species and addition species of trees around the landside of Hang Nadim Batam Airport in accordance with ecological, technical and aesthetic functions are necessary. Intensive treatment needs to be taken to maintain plants around the landside considering the type of soil in Batam which is quite dry.

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