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Conservation Area at Cirebon Quarry (Mt. Blindis) ands It's Potency in Carbon Sequestration
(Kawasan Konservasi di Quarry Cirebon (Gunung Blindis) dan Potensinya dalam Sekuestrasi Karbon)

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ABSTRACT
The biodiversity conservation areas of Cirebon quarry, in this case Blindis and Sari mountains is a limestone ecosystem. Limestone ecosystems play an important role in climate regulation. Quantifying the organic carbon storage of limestone ecosystems in this area definitely helps to evaluate the roles of these ecosystems in both global and regional carbon cycles and also their impact on climate. This research was carried out to know the complete data of carbon storage in Cirebon quarry on each ecosystem types. In deep, it will give information which ecosystem and carbon pool that contributes the highest carbon stock. The carbon stock calculating methods in above-ground was based on RaCSA (Rapid Carbon Stock Appraisal) methods. Based on the observation, there are three ecosystem types in Cirebon Quarry i.e. Opened Area, Thick Bushes and Secondary Forest. The result showed that Secondary forest had the highest total C-stock which was 87.18 t C ha^{-1}, while the C-stock on Thick Bushes and Opened Area were 42.95 and 17.92 respectively. The total C stock in biodiversity conservation area of Cirebon Quarry was 148.05 t C ha^{-1} comprises 48% of C plant biomass and 52% of C soil.

Key words: carbon stock, Cirebon quarry, limestone area

ABSTRAK
Kawasan konservasi biodiversitas di Quarry Cirebon (Gunung Blindis dan Gunung Sari) merupakan ekosistem batu kapur (*limestone*). Ekosistem batu kapur memiliki peranan yang besar dalam regulasi iklim. Estimasi kandungan karbon organik yang tersimpan pada area ini penting dilakukan untuk mengevaluasi peranan ekosistem batu kapur dalam siklus karbon baik global maupun regional dan juga pengaruhnya terhadap iklim. Penelitian ini dilakukan untuk melengkapi data karbon tersimpan dalam Quarry Cirebon pada masing-masing ekosistem. Lebih jauh lagi, penelitian ini dapat memberikan informasi ekosistem mana dan karbon pool mana yang memberikan sumbangan terbesar dalam menyimpan karbon. Penghitungan karbon pada atas tanah, berdasar pada metode RaCSA *(Rapid Carbon Stock Appraisal)*. Berdasarkan hasil pengamatan, ada tiga tipe ekosistem dalam kawasan konservasi biodiversitas Quarry Cirebon, yaitu area terbuka (OA), semak belukar (TB), dan hutan sekunder (SF). Hasil penelitian menunjukkan bahwa kawasan hutan sekunder memiliki total simpanan karbon terbesar, yang mencapai 87,18 t C ha^{-1}, sementara simpanan karbon di kawasan area terbuka dan semak belukar adalah berturut-turut 42,95 t C ha^{-1}dan 17,92 t C ha^{-1}. Total karbon stok dalam area konservasi biodiversitas Quarry Cirebon adalah 148,05 t C ha^{-1} terdiri dari 48% karbon dari biomasa tanaman dan 52% karbon tanah.

Kata Kunci: Stok karbon, tambang galian Cirebon, area batu gamping

INTRODUCTION

Karst ecosystem is an important type of landscape, since its cover 12% of the land area in the world. In South-East Asia, karsts cover an area of about 400.000 km^2. However, this karst area is covering about 154.000 km^2 in Indonesia and lay on about 5.414,48 km^2in Java island (Indonesia) (Anonymous 2015). Most of the karst region in Indonesia is composed of limestone.

Tropical forests over limestone are an important component of land cover in the tropics and for this reason they play an important role in carbon balance of this region. Moreover, tropical forests over limestone can store huge amounts of C in both above ground biomass and soil (Proctor *et al.* 1983). However, tropical forests over limestone in Xishuangbanna, South West China resulted in C stock (about 214 ± 28 t C ha^{-1}) (Tang *et al*. 2012) was still lower than C stock of Tahura R.Soerjo nature forest (East Java) on non-limestone (300 t ha^{-1}) (Hairiah *et al. in* Sari *et al.* 2011). From the C-stock of tropical forests over limestone in Xishuangbanna was known that the contribution of plant biomass in storing C was substantial, accounting for 80% of the total ecosystem C storage. The mean C stock of tree layer was 155 ± 24 t C ha-1 and the soil C stocks in this area were 50 ± 10 t C ha-1 (Tang *et al*. 2012). Higher percentage of C stock in plant biomass while lower percentage in mineral soil indicated that C stocks of the tropical forests over limestone would be more vulnerable to vegetation destruction than other tropical forests on non-limestone substrate. Unfortunately, the C storage and partitioning for tropical forests over limestone are rarely known.

Quarrying is now regarded as the primary threat to the survival of karst-associated species, and it will certainly exacerbate the biodiversity crisis in Southeast Asia, a megadiverse region that has the highest rate of natural habitat loss among the tropics. Cirebon quarry is located approximately 15 km west of Cirebon in the Kromong Mountains which is in area of sloping hills, moderate and steep with a height of about 250 meters above sea. To the north side of the active mining area, there is a small hill, called Mount Blindis. Further, the mount of Blindis is an area which is not accessed for mining activity, since it was dedicated as a biodiversity conservation area. Based on the biodiversity survey report in Heidelberg Cement 2014, this steep hill is entirely covered by the rocks making up this mountain is a rock and clay-limestone and also clay.

So far, there is no intensive research in Indonesia about the limestone area and its potency in Carbon storage. Due to this condition, this research becomes interesting and important to do.

The research was carried out to estimate the carbon storage in on each ecosystem types in Blindis mountain. In deep, it will give information which ecosystem that contributes the highest carbon stock and the carbon pool which will contribute highest carbon storage. Furthermore, the study could also become a pilot project of mining conservation area in Indonesia, in order to attract the others to do the similar action to save the environment.

METHODS

The study of carbon storage in biodiversity conservation area was located in M. Blindis, between 6°42'30" and 6°42'59" S and 108°23'15" and 108°23'50" E. The elevation of this area ranges from 60 and 250 m above sea level (Figure 1 and 2). Regarding the Indocement presentation 2014, the mean annual precipitation (2003-2013) is 1919 mm, and occurring between November and May, while the average annual temperature is 28°C.

Cirebon Quarry Biodiversity Conservation Area was divided into three area based on their ecosystems types. The three ecosystems types are Opened Area (OA), Thick Bushes (TB) and Secondary Forest (SF). The Opened Area (OA), were start opened since 1991, while there are no specific information about the age of vegetation in the other two areas. Next, the entire area was delineated using GPS (Global Positioning System), to assist determine the number of plot in the each area based on the extent of the area. This process further will analyze and produce a map by using Arc View GIS software.

Plots were made in each ecosystem types to calculate the carbon stock in the area. In total 11 representative plots of 2000 m^2(20m x 100m) for measuring woody plants with dbh (diameter at breast height) > 30cm (trees).While woody plants with dbh 5-30cm (saplings) were measured in 11 subplots of 200m^2 (40m x 5m).While ground cover was measured in 55 sub-subplots of 0.25 m^2 (0,5m x 0,5m) set up in each plot of all ecosystems types. Carbon

Figure 1. The Overview of Biodiversity Conservation Area (Mount Blindis)

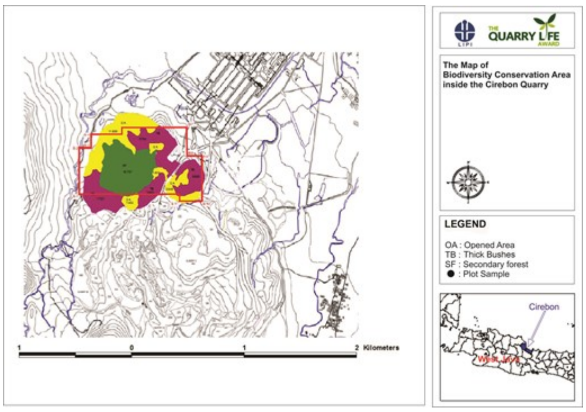

Figure 2. The Map of Biodiversity Conservation Area at the Cirebon Quarry

storage on each ecosystem type was estimated from five pools of carbon stock, which is above ground pools; consist of trees (dbh > 30cm), saplings (dbh 5-30cm), ground covers (plant that dbh< 5cm i.e. shrubs, herbs, seedling, and woody climbers) and the last one are litters. Whereas below ground pool is soil (0-20cm in depth).

The carbon stock calculating methods in above-ground was based on RaCSA (Rapid Carbon Stock Appraisal) methods (Hairiah *et al*. 2011). There are two allometric equations to calculate tree biomass such as $(AGB)est = 0.11\ \pi\ D^{2.62}$ (Ketterings *et al*. 2001) and $(AGB)est = \pi * \exp(-1.499+2.148\ \ln(D)+0.207(\ln(D))^2 - 0.0281\ (\ln(D))^3$. To be known, (AGB)est = tree biomass (kg/tree); D = dbh (diameter at breast height) (cm) ; π = wood density, ($g.cm^{-1}$). Harja *et al*. (2011), proved that the tree biomass (carbon stock) that assessed by allometric equation of Ketterings *et al.* (2001) and Chave *et al.* (2005) showed no significant difference in trees with diameter (DBH) < 60 cm. However, Harja *et al.* (2011) also showed that carbon stock assessment using Ketterings *et al.* (2001) allometric equation for DBH trees > 60 cm showed higher result than the Chave *et al.* (2005) equation. Due to the mean annual rainfall in Cirebon which is reach 1919 mm per year and also the specific ecosystem (limestone) that owned by Mt Blindis, allometric equation that used to estimate the tree biomass were based on the specific ecosystem (mean annual precipitation range 1500-4000 mm per year).

Wood densities of each species were measured manually. Each of the branches (three samples), were measured their length and diameter to get the volume. Then, these samples were dried in the oven at 100°C for 48 hours. Finally, their dry weights were weighed to get the wood density. The wood densities measurement was using branches and not the stem, to minimize the tree destructions. This method is already proven by Swenson and Enquist (2008), as a proper method to define the wood density on a tree species.

To measure groundcover biomassa is by weighing the wet and dry matter of groundcover samples. All groundcover materials that completely harvested from the subsubplots were transported to the laboratory for the next process. Similarly, litters that collected in the subsubplots also given the same treatment. The groundcover materials and litter samples were oven dried at 80□C for 48 hours and finally weighed. Estimation of root biomass was done by using default value that is based on the ratio of trees and root. The biomass ratio of trees and roots in the dry lands wet tropical forest is 4:1. Next, the trees, sapling, groundcover, litter and root biomass was converted into C-stock with with formula Hairiah *et al*. (2011):C = 0.46 x biomass

The soil organic carbon was calculated by determining the soil weight per hectar, in depth 0-20 cm. Then in the laboratory, the organic matter was determined by Walkey & Black oxidation method. While, soil bulk density was determine by gravimetric methods, which is taking soil sample at 0-10 cm and 10-20 cm depth with a cylindrical soil sampler in each plot. All of the carbon stock in each area was compared with the ecosystem types by the Analysis of Variance (ANOVA) with F test. And only $P < 0.05$, was listed as consider significant. The statistical analysis was done by MINITAB 14.0.

RESULTS

The biodiversity conservation area (Mt. Blindis) was divided into three ecosystem types which were Opened Area (OA), Thick Bushes (TB) and Secondary Forest (SF). The Opened Area comprised only groundcover lived there without any trees and saplings. In the Thick Bushes area, various types of bushes, shrub, herb or woody climber grown well. However, some trees and sapling still could found in a small number, while in the secondary forest was more difficult to access, since it had a sharp slope (45-60°). Based on the large of the area, thick bushes area had the largest area, that coverage 25.94 ha, while opened area had almost the same large as a secondary forest (Figure 3).

Based on the calculation, there was a significantly different of estimation carbon stock among the three ecosystem types ($P = 0.000$). Secondary Forest had the highest C stock reached 87.17 t C ha^{-1}, comprised about

59% of total C stock on the biodiversity conservation area of Cirebon quarry (Table 1.). While Thick Bushes and Opened Area ecosystem, contributed C stock 42.96 t C ha^{-1} (29 %) and 17.92 t C ha^{-1} (12 %) respectively.

There were six C pool in the ecosystem of Mt. Blindis such as trees, saplings, roots, ground covers, litters and soil (Table 1). C stock on trees in the Secondary Forest is 15.78 ± 8.72 t C ha^{-1} (mean ± standard error, the same below) which was higher than C stock of trees in Thick Bushes (1.65 ± 4.05 t C ha^{-1}). Other C pools in Secondary Forest (saplings, roots and litters) showed significantly different from C stock of same C pools in Thick Bushes and Opened Area. Whereas ground covers in Secondary Forest resulted lowest C stock.

In the Secondary Forest, C stock of biomass (trees, saplings, root, ground cover and litter) was higher than C stock of soil (Figure 4). Total C stock of biomass was 51.39 t Cha^{-1}, while C stock on soil 0-20 cm in depth was 35.80 t C ha^{-1}. Trees and saplings became the highest carbon pool (48.62 t C ha^{-1}) in this area.Whereas ground cover and litter contributed low C stock i.e. 1.14 t C $ha^{-1}$and 1.61 t C ha^{-1}, respectively. However, C stock of biomass in two other ecosystemswas lower than C stock of soil. In Thick Bushes area, the total C stock of trees, saplings, root and groundcover reached 11.73 t C ha^{-1}, stated lower than the C stock on soil 0-20 cm in depth, which is 26.45 t C ha^{-1}. Similarly, the C stock of biomass in the Opened Area only reached 2.53 t C ha^{-1} (ground cover biomass), while soil contributed 15.39 t C ha^{-1}.

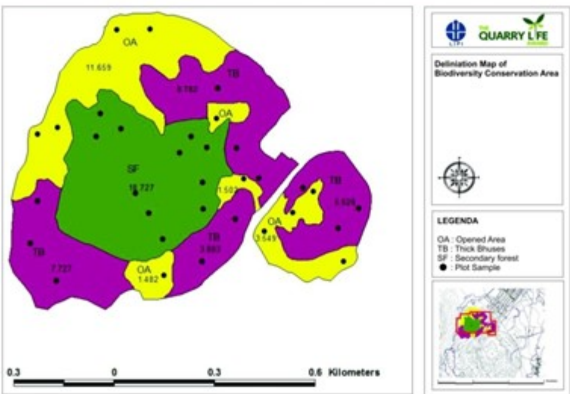

Figure 3. Delineation Map of Biodiversity Conservation Area (Mt. Blindis)

DISCUSSION

Since the biomass of tree/sapling was stated as the highest carbon pool, Secondary Forest became the highest carbon contributor in conservation area of Cirebon Quarry that was 87.17 t C ha^{-1}. Carbon stock of vegetation and soil in tropical forests over limestone was vary greatly depends on the topography, climate and geologic substrate (Vieira *et al.* 2004). C stock of secondary forest over limestone in Cirebon Quarry was much lower than forest over limestone in Xishuangbanna (183 t C ha^{-1}) (Tang *et al.* 2012). Xishuangbanna is one of karsts ecosytem in SW China with mean annual precipitation characterization about 1539 mm per year and that is meant not much different from Mt Blindis (1919 mm). The lower C stock of secondary forest in Cirebon Quarry than in Xishuangbanna was related to the lower contribution of trees/saplings biomass (48.62 t C ha^{-1}) compared with tree biomass on forest over limestone in Xishuangbanna (155 t C ha^{-1}) (Tang *et al.* 2012) and in Serawak (178 t C ha^{-1}) (Proctor *et al.* 1983). This condition was suspected due to thedensity of tree and saplingwhich was only 38 trees ha^{-1} and 682 saplings ha $^{-1}$.C stock of tree/sapling biomass in Cirebon Quarry conservation area was also lower than the non -limestone secondary forest in Prigen District, Pasuruan, East Java, (70.7 vs 48.62 t C ha^{-1}) (Sari *et al.* 2011). The difference of C-stock in this different area was related to the limited soil volume in forest over limestone that affects the limitation of water retention capacity and nutrient absorption. The limestone soils is shallow, in the Cirebon Quarry conservation area, the average depth of the soil was only 37 cm.

The other C pools in the Secondary Forest were root, groundcover and litter. C stock of root on this ecosystem that reached 9.72 t C ha^{-1} was lower than root C-stock in the forest over limestone in Xishuangbanna (31.72 t C ha^{-1}) (Tang *et al.* 2012). Sari *et al.* (2011) reported that in non-limestone secondary forest in Prigen District, Pasuruan, East Java was 14.12 t C ha^{-1}, higher than C stock of root biomass in Cirebon Quarry conservation area that only 9.72 t C ha^{-1}. These comparisons indicated that a higher proportion of tree biomass consequently will increase C stored in the roots.

Table 1. Carbon Stock on Each Carbon Pool in the Three Ecosystem Types (P<0.00, α< 0.05)

C pool/ Ecosystem Types	Trees (t C ha^{-1})	Saplings (t C ha^{-1})	Roots (t C ha^{-1})	Ground covers (t C $ha^{-1)}$	Litters (t C $ha^{-1)}$	soil (0-20 cm) (t C $ha^{-1)}$	Total C Stock (t C $ha^{-1)}$
OA	0 ^{a}	0 ^{a}	0 ^{a}	2.54 ± 0.54 ^{a}	0 ^{a}	15.39 ± 1.24 ^{a}	17.92 ^{a}
TB	1.65 ± 4.05 ^{a}	6.77 ± 10.11^{a}	3.31 ^{a}	4.78 ± 5.78 ^{b}	0 ^{a}	26.45 ± 7.25 ^{b}	42.96 ^{b}
SF	15.78 ± 8.72 ^{b}	22.93 ± 18.05 ^{b}	9.72 ^{b}	1.14 ± 0.64 ^{a}	1.61 ± 0.63 ^{b}	35.80 ± 10.35 ^{b}	87.17 ^{b}

Remarks: Different lowercase letters in one column denote significance difference among C pools in three ecosytems

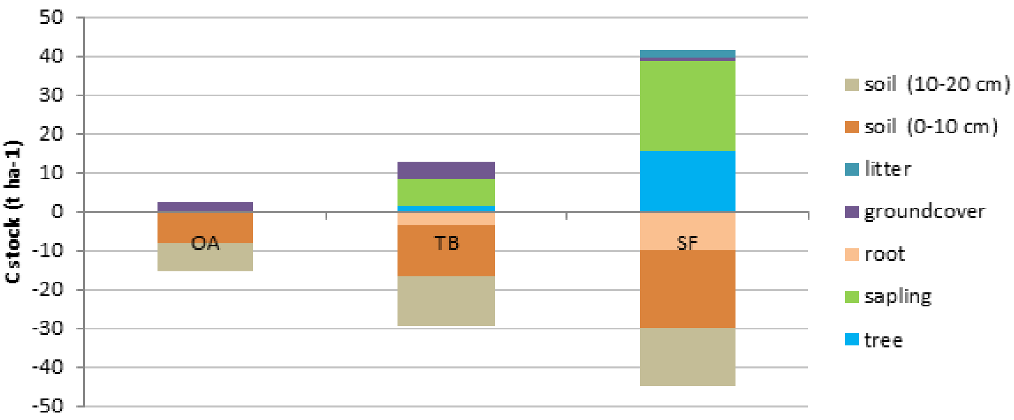

Figure 4. Total Carbon Stock in The Various Ecosystem Types of Cirebon Quarry Biodiversity Conservation Area

In the other hand, the C stock of ground cover in Secondary Forest showed higher than C stock of groundcoveron tropical forest over limestone in Xishuangbanna which is 1.14 t C ha^{-1} and less than 1 t C ha^{-1}respectively. However, this C stock was slightly lower than C-stock in the Prigen Districtsecondary forest that is 1.93 t C ha^{-1}. The last biomass C-pool is litters that constitute an important flux of soil organic C.

The litter C stock in the Secondary Forest of Cirebon Quarry reached 1,61 t C ha^{-1} that was slightly the same as the litter C-stock of tropical forest over limestone in Xishuangbanna but lower thanin thePrigen District secondary forest (Pasuruan, East Java) that reached 5.89 t C ha^{1}. Higher C stock in the litter was related to the higher precipitation (4267.5 mm yaer-1) and the lower average day temperature (21.9□C) in Prigen East Java than the rainfall and average day temperature in the Cirebon quarry, so the higher litter was produced (Sari *et al.* 2011).

The C stock of the top 10 cm soil in Secondary Forest in Cirebon Quarry reached 10 -20 t C ha^{-1}. This value was similar to the C stock soil of tropical forest over limestone in Xishuangbanna, but lower than the corresponding value which stated 50 t C ha^{-1} in the top soil of non-limestone tropical rainforest in Tahura R. Soerjo (Malang, East Java) (Hairiah *et al.* 2010). Soil C densities in forests of tropical Asia ranged from 50 to 120 t C ha^{-1} (Palm *et al.* 1986). The soil condition in the Cirebon Quarry was indicated as the lower end of tropical forest ecosystem in tropical Asia. Based on C pool contribution, C-biomass in Cirebon Quarry Secondary Forest contributed 52% of the total C pool while soil contributed 48%. In contrast, plants biomass in Xishuangbanna forests limestone contributed 80% of the total C pool while soil only 20%. This condition showed that the Secondary Forest in Cirebon Quarry was being degraded.

In the other case, C stock biomass in Opened

Area (2.53 t C ha^{-1}) and Thick Bushes (4.78 t C ha^{-1}) were lower than C stock of soil which were 15.39 t C ha^{-1} and 26.45 t C ha^{-1} t C ha^{-1} respectively. The comparison between C stock of plant biomass and C stock of soil in these two ecosystems was 20-40%: 80 -60%. This was indicated that Opened Area and Thick Bushes ecosystems were formed after the forest was degraded in the past. Compared with other tropical forests in other areas and on non-limestone like in Venezuela, Delaney *et al*. (1997) found that soil contained as much or more C than plant biomass. Similarly, soil comprised more than 40% of the ecosystem C stocks in a secondary tropical forest in Philippines. So didthe C stock of soil in the degraded forest in Konto Watershed which showed 55% of C soil and 45 % C plant biomass (Sari *et al.* 2011)

Generally, total C stock in biodiversity conservation area of Cirebon Quarry was148.05 t C ha^{-1} comprised 48% of C plant biomass and 52% of C soil. While overall, ecosystem C stock in tropical forests over limestone in Xishuangbanna was 214 t C ha^{-1} comprises 80 % of C plant biomass and 20% of C soil (Tang *et al.* 2012). This condition was indicated that the C soil was stored before forest degraded. The low C stock plant biomass condition in Cirebon Quarry indicates that there is should be an increasing carbon sequestration from 48.62 (C stock of tree/sapling in Cirebon Quarry) to 155 t C ha^{-1} (C stock of tree/sapling in Xishuangbanna).

The tropical limestone forest like forest in Mt Blindis has potency as a large reservoir of atmospheric CO_2; this information can be added by calculating the carbon stock in biodiversity conservation area of Cirebon Quarry. In addition, by applying result suggested in the research, which is planting native species in restoration program this ecosystem could increase their C sequestration and also maintain and enrich its biodiversity. This program could be done with native species that had high wood density and easily propagated, such as Tutup (*Malotus tanarius),* Walikukun (*Schoutenia ovata*), Rukam lanang (*Scolopia spinosa*), kemloko (*Emblica officinalis*), Kesambi (*Schleichera oleosa*) and Anggrung (*Trema orientalis*). In fact, needs more than 30 years to reached C-stock to the ideal condition, but it will worth since the ecosystem services (the amount of CO_2 absorption) that resulted will also increase. In addition, other program such as monoculture plantation system will result lower C stock. Monoculture plantation such as sengonbuto (*Enterolobium cyclocarpum*), pine (*Pinus merkusii*), mahogany (*Swietenia mahagony*) and *Paraserianthes falcataria* are timber trees, that will be harvest in 30, 50, 15 years later, so that carbon emission will be happened. In contrast, forest conservation area will provide the highest carbon stock and store carbon for longer time. Forest conservation with native plants also conserves local animals such as birds and mammals. Restoration with mango (*Mangifera indica*) at the buffer zone between the quarry and a nearby village could be alternatives, since mango trees could be utilized by local people. Study result on mango plantation inside the Cirebon quarry showed that this plantation could store 61.5 t C ha^{-1}in 5 years. However, since Mount Blindis was stated as the biodiversity conservation area, it is important to increase the species diversity and species richness inside the area by doing the proper restoration program.

CONCLUSION

Secondary forest had the highest C-stock which was 87.18 t C ha^{-1}, while the C-stock on Thick Bushes and Opened Area were 42.95 t C ha^{-1}and 17.92 t C ha^{-1}respectively. The total C stock in biodiversity conservation area of Cirebon Quarry was 148.05 t C ha^{-1} comprised 48% of C plant biomass and 52% of C soil. Restoration program could be the suitable solution to increase C sequestration in this area.

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REFERENCES

Anonymous, 2015. Profile Ekoregion Jawa: Ekosistem Karst http://ppejawa.com/ekoregion/ekosistemkarst/. Diakses tanggal 10 Mei 2015

Delaney M, S. Brown, AE. Lugo, A. Torreslezama & NB. Quintero. 1997. The distribution of organic carbon in major components of forests located in five life zones of Venezuela. *Journal of Tropical Ecology* 13: 697–708

Hairiah, K., A. Ekadinata, RR. Sari & S. Rahayu. 2011. Pengukuran Cadangan Karbon : dari tingkat lahan ke bentang lahan. Petunjuk Praktis. Edisi ke dua. Bogor World Agroforestry Center, ICRAF SEA Regional Office, Universitas Brawijaya. Malang. 66 p.

Harja D, S. Dewi, FX. Heryawan, & M. van Noordwijk. 2011. Forest carbon-stock estimates based on National Forest Inventory data. ALLREDDI Brief 02. World Agroforestry Centre (ICRAF) Southeast Asia Program. Bogor, Indonesia:

Palm, CA., RA. Houghton & JM. Melillo. 1986. Atmospheric carbon dioxide from deforestation in Southeast Asia. *Biotropica* 18: 177–188.

Proctor J, JM. Anderson, P. Chai & HW. Vallack. 1983. Ecological studies in four contrasting lowland rain forests in Gunung Mulu National Park, Sarawak. I. Forest environment, structure and floristics. *Journal of Ecology* 71: 237–260.

Sari. RR., K. Hairiah, Widianto, S. Rudianto, & F. Rahman. 2011. Potensi Hutan Alam dan Agroforestri sebagai Cadangan Karbon di Kecamatan Prigen, Kabupaten Pasuruan. Proceeding of Seminar National 47 th Dies Natalis Forestry Departemen. Gajah Mada University. Yogyakarta. Indonesia. 341-353 p.

Swenson, NG & BJ. Enquist. 2008. The Relationship Between Stem and Branchwood Specific Gravity and The Ability of Each Measure to Predict Leaf Area. *American Journal of Botany* 95 (4): 516-519.

Tang, JW, JX Yin, JF Qi, MR Jepsen, XT Lu. 2012. Ecosystem Carbon Storage Of Tropical Forests Over Limestone In Xishuangbanna, South West China. *Journal of Tropical Forest Science* 24(3): 399–407.

Vieira S, PB. De Camargo, D. Selhorst, R. Da Silava, L. Hutyra, JQ. Chambers, IF. Brown, N. Higuchi, J. Dos Santos, SC. Wofsy, SE. Trumbore & LA. Martinelli. 2004. Forest structure and carbon dynamics in Amazonian tropical rain forests. *Oecologia* 140: 468–479.