ECODEV ECODEVELOPMENT JOURNAL

Ecodevelopment Journal
Vol. 3 No. 1 (8-13)
https://jurnal.unpad.ac.id/ecodev

cess.unpad.ac.id

# CARBON STOCK IN TREE BIOMASS IN FOREST- AGRICULTURAL LAND USE IN WEST JAVA (CASE STUDY: CIJENDIL VILLAGE, CIANJUR)

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## ABSTRACT

*The study was attempted to reveal the biomass carbon (C) stock in forest-agricultural land use in West Java agricultural landscape. We scoped on agroforestry as agricultural land use and identified three main types of agroforestry in the study site: bamboo talon, mixed-tree talun and albizia {Albania falcataria (L.)) talun. For this study purpose, a survey method was used. Carbon stock measurement was done by using RaCSA (Rapid Carbon Stock Appraisal) method. In this measurement, we used two different approach to acquire biomass C stock data: sampling approach in the forest and census approach in agroforestry. The result showed that the average biomass C stock in natural forest was higher than in agroforestry. The natural forest stored biomass C stock around 97.30 MgC/ha while bamboo /ofun, mixed-tree talun and albizia talun [Albania falcataria (L.)) approximately stored 50.01 Mg C/ha, 38.57 Mg C/ha, 17.39 Mg C/ha respectively. However, comparing with other similar studies, the average of biomass C stock in both of natural forest and agroforestry land was categorized in a medium and small range.*

**Keywords:** Agroforestry, Carbon Stock, Climate Change, Forest, Tree Biomass.

## INTRODUCTION

Both forest and agroforestry have a variety of functions in terms of ecological and socio-economic aspect. While forest functions are much more stressed in ecological function such as biodiversity and ecosystem integrity (Soemarwoto et al., 1992), agroforestry compromises both of ecological and socio- economic function in order to fulfill local people's basic needs while maintain ecosystem function (Muhamad et al, 2013). Thus, many agroforestry systems are developed based on biophysical and socio-economic aspects, which make many variations of its vegetation structures (Parikesit et al, 2004).

*Talun* is one kind of popular agroforestry system in West Java which has important role for supporting the needs of society, such as the need for firewood for household energy and its sustainability (Okubo et al, 2010; Muhamad et al, 2014). In addition, *talun* also has ecological function as barriers to erosion, soil water storage, maintain organic matter dynamics (Christanty et al, 1996) and carbon storage in terms of indirect benefits ecosystem services which those functions are found in the forest as well (Millenium Ecosystem Assessment, 2005).

In the context of climate change, talun as one of agroforestry systems could be the reliable option to mitigate climate change issue as the forest cover has been shrinking (Albrecht et al 2003; Verchot et al 2007). With its dominance of perennial plants and variety, talun has similarities stratification with forest which lead talun to have a high potential carbon stock in terms of regulating services as high as in the forest. Moreover, agroforestry systems are believed to have a higher potential to sequester carbon than pastures or field crops (Albrecht et a1 2003; Nair et a1 2009) by maximizing individual density and multistratifying canopy layers (Okubo et a1, 2010). By incorporating tree in croplands and pastures, it would result in greater net aboveground as well as belowground carbon sequestration (Palm et al, 2004; Haile et al, 2008).

Therefore, regarding with the climate change issue, *talun* system can be used as carbon sink pool despite the presence of forests as a primary carbon pool to sink carbon. In addition, this system can be the best alternative for mitigating climate change when natural forest especially in Indonesia is still experiencing many problems such as deforestation or converted into other type of land use.

On the other hand, disappearance *talun* may give significant effects on the environment which associated with its ecological functions such as carbon loss. In fact, many existence of agroforestry systems has changed and converted to other land use as the fulfillment of human needs such as population growth, expansion of intensive farming systems and industrial sector emerges (Parikesit et al, 2004).

Cijedil village in Cianjur is one of village which still maintains the concept of *talun* as for fulfilling the needs of livelihood subsistence, such as the need of animal feeds, firewood, and others for its local people (Muhamad et al, 2014). In addition, that village also nearby the forest which make forest and *talun* as a landscape unity. Furthermore, this landscape is part of national strategic area as a water catchment area to maintain hydrological function ruled by Government Regulation No. 26/2008 about spatial planning of Jabodetabekpunjur as well as designated to be agropolish, economic and environmental conservation strategic area as ruled by local government regulation No. 17/ 2012. However, the information about carbon stock potential in the study area are poor. Thus, the carbon stock study in forest and agroforestry in this village is relevant to reveal the potential carbon stockto deal with sustainable land use planning and management in further.

## METHODS

### 2.1. Study Site

Research location was the agricultural landscape in Cijedil, including natural forest under management of the Regional State-owned Forest Enterprise *{Perum Perhutani)* of Cianjur, Perhutani Unit III West Java and Banten and agroforestries owned by local people. Administratively, the location is included in the Cijedil Village, Subdistrict of Cugenang, Cianjur City. This location was located around 7 — 9 km from City of Cianjur and around 62 — 65 km from provincial city capital in elevation of 600 — 1200 meter above sea level (asl). The mean daily temperature is about 22 °C and the daily maximum temperature ranges from 25 to 30 °C. The annual precipitation is approximately 2,000 mm, with a rainy season (October—June) and short dry season (July—September). The following is a map of study site.

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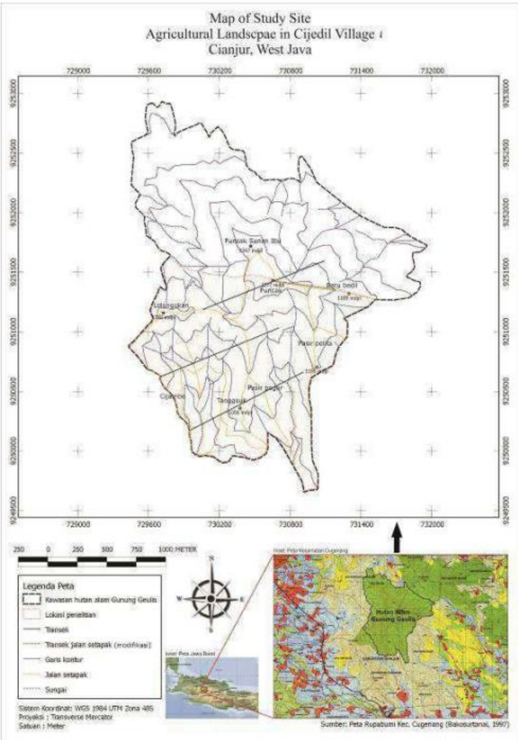
**2.2. Carbon Stock Measurements**

Technique of RaCSA (Rapid Carbon Stock Appraisal) was applied to measure the carbon stock. The first step was identification of biophysics characteristics in study area so that zonation and stratification system of land cover or land use could be obtained. Further, determination of sampling plot design was done to measure carbon in plot scale. In this study, sampling technique approach was used for estimating carbon stock in natural forest and census technique approach was used for measuring carbon stock in agroforestry.

This carbon stock measurement was carried out on the aboveground, which is focused on tree biomass as carbon pool. This was considered in total calculation of this assessment based on the significant carbon pool in the calculation of C in forest cover, i.e. tree biomass (Brown, 1999). For both tree biomass measurement in natural forest and agroforestry, non- destructive sampling was applied (Hairiah & Rahayu, 2007).




1) Carbon Stock Measurement in Natural Forest.

In carbon stock measurement, different tree category based on Hairiah & Rahayu (2007) was used. C stock sample plot measurements using rectangular plots of 5x40 meters (sub-plot) for small trees category (DBH 5-30 cm) and 20xl00 meters (large plot) for large trees category (DBH> 30 cm). Each plot was placed at the interval of 100 meters elevation, and plots were layed along three line transect, so there were 6 sample plot measurements over a range of 800-1300 meters elevation.

For measuring tree biomass, data collected included DBH (Diameter at Breast Height) of each individual tree of plant species. If there were a monocot and unbranched trees, the DBH was also counted for that species (Hairiah & Rahayu, 2007). Density (p) of each plant species mainly referred to Brown (1997) and global wood density database compiled by Zanne et al (2009). Density which was not found in the literature was calculated directly by cutting wood sample from one of the branches then measured the length and diameter as well as weighed its fresh weight. Wood sample was dried into the oven at 100° C for 48 hours. Then the volume and its density were calculated by the following formula;

$$Volume\ (cm^3) = \pi r^2 T \quad and \quad \rho\ (g/cm^3) = \frac{Dry\ weight\ (g)}{Volume\ (cm^3)} \qquad (1)$$

where *r* is the stem diameter (cm), *T* is the length of wood sample (cm), and *p* is the density.

In case the plant species is not known in the literature, characteristics of plant species was also identified to know the exact species of plants so that specific density could be analyzed. Wood sample was taken with a size of 10 cm x 10 cm x 10 cm. That sample was measured and then putted into the oven at 80°C for 48 hours to calculate its density as the previous formula (Hairiah & Rahayu, 2007).

2) Carbon Stock Measurement in Agroforestry.

Based on preliminary survey, there were 113 *talun* divided in three main type, namely bamboo *talun,* mixed-tree *talun* and Albizia *talun.* The numbers of those selected talun were 66, 37 and 10 for bamboo *talun,* mixed-tree *talun* and Albizia *talun* respectively. Then, we determined *talun's* sample size which were going to be sampled. We used Lynch's equation with *simple random sampling* approach (1974) to determine those sample size. The equation as following:

$$nT = \frac{NT.Z^2.P.(1-P)}{NT.d^2+Z^2.P.(1-P)} \qquad (2)$$

Note:
nT : Total sample number
NT : Total population number
Z : Value of normal variable (1,96)
P : The highest possibilities proportion (0,50)
D : Sampling error (0,10)

Based on Lynch's formula, the numbers of ia/on which must be sampled were 74 in total; 39 for bamboo *talun,* 26 for mixed-tree *talun* and 9 for Albizia *talun.*

In general, carbon stock measurement in agroforestry same as its measurement in natural forest which refers to RaCSA. The differences was that we used census approach in this measurement. The plot size was the *talun* size its self due to the *talun's* size depend on the owners and its vary. All tree species in the selected *talun* was recorded. Further, the mesurement method that was used same as the measurement in natural forest.

**2.3 Data Analysis**

The first step for carbon stock analysis was calculating the carbon content, which was stored in trees biomass. Tree biomass was calculated using allometric equations developed by some reliable authors as shown in Table 1. For branched and unbranched tree biomass equations, according to Kettering, et al. (2001), this equation was not site-specific model but it has converted into more flexible model to measure tree biomass upon cutting and weighing the tree was not possible to carry out. In order to obtain a total tree biomass per area (kg/m$^2$), tree biomass of all trees found on the study site were summed, both categories of large trees and small trees. For measuring trees biomass both of in natural forest and agroforestry, the formula showed in the following equation:

**Tabel 1.** Biomass estimation using allometric equation

| Plant species | Biomass estimation (kg/tree) | References |
|---|---|---|
| Branched trees | BK = 0.11 ρ D $^{2.62}$ | Ketterings, 2001 |
| Unbranched trees | BK = π ρ H D$^2$/40 | Hairiah et al, 1999 |
| *Musa* spp. | BK = 0.030 D$^{2.13}$ | Arifin, 2001 |
| Bamboo | BK = 0.131 D$^{2.28}$ | Priyadarsini, 2000 |
| Albizia | BK = 0.0272 D$^{2831}$ | Sugiharto, 2002 |

where *biomass* is expressed in kg, *BK* is dry weight, *H* is length or height of tree (cm), *D* is tree diameter (cm) and p is wood density (g/cm$^3$)

Data processing of tree biomass was distinguished between the large trees category (DBH> 30 cm) and small trees category (DBH = 5-

30 cm). Total of trees biomass data were summed and estimated of the total amount of biomass stock at the site. The concentration of C in organic materials was usually around 46%, therefore the estimated amount of C stock per component or category can be calculated by multiplying the total weight of the mass concentration of C; biomass dry weight (kg/ha) x 0.46. Then, the weight unit kilogram (kg) was converted to megagram (Mg) and summed in each component or category.

## RESULTS AND DISCUSSION

### 3.1 Carbon Stock in Natural Forest

Based on carbon measurement using RaCSA method, the result of C stock amount in trees biomass in forest-agricultural land use in study site can be seen in following table.

**Tabel 2.** C estimation in tree biomass in forest-agricultural land use in study site

| Type of land use | Study site size (ha) | C Total (Mg C) | Average (Mg C/ha) |
|---|---|---|---|
| Natural forest | 1.2 | 295.06 | 98.35 |
| Bamboo *talun* | 2.1 | 1951.02 | 50.01 |
| Mixed-tree *talun* | 2 | 982.59 | 38.57 |
| Albizia *talun* | 0.4 | 156.55 | 17.39 |

According to Tabel 2, namral forest still has a higher carbon amount than ta/on by 98.35 Mg C/ha. This amount even still twice as much as the highest carbon content in iafon with approximately 50.01 Mg C/ha in bamboo *talun.* It shows that the trees density and biomass in the forest are higher than in *talun* land use.

In the context of forest carbon, Harja et al (2011) recorded the typical aboveground carbon stock of forest in Indonesia ranges from 16.92 — 92.73 Mg C/ha based on National Inventory Data (NFI). In addition, some list of carbon stock estimates of forest in some regions is showed in the following table 3.

This forest carbon stock tend to have a high potential for carbon storage compared to other type of forests listed in Table 2 and compared to the range of aboveground carbon stock estimates based on NFI data. Based on FAO statistics, aboveground area of forest stores the second biggest amount of carbon, as much as 234 Pg C, after the soil component (Kindermann et al, 2008). One of factors affecting C stocks in an area is depend on the density of vegetation. The higher rate of tree density will determine the higher biomass. Thus, the C stock would be larger (Rahayu, et al, 2005). In addition, the main factors influencing tree biomass were the height of the trees and wood density.

However, carbon stock amount in study site tend to be lower when compared to some similar studies on the type of same land use as natural forest. PHKA-TNGHS (2007) recorded 134.10 MGC / ha of C stock contained on tree biomass in the Mount Halimun-Salak National Park (TNGHS). Widyatmoko, et al. (2011) recorded 332.62 MGC / ha of C stock located in the Mount Gede Pangrango National Park (TNGP). Also, Tuhono (2010), who reported 279.55 MGC / ha of C stock in the region Mount Leuseur National Park (TNGL). By those recorded datas, we found that there were differences amount of potential carbon stock between the national park and the secondary forest such study site in this forest.

It was happened because of the differences in the composition and trees abundance. Natural Reserves Park or National Park such as TNGHS, TNGP, and TNGL, which are a conservation area, has undisturbed or less-disturbed vegetation conditions compared to natural forest in study site which is not

a conservation area. In the study site, there were several open space areas, especially around the peak, which indicate disturbance in this forest. In addition, historically, there was a massive illegal logging in this forest by local people due to economic crisis in the past. Thus, tree abundance that was still well maintained in conservation area gives a great contribution to the high carbon stock in the forest.

**Table 3.** List of carbon stock estimation in different forest type and region

| Region | Forest Type | C stocks estimates (Mg C/ha) in AGB | References |
|---|---|---|---|
| Asia | Tropical Forest | 144 | Brown et al, 1993 |
| | Tropical Forest | 185 (average maximum) ; 25 - >300 (range) | Iverson et al, 1993 |
| | Tropical Forest | 40 - 250 | Palm et al, 1986 |
| Southeast Asia | Tropical Forest | 25 - 215 | Brown et al, 1991 |
| | | 175 - 200 (condition before human incursion) | |
| Indonesia | Tropical Forest | 161 - 300 [1] | [1] Mudiyarso, 1995; [2] Noordwijk, et al, 2000; [3] Hairiah, et al, 2000 |
| | Highland Secondary Forest (Agathis forest 40y) | 113.2 | Dharmawan, 2010 |
| | Highland Secondary Forest (Agathis forest 17y) | 39.48 | Dharmawan, 2010 |
| Philippines | Natural Forest | 86 - 201 | Lasco, et al, 1999 |
| | Old growth forest | 185 - 260 | Houghton, et al, 1997 |
| Thailand | Various forest type | 72 - 182 Mg/ha (C density) | Boonprago b, 1998 |
| Malaysia | Tropical Forest | 100 - 160 Mg/ha (C density) | Abu Bakar, 2000 |
| | Lowland forest | 216 | |
| Singapore | Secondary Forest, Bukit Timah Nature Reserve | 104.5 (38% of total) | Ngo, et al 2013 |

*AGB = Above-Ground Biomass *BGB = Below-Ground Biomass

### 3.2 Carbon Stock in Agroforestry

Based on Table 2 previously, bamboo *talun* has the highest amount of carbon stock from the two others type although both of these *talun* types are dominated by perennial plant. This condition, however, make improperly with Widianto's (2003) statement. He stated that the highest carbon stock was contained in biomass perennial plants which categorized as timber plants or used timber. In this study, we found the highest carbon stock in bamboo *talun* while bamboo is considered non timber perennial plant categorized.

There is an explanation that the carbon stock on bamboo *talun* has a higher amount than the other *talun* types. Bamboo is a plant species from Poaceae family, which has clumps characteristic. One clump of bamboo is defined or counted as one individual. In the study site itself, we found that in one clump of bamboo may be composed by 20 until 30 bamboo stem. Thus, the carbon stock in bamboo talun has a higher amount than mixed-tree *talun* and Albizia *talun.*

In addition, the use of allometric equations reference can allow any difference calculation result as well. Time and cost consideration become the main reasons to use the allometric equation. In this study, the bamboo has been putted into the category unbranched trees allometric equation (Hairiah et a1, 1999). The allometric equation for unbranched trees is used for general condition, as it can also be used for other unbranched types of crops such as palm or coconut. Thus, it is still allowing a bias and is less specific.

Another factor that determines the difference in carbon stock amount is in terms of the age of plant. In this study, we hardly determines age of plant in mixed-tree *talun* due to irregular planting pattern so that we could not discover and obtain the information its age of plants. Thus, we did not analyze the carbon stock in *talun* regarding the age of its plant, which we admit that it was the handicap in this study.

Furthermore, the plant species planted and dominating in mixed-tree *talun* derived from the fruit production category, which means no logging activities on individual plants for the benefit of its timber production. It is different with bamboo and Albizia *talun,* where the purpose used in those *talun* are for the harvesting of the planted individuals. Periode of harvesting time makes it quite easy to determine the age of the plant.

In bamboo talun, it usually will be harvested when 4-6 years old, while Albizia is harvested when approximately 8 years old. In the study site, the ages of Albizia plant were found to be quite relatively young, most of it often found at the age of 4 years old, and the oldest was 6 years old, but in small proportion. This leads to the condition of small amount of carbon storage in this *talun.*

Albizia crops ‹*Albania falcataria* (L.)) is still relatively new in this village. This commodity came around in early 2000, which introduced by one of the owners *talun* which is not a native peoples of Cijedil Village. By the time goes by, just a few villagers started following to plant Albizia, therefore the amount of Albizia *talun* in this village just a less amount. In addition, some other *talun* owners prefer to plant Albizia with other commodities such as fruit production plants, so their land uses are more diverse in composition (mixed-tree *talun).*

However, although the amount of carbon stock in bamboo *talun* in study site is lower than carbon stock in natural forest, it has a higher amount when it is compared with other several type of agroforestry in some regions. The following table is listed some of similar studies which assess carbon stock in agroforestry system.

From Table 4, it is known that there are a wide variety of carbon stock amount in agroforestry systems. Basically, this is happened due to these agroforestry systems have diverse composition of plants in the area which will affect to the amount of carbon stock.

**Table 4**. Vary studies of the potential of carbon stock on tree biomass in agroforestry systems

| Area | Type of agroforestry | C stock average | References |
|---|---|---|---|
| Northern Japan | Bamboo garden *Sasa kurilensis* | 63.1 Mg C/ha | Aoyama et al, (2011) |
| Riau, Indonesia | Bambo garden Belangke (*Gigantochloa pruriens*) | 14.08 Mg C/ha | Suprihatno, et al (2012) |
| Jawa Barat, Indonesia | Homegarden agroforestry | 23.60 Mg C/ha | Kurniawan (2010) |
| Jawa Tengah, Indonesia | Hutan Rakyat Albizia 6.5 year | 57.40 Mg C/ha | Sianturi (2004) |

When the study result is compared with similar studies with bamboo plantation as a main studies as shown in Tabel 3, the results of the carbon stock in bamboo *talun* at Cijedil village has adequate higher amount (50.01 Mg C/ha) than Suprihartono's et al study (2012) in Riau (14.08 Mg C/ha). It is even almost equal to the amount of carbon stock in biomass of dwarf bamboo *{Sasa kurilensis)* plantation (Aoyama et al, 2011). This indicates that the potential of the local bamboo at Cijedil village which dominated by *Awi tali (Gigantochloa apus* (JA & JH Schultes) Kurz) has almost equal potential with foreign bamboo commodities. This bamboo's potential could be developed due to the presence of bamboo is already shifted, because the prices for this commodity are much lower than other crops such as Albizia.

On the other hand, we tried to compare mixed-tree talun with another similar study conducted by Kurniawan (2010) on carbon stock assessment of tree biomass in homegarden agroforestry. The similarity between mixed-tree *talun* and homegarden is in the plant component, which is dominated by fruit trees and annual crops. As shown in Table 3, mixed-tree *talun* has higher level of carbon stock than homegarden agroforestry.

For Albizia *talun,* carbon stck potential in tree biomass at Cijedil Village lesser than Sianturi's research results (2004) who assess the potential of carbon stock in Albizia/Sengon's
*{Albazia falcataria* (L)) biomass. Even so, the age of the plants that were examined in this study are much younger around 4 years old so that the carbon stock amount is still could be enhanced as the time goes by.

### 3.3 Agroforestry as Green House Gases Mitigation

Using agroforestry system, including *talun,* as option to mitigate climate change is well recognised (Albrecht et al, 2003) yet performance of mitigation options in agroforestry will depend on the relative influence of tree species selection and management, design of planting schemes (Nair et al, 2009) soil characteristics, topography, rainfall, agricultural practices, priorities for food security, economic development options, among others (Mbow et a1, 2013). These agroforestry practices are based on a variety of management approaches and have potential positive implications for climate change mitigation (Kandji, 2003). It has been shown that agroforestry systems have 3—4 times more biomass than traditional treeless cropping systems (Smith & Wollenberg, 2012).

Furthermore, Mbow et a1 (2013) described fully about positive and negative implications of agroforestry for mitigation and adaptation on climate change as shown in Table 5.

However, the example of positive and negative implications as Mbow et al (2013) proposed is not quite shown in agroforestry practices in our study site. According to Muhamad et al (2014), just a few people who use fertilizer for their own bamboo *talun,* over-used extract of non-timber product and timber product in theirs another talun. In contrast, the most dominant bamboo *talun* in the agricultural landscape ensures that non-organic fertilizer is less used, soil and biomass carbon sequestration is maintained and it becomes as a part of integral protection of forest reserves simultaneously.

**Table 5.** Examples of positive or negative implications of agroforestry practices for adaptation or mitigation to climate change (Mbow et al, 2013)

| | | Mitigation | |
|---|---|---|---|
| | | Positive | Negative |
| Adaptation | Positive | Soil carbon sequestration, improved water holding capacities, use of manure instead, mixed agroforestry for commercial products, income diversification with trees, reduced nitrogen fertilizer, fire management | Dependence on biomass energy, overuse of ecosystem services, increased use of mineral fertilizers, poor management of nitrogen and manure, over extraction of non-timber products, timber extraction |
| | Negative | Integral protection of forest reserves, limited rights to agroforestry trees, forest plantation excluding harvest | Use of forest fires for pastoral and land management, tree exclusion in farming lands |

In addition, agroforestry systems can meaningfully reduce the pressure on natural forests for energy needs. Some authors assume that higher consumption of tree products would motivate farmers to adopt agroforestry (Mitchell et a1, 2011), in particular where fuel wood is diminishing. Development of agroforestry for sustainable fuel wood can contribute to energy substitution and becomes an important carbon offset option (Unruh, 1993; Mbow et al, 2013).

Moreover, Rao et al (2007) outlined that agroforestry systems with appropriate shade trees offer a promising option to moderate the effects of heat stress locally. It is apparent that shade would create microclimates with lower seasonal means in ambient temperature and solar radiation as well as smaller fluctuations (Rao et al, 2007). In other words, agroforestry play a critical role in moderating the microclimate.

Beyond the function as carbon pool, agroforestry options also may provide a means for diversifying production systems and increasing the sustainability of smallholder farming systems. The most worrisome component of climate change from the point of view of smallholder farmers is increased interannual variability in rainfall and temperature (Verchot et a1, 2007). In this case, agroforestry also has a role to play in helping smallholder farms adapt to climate change (Verchot et al, 2007).

Based on our observation, agroforestry practices in the study site seemed as some authors described above which means it is highly possibility to promote agroforestry practices in our study site to be designed and developed as local initiative for climate change adaptation and mitigation. However, the limitation of understanding of socio-economic of the local farmer and some relevant data related to this issue is the main challenge for further research.

## CONCLUSION

The study reveals that the amount of carbon stock in natural forest was twice higher than *talun.* However, although the *talun* lands have lower carbon amount than forest, by the result we have shown and discussed above, it still has a high potentiality to be improved in order to enhance its carbon stock considering the socio-economic of the local farmer and some other relevant factors aimed to promote the importance of traditional agriculture model practiced by local people as part of mitigation response to climate change issue.

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