The availability of open green space and tree architecture at public senior high schools

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Abstract. Schools in Banda Aceh city are often traversed by traffic passing vehicles that exhaust emissions such as Pb, CO, NOx, SOx and CO2. The presence of open green space (OGS) is beneficial in cleaning air pollution. Thus, it is necessary to identify the tree architecture model to ensure suitable types of plants in the school's green space area. This study used an exploratory survey method. To measure the OGS ratio, the GPS was used to collect the data to get the proportion of the school area with canopy and then the result was converted to a percentage. The architectural model was identified according to the guidelines from Halle and Oldeman. The results showed that 12 schools in Banda Aceh city meet ideal requirements for the proportion of OGS according to Law No. 26 of 2007, and only one school (SHS 13) does not satisfy the requirements. The highest OGS was identified at SHS 16 (79%); while the lowest is at SHS 13 (28%). The tree architectural models found in this study are Scarrone, Corner, Attims, Troll, Roux, Leeuwenberg, Koriba, Rauh, Aubreville and Stone. The dominating tree architecture model of those schools is the Troll model (35.7%) with 15 species.

1. Introduction
Public Senior High Schools (SHS) in Banda Aceh are often traversed by many traffic passing vehicles. The schools in the capital city of Aceh Province are located side by side with residential housing and other buildings such as government buildings, offices and other public and private facilities. Many vehicles around the schools produce vehicle exhaust gases such as Pb, CO, NOx, SOx and CO2 which can pollute the air quality around the area. The source of air pollution consists of five things: one of them is from a moving thing. The source of emissions that move or remain in a place comes from a motorised vehicle [1].

Furthermore, the Ministry of Environment explained that air pollution from gasoline vehicles contributed 70% of carbon monoxide (CO), 100% of lead (Pb), 60% of hydrocarbons (HC) and 60% of nitrogen oxides [2]. On the other hand, the schools as places to gain knowledge should be in an eco-friendly atmosphere to support learning activities. The learning environment is part of students’ life [3].

Additionally, air pollution produced by vehicles can cause health problems and affect the power to work [4]. In this case, air pollution can disrupt the concentration of student learning. Extended exposure to air pollution can also interfere with cognitive activity verbally and mathematically [5]. Thus, schools in a city need open green space (OGS) to balance air pollution. According to the Minister of Public Works’ Regulation on guidelines for the provision and utilisation of open green space and tree architecture in 2017 [6].
space in urban areas No 1 2008, open green space is an elongated area or pathway or group that uses more open spaces, where plants grow both naturally and intentionally planted. Open green space aims to maintain the harmony and balance of the ecosystem of urban environments, to create a balance between the natural environment and the artificial environment in urban areas, and to improve the quality of clean, healthy, beautiful and comfortable environments [6]. Interacting with nature can improve cognitive function, especially in improving the working memory and mood [7]. Open green space arrangement is regulated by Law No. 26 of 2007, which regulates that the proportion of OGS is by 30% of the total urban area. So far, the existence of OGS in urban forests has been measured and known, but the measurement of the OGS ratio in city schools has not yet been conducted.

Tree architecture is a description of morphology at a time which is a phase at a particular time in a series of tree growth sequences, real and can be observed at any time. The form of growth that determines the range of phases of tree architecture is called architectural model [8]. The measurement of OGS was only carried out in urban forests and has not yet identified the suitability of plant species based on tree architectural models. This study aims to measure the proportion of open green space in schools per Law No. 26 of 2007 as well as to identify the tree architecture model in the schoolyard.

2. Method
The research was conducted from March to April 2019. The study applied an exploratory survey method. In this study, several observations were carried out, which calculated the percentage of open green space in schools and finding out the architectural models in school OGS. To identify the availability of open green space in schools, the subtraction of the school area with canopy area was calculated and then converted it to a percentage. In this research, data measurement for school area was obtained by using GPS. The open green space area based on Law number 26 of 2007 concerning the arrangement of OGS is that the ideal urban area is 30% of the total area/region. Data of OGS was presented in graphs and percentage of OGS at each field station. Tree architecture will be analyzed through direct observation. The branching pattern then forms a tree architecture. Then the tree architecture models were identified using Tree Architecture book by Halle & Oldeman.

3. Results and Discussion
3.1. Percentage of Open Green Space
The results of the calculation of the percentage of OGS in 13 high schools in Banda Aceh are presented in Figure 1. Figure 1 shows that 12 senior high schools in Banda Aceh city meet the proportion of Law No. 26 of 2007 and only one school (SHS13) does not satisfy the requirements of the law. Figure 1 shows that SHS 16 has the largest proportion of open green space (79%), while SHS 13 has the smallest (28%).

![Percentage of Open Green Space in Schools](image-url)
In general, open green space is an elongated area/path and group used both as a place to grow plants that are planted naturally and intentionally planted. The function of open green space, especially public green space viewed from an ecological aspect is as a provider of oxygen, carbon filtering and as water absorption. The function of open green space is divided into two types: as social function which are place for social communication, research and education; while as ecological functions, as air refreshment, affecting and improving the microclimate, absorbing rain, controlling flood and regulating water systems, as well as the stability of the ecosystem [9]. The more vehicles in the city, the more fuel burning occurs. Action is needed to reduce pollution levels below the pollution threshold [10]. The Institute for Ecology and Wetlands Conservation Study and the National Research and Development Center have researched the ability of plants to reduce air pollution in urban areas. The results show that open green space can reduce air pollution by 5% to 69%. The reduction process occurs due to the mechanism of photosynthesis through the presence of leaves and sunlight [10].

Furthermore, the function of OGS as stipulated in the Minister of Home Affairs instruction No. 14 of 1988 explains that open green space whose population is dominated by greening either naturally or plant cultivation, function as an area of ecological and buffer functions. Figure 1 indicates that the difference in the percentage of open green space in 13 Banda Aceh High Schools. It is due to several things that affect the availability of green space which are an area of tree cover, the absorption of trees against CO₂, plant type factors, and land availability. A similar opinion is also explained by [11] that several factors that influence the availability of open green space are the portion of tree cover area, tree absorption, and plant species [11].

[12] stated that trees and green scenery in schools lead to high scores on academic performance. Furthermore, [13] added that greening has the potential to increase academic achievement in schools located in the suburbs. Greening in schools is also predicted to affect improving academic performance. Schools are a place where learning supposed to be in the green area, so this can provide peace and comfort in the learning process. Therefore, schools in urban areas must have green open space following the proportions that have been determined in Law No. 26/2007 article 29 concerning Urban Green Open Space Arrangement.

3.2. Tree Architecture

Eleven tree architecture models were found in the study (Table 3.1) that are Scarrone (4.8%), Corner (23.8%), Attims (4.8%), Troll (35%), Roux (11.9%), Leeuwenberg (2.3%), Koriba (4.8%), Rauh (4.8%), Aubreville (2.3%) and Stone (2.3%) (Table 3.1). The most dominant tree architecture model is the Troll model (35.7%) with sixteen total species followed by the Corner model (23.8%) with ten species, and Roux (11.9%) with five species. Other architecture models such as Leeuwenberg, Aubreville, and Stone are the least dominant architecture model with 2.3% consisting of only one species. The Troll model is the most dominant architecture model in schools. The reason is most of the plants from the troll model have a wide canopy and dense leaves that function as shade plants. *Pterocarpus indicus* L. One of Troll model has a lush canopy, so it is appropriate to shade the road while absorbing pollutant gases such as CO₂. Some of the benefits in recognizing the variety of tree architecture models are one of them as an indicator of gene function [14]. In the normal environment, the shape of a tree can be considered as an indicator of gene function and then morphological changes can be expressed as indicators of variations in that functions [15]. Branching patterns and branch differentiation are the main criteria in the analysis of tree reactions and their environment. One side of the reaction is toward the shape of the canopy and the spread of the leaves in absorbing light, and other growth factors are then passed on to the plants below. On the other hand, the growth of the shapes and patterns distribution of branches is one of the tools through which trees can regulate environmental influences. Simulation of plant growth and its relationship to light shows the importance of branching patterns. In the development of urban forests, information on tree architecture models is useful as a basis for consideration of selecting suitable tree species for good urban forest development as well as for applying the architectural model concept to the development of urban forests to add aesthetic value [16].
The tree architecture model should be a reference for the selection of plant species in open green areas. It is due to the function of open green space whose population is dominated by reforestation either naturally or plants cultivation in its use and function as an area of ecological and buffer function [17]. The existence of open green space also affects students in the learning process. Trees in schools and green scenery show high scores on academic performance [18]. Furthermore, reforestation has the potential to increase school academic achievement in the suburbs [19]. The tree architecture model can also be used as a source of education for the community at schools as a biology subject in recognizing the characteristics and grouping the plants. The use of tree architecture models can be applied in plant practicums which can be observed directly as open laboratories [20].

The tree architecture model can be applied in soil and water conservation related to the function of trees in transforming rainwater into stem flow, and canopy flows, surface flow and erosion. Tree architecture with a particular model will transform rainwater with varying proportions so that its role in several hydrological parameters in controlling floods and erosion can be recognized [12]. The tree architecture model can provide information as a basis for applied development and urban forests, city parks, soil and water conservation. Based on the results of the study, the presence of trees in the open green space of the school functions in ecological aspects as an air filter absorbs carbon dioxide and produces oxygen from photosynthesis process. It explains that the tree architecture model can determine the structure and function of the presence of plants in an area.

Table 1. Tree Architecture Models

| No | Local Name | Binomial Name | Familia | Architecture | % |
|----|------------|---------------|---------|--------------|---|
| 1  | Pucuk Merah | Syzygium oleina L. | Myrtaceae | Scarrone | 4.8% |
| 2  | Mangga     | Mangifera indica L. | Anacardiaceae | Scarrone | 4.8% |
| 3  | Kelapa     | Cocos nucifera L. | Arecaceae | Corner | 11.9% |
| 4  | Palam pati | Vernicia rhynoides Becc. | Arecaceae | Corner | 35% |
| 5  | Palam lipas | Livistona siali (Lour.) Merr. ex A.Chev. | Arecaceae | Corner | 4.8% |
| 6  | Palam ekor ikan | Wodyera bifurcata A.K.Irvine | Anacardiaceae | Corner | 4.8% |
| 7  | Palam merah | Ceylonisium retusa Blume | Arecaceae | Corner | 4.8% |
| 8  | Palam salab | Sabal palmetto (Walt.) Lodd. | Arecaceae | Corner | 23.8% |
| 9  | Palam kuning | (J.Wendl.) Reute & J.Drans. | Arecaceae | Corner | 4.8% |
| 10 | Pinang merah | Chrynosia lucia Becc. | Arecaceae | Corner | 4.8% |
| 11 | Palam botol | Hypoicorbo lagacioides | Arecaceae | Corner | 4.8% |
| 12 | Palam raja | Hoystena reta Coox. | Arecaceae | Corner | 4.8% |
| 13 | Cemara laut | Canarium quaternafolia L. | Casuarinaceae | Attins | 4.8% |
| 14 | Das Kari | Moraya keoriati L. | Rutaceae | Attins | 4.8% |
| 15 | Belimbing bintang | Averrhoa carambola L. | Oxalidiaceae | Troll | 4.8% |
| 16 | Sawo | Manikara zupera L. | Sapotaceae | Troll | 4.8% |
| 17 | Belimbing | Averrhoa balimbi L. | oxalidiaceae | Troll | 4.8% |
| 18 | Jambu | Syzygium aqueum (Burm.) Alston | Myrtaceae | Troll | 4.8% |
| 19 | anggasa | Pterocarpus indicus Wild | Fabaceae | Troll | 4.8% |
| 20 | Trenbosi | Samanea samane Merr | Fabaceae | Troll | 4.8% |
| 21 | Jambu Bol | Syzygium malaccense (L.) Merr & L.M.Perry | Myrtaceae | Troll | 4.8% |
| 22 | Nangka | Artocarpus heterophylus Lamk | Moraceae | Troll | 35% |
| 23 | Sawo Daren | Chrysophyllum caffato L. | Sapotaceae | Troll | 35% |
| 24 | Asam jawa | Tamarindus indica L. | Fabaceae | Troll | 35% |
| 25 | Tanjung | Mitouga elion L. | Sapotaceae | Troll | 35% |
| 26 | Sesak | Annona muricata L. | Annonaceae | Troll | 35% |
| 27 | Karet kebo | Ficus elastica Rooth | Moraceae | Troll | 35% |
| 28 | Ki Acret | Spottedroc Moreus P.Bean. | Bignoniaceae | Troll | 35% |
| 29 | Cermui | Phyllanthus acidus (L.) Skeels | Euphorbiaceae | Troll | 35% |
| 30 | kedondong | Spondias cytherea L. | Anacardiaceae | Roux | 35% |
| 31 | Mengkuah | Muntingia calabura L. | Rubiaceae | Roux | 35% |
| 32 | Renang | Cananga odorata (Lamk) Hook. | Annonaceae | Roux | 35% |
| 33 | Cemara Norkok | Anacariia heterophylle. Salib. | Anacardiaceae | Roux | 35% |
| 34 | Golooban ting | Polyalthia longifolia Som. | Annonaceae | Roux | 35% |
| 35 | Jambang | Syzygium cumini L. | Myrtaceae | Korbu | 4.8% |
| 36 | Kiara Puyong | Ficus decipsis (Wght & Am.) | Sapindaceae | Korbu | 4.8% |
| 37 | Mahon | Swietenia mahogany Jack | Meliaceae | Rauh | 4.8% |
| 38 | Bering | Ficus benjamina L. | Moraceae | Rauh | 4.8% |
| 39 | Ketapang | Terminalia catappa L. | Combretaceae | Aubenka | 2.3% |
| 40 | Jambu klimuk | Pidium guajava L. | Myrtaceae | Stone | 2.3% |
| 41 | Kamboja | Plumeria acuminata L. | Euphorbiaceae | Leesentberg | 2.3% |
4. Conclusions
This study found that twelve schools in Banda Aceh City have met the ideal requirements for the proportion of OGS according to Law No. 26 of 2007 and only one school (SHS 13) has not met the requirements. SHS 16 has the highest OGS (79%) while SHS 13 has the lowest one (28%). The tree architectural models found in this study are Scarrone, Corner, Attims, Troll, Roux, Leeuwenberg, Koriba, Rauh, Aubreville and Stone. The tree architecture model that dominated the schools was the Troll model (35.7%) with 15 species.

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