Carbon Stock in Integrated Field Laboratory Faculty of Agriculture University of Lampung

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ABSTRACT

This study aimed to determine the amount of carbon stock and CO$_2$ plant uptake in the Integrated Field Laboratory (IFL) Faculty of Agriculture University of Lampung. The research was conducted from April to November 2015. The study was arranged in a completely randomized block design (CRBD), consisting of five land units as treatment with four replications for each treatment. Biomass of woody plants was estimated using allometric equation, biomass of understorey plants was estimated using plant dry weight equation, and organic C content in plants and soils were analyzed using a Walkley and Black method. The results showed that land unit consisting of densely woody plants significantly affects total biomass of woody plants, organic C content in woody plants and total carbon content (above and below ground). The highest amount of woody plant biomass was observed in land unit 5, i.e. 1.196.88 Mg ha$^{-1}$, and above ground total carbon was 437.19 Mg ha$^{-1}$. IFL Faculty of Agriculture University of Lampung has a total carbon stock of 2,051.90 Mg and capacity to take up total CO$_2$ of 6,656.88 Mg.

Keywords: Allometric equations, biomass, CO$_2$ plant uptake, organic-C, total carbon

INTRODUCTION

Forest plays an important role, among others, as a source of carbon stock in nature, in which carbon is stored as vegetative biomass and soil carbon. Conversion of forest into other land uses has led an increase of CO$_2$ emission into atmosphere, which is derived from biomass burning and mineralization of soil organic carbon during clearing, and loss of vegetation as carbon sink (C-sink) (Wudianto et al. 2003).

A strong increase of CO$_2$ concentration has a direct effect on climate change, Mudiyarso (2004) suggested that climate change is caused by an increase of greenhouse gases (GHG) concentrations, such as CO$_2$, N$_2$O, CH$_4$, CO, etc. Intergovernmental Panel on Climate Change (IPCC 2007) reported three major greenhouse gases, namely CO$_2$, CH$_4$, and N$_2$O, since their concentrations in atmosphere are increasing up to twofold recently (Hairiah 2007). At this moment, the amount of carbon dioxide in atmosphere has been enormous, which is about 1,305
One way to control the amount of CO$_2$ in the atmosphere is by increasing the amount of CO$_2$ uptake by plants as much as possible and mitigating CO$_2$ emission into atmosphere as low as possible (Lasco 2002). Forest preservation, tree cultivation on agricultural land and peat preservation are important actions to mitigate excessive amounts of CO$_2$ in the atmosphere. On the other hand, long term intensive farming can decrease the amount of soil organic matter and increase CO$_2$ emission into atmosphere (Sleutel et al. 2006; Nieder and Richter 2000). Therefore, measuring the amount of carbon stored in plants (biomass) on a certain land use can indicate the amount of CO$_2$ in the atmosphere that is taken up by plants (Hairiah and Rahayu 2007).

The amount of carbon stock in each land use varies, depending on diversity and density of vegetation, soil types, and soil management. Carbon stock in a land use can be higher if the soil has good fertility status, or in other words the above ground of carbon stock (vegetative biomass) is determined by the amount of carbon stock in soil (soil organic matter, SOM) (Hairiah and Rahayu 2007). Negash and Starr (2015) reported that the carbon stock in herbage was lower than that in coffee plants, and the highest carbon stock was found in trees. In addition, Chiti et al. (2012) indicated that different amount of carbon stock is also determined by climate regime and landscape.

Integrated Field Laboratory (IFL) Faculty of Agriculture University of Lampung is a field that can be used for doing research and practicum for lecturers and students of Faculty of Agriculture University of Lampung, which is located at the campus of University of Lampung, covering about 6.784 ha. Banuwa, Syam and Wiharso (2011) showed that IFL has various slopes, based on slope classification IFL has five different land units, namely land unit 1 with slope of 0-3% (level) covering about 0.737 ha; land unit 2 with slope of 3-8% (gently sloping) covering about 0.245 ha; land unit 3 with slope of 8-15% (undulating) covering about 3.417 ha; land unit 4 with slope of 15-30% (hilly) covering about 2.034 ha; and land unit 5 with slope of 30-45% (gently steep) covering about 0.351 ha. With various slopes (level up to gently steep) IFL has a high potential erosion, as a result the soil is vulnerable to lose nutrient and organic matter, which are important for plant growth and development. As a supporting facility of learning activities for academia at the University of Lampung, environmental sustainability and soil fertility of IFL should be maintained.

The objective of this study was to determine the carbon stock in IFL Faculty of Agriculture University of Lampung with various slopes.

**MATERIALS AND METHODS**

**Location of the Study**

The study was conducted at Integrated Field Laboratory and analysis of soil organic carbon was conducted at Laboratory of Soil Chemistry, Faculty of Agriculture, University of Lampung. The research was performed in April until November 2015. The map of IFL was presented in Figure 1.

**Calculation of Carbon Stock**

Biomass of woody plants was estimated using allometric equation, without destructing the plants (non destructive). Observations were conducted by recording the names of trees, measuring the diameters of trees at breast height (dbh), i.e. 1.3 m above ground using a measuring tape, and measuring the height of woody plants at the experimental plots (5m x 5m) for each land unit using christen meter, then the biomass was calculated using allometric equation. Allometric equation used in this study was developed by Alternative to Slash and Burn (Table 1) (Hairiah and Rahayu 2007). Biomass of understorey plants was estimated by destructing the plants and then the biomass was calculated using plant dry weight equation. Observation was performed by cutting the understorey plants at the experimental plots (1m x 1m) and weighing the plants, and then 100 g of understorey plants were oven-dried at 80°C for 48 h and weighed in. Biomass of understorey plants was calculated using total plant dry weight equation, namely:

$$\text{Total dry weight} = \frac{\text{dry weight of sub sample (g)} \times \text{total fresh weight (g)}}{\text{fresh weight of sub sample (g)}}$$

The content of organic C in woody plants and understorey plants were analyzed using Walkey and Black method (Thom and Utomo 1991). About 0.03
Figure 1. Map of Integrated Field Laboratory Faculty of Agriculture University of Lampung, Lampung, Indonesia (Banuwa et al. 2011).

9406850 9406800 9406750 9406700 9406650 9406600 9406550 9406500 9406450

Observation spot in each land unit
North

Map of Land Units

Sumatera

Slope classification:
0 - 3% Gently slope
3 - 8% Gently sloping
8 - 15% Undulating
15 - 30% Hilly
30 - 45% Gently steep

Size (m²)

1 to 5:
7.374
2.445
3.510

Code of land units

30.170
20.340
0

56789 1011

1234

526650
526700
526750
526800
526850
526900
526950
527000
527050
527100
527150
527200

Observation spot in each land unit

Map of Land Units

Sumatera

The above ground carbon stock was calculated after the data of plant biomass and organic C content in plants were collected, then the above ground carbon stock was calculated using equations developed by Alternative to Slash and Burn (Hairiah and Rahayu 2007). The amount of carbon uptake by plants was calculated using the following equation (Rifyunando 2011).

$$\text{CO}_2 \text{ uptake} = \frac{\text{Mr CO}_2 \times \text{C content}}{\text{Ar C}}$$

Mr CO$_2$ = molecular weight of CO$_2$ (44)
Ar C = atomic weight of C (12)

Data Analysis

The data of woody plant biomass, understorey plant biomass, organic C content in woody plants, organic C content in understorey plants and total

Table 1. Estimation of Tree Biomass using Allometric Equations.

| Type of tree          | Estimation of tree biomass, kg per tree | Reference               |
|-----------------------|----------------------------------------|-------------------------|
| Branched tree         | BK = 0.11p D$^{2.62}$                  | Ketterings (2001)       |
| Non-branched tree     | BK = πp H D$^{2.40}$                   | Hairiah et al. (1999)   |
| Banana tree           | BK = 0.030 D$^{2.13}$                  | Arifin (2001)           |
| Bamboo                | BK = 0.131 D$^{2.28}$                  | Priyadarsini (1999)     |
| “Sengon” tree         | BK = 0.0272 D$^{2.831}$                | Sugiharto (2002)        |
| Necromass             | BK = πp H D$^{2.40}$                   | Hairiah dan Rahayu (2007) |

Notes: DW = Dry Weight; D = diameter of stem; p = wood density; H = Height of tree
carbon were statistically tested using analysis of variance (ANOVA) and least significant difference test (LSD) with a significance level of 5%.

RESULTS AND DISCUSSION

Above ground Carbon Stock

The amount of woody plant biomass in each land unit at IFL varies. The highest amount of woody plant biomass was observed in land unit 5, i.e. 1,196.88 Mg ha\(^{-1}\) and the lowest amount of biomass was found in land unit 2, i.e. 237.43 Mg ha\(^{-1}\). The amount of plant biomass is determined by the number of stands and the number of population of woody plants in a land unit, land unit 5 with slope of 30 – 45% (gently steep) is rarely used for cultivation for both practicum and research, as a result the population of woody plants in land unit 5 is abundant and diverse, and the predominant plant species observed is woody plants. In addition, land unit 5 is densely covered by woody plants. In contrast, in land unit 2 (slope of 3 – 8%), which is classified as gently sloping, the amount of woody plant biomass is very low because the land unit 2 is frequently used as experimental plots for both practicum and research, which are cultivated with food crops, such as maize, sorghum and cassava, and interplanted with some coconut trees, consequently the amount of plant biomass in land unit 2 is the lowest among other land units (Table 2).

The results of this study showed that the amount of understory plant biomass in different land units is not significantly different. Land unit 1 is dominated by paddy fields and fish ponds including some coconut trees and “pasiran” trees. As a result, the land was uncovered and hardly any shade that can hamper the growth of understory plants was observed. Chang (1968) and Chambers (1978) suggest that shade can affect environmental factors, such as temperature, soil moisture, aeration, nutrient immobilization and weed control. The non-significantly different of the amount of understory plant biomass in different land units is also observable for the non-significantly different of organic C content in understory plants.

The content of organic C in woody plants among land units is significantly different, which is due to the diversity of woody plants in each land unit, land unit 4 has the lowest organic C content in woody plants among other land units, i.e. 36.07%, which is not significantly different from land unit 1 that has 41.02% organic C content. This finding is due to the diversity of plant species in land unit 4 and 1 is relatively similar, which is dominated by banana trees and some coconut trees. On the other hand, land unit 2 (46.50%), land unit 3 (44.49%) and land unit 5 (43.02%) have the highest organic C content in woody plants among other land units, due to the number of plants in those land units are higher than that in land unit 1 and 4.

The above ground carbon stocks in land unit 1, 2, 3, 4 and 5 are 143.07 Mg ha\(^{-1}\); 88.79 Mg ha\(^{-1}\); 260.71 Mg ha\(^{-1}\); 327.04 Mg ha\(^{-1}\); and 437.19 Mg ha\(^{-1}\), respectively, in which land unit 5 has the highest total carbon stock, i.e. 437.19 Mg ha\(^{-1}\). The main source of above ground carbon stock is woody plant biomass that grows in land unit 5 including ketapang trees (*Terminalia catappa*), bayur trees (*Pterospermum acerifolium*), “pasiran” trees, randu trees (*Ceiba pentandra*), coconut trees, sugar palm trees (*Borassus falbellifer*), waru trees

| Land Unit | Biomass of Woody Plants Mg ha\(^{-1}\) | Biomass of Understory Plants Mg ha\(^{-1}\) | Organic C in Woody Plants % | Organic C in Understory Plants % | Total Aboveground Organic C Mg ha\(^{-1}\) |
|-----------|--------------------------------------|------------------------------------------|-----------------------------|---------------------------------|---------------------------------|
| 1         | 372.97 ab                            | 0.147 (0.38) a                          | 41.02 ab                    | 34.34 a                         | 143.07 ab                      |
| 2         | 237.43 a                             | 0.098 (0.31) a                          | 46.50 b                     | 27.79 a                         | 88.79 a                        |
| 3         | 655.28 abc                           | 0.11 (0.33) a                           | 44.9 b                      | 35.54 a                         | 260.71 abc                     |
| 4         | 938.80 bc                            | 0.12 (0.34) a                           | 36.07 a                     | 31.13 a                         | 327.04 abc                     |
| 5         | 1,196.88 c                           | 0.11 (0.33) a                           | 43.02 b                     | 29.66 a                         | 437.19 c                       |

LSD 5% 669.26 0.07 (0.09) 5.51 8.76 254.91

Note: Value followed by the same letter in the same column were not significantly different according to LSD test for 5%. Value in parantheses were transformation by $\sqrt{x}$.
(Hibiscus tiliaceus) and bamboo. Plants take up CO\textsubscript{2} from the atmosphere, which is further converted into C\textsubscript{6}H\textsubscript{12}O\textsubscript{6} and O\textsubscript{2} that is released into atmosphere, and food stock (i.e. carbohydrate molecules) that is stored as biomass. On the other hand, land unit 2 has the lowest above ground carbon stock, i.e. 88.79 Mg ha\textsuperscript{-1}. With slope of 3-8% that is classified as gently sloping, land unit 2 is an ideal land for cultivation, consequently land unit 2 is frequently used for experimental plots for both practicum and research, and generally cultivated with annual crops and food crops. As a result, the above ground organic carbon stock in this land unit is the lowest among other land units.

Bouwman (1990) suggested that plants as carbon sink helps to mitigate CO\textsubscript{2} in the atmosphere via photosynthesis, in which CO\textsubscript{2} is taken up and converted by plants into organic carbon in the form of biomass. Biomass can absorb energy, which is further converted into carbon in plants, especially in woody plants. The absolute carbon content in biomass or the amount of carbon stored in biomass is called carbon storage or carbon stock (Apps et al. 2003).

**Soil Organic Carbon**

The content of organic C in top soils (0 – 20 cm) is between 1.51% and 1.96%. Table 3 presents the content of soil organic C in each land unit.

The content of soil organic C indicates the amount of carbon taken up by plants via photosynthesis, which further goes into soil via decomposition and accumulate in soil. High soil erosion rate can lose carbon that stored in soil (Banuwa 2013). The content of soil organic carbon also indicates the condition of plants that cover the land. In uncovered lands, the ability of plants to take up carbon via photosynthesis is smaller than that of plants in covered lands. Higher organic carbon content in soil indicates higher above ground photosynthesis process in which carbon is found.

Table 3. The content of soil organic C.

| Land Unit | Size (ha) | Organic C (%) | Organic C (Mg ha\textsuperscript{-1}) | Organic C (Mg per size of land unit) |
|-----------|-----------|---------------|---------------------------------------|-------------------------------------|
| 1         | 0.737     | 1.59          | 31.8                                  | 23.44                               |
| 2         | 0.245     | 1.96          | 39.2                                  | 9.60                                |
| 3         | 3.744     | 1.89          | 37.8                                  | 129.16                              |
| 4         | 1.708     | 1.51          | 30.2                                  | 61.43                               |
| 5         | 0.351     | 1.84          | 36.8                                  | 12.92                               |
| **Total** | **6.785** | **-**         | **-**                                 | **236.55**                          |

Sumber: Banuwa et al. (2011)
Table 4. The amount of plant biomass, total aboveground organic C and CO₂ uptake.

| Land unit | Total biomass (Mg ha⁻¹) | Total aboveground organic C (Mg ha⁻¹) | CO₂ uptake (Mg ha⁻¹) |
|-----------|-------------------------|-------------------------------------|---------------------|
| 1         | 373.35                  | 143.07                              | 524.65              |
| 2         | 237.74                  | 88.79                               | 325.60              |
| 3         | 655.60                  | 260.71                              | 956.03              |
| 4         | 939.14                  | 327.04                              | 1,199.27            |
| 5         | 1,197.21                | 437.19                              | 1,603.17            |
| total     | 3,403.05                | 1,256.81                            | 4,608.72            |

Table 5. Total biomass, total aboveground organic C and CO₂ uptake.

| Land unit | Size (ha) | Total biomass (Mg per size of land unit) | Total aboveground organic C (Mg per size of land unit) | Total CO₂ uptake (Mg per size of land unit) |
|-----------|-----------|------------------------------------------|------------------------------------------------------|------------------------------------------|
| 1         | 0.737     | 275.16                                   | 105.45                                               | 386.67                                   |
| 2         | 0.245     | 58.25                                    | 21.75                                                | 79.77                                    |
| 3         | 3.744     | 2,454.59                                 | 976.11                                               | 3,579.38                                 |
| 4         | 1.708     | 1,604.05                                 | 558.59                                               | 2,048.35                                 |
| 5         | 0.351     | 420.22                                   | 153.45                                               | 562.71                                   |
| total     | 6.784     | 4,812.27                                 | 1,815.35                                             | 6,656.88                                 |

**Total Carbon**

Total carbon stock in IFL Faculty of Agriculture University of Lampung is presented in Table 6.

The results showed that land unit 5, which is densely covered by woody plants, significantly affect total biomass, total above ground organic C and CO₂ plant uptake, i.e. 1,197.21 Mg ha⁻¹, 437.19 Mg ha⁻¹ and 1,603.17 Mg ha⁻¹, respectively. The more plants with dense canopy, the more CO₂ is taken up by plants (Table 4). This finding corresponds to the study of Banuwa and Buchori (2010) about carbon stock in various farming systems of coffee plantation. The study showed that P5 farming system (i.e. mixed farming system including coffee, pepper, banana and cocoa) consists of more plant population with highly dense canopy, as a result the availability of soil organic carbon is abundant, which further leads to high soil microbial activity. Based on this condition, P5 farming system has the highest stock of organic carbon. However, because the size of land unit 5 at IFL Faculty of Agriculture University of Lampung is only 0.351 ha, its contribution to total carbon and CO₂ plant uptake at IFL Faculty of Agriculture University of Lampung is not that high (Table 6).

**CONCLUSIONS**

Land unit 5 (gently steep with slope of 30-45%) has the highest total biomass of woody plants among other land units, i.e. 1,196.88 Mg ha⁻¹ and the highest total above ground carbon, i.e. 437.19 Mg ha⁻¹. IFL Faculty of Agriculture University of Lampung has total carbon stock of 2,051.90 Mg and total CO₂ plant uptake of 6,656.88 Mg.
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