Comparative Analysis of Carbon Sequestration Potential of Secondary Forest and Mango (*Mangifera indica*) + Coconut (*Cocos nucifera*) Multistorey Agroforest Stand in Salikneta Farm-De La Salle Araneta University - Agrivet Science Institute, San Jose Del Monte, Bulacan, Philippines

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Abstract: Global warming is now considered one of the most serious environmental problems brought about by the excessive emissions and accumulations of greenhouse gases (GHG) in the atmosphere with carbon dioxide being the most detrimental. At present, this phenomenon is already inevitable but mitigation can still be done through the regulation of GHGs emissions from several sources. Terrestrial ecosystems like forests have the ability to absorb carbon dioxide from the atmosphere and use it for their growth and food production via the process of photosynthesis. This study therefore aims to estimate the carbon sequestration potential of two land-uses namely, secondary forest and mango + coconut multistorey agroforest stand inside Salikneta Farm-De La Salle Araneta University – Agrivet Science Institute in San Jose, Del Monte, Bulacan. To accomplish this, a one-hectare sample area was laid-out in both sites and followed by the measurements of diameter at breast height (dbh) and tree height for all trees above 5cm dbh. Soil samples were likewise collected for soil bulk density and percent soil carbon determination. The data gathered from tree measurements were plugged in the biomass allometric equation published by Chave et al. (2014). Results of soil carbon density and tree carbon density were combined to provide a complete estimate of the potential of a particular stand of its carbon stock. Total carbon density and total carbon sequestered were estimated and the values for both stands were subjected to t-test. With a value of 73.630 MgC ha^{-1} in secondary forest and 60.084 MgC ha^{-1} for Ma+Co multistorey agroforest stand for total carbon density, analysis suggests that no significant difference exists between the two land-uses. Similarly, there was also no significant difference between the two land-uses in terms of potential carbon it can sequester with values of 269.977 MgC ha^{-1} and 220.308 MgC ha^{-1} for secondary forest and agroforest, respectively. With regard to the most dominant vegetation in both stands, *Ficus nota* and *Bursera graveolens* were found to be the most numerous species in multistorey and secondary stands, respectively, thereby suggesting that these species must be properly conserved in the area to maintain its potential for carbon dioxide sequestration. On the other hand, *Mangifera indica* and *Delonix regia* registered the highest carbon stored in its biomass in multistorey agroforest stand and secondary forest, respectively, hence, they are also recommended to be conserved by the Salikneta management.

Key Words: Global warming; Biomass; Carbon sequestration; Carbon density; Allometric equation; Importance values; Species-area curve

1. INTRODUCTION

Global warming is one of serious environmental concerns of the current generation primarily caused by the excessive emissions of greenhouse gases (GHGs) particularly carbon dioxide (CO_2) being the major culprit (Rohrer, 2007.). This particular phenomenon is now on the stage where it cannot be stopped but its adverse effects can be attenuated by regulating the emissions of GHGs. Forest ecosystems can play two distinct roles in terms of regulating CO_2 emissions into the atmosphere. They can act either as a source of or a sink for carbon (Lasco et al., 2004). As a source, the trees inside the forest contribute to the amount of CO_2 in the atmosphere via the processes of cellular respiration/metabolism and decomposition. In general, decaying organisms release their organic molecules i.e. carbon into their environment. As a sink, on the other hand, these trees absorb CO_2 from the atmosphere and use it for their growth and food production via photosynthesis. This study therefore aimed to estimate and compare the carbon sequestration potential of the two land-use systems inside Salikneta Farm-De La Salle Araneta University – Agrivet Science Institute in San Jose Del Monte, Bulacan in order to provide additional information to the current knowledge about the significant role of trees in global warming.

2. METHODOLOGY

For the secondary forest and mango (*Mangifera indica*) + coconut (*Cocos nucifera*) multistorey agroforest stand of Salikneta Farm, a one-hectare sample area was demarcated for both. Trees found inside each stand were subjected to diameter at breast height (dbh) and height measurements in which only those with at least 5 cm dbh were considered. The data gathered here were plugged in the biomass estimation allometric equation published by Chave et al (2014). From here, the aboveground biomass was and carbon stocks were estimated.

$$Y = 0.0673\, x\, (\rho D^2 H)^{0.976} \qquad \text{(Eq. 1)}$$

where:

Y = tree biomass
ρ = wood density
D = diameter at breast height
H = tree height

To provide a more complete picture of the total carbon stocks of each stand, soil samples were collected for soil bulk density and percent soil carbon determination to represent the belowground carbon pool which was then added to the data of aboveground carbon stocks.

$$\text{Bulk density} = \frac{Mass\ of\ dried\ soil\ (g)}{Canister\ volume\ (cc)} \quad \text{(Eq.2)}$$

Soil Carbon density = Weight of soil * %SOC (Eq. 3)

where: Weight of soil (kg) = bulk density * 3000 m^3
%SOC is percentage of soil carbon

Additional methods performed include vegetation analysis in which the most dominant species for both stands were determined in terms of their importance values (Equations 4-7). Another was the species-area curve which determined what should be minimum area required for the study (Cencini et al., 2012).

$$\text{Relative Density} = \frac{No.of\ individuals\ of\ given\ species}{Total\ number\ of\ trees} \quad \text{(Eq.4)}$$

$$\text{Relative Frequency} = \frac{Frequency\ of\ given\ species}{Total\ frequencies} \quad \text{(Eq. 5)}$$

where: Frequency of species = $\frac{ji}{k}$
ji refers to the number of sampling points the individual trees of the given species are found
k refers to the total number of sampling points

$$\text{Relative Coverage} = \frac{Area\ covered\ by\ given\ species}{Total\ basal\ area\ covered\ of\ all} \quad \text{(Eq. 6)}$$

where: Tree basal area = πr^2, r is dbh divided by 2

Importance Value = RD + Rf + RC (Eq. 7)

3. RESULTS AND DISCUSSION

Total forest biomass consists of aboveground biomass, ground biomass, and belowground biomass. Aboveground biomass refers to the trees and its parts in general; ground biomass includes the understorey vegetation as well as literfall. Lastly, belowground biomass consists of the soil and the roots. This paper focused only on the aboveground and belowground biomasses which were represented by the trees and soil. For aboveground biomass calculations, the allometric equation of Chave et al. (2014) was used due to it being the most recently published one and more importantly it included more parameters for better accuracy.

Table 1. Aboveground biomass and carbon density of the two land-use systems

Land-use system	Aboveground biomass (Mg)	Aboveground carbon density (Mg C ha^{-1})
Secondary forest	10.863	4.888
Multistorey agroforest	12.498	5.624

Table 1 showed that the Ma+Co multistorey agroforest have a higher aboveground biomass and carbon density compared to the secondary forest. Carbon density was calculated from the biomass assuming that 45% of it was composed of carbon (Lasco & Pulhin, 2000). Possible reason for the difference could be that the trees inside the multistorey agroforest have wider diameter than the trees in the secondary forest as attested by Orpia (2003) that lower biomass accumulation can be related to smaller diameter at breast height. However, with regards to soil carbon, the results were different (Table 2).

Table 2. Soil bulk density and carbon density determined from the two land-use systems

Land-use system	Sample	Bulk density (g/cc)	%SOC	Carbon density (Mg C ha^{-1})
Secondary forest	1	20.336	1.24	75.649
	2	18.278		67.994
	3	17.808		66.245
	4	17.495		65.081
Multistorey agroforest	1	19.078	0.92	52.656
	2	20.997		57.952
	3	19.206		53.010
	4	19.585		54.055
	5	19.760		54.538

Table 2 showed that the secondary forest have a higher soil carbon density primarily due to the higher percentage of organic carbon present in its soil. According to Neumann-Cosel et al. (2010), the higher soil carbon storage can be attributed to the age of the land-use since the amount of time elapsed is directly proportional to the amount of carbon and accumulated in its biomass; hence suggesting that the secondary forest is much older compared to the Ma+Co multistorey agroforest stand. Furthermore, it was also worth noting that the soil from the Ma+Co multistorey agroforest have a higher bulk density which means the soil found there was more compact compared to the soil from the secondary forest.

Combining the aboveground and soil carbon densities of both stands would give an appropriate estimate of the total carbon density of each land-use system.

Table 3. Aboveground and belowground carbon stored from the two land-use systems

Land-use system	Carbon pool	Carbon stocks (Mg C ha^{-1})
Secondary forest	Trees	4.888
	Soil	68.742*
	TOTAL	73.630
Multistorey agroforest	Trees	5.624
	Soil	54.442*
	TOTAL	60.084

*Values displayed are mean of different samples

The amount of total atmospheric carbon dioxide sequestered was also obtained by simply multiplying the total carbon stocks into the factor of 44/12, which represents the molar ratio between carbon and carbon dioxide (Greenamity.org, n.d.).

Table 4. Estimated carbon dioxide sequestered by the two land-use systems

Land-use system	Sequestered CO_2 (Mg CO_2 ha^{-1})
Secondary forest	269.977
Multistorey agroforest	220.308

The overall carbon stocks of the secondary forest was higher compared to the total carbon stored in the Ma+Co multistorey agroforest, however, the difference was small enough to be considered not statistically significant to one another. One reason for this was the close proximity of the two sites being just adjacent to each other and the only possible factors which contributed to the difference could be the variation in species of trees found in each stand, the degree of cultivation and maintenance, and could also be the age of the two systems.

To further examine the potential of the two stands in carbon sequestration, vegetation analysis was performed in order to look which tree species were dominant for both stands and to also provide a database of the different tree species found in each stands for monitoring and maintenance purposes.

Table 5. Importance values of the different tree species found within the secondary forest of Salikneta Farm

Species	RD	RF	RC	Importance Value
Bauhinia monandra	27.083	17.391	4.669	49.144
Bursera graveolens	27.083	21.739	2.938	51.761
Cassia fistula	6.250	8.696	9.130	24.075
Delonix regia	4.167	4.348	45.473	53.988
Ficus nota	14.583	17.391	2.198	34.173
Gmelina arborea	10.417	17.391	29.543	57.351
Pterocarpus indicus	4.167	4.348	4.815	13.329
Swietenia macrophylla	6.250	8.696	1.233	16.178

Table 6. Importance values of the different tree species found within the mango+coconut multistorey agroforest stand in Salikneta Farm

Species	RD	RF	RC	Importance Value
Cassia fistula	13.636	8.333	1.156	23.125
Cocos nucifera	4.545	8.333	1.632	14.511
Ficus nota	54.545	33.333	2.871	90.750
Mangifera indica	27.273	50.000	94.341	171.613

Tables 5 and 6 showed the different tree species present in both stands along with their respective importance values. Results showed that the most numerous species for secondary forest and multistorey agroforest are *Bursera graveolens* and *Ficus nota*, respectively. The most dominant species based on their importance values were *Gmelina arborea* for the secondary forest, while *Mangifera indica* for the multistorey agroforest. In terms of total carbon stored, species of *Delonix regia* and *Mangifera indica* registered the highest for secondary forest and multistorey agroforest, respectively. Thus, strongly suggesting that both stands to be properly conserved and monitored due to their carbon sequestration potentials.

Lastly, species-area curve was performed in order to address the optimum size of the sites for the study to be done by simply considering the dominant and common plant species (Cencini et al., 2012). Specifically, the carbon sequestration potential of using only 3 plots were compared to the carbon sequestration potential of using 5 plots, as well as 7 plots using single factor ANOVA.

Table 7. Results of the ANOVA for the secondary forest stand

Number of quadrats	*p*-value
3	0.100
5	0.169
7	0.314

Table 8. Results of the ANOVA for the mango+coconut multistorey agroforest stand

Number of quadrats	*p*-value
3	0.047
5	0.645
7	0.051

Table 7 showed that there was no significant difference in terms of carbon sequestration potential which means that it does not matter how many plots were used in this study since it would yield the same trend even when only three plots were used. Hence, suggesting that the optimum size, for the secondary forest of Salikneta Farm, in conducting carbon sequestration studies would be 300 m^2 only. On the other hand, Table 8 showed that the mean carbon sequestration potential computed using only three plots were significantly different compared to using five and/or seven plots. This means that using only three plots would not be enough in order to obtained good results. Furthermore, using five and seven plots did not show any significant difference to one another, therefore implying that using only five plots or 500 m^2 of sample area would be sufficient enough since the trend of the study would be only the same even if the number of plots used was to increase.

4. CONCLUSIONS AND RECOMMENDATIONS

Forest ecosystems can act either as source of or sink for carbon dioxide. This study looked at the ability of the two forest ecosystems of Salikneta Farm, the secondary forest and mango + coconut multistorey agroforest stand, to sequester and store carbon in their biomass. The results showed that the secondary forest have a higher total carbon density and total carbon sequestered than the multistorey agroforest but were not significantly different from each other. This can be attributed to the close proximity between the two stands approximated to have 250 m distance from each other.

This work is a baseline study to determine the carbon sequestration potential of the secondary forest and Ma+Co multistorey agroforest stand inside Salikneta Farm; therefore a follow-up study is recommended on the same sites to confirm the findings or obtain better results. This study focused only on the aboveground and belowground carbon pools hence it is recommended for the follow-up studies to consider as well the litterfall and understorey vegetation for a much complete result of the total carbon density of the two sites. Further recommendations would include a longer timeline and annual data collection for the study since carbon accumulations vary in time and as well as to properly monitor the conservation of the two stands.

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