PHYSIOLOGICAL CHARACTERISTICS RELATED TO CARBON SEQUESTRATION OF TREE SPECIES IN HIGHLAND FOREST ECOSYSTEM OF MOUNT HALIMUN-SALAK NATIONAL PARK

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ABSTRACT

Biological diversity can have significant contribution to reduce the build-up of greenhouse gases in the atmosphere. The trees in a forest stand form an essential part in the functioning of the terrestrial biosphere, especially in the carbon cycle. Yet tree photosynthesis is far less studied than crop photosynthesis for several reasons: the large number of species; difficulty in measuring photosynthesis of entire trees or of forest stands. This research aims to assess the contribution of biological diversity in carbon sequestration by analyzing the physiological characteristics (photosynthesis, transpiration, stomatal conductance, leaf chlorophyll content) of species native to tropical highland forest ecosystem of Mount Halimun-Salak National Park. The results showed that there was a wide range of variation of CO_2 assimilation rate between tree species. The overall CO_2 absorption rate ranged 1.1913 - 31.3875 $\mu molm^{-2}s^{-1}$, the highest rate was reached by *Lithocarpus* sp. (pasang parengpeng) (31.3875 $\mu molm^{-2}s^{-1}$), followed by *Litsea noronhae* (huru lumlum) (21.5750 $\mu molm^{-2}s^{-1}$), *Saurauia nudiflora* (kilebo) (11.8175 $\mu molm^{-2}s^{-1}$), *Vernonia arborea* (hamirung) (6.7125 $\mu molm^{-2}s^{-1}$) and *Litsea* sp. (huru bodas) (6.2725 $\mu molm^{-2}s^{-1}$). The rate of CO_2 assimilation was affected by incident radiation and thus the photon flux (Q leaf). Correlation between CO_2 assimilation and Q leaf under certain environmental condition was considerably high. Incident radiation and Q leaf also affected stomatal conductance and thus rate of transpiration.

Keywords: Biological diversity, photosynthesis, carbon sequestration, greenhouse gases

I. INTRODUCTION

Forests represent 21% of the continental area which are 76% of terrestrial biomass and 37% of its bioproductivity (Ceulmans and Sauger, 1991). A biologically diverse tropical forest holds 50 times more carbon per unit of area than a monoculture plantation. Thus, the trees in a forest stand form an essential part in the functioning of the terrestrial biosphere, especially in the carbon cycle. Yet tree photosynthesis is far less studied than crop photosynthesis for several reasons: the large number of species; difficulty in measuring photosynthesis of entire trees or of forest stands.

Biological diversity can make a significant contribution to reducing the build-up of greenhouse gases in the atmosphere. Each year about 60 gigatonnes (GT) of carbon (C) are taken up and released by land-based ecosystems and about 90 GT are taken up and released by ocean systems. These natural fluxes are large compared to the approximately 6.3 GT being emitted from fossil fuels and industrial processes, and about 1.6 GT per year from deforestation (CBD, 2008).

A reliable method for restoration of forest and reforestation is using native tree species. The trees which are suitable for CDM (Clean Development Mechanism) purpose should have the three following characteristics; (1) seedling that can adapt easily to open sites, after transplanting from shade (nurseries) to the sunlit conditions; (2) fast-growing species that is able to compete with weeds and fern (Ashton, 1998); (3) tree species that have high CO_2 assimilation

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capacity and long live. However, these physiological characteristics differ widely among tree species. In order to attain successful reforestation, it is necessary to carefully select appropriate trees for transplanting based on these characteristics. For evaluation of the appropriate trees, ecological (dominance, biomass, carbon content) and physiological (photosynthesis, transpiration) characteristics are suitable indicators (Takahashi *et al.*, 2005, 2006; Ashton, 1998).

Variance in CO_2 assimilation rate is large among trees grown under sunlit conditions not only across the continental transect as well as across tropical climate regions (Matsumoto *et al.*, 2003). Fast-growing trees often have relatively higher CO_2 assimilation rate in tropical climate zone suggesting that CO_2 assimilation rate can be an indicator for evaluating fast-growing characteristics (Press *et al.*, 1996, Matsumoto *et al.*, 2003).

In this study ecological and physiological characteristics of tree species native to humid highland forest ecosystem examined. This research aimed to provide informations on tree characteristics related to high carbon sequestration by analyzing their physiological characteristics (CO_2 absorption, CO_2 assimilation, stomatal conductance, chlofophyll content), and ecological characteristics (dominance, biomass production and carbon sequestration).

II. MATERIAL AND METHODS

A. Study Site

This study was conducted in two locations representing humid highland forest in Mount Halimun-Salak National Park : 1) Cikaniki and 2) Citalahab. Two plots were established in two different sites. The first plot of 100 m x 100 m was located in Cikaniki station of 06°44'57" S and 106°32'08" E, 1,100 m above sea level and the second one of 50 m x 50 m was located in Citalahab of 06° 44' 32.2" S and 116° 31' 44.0" E, 1,076 m above sea level (Figure 1).

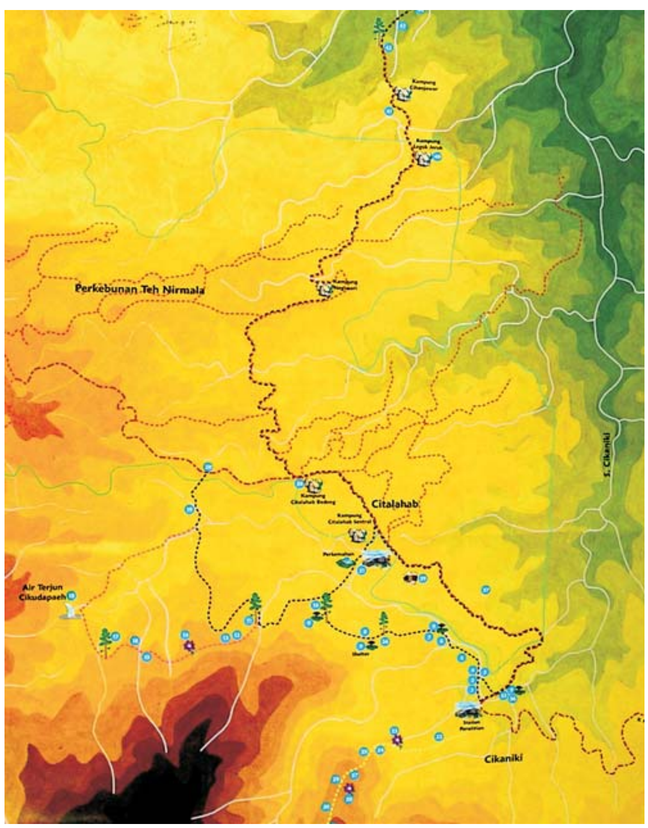

Figure 1. Cikaniki and Citalahab study sites in Mount Halimun-Salak National Park

B. Ecological Analysis

Analysis of vegetation was conducted by making plots of representative sizes. Each plot was divided into smaller plots 10 m x 10 m. From these smaller plots assessment and identification were made for name of the tree species, number of species, stem diameter (>10 cm), height, coordinate of the trees (x, y). For the unknown species, samples were collected for identification.

The collected data was analyzed using Cox (1967) and Greigh-Smith (1964) method for obtaining the values of basal area, relative frequency, relative density, relative dominance and value of importance by the following calculation:

BA = (0.5xD)2x3.14

Where BA ($m^{-2}h^{-1}$) is basal area; D is diameter and value of 3.14 is a constant.

Plant biomass and carbon content were estimated by using the following calculation :

$W = a D^{b}$

W= biomass; a and b = W= biomass; a and b = constant for estimating biomass of tree community (a =0.19 and b=2.37); D = stem diameter (Brown, 1997).

C = 0.5 W

C = carbon content; W = biomass.

C. Physiological Analysis

The measurement of physiological and photosynthetic characteristics were carried out in April and June 2010. The height of tree sampled was 50 cm – 150 cm. Simultaneous measurements of CO_2 assimilation, stomatal conductance and transpiration were conducted by using portable *LCi ADC Bioscientific Ltd. Photosynthesis System*. The measurement of carbon dioxide (CO_2) uptake is a direct method of measuring carbon exchange, with important advantages: it is instantaneous and non destructive and it allows measurement of the total carbon gain by a plant separation of photosynthetic gain from respiratory loss. This measurement of CO_2 exchange involved enclosure methods which is enclosure of a leaf in a transparent chamber.

The rate of CO_2 assimilation by the leaf enclosed is determined by measuring the change in the CO_2 concentration of the air flowing across the chamber. In this close system air is pumped from the chamber enclosing a leaf into an IRGA (Infra Red Gas Analyzer) which continuously records the CO_2 concentration of the system. The air is then recycled back to the chamber. No air leaves or enters the system. If the leaf enclosed in the chamber as photo-synthesizing, the CO_2 concentration in the system will decline, and continue to decline until the CO_2 compensation point of photosynthesis is reached. The rate of CO_2 assimilation is equal to the change in the amount of CO_2 in the system per unit time.

Rate of CO_2-assimilation was measured under certain range of CO_2 concentrations, photon flux, and leaf temperature (Table 1). For measurement of physiological characteristic, a fully expanded (young) and older leaves were chosen per sampling. Three different plants individuals of each species were measured. Simultaneous measurements of microclimate, photosynthesis, chlorophyll content and transpiration rate were conducted. The measuring time for each species was between 09.00 - 12.00 am under completely clear sky.

The measurement of microclimate was conducted for each plant species. Air temperature

Table 1. Range of CO_2 concentration in stomata, CO_2 reference, foton flux, vapour pressure and temperature (leaf and chamber) during the measurement.

Parameters	Halimun National Park	
	Cikaniki	Citalahab
CO_2 reference (cref: vpm)	370 – 750	371 - 433
Analytical CO_2 (can: vpm)	360 – 703	365 - 438
CO_2 in stomata (ci: vpm)	260 – 500	345 - 412
Foton flux (Qleaf: $\mu molm^{-2}s^{-}$)	8 – 250	10.25 - 957
Chamber temperature (Tch: ^{o}C)	24 – 29.5	21.6 – 30.8
Leaf temperature(Tie: ^{o}C)	29 – 30	20 - 29
Vapour pressure (P: mbar)	900	900

and relative humidity were measured using *Digital Thermohygrometer* AS ONE TH-321, soil pH and moisture content were measured using *Soil Tester*, and light intensity was measured by using *Lux meter* Luxor. Leaf chlorophyll content was measured using spectrophotometer and *chlorophyll meter SPAD-502;* Minolta Co.Ltd., Osaka, Japan.

III. RESULTS AND DISCUSSION

A. Results

1. Cikaniki Site

Tree distribution in the higher site was dominated by *Altingia excelsa* (rasamala) which contributed to 32% of the total basal area (BA), followed by *Schima wallichii* (puspa) (10%) and *Quersus lineata* (6%).

Microclimate and soil conditions during the measurements were presented in Appendix Table 1. Soil pH ranged from 5.58 - 6.60, soil moisture ranged from 55.5 - 90.3%, relative humidity was 62.5 - 29.4%, air temperature ranged from 23.5 - 29.4 °C and light intensity was 597.5 - 22893.5 lux.

Under such microclimate and soil conditions the overall CO_2 assimilation range from 1.1913 - 31.3875 µmolm^{-2}s^{-1}. The highest rate was reached by *Lithocarpus* sp.1 (pasang parengpeng) which was 31.3875 µmolm^{-2}s^{-1}, followed by *Litsea noronhae* (huru lumlum) 21.5750 µmolm^{-2}s^{-1}, *Saurauia nudiflora* (kilebo) 11.8175 µmolm^{-2}s^{-1}, *Vernonia arborea (*hamirung) 6.7125 µmolm^{-2}s^{-1} and *Litsea* sp.1(huru bodas) which was 6.2725 µmolm^{-2}s^{-1} (Table 2).

The rate of transpiration ranged between 0.4175 - 1.8975 molm^{-2}s^{-1}. The highest was reached by *Eugenia* sp.1 (kibeusi) which was 1.8975, followed by *Castanopsis acuminatissima* (kianak) 1.8950 molm^{-2}s^{-1}, *Quercus lineata* (pasang batarua) 1.7875 molm^{-2}s^{-1}, *Schima wallichii* (puspa) 1.6225 molm^{-2}s^{-1} and *Litsea noronhae* (huru lumlum) which was 1.5300 molm^{-2}s^{-1} (Table 2).

Chlorophyll content of the leaf varied between 0.6015 - 3.8370 mg chlorophyll. The highest leaf chlorophyll content was on *Symplocos fasciculata* (jirak) which was 3.8370, followed by *Litsea* sp.2 (huru hejo) 3.2862, *Litsea brachystachia* (huru hiris) 3.1232, *Litsea* sp.3 (huru buah) 2.7065 and *Litsea* sp.1(huru bodas) 2.6268 (Table 2).

Variation in microclimate conditions during the measurements resulted in variation of the measurements. The rate of CO_2 assimilation was affected by incident radiation intensity and thus the quantum leaf (Q leaf) (Figure 2). Incident radiation and Q leaf also affected stomatal conductance and thus rate of transpiration. Correlation between stomatal conductance and transpiration rate was R= 0.5741 (Figure 3).

CO_2 assimilation of young leaves was not significantly different with that of older leaves, although stomatal resistance of young leaves was commonly higher than that of old leaves (Appendix 2). Under such environmental conditions CO_2 assimilation was affected more by external factors (i.e. solar radiation) than by the leaf stomatal character although some theory stated that stomatal conductance correlates with photosynthetic capacity (Wong *et al.*, 1979). Under certain range of Q leaf, there was a linear

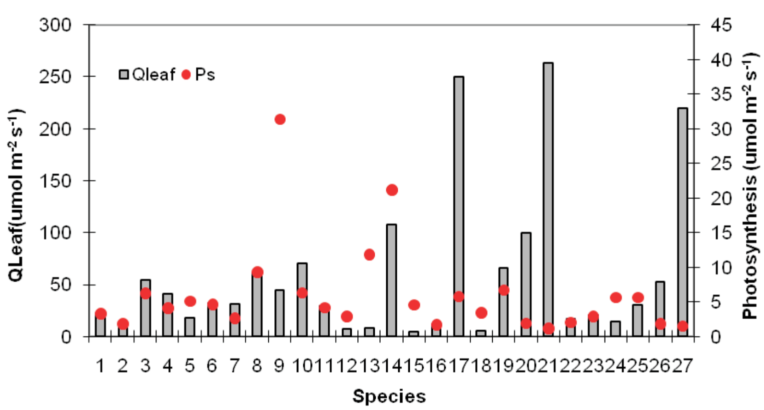

Figure 2. Correlation between photon flux (QLeaf) and photosynthesis (Ps) In Cikaniki plot (names of species are presented in Table 2)

Table 2. Variation in physiological characteristics related to CO_2 absorption of tree Species in Cikaniki plot - Halimun-Salak National Park

No.	Species (Local name)	Analytical CO_2 (vpm)	Q leaf (μmolm^{-2}s^{-1})	CO_2 Assimilation (μmolm^{-2}s^{-1})	Transpiration (molm^{-2}s^{-1})	Stomatal conductance (molm^{-2}s^{-1})	Chlorophyl content (mg)
1.	*Castanopsis acuminatissima* (kianak)	384.50	22.50	3.290	1.895	0.500	1.80
2.	*Eugenia* sp.1 (kibeusi)	417.00	10.28	1.835	1.898	0.585	2.04
3.	*Litsea* sp.1 (huru bodas)	396.25	54.75	6.273	0.790	0.133	2.63
4.	*Litsea* sp.2 (huru hejo)	402.25	40.75	4.110	0.950	0.293	3.29
5.	*Altingia excelsa* (rasamala)	384.50	17.50	5.138	0.650	0.365	2.10
6.	*Quercus lineata* (pasang batarua)	431.50	32.50	4.623	1.788	0.430	1.92
7.	*Litsea brachystachia* (huru hiris)	440.00	31.00	2.650	1.258	0.208	3.12
8.	*Castanopsis argentea* (saninten)	387.50	61.75	9.333	1.208	0.273	2.61
9.	*Lithocarpus* sp.1 (pasang parengpeng)	537.00	44.25	31.388	1.473	0.218	2.94
10.	*Syzygium polyanthum* (salam)	703.50	70.25	6.335	1.013	0.250	1.86
11.	*Lithocarpus pseudomoluccanus* (kalimorot)	410.00	29.25	4.153	1.058	0.180	1.93
12.	*Litsea* sp.3 (huru buah)	435.00	7.50	2.928	0.980	0.393	2.71
13.	*Saurauia nudiflora* (kilebo)	386.00	8.25	11.818	1.045	0.410	2.03
14.	*Litsea noronhae* (huru lumlum)	503.25	107.25	21.158	1.530	0.630	2.53
15.	*Vernonia arborea* (hamirung)	584.00	4.50	4.570	1.260	0.733	1.96
16.	*Prunus arborea* (hawoyang)	513.75	11.75	1.703	0.858	0.265	1.81
17.	*Garcinia dioica* (ceri)	381.00	249.75	5.778	1.133	0.328	1.09
18.	*Knema cinerea* (kinolka)	387.50	5.75	3.455	1.263	0.725	1.70
19.	*Vernonea arborea* (hamirung)	408.50	65.75	6.713	1.140	0.535	1.04
20.	*Macaranga tanarius* (marabodas)	440.75	99.25	1.913	1.355	0.173	2.45
21.	*Ardisia zollingeri* (kiajag)	367.00	263.00	1.198	0.835	0.065	1.47
22.	*Eugenia opaca* (kopo)	361.50	16.75	2.080	0.893	0.080	1.21
23.	*Symplocos fasciculata* (jirak)	377.75	20.75	2.918	0.418	0.053	3.84
24.	*Eugenia* sp.2 (kisireum)	396.25	14.75	5.628	1.258	0.223	1.25
25.	*Schima wallichii* (puspa)	384.75	30.00	5.668	1.623	0.545	2.30
26.	*Platea excelsa* (kibonteng)	392.25	52.50	1.868	0.858	0.103	1.32
27.	*Lithocarpus* sp.2 (pasang reuuey)	371.25	219.25	1.503	1.210	0.188	0.60

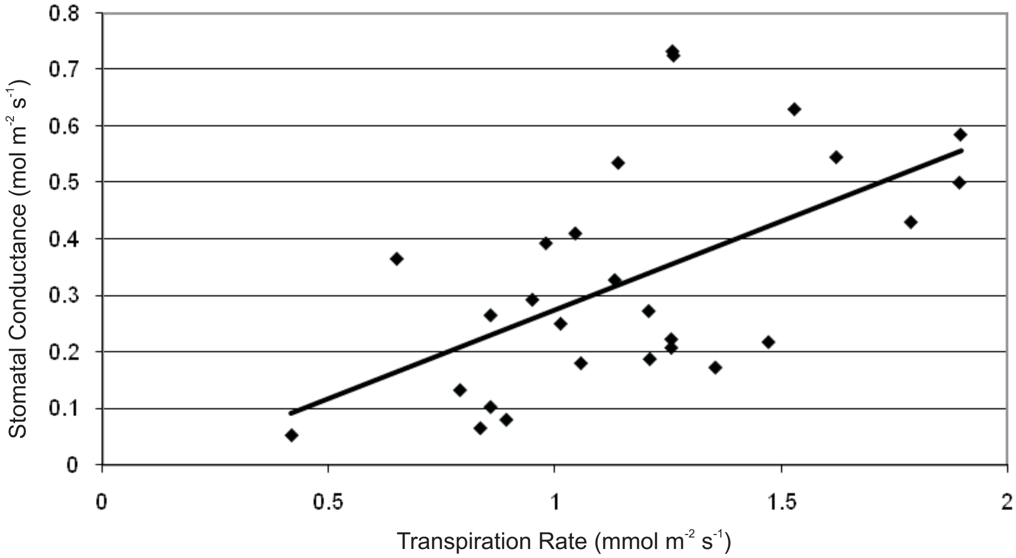

Figure 3. Correlation between stomatal conductance and transpiration in Cikaniki Plot (R= 0.5741)

relationship between CO_2 assimilation Q leaf. This findings agree with the report by Long and hallgren (1993). There was positive correlation between CO_2 assimilation and leaf chlorophyll content although the value was not significant. However this relationship need to be studied more thoroughly under controlled environment.

2. Citalahab Site

In Citalahab plot, there were 337 individual trees (diameter > 10 cm) which consists of 71 species from 32 genus and 50 families. The most commonly family found were Lauraceae, Fagaceae, Myrtaceae, Rubiaceae, Meliaceae and Euphorbiaceae.

There were 20 trees species that have the highest "value of importance" including *Altingia excelsa, Blumeodendron elateriospermum, Ardisia zollingeri, Gordonia excelsa, Tricalysia singularis, Castanopsis acuminatissima, Knema cinerea, Laportea stimulans, Vernonia arborea* and *Dysoxylum excelsum*.

Distribution of diameter classification was dominated by class 10-20 cm, that reached 51.63% of the total individu. The most common tree species within this class include *Ardisia zollingeri, Laportea stimulans, Gordonia excelsa* and *Urophyllum glabrum*.

Microclimate conditions during the measurement were relatively low temperature and low light intensity (Appendix 3). This microclimate conditions resulted in low photon flux (Q leaf) and relatively low in CO_2 assimilation rate. The highest CO_2 assimilation rate in this area was 8.77 $\mu molm^{-2}s^{-1}$ (*Altingia excelsa*), followed by *Tricalysia singularis* which was 7.10 $\mu molm^{-2}s^{-1}$ and *Litsea resinosa* which was 6.22 $\mu molm^{-2}s^{-1}$ (Table 3 and Figure 4). Variation in transpiration rate and stomatal conductance were relatively small under this environmental conditions. Under certain conditions, there was positive correlation between Q leaf and CO_2 assimilation and between stomatal conductance and transpiration rate although the values were relatively low due to the uncontrolled environmental factors.

Dry matter and carbon content reached 152,247.91 (152.3 ton ha^{-1}) obtained from basal area of 28.89 m^{-2} ha^{-1} and the number of individu 337 trees ha^{-1}. Five tree species with the highest biomass were recorded i.e.: *Altingia excelsa* (938.25 ton ha^{-1}), *Blumeodendron elateriospermum* (2882.31 ton ha^{-1}), *Castanopsis acuminatissima* (1930.21 ton ha^{-1}), *Engelhardtia serrata* (1608.47 ton ha^{-1}) and *Vernonia arborea* (1372.75 ton ha^{-1}). The ecological findings are discussed in different paper.

Table 3. Variation in physiological characteristics related to CO_2 absorption of tree species in Citalahab - Halimun-Salak

No.	Species	Local Name	Analytical CO_2 (vpm)	Q leaf (µmolm^{-2}s^{-1})	CO2 Assimilation (µmolm^{-2}s^{-1})	Stomatal conductance (molm^{-2}s^{-1})	Transpiration (molm^{-2}s^{-1})
1.	*Magnolia elegans*	maja	377.50	80.75	4.190	0.470	3.622
2.	*Blumeodendron elateriospermum*	burunynggul	411.25	26.00	3.308	0.575	3.315
3.	*Elaeocarpus ganitrus*	ganitri	368.25	130.50	1.825	1.1875	3.105
4.	*Knema cinerea*	kimokla	395.50	88.75	2.265	0.815	3.633
5.	*Vernonia arborea*	hamirung	402.00	65.75	5.595	0.668	3.553
6.	*Gordonia excelsa*	mumuncangan	382.25	94.25	3.605	1.168	3.443
7.	*Altingia excelsa*	rasamala	394.00	303.00	8.770	0.293	3.815
8.	*Schima wallichii*	puspa	372.25	72.00	2.890	0.358	3.638
9.	*Quercus lineata*	pasang batarua	380.50	17.00	2.498	0.278	3.338
10.	*Urophyllum corymbosum*	kokopian	380.00	127.25	2.168	0.305	3.908
11.	*Acer laurinum*	huru bodas	387.50	527.25	4.043	0.250	3.668
12.	*Castanopsis argentea*	saninten	372.25	41.50	2.610	0.305	3.220
13.	*Ardisia zollingeri*	kiajag	374.00	29.00	1.745	0.328	3.005
14.	*Quersus oidocarpa*	pasang parengpeng	379.50	10.25	1.123	0.363	3.653
15.	*Macaranga triloba*	mara	381.25	77.25	2.085	0.730	4.853
16.	*Castanopsis acuminatissima*	kianak	382.25	491.75	2.680	0.205	3.228
17.	*Prunus arborea*	kawoyang	389.50	957.25	4.235	1.613	4.148
18.	*Symplocos fasciculata*	jirak	389.00	292.75	3.990	0.223	2.983
19.	*Litsea resinosa*	huru minyak	399.75	66.75	6.218	3.518	3.370
20.	*Sandoricum koetjape*	kacapi	396.75	70.25	4.148	3.808	4.253
21.	*Litsea brachystachia*	huru hiris	385.75	86.75	3.798	0.685	3.390
22.	*Cinnamomum* sp.	huru buah	423.50	312.25	2.105	0.450	3.488
23.	*Tricalysia singularis*	dawolong	438.50	24.00	7.100	0.350	3.525
24.	*Platea latifolia*	kibonteng	398.50	11.00	0.970	0.745	3.430
25.	*Neesia altissima*	bengang	414.25	13.25	1.480	0.915	3.793

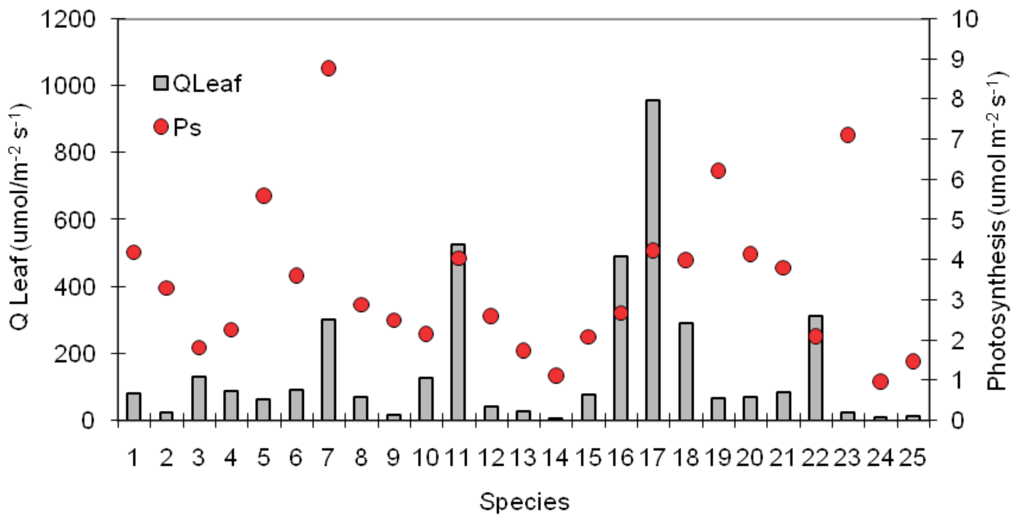

Figure 4. Correlation between photon flux (QLeaf) and photosynthesis (Ps) In Citalahab Plot (name of species is presented in Table 3)

B. Discussion

The significant differences between the response of physiological characteristics and environmental conditions were represented by tree species. The response of physiological characteristic showed typical acclimation to sunlit condition such as increasing CO_2 assimilation rate.

The results of this study agree with some findings that leaf photosynthesis in trees fairly variable with maximum values under natural conditions ranged from 3 - 30 µmolm^{-2}s^{-}. The values varies between 2 - 25 µmolm^{-2}s^{-1} for deciduous broad leafed trees, 2 - 10 µmolm^{-2}s^{-} for coniferous trees, 3 - 6 µmolm^{-2}s^{-} for certain broad leafed species such as *Quersus* and *Fagus*, more than 25 µmolm^{-2}s^{-} for poplar, oil palms and eucalypt (Raghavendra, 1991). Photosynthesis of *Shorea* was reported of 7 - 21 µmolm^{-2}s^{-} , *Shorea balangeran* 21.9 µmolm^{-2}s^{-} in Central Kalimantan, *Acacia mangium* of 24.2 µmolm^{-2}s^{-}, 16 for *Hopea odorata*, 27.8 µmolm^{-2}s^{-} for *Ochroma lagopus* (Chazdon *et al*., 1996; Press *et al*., 1996; Matsumoto *et al*., 2003). Photosynthesis of tropical woody plants for the first stage of succession ranged 10 - 20 µmolm^{-2}s^{-} , scarcely 25 µmolm^{-2}s^{-} (Larcher, 1995).

The plasticity of stomatal conductance (gs) under relatively shade and lower temperature was low, between 0.030 molm^{-2}s^{-1} to 0.263 molm^{-2}s^{-1} in Cikaniki and between 0.043 molm^{-2}s^{-1} to 0.223 molm^{-2}s^{-1} in Citalahab. Findings were reported that gs of fast growing of *S. balangeran* and *A. mangium* were 0.49 molm^{-2}s^{-1} (Takahashi *et al*., 2005; Takahashi *et al*., 2006) and 1.3 molm^{-2}s^{-1} (Matsumoto *et al*., 2003). The high gs play a role for high capacity of ventilation due to high transpiration rate in open site, being able to avoid extremely increase of leaf temperature.

This study suggested that for evaluation of the appropriate tree species, morphological and photosynthetic characteristic of leaves are suitable indicators. In general, sun leaf has higher light saturated CO_2 assimilation rate and lower apparent quantum yield of CO_2 assimilation rate compared with shade leaf (Boardman, 1977; Larcher, 1995; Press *et al*., 1996). Shade leaf has high light-use efficiency for CO_2 assimilation under low light condition due to high accumulation light harvesting system in photosynthesis, however, under open condition, shade leaf does not have high light-use efficiency and the reduction of CO_2 assimilation rate often occurs due to light oxidation by excess light energy called photo-inhibition (Clearwater *et al*., 1999). Furthermore, Press *et al*. (1996) demonstrated that the degree of photosynthetic plasticity in response to changes of light regimes was high in the most-light demanding species, therefore it is recommendable to select trees which have higher CO_2 assimilation rate of sunlit leaf and higher degree of plasticity.

Abiotic factors such as light, temperature, CO_2 concentration, vapour pressure deficit and nutrient status have a major effect on net photosynthesis, and thus on growth and productivity. All environmental conditions that tend to reduce photosynthetic rate (e.g. low light, low temperature, low nutrient availability) reduce the photosynthetic carbon gain (Ceulmens and Sauger, 1991).

Photosynthetic capacity varies not only with environment but also with age and position of the leaves in the canopy. Stomatal conductance (and net photosynthesis) in *Quersus* reached a maximum several weeks after maximum leaf size. Leaves of 10-year old oil palm remainded photosynthetically active for 21 months. This has important implications for the whole-tree photosynthetic CO_2 uptake (Ceulmens and Sauger, 1991).

Some important remarks should be made about the correct interpretation of the values of photosynthetic rate. First, growth conditions as well as the experimental methods have important implication on CO_2 exchange rate. Plant raised under natural conditions and/or measured in situ tend to have higher CO_2 exchange rate than do plants grown under controlled environment such as greenhouse condition. Therefore specification on tree size, measurements conditions and methods used are mentioned in this paper.

In many cases net photosynthesis has been found to be poorly correlated with growth rate for some reasons, i.e difference in leaf area, pattern of carbon partitioning and variation in wood and root respiration rate. The harvestable product of a tree (the stem) depends not only on the photosynthetic carbon uptake by the foliage but also on respiration of the various organs and carbon investment into renewable organs (leaves, fine roots) and non harvestable organs (branches and large roots). Consequently, there is no obvious relationship between photosynthesis and biomass production. However, a fast growing tree needs a high photosynthesis, but the reverse is not necessarily true (Raghavendra, 1991).

IV. CONCLUSION

1. The results showed that there was a wide range of variation of CO_2 assimilation rate between tree species. The overall CO_2 absorption rate ranged 1.1913 - 31.3875 $\mu molm^{-2}s^{-1}$, the highest rate was reached by *Lithocarpus* sp.1 (pasang parengpeng) (31.3875 $\mu molm^{-2}s^{-1}$), followed by *Litsea noronhae* (huru lumlum) (21.5750 $\mu molm^{-2}s^{-1}$), *Saurauia nudiflora* (kilebo) (11.8175 $\mu molm^{-2}s^{-1}$), *Vernonia arborea* (hamirung) (6.7125 $\mu molm^{-2}s^{-1}$) and *Litsea* sp.1 (huru bodas) (6.2725 $\mu molm^{-2}s^{-1}$).
2. Different microclimate conditions during the measurements resulted in variance CO_2 assimilation rate. The rate of CO_2 assimilation was affected by photon flux (Q leaf). Incident radiation and Q leaf also affected stomatal conductance and thus rate of transpiration. Correlation between stomatal conductance and transpiration under certain environmental condition was considerably high.
3. Some remark need to be measurement of CO_2 assimilation.

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Appendix 1. Microclimate and tree size measured in Cikaniki plot

No.	Local Name	Diameter (cm)	Height (cm)	Soil pH	Soil Moisture (%)	Relative Humidity (%)	Air Temperature (°C)	Light Intencity (Lux)
1.	kianak	1.9	282.0	6.6	77.5	88.5	23.5	1307.5
2.	kibeusi	1.3	236.5	6.4	78.0	86.5	24.8	1612.5
3.	huru bodas	2.0	264.0	6.3	82.0	78.3	26.2	3530.0
4.	huru hejo	2.6	283.0	6.4	79.5	80.3	25.8	2410.0
5.	rasamala	1.8	241.5	6.4	79.8	82.8	25.0	1407.5
6.	Ppsang batarua	2.4	363.5	6.5	83.3	81.5	25.3	830.0
7.	huru hiris	2.9	347.0	6.1	67.0	70.2	27.5	2560.0
8.	saninten	1.7	214.0	6.0	72.5	67.3	28.2	2427.5
9.	pasang parengpeng	1.3	192.5	6.0	65.0	70.8	29.4	3492.5
10.	salam	2.0	313.0	6.4	53.8	72.9	24.9	4780.0
11.	kalimorot	3.8	288.5	6.1	78.3	71.5	26.8	1315.0
12.	huru buah	2.0	270.0	6.2	72.5	73.8	26.8	1355.0
13.	kilebo	1.4	114.0	6.0	72.5	77.5	25.4	597.5
14.	huru lumlum	1.9	265.0	5.6	90.3	73.2	27.2	1960.0
15.	hamirung	2.9	396.0	6.1	77.0	77.0	25.1	930.0
16.	hawoyang	1.6	261.5	6.0	73.8	76.5	25.4	807.5
17.	ceri	3.1	404.5	5.8	85.3	74.8	25.3	2227.5
18.	kinokla	6.3	492.0	6.3	67.0	78.0	26.0	585.0
19.	kirung	2.4	280.5	5.8	77.5	70.3	26.3	2870.0
20.	marabodas	3.9	458.5	6.1	67.5	69.3	26.6	5162.5
21.	kiajag	4.5	416.5	5.9	71.3	68.3	26.4	18845.0
22.	kopo	4.8	424.0	6.2	55.5	69.8	26.3	952.3
23.	jirak	3. 8	354.5	6.1	62.8	71.4	26.0	2780.0
24.	kisireum	1.9	313.0	6.2	68.8	70.5	26.6	2327.5
25.	puspa	1.8	318.0	6.2	81.8	78.5	26.4	3587.5
26.	kibonteng	1.9	212.5	5.83	84.3	62.5	27.6	3455.0
27.	pasang reuney	3.4	443.0	5.8	73.0	69.3	26.9	22892.5

Appendix 2. Physiological characteristics of young and old leaves in Cikaniki plot

No.	Locak Name	Q Leaf ($\mu molm^{-2}s^{-1}$)		CO_2 Assimilation ($\mu molm^{-2}s^{-1}$)		Transpiration ($molm^{-2}s^{-1}$)		Stomatal Conductance ($molm^{-2}s^{-1}$)	
		Young	Old	Young	Old	Young	Old	Young	Old
1.	kianak	28.00	17.00	3.49	3.09	1.96	1.83	0.97	2.05
2.	kibeusi	11.85	8.70	2.39	1.28	1.94	1.86	0.72	0.46
3.	huru bodas	67.00	42.50	8.21	4.34	0.80	0.78	0.11	0.16
4.	huru hejo	46.00	35.50	3.91	4.32	0.82	1.09	0.12	0.47
5.	rasamala	25.50	9.50	6.13	4.15	0.49	0.81	0.07	0.66
6.	pasang batarua	28.00	37.00	5.76	3.49	1.68	1.90	0.37	0.49
7.	huru hiris	33.00	29.00	2.21	3.09	1.22	1.30	0.26	0.16
8.	saninten	76.00	47.50	6.39	12.27	1.47	0.96	0.37	0.18
9.	pasang parengpeng	161.00	88.00	29.41	33.37	1.64	1.31	0.26	0.18
10.	salam	56.00	84.50	8.21	4.470	1.12	0.91	2.22	1.83
11.	kalimorot	21.50	37.00	2.10	6.21	1.07	1.05	0.21	0.16
12.	huru buah	5.50	9.50	3.38	2.48	1.16	0.81	0.20	0.59
13.	kileho	128.00	8.50	22.59	1.05	0.91	1.18	0.49	0.33
14.	huru lumlum	126.50	88.00	14.66	27.66	1.61	1.46	0.52	0.74
15.	hamirung	4.50	4.50	4.79	4.35	1.16	1.37	1.08	0.39
16.	hawoyang	11.00	12.50	1.06	2.35	0.89	0.83	0.29	0.25
17.	ceri	228.00	71.00	5.06	6.46	1.04	1.23	0.35	0.31
18.	kinokla	7.00	4.50	1.29	5.62	1.47	1.06	1.14	0.32
19.	kirung	77.00	54.50	10.75	2.68	1.25	1.04	0.48	0.59
20.	marabodas	129.50	69.00	12.00	1.66	1.59	1.12	0.22	0.13
21.	kiajag	257.50	68.00	21.00	0.92	0.85	0.82	0.07	0.07
22.	kopo	21.50	12.00	2.38	1.79	0.87	0.92	0.080	0.08
23.	jirak	20.00	21.50	2.39	3.45	0.37	0.47	0.03	0.08
24.	kisireum	13.50	16.00	5.19	6.07	1.07	1.45	0.19	0.25
25.	puspa	36.00	24.00	10.15	1.19	1.28	1.97	0.27	0.83
26.	kibonteng	57.50	47.50	2.25	1.49	0.89	0.83	0.16	0.05
27.	pasang reuney	183.50	55.00	1.47	1.54	1.07	1.36	0.17	0.21

Appendix 3. Microclimate and tree size measured in Citalahab plot

No.	Local Name	Diameter (cm)	Height (cm)	Soil pH	Soil Moisture (%)	Relative Humidity (%)	Air Temperature (°C)	Light Intencity (Lux)
1.	maja	1.4	185.0	4.0	80.0	55.0	27.5	6102.5
2.	burunuggul	4.4	415.5	5.5	35.0	61.5	26.0	1238.0
3.	ganitri	1.8	146.5	3.7	90.0	60.5	24.0	12037.5
4.	kimolka	4.3	623.5	5.0	60.0	60.0	26.5	3521.7
5.	hamirung	2.4	369.0	6.5	30.0	57.5	27.5	5788.7
6.	mumuncangan	2.4	416.0	5.5	52.5	59.0	22.5	5745.0
7.	rasamala	1.1	147.0	5.5	40.0	53.0	26.0	15750.0
8.	puspa	1.7	241.5	6.5	20.0	48.5	25.5	32522.5
9.	pasang batarua	1.1	136.0	6.6	20.0	51.5	26.5	11369.3
10.	kokopian	1.5	197.5	7.0	10.0	51.0	25.0	25400.0
11.	huru bodas	3.9	382.5	6.1	41.0	57.0	26.0	35900.0
12.	saninten	2.1	262.0	6.0	30.0	50.0	25.0	3800.0
13.	kiajag	3.3	376.5	5.8	40.0	50.0	26.0	15245.0
14.	pasang parengpeng	1.2	254.0	7.0	10.0	49.0	27.0	513.5
15.	mara	1.1	148.5	5.0	60.0	39.0	30.0	4060.0
16.	kianak	0.8	121.5	4.0	75.0	40.0	30.0	26660.0
17.	kawoyang	2.2	157.0	5.8	50.0	70.0	25.0	42600.0
18.	jirak	2.6	133.0	5.5	50.0	72.0	20.0	4165.0
19.	huru minyak	2.8	204.0	4.0	80.0	68.0	23.0	4200.0
20.	kacapi	1.4	132.0	5.5	50.0	65.0	22.0	4970.0
21.	huru hiris	0.7	127.0	5.8	48.0	58.0	28.0	17950.0
22.	huru buah	2.7	504.0	4.5	60.0	50.0	29.0	1545.5
23.	dawolong	1.7	144.0	6.0	40.0	62.0	27.0	1580.0
24.	kibonteng	2.9	364.0	4.5	10.0	58.0	28.0	950.5
25.	bengang	3.1	231.5	6.8	10.0	60.0	28.0	1419.5