CARBON STOCKED AND CARBON DIOXIDE SEQUESTERED BY EIGHT-YR ALNUS (*Alnus japonica*)

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Abstract

The amount of carbon stocked and carbon dioxide sequestered by eight-year old *Alnus* trees were estimated using a destructive sampling method. The carbon contents were computed using the published average values for tropical trees which is 45 – 50 percent of dry matter and the CO_2 sequestered was computed based on the published CO_2 to C ratio which is 3.6663. The research was conducted in May 2012 at an *Alnus* stand at the BSU-College of Forestry, La Trinidad, Benguet.

The average above-ground biomass (AGB) and below-ground biomass (BGB) of the *Alnus* trees was 140.99 kg per tree, and their average oven-dry weight was 70.91kg per tree. The AGB was 71.56%, and the BGB was 28.44% of the total biomass. The computed biomass of the *Alnus* trees using a published formula is much lower; their average AGB is 24.665%, their BGB is 12.58%, and their total computed biomass is 21.18% of the actual biomass.

Based on the oven-dried weight data, the computed average carbon contents of the *Alnus* trees was 31.91kg per tree, and the average carbon dioxide they sequestered was 116.999 kg per tree in eight-years, or an average of 14.63 kg per tree per year.

Base on the findings, *Alnus* trees can approximate or exceed the published average CO_2 sequestration rate for mature trees which is 48 lb per year. Further, a hectare *Alnus* plantation with an average of 2m x 2m spacing cansequester about 292.6 tons of CO_2 in eight years, or an average of 36.575 tons of CO_2 per year which is equivalent to the CO_2 emissions of about 16 persons.

Key Words: Carbon stock, CO_2 sequestration, above-ground and below-ground biomass, artificial Alnus stand

INTRODUCTION

Human population and biodiversity are in peril due to the adverse climatic changes that include the continuing rise of the earth's temperature. Climate change is attributed mainly to human activities that enormously increase greenhouse gases in the global atmosphere (UNFCC, 1994). The human activities resulting to the increase of emissions of carbon, a major greenhouse gas, include logging, slash and burn cultivation, range land burning, mining and industrialization.

Scientists estimate that carbon emission in the atmosphere has increased by 30% since the pre-industrial time of the 1800's and continued to increase at an average rate of 0.4% per year (Lasco, 2004). Carbon dioxide concentration increased from 280 ppm during the pre-industrial period (1750-1800) to 353 ppm in 1990 (IPCC, 1990 as cited by Lofrango, 2006). As announced by US monitors, the level of CO_2 in the atmosphere has gone over 400 ppm for the first time in human history; data as of May 9, 2013 showed that daily CO_2 over the Pacific Ocean was 400.003 ppm (Esteves, 2013). Climate change mitigation measures are being promoted. In reducing carbon concentrations in the atmosphere, reforestation is a major strategy as the trees absorb CO_2 in the atmosphere and store it in their tissues through photosynthesis.

In the Cordillera Administrative Region, *Alnus japonica* (Figure 1) is among the exotic species used in reforestation. Bare-root and potted *Alnus* seedlings

are generally used as planting stocks. The species is recommended in areas with altitude over 600 m and with rainfall of less than 50 mm per month for 4-6 months.

The tree is planted to improve the stability of slopes through its extensive root system. *Alnus japonica* is also planted as shade of coffee plantations in many areas in Benguet and Mountain Province.

Lee (1992) noted that being a nitrogen fixer, *Alnus* enriches the fertility of degraded lands. This capability is made possible by the association of actinomycetes of genus *Frankia* with *Alnus* roots resulting in the development of root nodules (Figure 2).

Moreover, the tree is fast – growing which implies that it can sequester much carbon dioxide for its growth, an attribute essential in reducing pollution that mainly triggers adverse climate change. Knowing the value

of *Alnus* in carbon dioxide sequestration can promote people's interest in using the species in reforestation and agroforestation.

It is mainly in this aspect that this study was conducted.

A major problem associated with the continuous rise of earth's temperature is the increase of carbon emissions that adversely affects climate.

Planting trees remains the cheapest and most effective means of drawing excess carbon dioxide from the atmosphere; a single mature tree can absorb carbon dioxide at a rate of 48 lb per year and release oxygen back into the atmosphere enough to support two human beings (Nowak, undated).

The output of the study can be used to calculate the carbon dioxide sequestration by existing,or to be established *Alnus* stand as an aid for project development planning and environmental education. The results are also important in validating average values that are published

as to the shoot-root biomass ratio, and carbon sequestration rate in trees.

Figure 1. The *Alnus* stand beside the College of Forestry, Benguet State University, La Trinidad, Benguet; taken on May 3, 2012

Figure 2. *Alnus* root nodules; the left photo shows partly unearthed roots of a sample *Alnus* tree while the right photo shows a washed *Alnus* roots with the nodules; photographed on May 10, 2012

The study is limited to the eight-year old *Alnus* stand artificially established within the College of Forestry campus, Benguet State University, La Trinidad, Benguet. The data were obtained only from three selected trees representing the large, medium, and small sizes of the *Alnus* stand. The root system was carefully dug-out but some parts may not have been fully taken out. The biomass of the tree at the time they were harvested was the sole basis in estimating their carbon stock and carbon dioxide sequestration rate.

It is hypothesized that *Alnus*, being a fast growing tree species, sequesters CO_2 as efficiently as the other tree species.

This study aimed to obtain information that may promote people's appreciation of the environmental role of *Alnus* trees, thereby motivating them to use the trees in reforestation and agro-forestation. It specifically aimed to:

1. determine the average biomass of the shoot and root systems of eight-year old *Alnus* trees, and

2. estimate the carbon stored and carbon dioxide sequestered by the *Alnus* trees.

MATERIAL AND

METHODS Data Collection

Determination of the underground and above-ground biomass. To determine the total biomass of the *Alnus* trees, a destructive sampling method was used.

Three selected *Alnus* trees representing the big, medium and small (Figure 3) were felled, the branches separated from the trunk and the leaves removed.

The trunks (main stems) were bucked into 0.5 meters long (Figure 4) while the twigs and small branches were cut into 0.5 meters or shorter (Figure 5).

The sawdust resulting from felling and bucking were collected (Figure 6). The roots were carefully dug-out, washed and cut into 0.5 meter sections or shorter. The weights of bucked stems and roots were determined separately using a weighing scale.

Samples of the cut stems and roots were oven-dried to determine the oven-dried weights (Figure 7).

Figure 3. The three selected 8-year old *Alnus* tree samples; large (left photo), medium(center) and small (right) *Alnus* tree samples

Figure 4. Logs cut into 0.5 m sections of the selected *Alnus* trees: LT – large tree, MT – medium tree, and ST – small tree

Figure 5. Branches and twigs from the three *Alnus* tree samples: LTB = large tree branches, MTB = medium tree branches and STB = small tree branches

Figure 6. Collected sawdusts from bucking the three *Alnus* tree samples into 0.5 m sections

Figure 7. Photos of oven-dried *Alnus* specimens

Estimation of carbon stocked and carbon dioxide sequestered. The average carbon content of the trees was computed using the average for vegetation which is generally 45-50 percent of the total dry matter (Schlesinger, 1991; Chan, 1982).

According to Paladinic, *et al.* (2009), the carbon content in biomass based on the general result of laboratory analyses of samples of main tree components was around 50%. However, the lower value (45 %) was used in this research to avoid possible over estimation.

Similarly, CO_2 sequestered by the *Alnus* trees were computed using the CO_2 to C ratio which is 43.999915/12.001115 or 3.6663 as published http://www. broward . org/NaturalResources/ ClimateChange/Documents/Calculating%20CO_2%20 Sequestration%20by%20Trees.pdf.

For comparison purposes, the above-ground biomass (AGB) and average underground biomass (BGB) of the *Alnus* trees were computed using a published formula as follows:

Weight (lb) = 0.25 D2L (for trees < 11" in DBH), and 0.15 D2L (for trees ≥ 11" in DBH,

where: D = Diameter in inches, and

L = Length in ft.

Determination of the weight of CO_2 sequestered by the Alnus trees per year. The average weight of carbon dioxide captured by the *Alnus* trees per year was determined by dividing the weight of the carbon dioxide sequestered by the age of the *Alnus* trees which is eight.

RESULTS AND DISCUSSION

Average Biomass of Eight-Year Old *Alnus* Trees

The average AGB of the three eight – year old *Alnus* trees was 100.89 kg and the BGB was 40.10 kg, or an average total biomass of 140.99 kg per tree (Table 1).

The AGB has a range of 20.06 – 182.63 kg and the BGB has a range of 10.04 – 73.03 kg.

The results are shown in Table 2. The comparison between the actual recorded data and the computed values for the three eight-year old *Alnus* trees is shown in Table 3.

The computed biomass based on the published equation is very much lower. Based on the computed averages, the AGB is only 24.665%, the BGB is only 12.58%, and the total biomass is only 21.18 % of the actual recorded biomass.

Table 1. Average above-ground and below ground biomass of the *Alnus* trees

ALNUS TREE SAMPLES	ABOVE GROUND BIOMASS (kg)			BELOW GROUND BIOMASS (kg)	TOTAL
	Main Stem	Branches and Twigs	Total		
Large	135.47	47.16	182.63	73.03	255.66
Medium	61.95	30.03	91.98	37.24	129.22
Small	24.9143	3.148	28.06	10.04	38.1
Total	222.3343	80.338	302.67	120.31	422.98
Average	74.1114	26.779	100.89 (71.56%)	40.10 (28.44%)	140.99

Table 2. Computed biomass of the *Alnus* trees

ALNUS TREE SAMPLE	AGB* (kg)	BGB** (kg)	Total*** (kg)
Large	40.97	8.194	49.164
Medium	19.63	3.926	23.556
Small	14.054	2.811	16.865
Total	74.654	14.931	89.585
Average	24.88	4.977	29.86

**20% of AGB

*** AGB + BGB or AGB x 1.20

Table 3. Comparison between the actual recorded biomass data of 8- year old *Alnus* trees and the computed biomass based on published equation (0.25D2L and 0.15D2L for trees < 11" DBH and for trees ≥ 11" DBH, respectively)

TREE SAMPLE	AGB			BGB			TOTAL BIOMASS (AGB + AGB)		
	Actual (kg)	Computed		Actual (kg)	Computed		Actual (kg)	Computed (kg)	Percent of Computed Value Based on Actual
		(kg)	% Based on Actual		(kg)	% Based on Actual			
Large	182.63	40.97	22.39	73.03	8.194	11.22	255.66	49.164	19.23
Medium	91.98	19.63	21.34	37.24	3.296	10.54	129.22	23.556	18.229
Small	28.06	14.054	50.08	10.04	2.811	27.998	38.1	16.865	44.265
Total/ Percent	302.67	74.654	24.665	120.31	15.137	12.58	422.98	89.585	21.18
Average	100.89	24.885		40.103	5.046		140.99	29.861	

The discrepancies can be mainly due to the fact that the equation considered only the main stem or bole of the tree. The actual data included the mass of branches and twigs.

Less the twigs and branches, the discrepancies were lessened but were still very high (Table 4). The computed AGB is 33.58% of the actual values on the average with a range of 30.24 – 56.4%, as compared to only 24.67% (average) and a range of 22.39 – 50.08% when the branches and twigs were included.

The other source of discrepancy in the BGB and total biomass is attributed to the higher actual values of the BGB (average of 28.44% of the AGB). The published average values used in the computation is that, BGB is only 20% of the AGB; 8.44% less than the recorded data.

Other possible sources of the discrepancies are species, geographic, edaphic, and climatic variations. Lasco, *et al*. (undated) reported that plantation species have differing biomass density which could be due to age differences and uneven site conditions.

Shoot-Root Ratio of the 8-Year Old *Alnus* Trees

The root – shoot data from the three selected *Alnus* trees are shown in Table 5. The average shoot-root ratio of the *Alnus* trees is 2.516. This means that the shoot weight is about 2.5 times that of the root weight: root is 28.44% of the total greenweight.

This value is more by 8.44% than the average values for tropical trees as publishedinhttp://www.broward.org/NaturalResources/ClimateChange/Documents/Calculating%20CO_2%20Sequestration%20by%20Trees.pdfwhich is 20%.

The study conducted for eight-year –old Poplar in India showed that the above ground components contributed 78.68% and the below ground components contributed 21.32% of the biomass; the shoot-root ratio was 3.69 (Singh and Lodhiyal, 2009).The shoot-root ratios for most trees under normal conditions are 5:1 to 6:1 (Richard, 1992).

The recorded shoot-root ratio of *Alnus* in this study

Table 4. Comparison of the actual recorded biomass of the 8-year old *Alnus* with the computed values based on the published equation

TREE SAMPLE	AGB			BGB			TOTAL		
	Actual (Bole only) (kg)	Computed		Actual (kg)	Computed		Actual (kg)	Computed (kg)	% of Computed Value Based from Actual
		(kg)	%Based from Actual		(kg)	%Based from Actual			
Large	135.47	40.97	30.24	73.03	8.19	11.22	208.5	49.16	23.58
Medium	61.95	19.63	31.67	37.24	3.296	10.54	99.19	56.87	57.33
Small	24.91	14.05	56.4	10.04	2.811	28.00	34.95	24.09	68.93
Total/ Percent	222.33	74.65	33.58	120.31	15.14	12.58	342.64	130.13	37.98
Average	74.111	24.59		40.10	5.046		114.22	43.376	

Table 5. Shoot-root ratio by weight of the eight – year old *Alnus* trees

ALNUS TREE SAMPLES	ABOVE GROUND BIOMASS		BELOW GROUND BIOMASS		TOTAL	RATIO
	(kg)	Percent	(kg)	Percent	(kg)	
Large	182.63	71.435	73.03	28.56	255.66	2.500
Medium	91.98	71.18	37.24	28.82	129.22	2.465
Small	28.06	73.64	10.04	26.35	38.10	2.795
Total/Percent	302.67	71.56%	120.31	28.44%	422.98	
Average	100.89		40.103		140.99	2.516

is much lower (2.516:1). In this study, the leaves were not included. With the leaves, the shoot weight will be a little higher.These cited reports and this resultindicate that biomass productionvaries among trees.

Carbon and Carbon Dioxide Sequestered by Eight -Year Old *Alnus*

Table 6 shows the data on the biomass and equivalent carbon content and the carbon dioxide sequestered by the three eight-year old *Alnus* trees.

In vegetation, the carbon content constitutes between 45-50 percent of dry matter (Schlesinger, 1991; Chan, 1982), and the ratio of carbon dioxide to carbon is 3.6663 http://www.broward.org/NaturalResources/ClimateChange/Documents/Calculating%20CO_2%20Sequestration%20by%20Trees.pdf.Lasco, *et a*l. (undated) reported that the carbon content in trees in a secondary forest in Makiling Forest Reserve was 44 percent, similar with that of the land cover types biomass in Pantabangan-Caranglan Watershed.

Hence, the lower value (45%) was used in the computation in this study to avoid over estimation. Using the weights of the oven-dried wood samples of the *Alnus* trees and the above mentioned published values, the carbon contents and carbon dioxide sequestered by the eight-year old *Alnus* trees were computed.

The three *Alnus* trees were able to store a total of 95.73 kg of carbon or an average of 3.99 kg carbon per

tree per year. This amount of carbon stocked is equivalent to a total of 350.98 kg of CO_2 sequestered, or an average of 14.63 kg (32.186 lb) of CO_2 sequestered by each tree per year.

This result is less by 15.814 lbs as compared with the carbon dioxide sequestration rate of a mature tree which is 48lb per year as published in http:www.coloradotrees.org/benefits.htm, and the sequestration rate in 8-year-old Poplar (Populusdeltoides) which is 24 kg (52.8 lbs) per year (Singh and Lodhiyal, 2009). Since the trees are only eight years old (considered still young), their carbon dioxide sequestration rates canbe expected to increase as they further grow to reach their peak growth.

Based on the computed average carbon dioxide sequestration of *Alnus* at eight years, a hectare *Alnus* plantation with an average of 2m x 2m spacing can sequester 36,575 kg (36.575 t) of carbon dioxide per year which is equivalent to the amount of carbon dioxide emitted by 16 persons. This is based on the estimate that a person produces about 2.3 tons carbon dioxide each year (Nowak, undated).

Moisture Content of Eight–Year Old *Alnus* Trees

Table 7 shows the computed moisture content of wood samples from the 8 – year old *Alnus* trees. The moisture content of the oven – dried samples for the large, medium and small *Alnus* trees were 26.72 kg (48.14%), 17.36 kg (52.81%), and 5.324 kg (43.75%) respectively, or an average of 16.46 kg or 48.41%, while the computed moisture content based on the oven-dried samples were 121.89 kg (47.68%), 71.49 kg (55.32%), and 16.865 kg (44.27%), a total of 210.245 kg and an average of 70.08 kg or 49.71% per tree.

This means that in an eight-year old *Alnus*, the wood or the dry matter is just a bit more than half of its green weight. The computed moisture content is higher than the average value for trees published in http://www.broward.org/NaturalResources/ClimateChange/Documents/Calculating%20CO_2%20Sequestration%20by%20Trees.pdf which is about 27.5% (72.5% is dry matter).

Table 6. Summary of the total green and oven-dry weights, and carbon content and the carbon dioxide sequestered by eight-year old *Alnus* trees

TREE SAMPLE	AGB (kg)	BGB (kg)	TOTAL (kg)	OVEN* DRY WEIGHT (kg)	CARBON CONTENT (kg)	CO_2 SEQUESTERED (kg)	
						For Eight-Year	Per Year
Large	182.63	73.03	255.66	133.77	60.197	220.698	27.59
Medium	91.98	37.24	129.22	57.73	25.98	95.25	11.91
Small	28.06	10.04	38.1	21.235	9.556	35.034	4.38
Total	302.67	120.31	422.98	212.735	95.73	350.98	43.88
Average	100.89	40.10	140.99	70.91	31.91	116.994	14.63

* Computed based on data from Table 7 (Total fresh weight – total moisture content)

Table 7. Computed moisture content (MC) of wood of 8 – year *Alnus*old trees

TREE SAMPLE	FRESH WEIGHT (kg)				MOISTURE CONTENT OF OVEN-DRIED SAMPLES (kg and percent) *			COMPUTED MC IN KG (Based on MC of Oven-Dried Samples)			
	Main Stem	Branches	Total AGB	BGB	Total	Roots	Main Stem	Branches	Roots	Total	
Large	135.47	47.16	182.63	73.03	255.66	19.667	1.3626	5.69	26.72	67.45	20.66	33.78	121.89
						79%)(49.	81%)(43.	26%)(46.	66%)(48.				68%)(47.
Medium	9561.	0330.	91.98	37.24	22129.	1810.	830.	356.	3617.	0032.	19.62	8719.	4971.
						(51.66%)	(65.35%)	(53.35%)	(52.81%)				(55.32%)
Small	24.914	3.148	28.06	10.04	38.10	3.359	0.32	1.645	5.324	10.08	1.765	5.02	16.865
						47%)(40.	07%)(56.	00%)(50.	75%)(43.				27%)(44.
Total	334222.	338108.	330.67	120.31	422.98	33.206	2.5122	6913.	40449.	109.53	42.045	6758.	210.245
									(49.13%)				(49.71%)
Mean	1174.	11336.	22110.	40.10	140.99	11.07	0.8374	4.563	46816.	36.51	14.015	19.56	70.08
									(49.13%)				(49.71%)

* Percent MC is based on freshweight

CONCLUSIONS AND RECOMMENDATIONS

Results show that the total fresh weights of the above-ground biomass (AGB) and below-ground biomass (BGB) of the large, medium and small *Alnus* trees were 255.66 kg, 129.22 kg and 38.1 kg respectively, or an average of 140.99 kg per tree. Their total oven dry weights were 133.77 kg, 57.73 kg and 21.235 kg respectively, or an average of 70.91 kg per tree. The AGB is 71.56 %, and the BGB is 28.44 % of the total biomass, or an AGB – BGB ratio of 2.516. This BGB value (28.44%) is 8.44% more than a published average value for tropical trees.

The carbon contents of the large, medium and small *Alnus* tree samples were 60.1965 kg, 25.9785 kg and 9.56 kg respectively, or an average of 31.91 kg per tree, and the total carbon dioxide they sequestered were 220.698 kg, 95.25 kg and 35.034 kg respectively, or an average of 116.994 kg per tree. There was a total of 350.98 kg of carbon dioxide sequestered by the *Alnus* trees for eight years, or an average of 14.63 kg (32.186 lbs) per tree per year. Based on this average sequestration rate, a hectare of *Alnus* trees with 2m x 2m spacing and at least eight – year old can sequester 36.575 tons of carbon dioxide per year that can balance the carbon dioxide emission of about 16 persons.

The computed biomass of each of the *Alnus* tree is very much lower; their average AGB is only 24.67%, and their BGB is only 12.58%, of the actual recorded biomass, and their total computed biomass is only 21.18% (29.861kg) of the actual biomass (140.99 kg). The discrepancies are due to the fact that the equation considered only the main stem or bole of the tree; the twigs and branches are not included. The discrepancies are lessened if the weights of the branches and twigs are not included but the actual values are still very much higher.

The computed AGB value is 33.58% of the actual average values with a range of 30.24% – 56.4%, as compared to only 24.665% (average) and a range of 22.39 – 50.08% when the branches and twigs were not included.

The other source of discrepancy in the BGB and total biomass is attributed to the higher actual values of the BGB (average of 28.44% of the AGB). The published average value used in the computation is that, BGB is only 20% of the AGB. This value is 8.44% less than the actual values. Other possible sources of the discrepancies are age, species and site variations.

Furthermore, the moisture content of the oven – dried samples for the large, medium and small *Alnus* trees were 26.72 kg (48.66%), 17.36 kg (52.81%), and 5.324 kg (43.75%) respectively, or an average of 16.468 kg or 49.13%.This means that in 8-year *Alnus* trees, the wood or the dry matter is just a little higher than half of their total green weights. The computed moisture contents are much higher than a published average values for trees which is 27.5% (72.5% is dry matter).

Based on the results of the study, it is concluded that within 8-years, *Alnus japonica* grown at about 2m x 2m spacing on sites of similar conditions with that of the study site will have: 1) attained an average fresh weight of about 140.99 kg and an average dry matter of about 70.91kg per tree with the AGB and BGB constituting about 71.56% and 28.44%,respectively, and 2) stocked about an average of 31.91kg of carbonwhich is equivalent to14.63 kg or 32.186 lb carbon dioxide sequestered by a tree per year.

The following are recommended:

1. An *Alnus* tree, at least eight – year old, can sequester 14.63 kilograms or 32.186 lb of carbon dioxide per year, a significant environmental contribution that can help abate global warming and climate change. *Alnus* is known as Nitrogen fixer; a good nurse tree for Arabica coffee, and a source of excellent compost for fertilizer. Hence, planting of *Alnus* trees as a forest cover, nurse trees, hedgerows, and landscape components should be promoted.

2. Follow - up study to determine the carbon dioxide sequestration rate by older *Alnus japonica* and by *Alnus* grown in other geographic areas, as well as of other tree species should be conducted towards formulating equation and determining average values for computing the biomass and carbon dioxide sequestration rates.

ACKNOWLEDGMENT

The following helped facilitate the conduct of this research: Foresters Sano L. Ngiwas and Paquito P. Untalan of BSU-College of Forestry; Dr. Leoncia L. Tandang (dean), Prof. Darwin Basquial (College Secretary), Prof. Alexander Fagyan (Dep't. Chair – Soils & Chemistry Dep't.) and Mr. Lochinvar Contada (Science Aide) of the BSU-College of Agriculture; and the students of the BSU-College of Forestry, namely: Andy, Ronnie, Felix, Prado, Japet, Mendil, Jerry, Mechelle, Shiela, Marilou, Sheryl, Dorina, Marjie, Renalyn, Jorgette, Nowedel, Dario, Alma, and Dyesebel.

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