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Research article

Carbon storage potential of the tree species along the ultramafic forest in Sitio Dicasalarin, Barangay Zabali, Baler, Aurora, Philippines

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Abstract: Tree species play a very important role in storing and sequestration of carbon by preventing the accumulation of carbon dioxide in the atmosphere as greenhouse gases. Carbon stock assessment is a useful tool in estimation of the importance of an area in terms of its carbon storage capacity. Trees with at least 5cm-diameter at breast height were recorded from 27 plots with a total area of 10800 square meter. A total of 139 species with 2239 individuals were identified with a total of 306.48 t ha^{-1} carbon content based on the live trees' aboveground and belowground biomass. Regression analysis showed that there was no significant relationship between tree carbon stock and basic parameters namely, species richness, species abundance, and elevation. Ecologically important species, particularly the Philippine endemics and threatened, yielded a total of 172.65 t ha^{-1}. Among the species found within the area, Xanthostemon philippinensis Merr. (Myrtaceae) had the highest carbon stored of 68.60 tons. The study revealed that the ultramafic forest in Sitio Dicasalarin, Baler, Aurora, Philippines is a critically important area with tremendous carbon storage capacity mainly contributed by the endemic and threatened species as found.

Keywords: carbon stock; species richness; ultramafic forest; Philippine endemics; biomass

1. Introduction

Forests are armor and weapons against the global effects of climate change [1]. It was highlighted by FAO [2] that forests can act as carbon sink (sequestration) or source of carbon in different times.

Establishment and protection of forest and tree plantations can increase the carbon storage in aboveground and belowground biomass [3]. Trees are one of the crucial components of the ecosystem in carbon storage and sequestration through capturing carbon and using it in physiological processes such as photosynthesis [4].

Ecologically important tree species such as endemic and threatened greatly contribute to carbon storage [5], ecosystem sustainability, and biodiversity [6]. Endemic and threatened species are highly prioritized in conservation and protection [7]. Therefore, the species long-term effect on carbon storage and sustaining forest ecosystem and diversity is significant [8].

Sitio Dicasalarin is classified as an ultramafic forest. This type of forest has soil characterized by a high amount of heavy metals such as nickel, chromium, iron and magnesium. Usually, this type of forest is situated on ultrabasic rocks that have very low silica but high in magnesium oxide (MgO) and ferrous oxide (FeO) and has pronounced dark colored soil [9]. Dominant genera of trees include *Phyllanthus, Psychotria, Medinilla,* and *Syzygium*. These species that thrive in ultramafic forests commonly exhibit morphological adaptations to survive extreme conditions through minimization of water requirements and uptaking of nickel and magnesium [10].

Carbon storage potential of tree species is an interesting aspect to study. It is important to assess the carbon storage and sequestration capacity of trees to know the amount of carbon stored instead of emitting and letting it accumulate into the atmosphere as greenhouse gas [11]. There are no online scientific publications on carbon stock assessment in Baler, Aurora in the Philippines. Therefore, the present study will pioneer that issue.

2. Objectives of the study

The general aim of our study was to assess the carbon storage potential of the ultramafic forest in Sitio Dicasalarin, Barangay Zabali, Baler, Aurora, Philippines. Specifically, it aimed to: a. evaluate the relationship of tree carbon stock with factors like species richness, species abundance (number of individuals) and altitude, b. determine the carbon stock of ecologically important species, and c. identify the most important species in terms of carbon storage potential.

3. Methodology

3.1. Study site

The study was conducted in the ultramafic forest of Sitio Dicasalarin, Barangay Zabali, Baler, Aurora located at 15.75833 N 121.5625 E (Figure 1). The site is a part of the Sierra Madre Mountain Range. Sierra Madre is known to be one of the most important areas in terms of ecological value. It traverses through nine provinces namely, Cagayan, Isabela, Nueva Vizcaya, Quirino, Nueva Ecija, Aurora, Bulacan, Rizal, and Quezon [12].

The study site belongs to the Type IV climate with evenly distributed rainfall throughout the year [13]. It was also reported that rainfall is usually at maximum during the months of October, November, September, and May while at the lowest during the month of February.

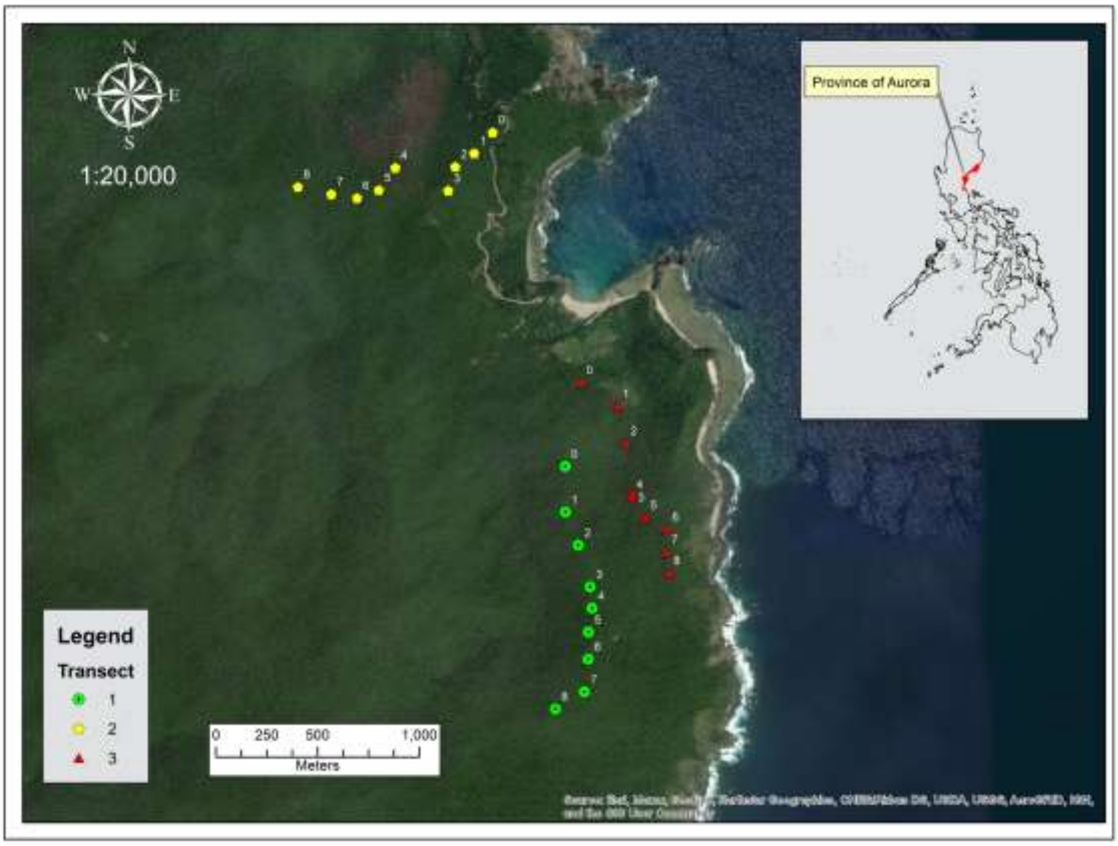

Figure 1. Location map of the study site in Sitio Dicasalarin, Province of Aurora in the Philippines (Source: ESRI, ArcGIS Online Basemap) [14].

3.2. Establishment of transects and quadrats

Three 2 km transect belts were laid following an existing trail in the area (Figure 1). For each transect, 9 20x20m quadrats were established at 250 m interval from the starting point at 0 m (Quadrat 0) to 2000 m (Quadrat 9) (Figure 2). Note that quadrats were placed at the left and right side of the trail in alternating manner to cover species at both sides. A total of 27 quadrats summing up to 10800m^2 or 1.08 ha was surveyed for the study. Locations of the quadrats were obtained together with the elevation which will be used in the data analysis (Table 1).

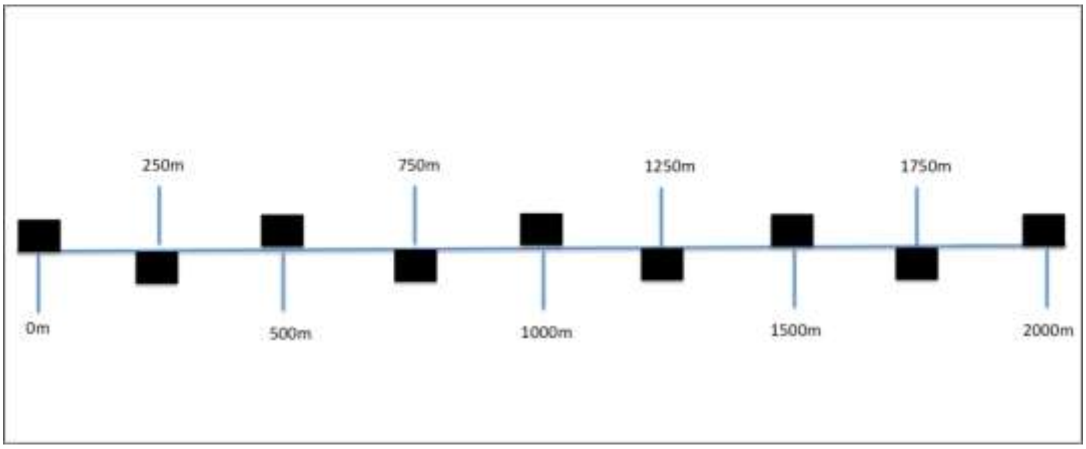

Figure 2. Form of quadrat establishment per transect (block boxes are the 20x20m quadrats).

Table 1. Location and elevation of each quadrat.

Transect	Quadrat	Latitude	Longitude	Elevation (masl)
1	0	15.73213	121.6337	153.2
1	1	15.73009	121.6337	171.9
1	2	15.72863	121.6343	200.5
1	3	15.72678	121.6348	227.3
1	4	15.72583	121.6349	247.7
1	5	15.72477	121.6348	265.6
1	6	15.72356	121.6348	293.3
1	7	15.72211	121.6346	313.1
1	8	15.72133	121.6333	320.5
2	0	15.74697	121.6302	170.8
2	1	15.74603	121.6294	202.1
2	2	15.74543	121.6285	231.4
2	3	15.74436	121.6282	253.5
2	4	15.74536	121.6258	252.1
2	5	15.74437	121.625	263.6
2	6	15.74401	121.624	259
2	7	15.74418	121.6228	256.4
2	8	15.74448	121.6213	260.2
3	0	15.73588	121.6344	21.6
3	1	15.73485	121.636	26.5
3	2	15.73318	121.6364	39.9
3	3	15.73099	121.6368	72.1
3	4	15.7308	121.6367	73.4
3	5	15.72989	121.6373	94.9
3	6	15.72937	121.6383	105
3	7	15.72837	121.6383	104.3
3	8	15.72743	121.6384	109.7

3.3. Floristic (tree) inventory

Tree inventory commenced from June to July 2017. All trees with a diameter at breast height of at least 5cm inside the quadrats were identified, counted and recorded. The diameter at breast height (DBH) at 1.3 meters of the trees were measured. Observations in the field like flowering and fruiting species were noted and photo documented.

Voucher specimens of species were collected, photographed and placed inside herbarium bags for identification and verification purposes. Specimens were properly tagged and pressed in newspaper. After pressing, the voucher specimens were placed inside the herbarium bags. Each bag contained 20 specimens at most. Denatured alcohol was then poured in each bag enough to soak all the specimens to avoid fungal attacks and leaf deformation. After the three-week long data collection, the specimens were oven dried at 60 °C in the Botany Laboratory of the Forest Biological Sciences Building in the College of Forestry and Natural Resources University of the Philippines Los Baños (CFNR-UPLB).

Plate 1. Photograph of flowering *Decaspermum fruticosum* J.R.Forst. & G.Forst. (left), and properly tagged and labeled voucher specimen of *Teijsmanniodendron ahernianum* (Merr.) Bakh. (right).

A total of 139 species with 2239 individuals from 87 genera and 46 families was recorded from the forest ecosystem of Sitio Dicasalarin (Table S1). After the identification of species, each was assessed in terms of conservation status and endemism. Conservation status of species was based on the IUCN Redlist of Threatened Species [15] and DAO 2017-11 or the Updated National List of Threatened Philippine Plants and their Categories [16]. Endemism of species, on the other hand, was obtained from the Co's Digital Flora of the Philippines website [17].

3.4. Data analysis

Species richness and abundance was calculated based on the data collected in the field. Soecies richness was based on the number of species found while abundance was obtained by counting the number of individuals of the species.

In the estimation of carbon storage potential of the tree species in the area, a series of formulas [18] were used. The standard formula for carbon stock in biomass (CS) is CS = (AGB + BGB) x 0.5, wherein AGB is aboveground biomass, BGB is belowground biomass, and 0.5 is the conversion factor. To compute for the estimate of AGB denoted as Y (in kilograms), the formula is $Y = 34.4703–8.0671 D + 0.6589 D^2$. BGB, on the other hand, is only 15% of AGB expressed as BGB = AGB x (15/100) [18]. This formula is considered standard in tropical forests just like the Philippines, as well as the conversion factor of 0.5 or 50% as used in many similar studies [19]. These series of formulas used were from recent studies within Asia having generally the same forest types with the Philippines being a tropical region.

Overall computation of the CS of the study site was done to show the importance of the area in storing carbon. Also, a separate computation of the carbon stock of Philippine endemic and threatened species was done to highlight the contribution of these ecologically important species in carbon storage.

Regression analysis of the data was also done to know the relationship between tree carbon stock and factors such as species richness, species abundance, and elevation. Regression analysis can help in determining the following if independent variables have significant effect or relationship with the dependent variable [20].

4. Results and discussion

4.1. Carbon storage potential of the area

The sampling area had a total carbon stock of 306.48 t ha^{-1} while per transect value ranges from 69.57 to 160.82 tons (Table 2). This was a relatively high value compared the studies conducted in the Philippines. Labata et al. [21] found that the three agroforestry systems in Bukidnon had a total carbon stock of 54.83 t ha^{-1} which is three times less than the estimated CS value of at Sitio Dicasalarin. In the urban setting in Cebu City, the trees were found to have CS of 87.81 t ha^{-1} [22]. Moreover, the CS value of Sitio Dicasalarin is more than that of the yield of study conducted by Tulod [23], wherein the five reforestation sites (aged 15 to 34) in the Southern Philippines had a CS value of around 210 t ha^{-1}. Sitio Dicasalarin exceeded the general standards that Lasco and Pulhin [24] mentioned in their study on Philippine forest ecosystems that secondary forests in the Philippines were found to have a mean of 207.9 tons/ha. Results showed that Sitio Dicasalarin is superior in terms of carbon storage than other areas in the Philippines.

There were also a number of carbon storage potential studies abroad. In China, Liu et al. [25] found that the subtropical forest in Gutianshan National Nature Reserve (GNNR) in Zhejiang Province, southeast China yielded a total of about 149 t ha^{-1}. Another carbon study in Majiya Fuelwood Reserve, Sokoto State in Nigeria revealed a total CS (based on AGB and BGB) of 53.5 t ha^{-1} [26]. In Western Odisha, India, a sacred natural forest was assessed and found to have a stored carbon of 125.21 t ha^{-1} [27]. The CS values estimated in the findings of the studies mentioned were all less than the computed CS value for the present study in Sitio Dicasalarin. The strict management being implemented by the property owner of the forest prevented the loss of tree species contributing to the preserved natural resources in the area. On the other hand, there were also some studies within Asia that had higher carbon stock amounts than in Sitio Dicasalarain. One of the areas mentioned by the re-evaluation made by Keith et al. [28] was the lowland evergreen dipterocarp forest in Sebulu, East Kalimantan, Indonesia with carbon stock of 436 tons/hectare. This was not surprising since dipterocarp forests were known to have tall trees with large diameter especially in the East Kalimantan, Indonesia [29]. Furthermore, a study in the *Sequoia sempervirens* forests in the USA exhibited a total carbon stock of about 2201 tons/ha [30]. This is about 7 times of the CS of Sitio Dicasalarin. Another study in the temperate forests of South-eastern Australia yielded carbon stock amount of at least 550 tons/ha which is more than that of the CS in Baler, Aurora [31]. Thus, Sitio Dicasalarin, being a secondary growth tropical forest over ultramafic rocks, had more carbon stock than some areas within Asia only based on the studies mentioned.

Table 2. Overall and transect values of species richness, species abundance, and carbon stock.

	Species Richness	Species Abundance	Carbon Stock
Transect 1	88	699	100.69 tons
Transect 2	79	934	160.82 tons
Transect 3	85	606	69.57 tons
OVERALL	139	2239	331.08 tons or 306.48 t ha^{-1}

The CS values of each quadrats varied from 2.7 to 83.48 tons with Quadrat 3 in Transect 2 having the highest carbon stock among all quadrats. The relationship of tree carbon stock between the basic parameters (species richness, species abundance, elevation) was tested in the regression analysis. The analysis of the relationship between tree carbon stock and key factors yielded the following results: a. species richness ($r^2 = 0.001$), species abundance or count of tree individuals ($r^2 = 0.0067$), and elevation ($r^2 = 0.0849$) (Figures 4–6). As per the very low r^2 values obtained, it was very clear that there are no significant relationships between tree carbon stock and to any of the key factors. Study of Liu et. al (2018) showed that there was no direct or significant relationship between tree species richness and belowground carbon ($r^2 = 0.32$) and aboveground carbon ($r^2 = 0.39$). The findings at Sitio Dicasalarin can also be supported by the research of Khadanga & Jakayumar [32] at the Mahendragiri Hill Forest. It was found in their study that species richness, elevation, and abundance had no significant effect to the biomass and carbon stock of the tree species in an area. Studies found that one of the best predictors and factors affecting CS is the amount of biomass as it has direct relationship with carbon stock [33]. Other factors in their study include the disturbance level of forests wherein high level of disturbance means less CS amount. Other factors affecting the amount of carbon stock of an area such as topographic factors (water flow, etc.) were not assessed in this study since there were no data collected on soils.

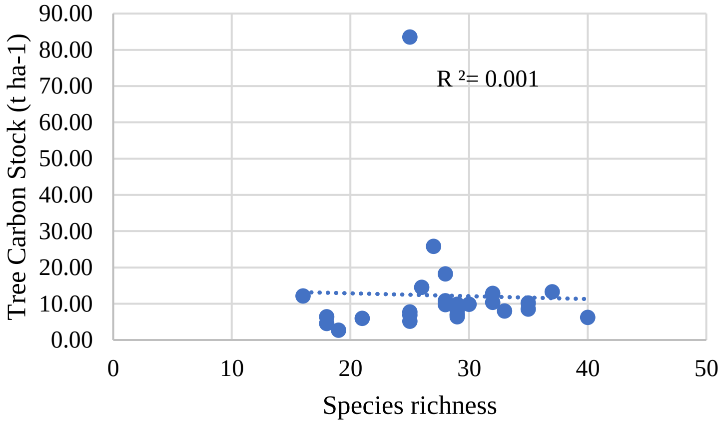

Figure 4. Regression analysis between tree carbon stock and species richness.

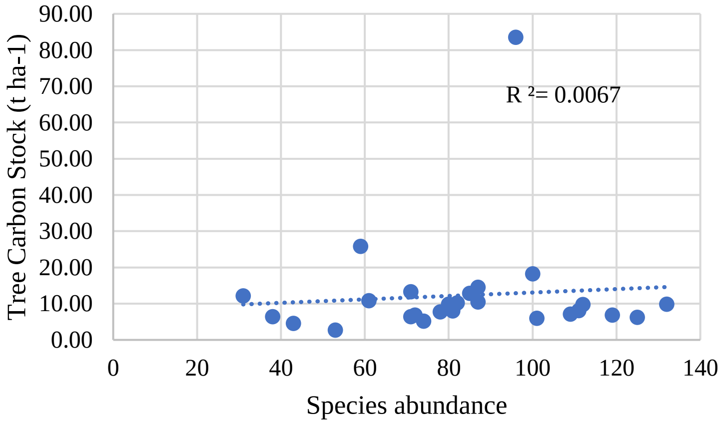

Figure 5. Regression analysis between tree carbon stock and species abundance.

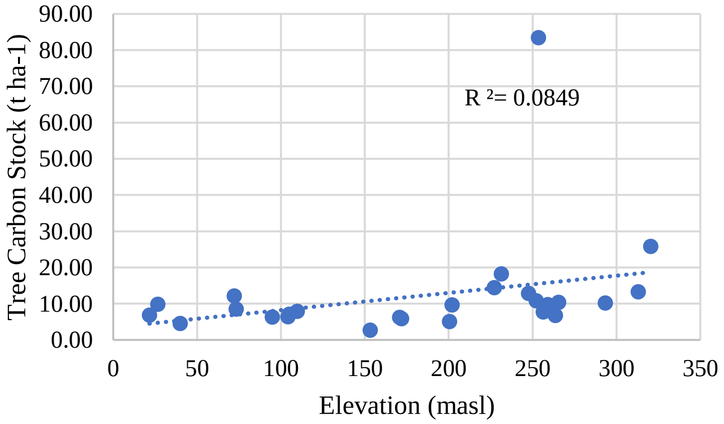

Figure 6. Regression analysis between tree carbon stock and elevation.

4.2. Carbon stock of ecologically important species

Two classifications of ecologically important species were included in the study, the Philippine endemics and threatened species. Forty-eight endemic and 29 threatened species out of the 139 morpho-species found within the area were listed either in IUCN or DAO 2017-11 (Table 3). These species had a total CS of 172.65 t ha^{-1} or 56.33% of the overall CS of the sampling area. As found in the study of Coracero and Malabrigo [34], the area was critically important because of having tremendous endemic and threatened species. These findings in carbon potential revealed that the area was also important in having high amount of stored carbon in tree species, especially in the endemics and threatened species.

Table 3. Carbon stock values of Philippine Endemic Species with their corresponding conservation status.

Scientific Name	Family	IUCN Redlist	DAO 2017-11	Carbon Stock (t ha^{-1})
Xanthostemon philippinensis Merr.	Myrtaceae	CR	CR	68.60
Shorea malibato Foxw.	Dipterocarpaceae	CR	CR	27.62
Madhuca oblongifolia (Merr.) Merr.	Sapotaceae	VU	EN	17.69
Tristaniopsis micrantha (Merr.) Peter G.Wilson & J.T.Waterh.	Myrtaceae			9.46
Mangifera altissima Blanco	Anacardiaceae	VU		7.49
Terminalia darlingii Merr.	Combretaceae	EN	EN	7.32
Lithocarpus apoensis (Elmer) Rehder	Fagaceae		VU	6.55
Garcinia rubra Merr.	Clusiaceae			5.52
Discocalyx psychotrioides Elmer	Primulaceae			4.52
Dillenia luzoniensis (Vidal) Merr.	Dilleniaceae		VU	4.00
Memecylon symplociforme Merr.	Memecylaceae			3.66
Diospyros vera (Lour.) A.Chev.	Ebenaceae	EN	VU	2.95
Homalium bracteatum Benth.	Proteaceae			2.89
Actinodaphne dolichophylla (Merr.) Merr.	Lauraceae			1.89
Trigonostemon longipes (Merr.) Merr.	Euphorbiaceae			1.66
Weinmannia luzoniensis S.Vidal	Cunoniaceae			1.65
Hopea acuminata Merr.	Dipterocarpaceae	CR	EN	1.51
Hopea malibato Foxw.	Dipterocarpaceae	CR	CR	1.26
Artocarpus blancoi (Elmer) Merr.	Moraceae			1.23
Podocarpus macrocarpus de Laub.	Podocarpaceae	EN	EN	1.10
Sindora supa Merr.	Fabaceaea	EN	EN	1.06
Brackenridgea fascicularis (Blanco) Fern.-Vill.	Ochnaceae			1.04
Artocarpus rubrovenius Warb.	Moraceae			1.04
Myrsine fastigiata (Elmer) Pipoly	Primulaceae			0.57
Radermachera coriacea Merr.	Bignoniaceae		VU	0.50
Shorea polysperma Merr.	Dipterocarpaceae	CR	CR	0.48
Syzygium ramosii (C.B.Rob.) Merr.	Myrtaceae			0.38

Continued on next page

Scientific Name	Family	IUCN Redlist	DAO 2017-11	Carbon Stock (t ha^{-1})
Greeniopsis discolor Merr.	Rubiaceae		CR	0.38
Mitrephora multifolia Elmer ex Weeras. & R.M.K.Saunders Elmer	Annonaceae			0.31
Discocalyx micrantha Merr.	Primulaceae			0.26
Diospyros pilosanthera Blanco	Ebenaceae	EN		0.23
Cinnamomum mercadoi S.Vidal	Lauraceae	VU	OTS	0.21
Psychotria luzoniensis (Cham. & Schltdl.) Fern.-Vill.	Rubiaceae			0.20
Cinnamomum nanophyllum Kosterm.	Lauraceae			0.19
Canthium obovatifolium (Merr.) Merr.	Rubiaceae			0.19
Palaquium glabrum Merr.	Sapotaceae			0.12
Myristica colinridsdalei W.J.de Wilde	Myristicaceae	VU	CR	0.12
Guioa discolor Radlk.	Sapindaceae	EN	VU	0.12
Canthium subcapitatum (Merr.) Merr.	Rubiaceae			0.11
Kibatalia elmeri Woodson	Apocynaceae	VU	OTS	0.11
Helicia rigidiflora var *robusta*	Proteaceae			0.09
Litsea leytensis Merr.	Lauraceae	VU	EN	0.08
Syzygium curranii (C.B.Rob.) Merr.	Myrtaceae			0.07
Chionanthus remotinervius (Merr.) Kiew	Oleaceae			0.03
Ficus balete Merr.	Moraceae			0.03
Osmoxylon eminens (W.Bull) Philipson	Araliaceae			0.01
Adenanthera intermedia Merr.	Fabaceaea	VU	OTS	0.01
Madhuca lenceolata (Merr.) Merr.	Sapotaceae	EN		0.01
TOTAL				186.51 or 172.65 tons/ha

*Legend: CR – Critically endangered, EN – Endangered, VU – Vulnerable, OTS – Other threatened species.

4.3. *Top species in terms of carbon stock*

Top ten species when it comes to amount of carbon stored were identified (Table 4). These species had a total of 212.27 t ha^{-1} which is equivalent to 64.11% of the total carbon stock of all recorded species in the area. *X. philippinensis* (Bagoadlau) topped with 68.60 t ha^{-1} or 20.72% of the total CS of all species. Bagoadlau was found to be the second most important species in Sitio Dicasalarin next to Dangula in terms of importance values [34]. But in terms of carbon stock, Dangula was only the second highest storeroom of carbon in the area. There are more large diameter individuals of Bagoadlau than Dangula, which affected the estimated carbon stock.

Table 4. Top ten species in terms of Carbon Stock.

Scientific Name	Family	Common Name	Carbon Stock (t ha^{-1})
Xanthostemon philippinensis Merr.	Myrtaceae	Bagoadlao	68.60
Teijsmanniodendron ahernianum (Merr.) Bakh.	Lamiaceae	Sasalit	28.41
Shorea malibato Foxw.	Dipterocarpaceae	Yakal Malibato	27.62
Palaquium obovatum (Griff.) Engl.	Sapotaceae	Lahas	23.68
Madhuca oblongifolia (Merr.) Merr.	Sapotaceae	Malabetis	17.69
Aglaia edulis (Roxb.) Wall.	Meliaceae	Malasaging	11.44
Calophyllum blancoi Planch. & Triana	Calophyllaceae	Bitanghol	10.54
Tristaniopsis micrantha (Merr.) Peter G.Wilson & J.T.Waterh.	Myrtaceae	Tiga	9.46
Mangifera altissima Blanco	Anacardiaceae	Pahutan	7.49
Terminalia darlingii Merr.	Combretaceae	Malaputat	7.32
TOTAL	-	-	212.27

5. Conclusion

Sitio Dicasalarin is a very important area in terms of having a lot of endemic and threatened species with exceptional carbon storage capacity. Locally and in some parts of Asia, the amount of carbon stored by the tree species in the area is relatively high but is less than the amount of carbon stock in other studies within Asia and in the USA and Australia. Carbon stock potentials of tree species were not affected by any of the factors tested (species richness, species abundance, and elevation). The findings of this study is a pioneer research on carbon storage potential assessment in Baler, Aurora inclusive of the ecologically important species (threatened and endemics) that can serve as a guide in planning conservation and protection efforts by public and private agencies.

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Conflict of interest

All authors declare no conflict of interest in this paper.

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