System Dynamic Modelling of Urban Forest as Absorber of Carbon Dioxide in the City of Banda Aceh

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Abstract

Limitations of urban land and high rate of population growth in Banda Aceh led to the growth of physical development which is done by converting agricultural land and other open spaces to become built up area. This condition leads to reduction of green open space which will impacted in reducing the role of the ecological functions of the plants in the city. One of the ecological function is CO2 absorption by plants, particularly by number of trees in the urban forest which have high capability in the absorption of CO2. If decreasing trend of green open space and urban forest keep goes on, while number of energy consumption in the activity of population and numbers of vehicles keep goes up, then it's predicted there will be an increase volume of CO2 in the city. This condition will impact in declining health quality in the city of Banda Aceh.

This study aims to determine the extent of the urban forest required to absorb CO2 due to population activities and vehicle numbers in Banda Aceh using system dynamic modelling. The model was built using Powersim 2.5 software, which consisting of interrelated sub systems of population, number of vehicles and the number of plants.

Simulation results from year 2010 to 2020, showed increasing number of population and vehicles, and the needs for the number of plants and urban forest area. Simulation results is made in three scenarios, namely progressive, conservative and sustainable, which may be used as consideration in the arrangement of green open space policy in the city of Banda Aceh.

Keywords: carbon dioxide absorption, urban forest, green space, system dynamic.

1. INTRODUCTION

After the rehabilitation and reconstruction process of tsunami disaster in 2004, the development of Banda Aceh showed progress in multi sector development where variety of activities grew in the city. As capital city of Aceh province, Banda Aceh serves as center of government activities and center of socio-economic and community services. The city has area of approximately 6,135.9 hectares with growing population of 223,446 people (BPS, 2011). As the population and economic activity growth. varies physical development proceeded rapidly in the city.

One of the most noticeable activities impact due to the rapid physical development of infrastructure in the city of Banda Aceh is decreasing area of urban green open space and increasing gas emissions such as CO2 due to increasing transportation activities and other energy consumption. Increasing levels of CO2 pollution is not healthy to the city environment and can reduce human health, therefore the concentration of CO2 in the air should be maintained low.

One way to decrease CO2 levels in urban areas is to reduce carbon emissions and the other way is to build urban forest (Dachlan, 2011). Urban forest is the most effective carbon sinks to reduce the increasing carbon emissions in the atmosphere. Photosynthesis process by plants in the urban forest is important process in the carbon cycle and maintaining CO2 in atmospheric at the same time. This process also plays role in oxygen cycle. To help address natural forest degradation, it is necessary to build urban forest, because of the presence of urban forest is important in neutralizing the effects of air pollution as well as maintaining the quality of the air to keep them clean (Irwan, 2005).

The presence of trees in green open space in the city is part of the urban landscape ecology which is important to keep balance of ecosystem in the city (Irwan, 2005). Furthermore Cadenassso and Pickett (2008), stated the principle in the concept of urban landscape ecology are (a) the city as an ecosystem; (b) the city as spatial heterogeneous ; (c) city are dynamic; (d) natural and artificial processes influence each other, and (e) The process continues and ecologically important to city life. The first three principles (a, b and c) shape and influence the structure of the city while the last two principles (d and e) shows the process of ecological city.

According to Purnomohadi et al (2006), urban green open space can be interpreted as open space or area in the city which is overgrown greenery, either in the form of large trees, bushes, shrubs, and grasses. Meanwhile, according to Nazarrudin (1996), green open space is a space that is dominated by the natural environment outside as well as inside the city, in the form of garden, courtyard, city recreation area, urban forest and green belt. While according to the DPU (2008), urban green open space is green space in the city or the wider region in the form of area or region as well as in the form of elongated area or path which in its use more open and basically without buildings.

Researches on urban forest as part of the green open space and its ecological function of CO2 absorption have been done by many researchers. Tinambunan (2006) has conducted research to determine the needs of urban green space based on area, population, and the amount of CO2. And so Li (2005), has developed a conceptual framework to examine the green open spaces of Beijing in China based on ecological principles. While Mahmoud (2011) has conducted research to develop a method of maintaining the ecological balance and organization of urban green open spaces which apply in the city of El Sadat in Egypt with the desert environment. Results of the research suggest a method of network planning of green space that will help improve connection and reduce distance between parts of the city with green space system integrating which support city life ecologically.

Researches on system dynamic of urban green open space have been done by many researchers. Faizah (2011) has conducted research to carry out on two districts in the city of Medan, which aimed to describe the system dynamic model of green open space in the district of Medan Polonia and Medan Area. And so Suwarli (2011) has conducted research to analyze the dynamic of land use change in Bekasi, and provided model of urban green space based on city budgeting. While Dinariana (2011) has conducted research to build a system dynamic model of green open space management as regional infiltration area in order to increase the availability of water in the city of Jakarta.

This study aims to determine the extent of the urban forest required to absorb CO2 due to population activities and vehicle numbers in Banda Aceh using system dynamic modelling. The

benefits and practical contribution of this research is that it can be used as consideration for decision makers or policy makers in planning for the sustainable city of Banda Aceh, especially with regard to the presence of green open space and urban forest.

2. METHOD

Supporting material used in this quantitative research as secondary data collected from several government offices such Master plan of Banda Aceh in 2009-2029 by Bappeda, Banda Aceh in figure 2011 by BPS, and document of green open space management from the Department of Hygiene and Beauty of the city of Banda Aceh. It also made direct observations of the use of spaces in the city which include recording images as the primary data. Other secondary data also had been collected from a variety of other related literatures.

This research analyze and compile urban forest model in Banda Aceh based on aspect of its ecological function of CO2 absorption with system dynamic approach using Powersim 2.51 software. Model compilation of system dynamic of urban forest divided into population sub model and urban forest CO2 absorption sub model. Based on model of system dynamic, it will show the prediction of each variable behavior in simulation period of 2010-2020.

Powersim software will help to see the behavior of the model created. The stages in making a model of system dynamic are (a) identification of problem behavior, (b) create a computer model, (c) testing and analysis the models. At the time of running the simulation model, the variables will be interconnected to form a system that can mimic the actual conditions. These variables will be illustrated with some of the symbol, which is the main symbol of the flow symbol and always associated with the level symbol. In this study the condition level is urban forest as part of green open space in city of Banda Aceh. Powersim software will work to build a causal loop diagrams, flow chart, make a graph of time which describes the behavior of the model in the time table.

The systems dynamics model of green open space for the city of Banda Aceh is arranged for several purposes, namely:

a. Understanding the processes that occur in the system. Models must be able to describe the mechanisms of the processes that occur in the system in relation to achieved the research objectives.
b. Prediction; only quantitative models that can make predictions. In this connection, accuracy of the model becomes important.
c. Support decision making. The model is based on the understanding of the process and has the ability to be used as a predictive tool for planners to assist in the decision making process.

The model is a simplification of the system. According to Amirin (2011), since the system is so complex, it is not possible to make a model that can describe the whole process that occurs in the system. Systems dynamics model is developed and used to facilitate the assessment of the system because it is difficult and almost impossible to work on the real dynamic situation. Therefore, the model only takes into account several factors in the system in order to achieve predetermined goals, so the numbers of components in the system need to be considered in the model and should be limited.

According Avianto (2006), modeling using the method of system dynamic, will use three types of variables, consist of the level, rate and auxiliary.

a. Variable Level, represents the level of accumulation or integration of flow over time. In real system there are basically two types of levels depends on the kind of subsystem involved, physically and information subsystem.

b. Variable Rate, is essentially in the system, as decision variable that is set by one or more policy structures. Flow rate will determine the entry or exit either from or towards a level. The decision taken was to determine the influence of rate within a time to level and information in the system.
c. Auxiliary variables, although it is only theoretically complementary variable, but may represent a better and clear policy structure. If the auxiliary variables omitted the details of the structure can not be reflected in the model.

These three types of variables and flow that occurs between variables can be seen in figure 1.

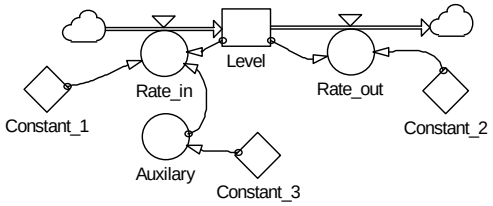

Figure. 1. Type of Variables in System dynamic Model

3. RESULT

3.1 Population and Land Use Changes in Banda Aceh

Development of Banda Aceh after being reconstructed and rehabilitated shows changes in land use as shown in table 1, which indicated increasing numbers of population and built up space while open space or unbuilt spaces tend to be decrease.

Table 1. Population And Land Use Changes In Banda Aceh

Element	Year 2005		Year 2009		Changes (%)
Population (people)	177,881		212,241		19.32%
Built up Space (ha)	2,124.95	34.63%	3,789.19	61.75%	27.12%
Open Space (ha)	4,010.95	65.37%	2,346.71	38.25%	-27.12%

Sources: BPS (2011) and Bappeda (2009)

Existing land use data shows a decrease in open space in the city of Banda Aceh at 27.12% during the 2005-2009 periods from 4,010.95 hectares (65.37%) in 2005, became 2,346.71 hectares (38.25%) in 2009. Although the existence open space shows there still area of 2,346.71 hectares or 38.25% of city area, but the trend in the changes will affect the adequacy of urban green open space in the future if not immediately anticipated. The adequacy of urban green open space should be maintained properly so its ecological function could support the quality of life in the city.

Approximate calculation of carbon dioxide absorption was conducted to determine the distribution and number of vegetation in each district in the city of Banda Aceh. Results of carbon dioxide absorption by vegetation will be compared with the amount of carbon dioxide emissions. Broad valuesthat have been classified in vegetation classes are presented in Table 2. The ability to absorb by vegetation class is known as ability of the existing condition of vegetation to absorb carbon dioxide .

Table 2. CO2 Absorption by Vegetation

Green Open Space Vegetation	**CO2 Absorption (ton/ha)**
Plantation	52.3952
Grass	3.2976
Forest	58.2576
Bushes	3.2976

Source: Tinambunan (2006)

The ability of vegetation to absorb carbon dioxide by Iverson in Tinambunan (2006) are: (a) for plantation vegetation is 52.3952 tons of CO2/ha/year; (b) grass is 3.2976 tons of CO2/ha/year; (c) forest is 58.2576 tons of CO2/ha/year; and (d) bushes are 3.2976 tons of CO2/ha/year. To estimate the carbon dioxide absorption using secondary data that will be obtained vegetation absorption value for each of the districts in the city of Banda Aceh. Calculation of carbon dioxide absorption by vegetation type are presented in Table 3.

Table 3. CO2 Absorption By Vegetation In Banda Aceh

No	**District**	**Plantation**	**Grass**	**Forest**	**Bushes**	**Total**
1	Meuraxa	1,019.61	23.08	116.52	206.10	1,365.31
2	Jaya Baru	597.31	-	-	209.40	806.70
3	Banda Raya	1,309.88	-	-	649.63	1,959.51
4	Baiturrahman	-	-	-	87.39	87.39
5	Lueng Bata	1,257.48	3.30	-	77.49	1,338.28
6	Kuta Alam	-	-	-	13.19	13.19
7	Kuta Raja	2,910.03	-	-	-	2,910.03
8	Syiah Kuala	7,602.54	-	233.03	98.93	7,934.50
9	Ulee Kareng	9,630.24	3.30	-	346.25	9,979.78
	Total	**24,327.09**	**29.68**	**349.55**	**1,688.37**	**26,394.69**

Sources: BPS (2011) and Results Analysis

Based on calculations in Table 3, the estimated carbon dioxide absorption by the vegetation found on the Ulee Kareng district is about 9,979.78 tons of carbon dioxide. Greatest absorption due to the amount of vegetated area in this district is quite extensive. While the smallest absorption found in Kuta Alam district in the amount of 13.19 tons of carbon dioxide .

Estimated total amount of carbon dioxide that can be absorbed by vegetation type based on the existing condition of vegetation in the city of Banda Aceh is approximately 26,394.69 tons. Two districts which are located in the city center: Kuta Alam and Baiturrahman have less absorption, where very small area of vegetation growth.

Value of total carbon dioxide emissions are calculated based on the energy used in the city of Banda Aceh. Energy is calculated by tabulating the data derived from the use of electricity, kerosene, gasoline and diesel. Total value is obtained based on the value of carbon dioxide calculated in accordance with Table 4 and 5.

In Table 4 it can be seen that the amount of carbon dioxide emissions in the city of Banda Aceh derived from the consumption of electricity, kerosene, gasoline and diesel was approximately 109,015.42 tons. Carbon dioxide emissions that most of it comes from the source of electricity production in the amount of 108,328.79 tons.

Table 4. CO2 Emissions in The City of Banda Aceh

Source	Capacity (Kwh) / Consumption (ltr)	Emission Factor (gr/Kwh - gr/ltr)	CO2 (gr)	CO2 (ton)
Electricity	238,609,598	454.00	108,328,757,492	108,328.76
Kerosene	38,171,000	2.52	96,190,920	96.19
Gasoline	111,110,000	2.30	255,553,000	255.55
Diesel	124,045,000	2.70	334,921,500	334.92
Total				109,015.42

Sources: BPS (2011) and Results Analysis

Difference in carbon dioxide emissions generated and the ability of vegetation absorption obtained from the classification of the type of vegetation to absorb carbon dioxide emissions are presented in Table 5.

Table 5. Difference in CO2 Emissions to CO2 Absorption by Vegetation

Region	Emission CO2 (ton)	CO2 Absorption by Vegetation (ton)	Difference (ton)
City of Banda Aceh	109,015.42	26,394.69	-82,620.74

Source: Results of Analysis

Calculating the difference in absorption of carbon dioxide by vegetation on carbon dioxide emissions in the city of Banda Aceh, obtained the results of the high existing lack of green space ability in the absorption of carbon dioxide which is about 82,620.74 tons due to the lack of vegetation in the city.

3.2 Conceptualization of System Dynamic Model

According Avianto (2006), the conceptualization of the system in system dynamic model aims to provide an overview of the systems studied in the form of a diagram. Diagram is used in the form of a causal loop diagram. This diagram illustrates the relationship between the components in the system which are interrelated.

Basically the city is formed by several components or elements. Components of urban divided into two main components, namely the physical and non-physical components. Urban constituent components are basically linked interconnections, therefore in the process of structuring and management of urban space should need to pay attention to all components and assume that each of these components are interrelated and are in one unified system.

Urban green open space is one of the components of the city whose existence is strongly influenced by the constituent components of the city, therefore, to optimize the arrangement of urban green open spaces also need to pay attention to all components of the existing urban areas.

Presented in Figure 2 below circumference causal diagram (causal loop diagram) of green open space system of Banda Aceh .

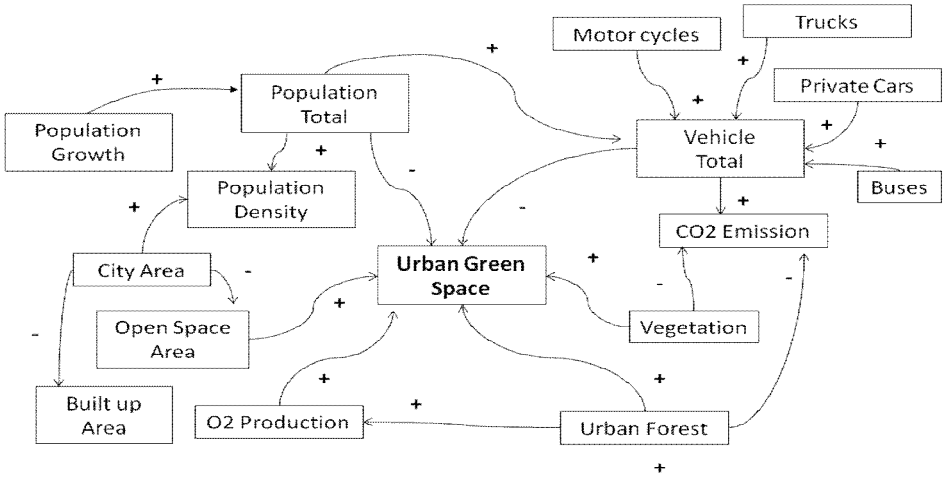

Figure. 2. Causal Loop Diagram of Urban Green Open Space
(source: analysis)

From the diagram it shows growing population will lead to the increasing demand for land. Increasing levels of land requirement will result in increasing accretion of land which will be use as for housing development and others that in the end will have impact on the reduction of urban green open space. Another activity which affects the green open space and its ecological function are domestic and transportation activities on using energy of fossil fuel which require oxygen and produce carbon dioxide. The availability of urban green open space and its ecological function has to be prepared properly to balance the ecosystem and keep the city in health.

3.3 Model Formulation

Model is built and divided into two sub models which are (a) the population sub model and (b) urban forest CO2 absorption sub model. In the sub model, it shows the relationship and interconnections between the components that exist. Flow diagram and explanation of the relationship between components in each sub model will be presented in the following pictures.

3.3.1 Population Sub model

In this model, the population is considered as a level (accumulation) which can increase and decrease due to certain processes. Technically flow causes an increase or decrease in the level called flow or rate. In this model the process that led to the growth of population due to births and in-migration (immigration) factors, while the rate which reduces the number of population in the city caused by the deaths and out-migration (emigration) factors.

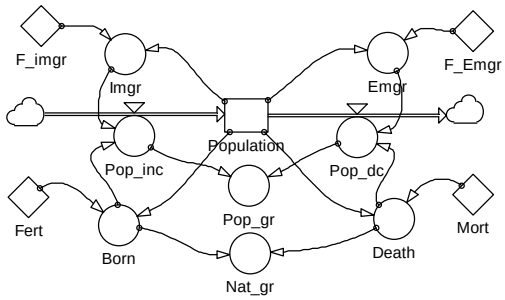

Figure. 3. Flow Diagram of Population Sub model
(source: analysis)

3.3.2 Urban Forest CO2 Absorption Sub model

In this model, urban forest is considered as variable rate to variable decision systems which are regulated by one or more policy structures. In this model the process that led to the needs for urban forest and its vegetation as an absorber of carbon dioxide (CO2) is to offset the amount of carbon dioxide emissions from domestic activities in the use of electricity, gasoline, diesel and kerosene.

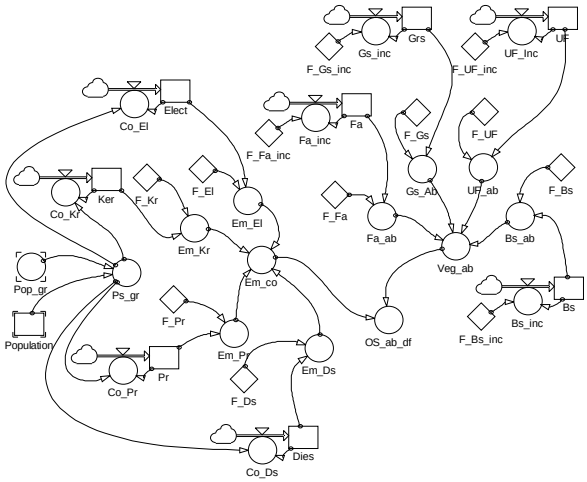

Figure. 4. Flow Diagram of UF-CO2 Absorption sub model
(source: analysis)

3.4 Analysis of Model Behavior

Analysis of the model behavior is an attempt to understand the behavior of the system as a result of the assumptions in the model. Understanding models by computer simulation will inform the behavior of all variables in the model with respect to time.

3.4.1 Population Sub model Behavior

Based on the results of simulations carried out on the population sub model, increasing numbers of population in the city of Banda Aceh, from 223,446 peoples in the beginning of the simulation year (2010), increase to 254,254 peoples by the end of the simulation year (2020). The following graph is presented in Figure 5, shows changes in the population of the city of Banda Aceh during the period of the simulation.

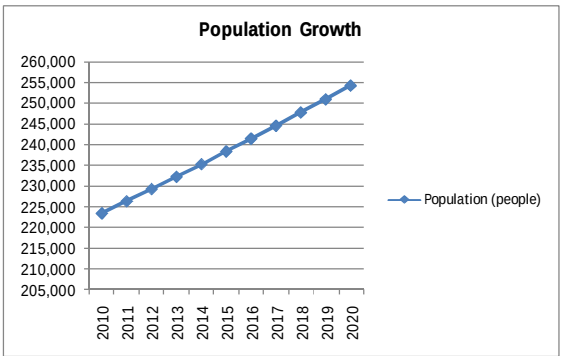

Figure. 5. Population Growth
(source: analysis)

3.4.2 Urban Forest CO2 Absorption Sub model

The needs for urban forest as part of urban green open space to absorb carbon dioxide (CO2) emissions from domestic activities in the use of electricity, gasoline, diesel and kerosene. Based on the results of simulations performed, it shows increasing needs of urban green open space. Carbon dioxide emission rise from 109,015.42 tons in 2010 to 132,889.19 tons in 2020, while the absorption capacity of the existing vegetation only 26,394.69 tons in 2010 and 32,174.98 tons in 2020. Assuming the ability of carbon dioxide absorption by urban forest in urban green open space is 800 tons/ha (Dachlan, 2011), then the needs of green open space should be 166.02 ha of urban forest at the end of the simulation (2020) to balance the carbon dioxide emissions rate.

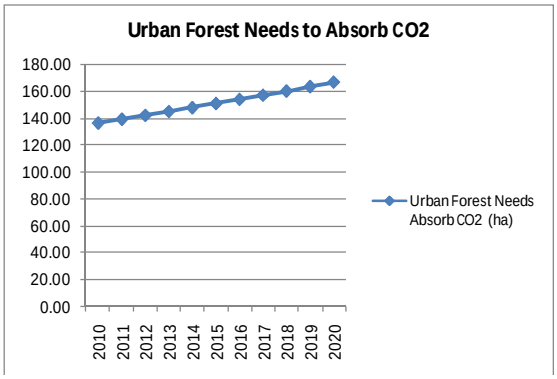

Figure. 6. Urban Forest Needs to absorb CO2
(source: analysis)

Based on the simulation, results shows increasing needs for the amount of vegetation in urban forest and especially the tree that has high ability to absorb carbon dioxide. However, due to the small rate in the growing urban green space, resulting insufficiency of oxygen production and vegetation ability to absorb carbon dioxide emissions. The urban forest need to be planned for the adequacy of its wide and types of vegetation that has high ability to absorb carbon dioxide.

3.5 Policy Analysis

Policy analysis was started by establishing scenarios. Three scenarios were applied for urban forest development simulation. Intervention variables applied are presented in Table 6 and vegetation composition in urban forest is presented in Table 7.

Table 6. Intervention Varibles of Three Scenarios

Variable	Progressive	Sustainable	Conservative
Population	Population growth rate increase by 1%	Population growth rate increase by 0.5%	Population growth rate increase by 1%
Urban Forest	Green space increase by 0.1%	Green space increase by 0.5%	Green space increase by 0.1%
Vegetation	Composition 1 Trembesi (30%), Mahoni (30%), Angsana (20%), Asam (10%)	Composition 2 Trembesi (60%), Mahoni (20%), Angsana (10%), Asam (10%)	Composition 3 Trembesi (10%), Mahoni (10%), Angsana (60%), Asam (20%)

Table 7. Vegetation Composition in Urban Forest

Local Name	Scientific Name	CO2 Absorption (kg/tree/year)	Absorption Availability
Trembesi	Samanea saman	28,448.39	High
Mahoni	Swettiana mahagoni	295.739	Medium
Angsana	Pterocarpus indicus	11.1226	Low
Asam	Tamarindus indica	1.4931	Very Low

Scenario simulation showed that for all scenarios it is difficult to maintain urban forest existence (see Table 8). The most realistic scenario is sustainable scenario. A strong policy should be created to maintain urban green space and urban forest existence.

Table 8. Result of Three Scenario Simulation on Population, Urban Forest and CO2 Absorption

Variable	Year	Scenario		
		Progressive	Sustainable	Conservative
Population (people)	2010	223,446	223,446	223,446
	2020	246,823	234,873	246,823
Urban Forest (ha)	2010	25.39	25.39	25.39
	2020	41.36	65.86	30.95
CO2 Absorption (ton/year/ha)	2010	45.50	22.91	136.26
	2020	50.26	24.08	150.52

4. DISCUSSION

In line with the plan to develop Banda Aceh as sustainable city, the future development should be done properly and in balance between physical development and the maintenance of ecological functions of the environment. According to Chen (2004), Pauliet and Kaliszuk (2005), green open

space as urban green structure act to support sustainable urban life, hence the existence of the natural environment and green open spaces is important to consider in order to continue to support human and development needs in the future. Similarly, according to Irwan (2005), Purnomohadi (2006) and Carreiro (2008), the presence of urban forest as part of green open space is important in controlling and maintaining the integrity and quality of the environment in the city.

According to Irwan (2005), urban forest as part of green open space is forest in the city in the form of trees and associated vegetation that grow in the land around the city or town, forming in lines shaped, spread or clustered with a structure resembling a natural forest. Urban forest also forming as habitat for animals and cause healthy, comfortable and aesthetically environment. While according to DPU (2008) and Waryono (2005), urban forest is a stretch of land that trees grow in compact and tightly in both urban areas on state land and private land, which is defined as the urban forest by competent authority. Criteria for units of urban forest, at least in the area of 0.25 hectares with plant density of at least 10%, equivalent to a spacing of 10 x 10 meters or 100 large trees per hectare, coupled with stretch of scrub and undergrowth vegetation.

Urban forest can serve as an absorber of carbon dioxide gas which is quite important, aside from the phytoplankton, algae and seaweed in the ocean. Since the ability to absorb gas by natural forests is reduce as a result of the shrinking of forest area due to shifting cultivation, logging and fires, it is necessary to build urban forest in the city to help address the decline of natural forest. Sunlight will be used by all plants, both green open spaces, natural forests, agricultural crops and other functions in the process of photosynthesis to convert carbon dioxide and water into carbohydrates ($C_6H_{12}O_6$) and oxygen (O_2).

The process of photosynthesis is very beneficial to humans. The process of photosynthesis can absorb increasing gas emission which can be toxic to humans and animals and will lead to the greenhouse effect. On the other hand, the process of photosynthesis produces oxygen gas which is needed by humans and animals.

Urban forest can freshen air or commonly known as the lungs of the city, where the vegetation in urban forests take CO_2 in photosynthesis and produce O_2 indispensable for breathing creatures. According to Grey and Deneke (in Irwan, 2005), every 1 hectare of green leaves will absorbs 8 kg of CO_2 which is equivalent to the CO_2 exhaled by humans breathing of 200 people at the same time as a result of breathing. O_2 as result of photosynthesis by most of plants will be used again by the passage of the process of respiration (breathing). As for the process of respiration it requires O_2 and produce CO_2.

Following Irwan (2005) urban forests in Banda Aceh can be grouped according to the form and structure. Forms of urban forests can be classified into three types, namely (a) Clustered or accumulate, the urban forest with vegetation communities concentrated in an area with a minimum amount of vegetation at a spacing of 100 trees that are not meeting in the arrangement; (b) Spread, the urban forest that does not has specific pattern, with vegetation growing spread scattered in small clumps or clusters; and (c) Shaped pathway, which is grown in the form of straight or curved lines, following the formation of rivers, roads, beaches, channels and so on.

Structure of the urban forest, can be form by the vegetation communities that make up the urban forest. Urban forest structure is determined by the diversity of vegetation in urban forests planted in layered and stratified both vertically and horizontally that mimic natural forests. Urban forest structure are classified into (a) Stratified two, the vegetation community of urban forest consisting only trees and grass or other ground cover; (b) Stratified more than two, the vegetation community of urban forest in addition consists of trees and shrubs and also grass, herb, lianas, epiphytes, overgrown with saplings and cover a lot of ground, spacing irregular meetings with the strata, as well as the composition of the lead mimic vegetation communities of natural forest.

The general criteria for the selection of urban forest vegetation types in Banda Aceh based on characteristics of plant which are (a) not gummy/toxic, not easily broken branches, roots do not interfere with the foundation, the structure leaves a half meeting to meeting; (b) the type of tree height varies, the green color and other color variations balanced; (c) speed of growth medium; (d) from local plant habitat and plant cultivation; (e) annual or seasonal crop type; and (f) distance plants meeting half of the total area to be reforested.

Some other things to be consider in the selection of plant in the city of Banda Aceh, is the shape and type of tree. Selection of tree species that are not exactly going to lead to the intention of getting a high volume of greening is not reached. Tree forms an important element in the design of urban landscape and really should be considered when to plant trees for greening the city. There are two basic forms of trees: (a) canopy and non canopy trees shape. Tree canopy shape is generally used as a shade tree, while the tree canopy forms not for aesthetic purposes, limiting or steering. Tree canopy shape can be subdivided into five forms, namely irregular, diffuse upward, oval, round and dangle; (b) While the non canopy shape is divided into three forms, namely the shape of a pyramid, whips and palm.

For the needs of trees along the edge of the road, the trees form a canopy with spreading branches and twigs is the most appropriate, because the branch does not interfere with the underlying activities and can provide shade. The form of a whip when planted close together, most suitable for masking purposes (screening) and soften accent line for high building. This form can not provide shade. Pyramid shape, for example pine, not appropriate when planted along the edge of the road, because it can not provide shade. Trees can be planted in the shape of a pyramid among other shady trees to absorb dust and noise, or planted in a fairly wide area. Trees are also divided into three based on the height that can be achieved when the trees mature, namely (a) small trees, height of less than 9 meters; (b) moderate trees, reaching a height of 9 meters; and (c) large tree, reaching a height of 18 meters.

5. CONCLUSION

The presence of urban forest as element of the natural environment plays an important role in maintaining the quality of city life. The concept of landscape ecology in the city of Banda Aceh attempts to achieve ecologically healthy city. The needs of urban forest as part of urban green space appropriate to ecological functions of CO2 absorption which known from the calculation are:

a. Urban forest requirements based on the role of tree as a carbon dioxide absorber there is a lack of 82,620.74 tons due to the lack of vegetation in the absorption of carbon dioxide.
b. The needs for urban forest to absorb carbon dioxide in the area of 166.02 hectares in 2020 to balance the carbon dioxide emissions rate.
c. Land use control should be taken seriously by the government so that the presence of urban forest in the city will not degrade in the quality and quantity.

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