Journal of Tropical Biology and Conservation 20: 63–80, 2023
ISSN 1823-3902
E-ISSN 2550-1909

Research Article

# Diversity and Aboveground Carbon Stocks of Trees and Understorey Plant Species in Matalom, Leyte, Philippines

**Carollina S. Gumela, Jay Ann G. Lantajo, Pearl Aphrodite Bobon-Carnice***

*Department of Natural Sciences, Eastern Visayas State University, Arch. Lino R. Gonzaga Avenue, Tacloban City, Leyte, Philippines.*

***Corresponding authors:** pearl.carnice@evsu.edu.ph
Received 03 October 2022|Reviewed 20 February 2023|Accepted 12 April 2023|Published 15 October 2023
Doi: https://10.51200/jtbc.v20i.4646

## ABSTRACT
The biggest threats to plant species degradation must be the cutting of trees, conversion into croplands, and natural circumstances. Degradation of land cover has negatively affected plant diversity before the carbon stocks. This study utilized a stratified random sampling technique and allometric equation to determine the plant species, diversity level, and aboveground carbon stocks of trees and understorey found in Matalom, Leyte, Philippines. Results showed thirteen (13) trees and forty-nine (49) understorey species were present in the sampling area. The abundance of species or the total number of individuals per species of trees and understorey is 98 and 2814 respectively. For the diversity index, the result was led by tree species, then understorey species, respectively 1.76, interpreted as very low, and 2.83, which is moderate based on the Modified Fernando Biodiversity Scale. The species evenness, 0.69 and 0.73, was led by understorey plant species. Both signify unequal distribution of plant species in the study area. Moreover, tree species have a higher carbon stock of 34.15 t C $ha^{-1}$ compared to understorey, contributing about 0.03 t C $ha^{-1}$. There are significant differences in the diversity and c-stocks between trees and understorey plant species based on independent t-test results.

**Keywords:** Species diversity; richness; evenness; abundance; aboveground carbon stocks

## Introduction
Plant species diversity is strongly linked to the various functions of our ecosystems. Plants serve as an ecological buffer against undesirable events such as drought (Li et al., 2017). Plants are the primary source of food, medicine, livestock feed, and provide other essential products and services, including

fibers, timber and clean water, and they also help prevent soil erosion (Corlett, 2016). However, as forests are destroyed, plants are also destroyed, affecting the ecosystem's cycle and societal function (Sorecha and Deriba, 2017).

On the other hand, above- and below-ground carbon stores make up terrestrial carbon stocks. The aboveground carbon stocks comprise plant parts and aboveground biomass, such as stems, twigs, leaves, vines, epiphytes, and understorey. The amount of carbon in a pool or a plant's body system is referred to as carbon stock. It is necessary to protect and manage our plant species for future ecosystem restoration to maintain and manage our diverse plant species to restore ecosystems for future uses (Li et al., 2017). Hence, increased carbon stocks sequestered from the atmosphere could be achieved by improving woody vegetation and expanding forest growth to reduce carbon emissions and global warming (Rahayu et al., 2016).

Recent research exposes Jubilee Cross Hill's situation considering its trees, understorey plant species diversity, and aboveground carbon stocks. According to natives, Jubilee Cross Hill contained many tall-huge trees and cogon grass. However, as an unintended fire occurred, a few trees grew and were brought back to life. With that, people near the area utilize the land by converting some parts of the hill into agricultural lands, such as croplands, as a source of food for the people living near Jubilee Cross Hill, along with other primary sources of income for the residents in Barangay San Juan, Matalom such as farming, sinamay weaving, and different types of labour. One of the agricultural processes is slash-and-burn (kaingin) and cutting some trees.

The person in charge of Matalom LGU information said that no government agency bureau focuses on forest management in the municipality of Matalom. Therefore, when it comes to issuing permits for converting some parts of land into cropland, the process will occur first in the barangay. However, people who transform the land into croplands do not ask permission from the barangay since the land is privately owned. Conjointly, only 10 m x 15 m on the top part of the hill is donated, according to the caretaker in charge of the Jubilee Cross.

Further, Jubilee Cross Hill also has the quality of becoming a tourist spot since the top of the hill offers a relaxing view of the seas, Canigao Island, and is a perfect spot for sunset viewing. It is also often visited by the people of Matalom and from nearby towns. However, some parts are relatively degraded, trees are cut, and the land is converted into croplands, which may end in the worst situation if ignored. It is in this regard this study is designed to identify the plant species and diversity level and quantify of the aboveground carbon stocks in Jubilee Cross Hill.

Additionally, investigating plant species diversity and aboveground carbon stocks in trees and understorey is a crucial area of research in the Philippines. It provides vital information for assessing plant species diversity levels and aboveground carbon stocks significantly influenced by anthropogenic activities along with climatic, topographic, and grazing pressures (Rahman et al., 2021). It is critical for policymaking and recommendations for sustainable environmental practices. However, despite its significance, this area remains understudied.

Considering this research gap, this study determines the plant species, diversity levels, and aboveground carbon stocks in Jubilee Cross Hill. The study employed scientific and local names to identify the plant species accurately. Additionally, the richness, abundance, species evenness, and the Shannon-Wiener diversity index were used as crucial indices to identify the diversity levels accurately. The findings of this study have implications for future research and environmental management in the Philippines. This underscores the need for more comprehensive studies that examine the possible relationships between plant species diversity and aboveground carbon stocks, and the effects of human activities on these variables. Such studies will better understand the ecological processes that underlie plant species diversity and carbon stocks and inform more effective policies and recommendations for sustainable environmental practices.

## Methodology

### *Study Site*

The study site (**Figure 1**) is in Jubilee Cross Hill, Matalom, Leyte, with a geographical position of 10°15'43.2" North latitude and 124°49'45.2 East longitude. The site was selected based on observable threats of degradation due to land conversion into croplands which is believed to be a dipterocarp forest as tree species of such forest can be easily seen in the area. Matalom is located on the southwest coast of Leyte, approximately 22 km north of Maasin, and has a type IV climate category (Pomeroy, 1987; Bendimerad et al., 2014).

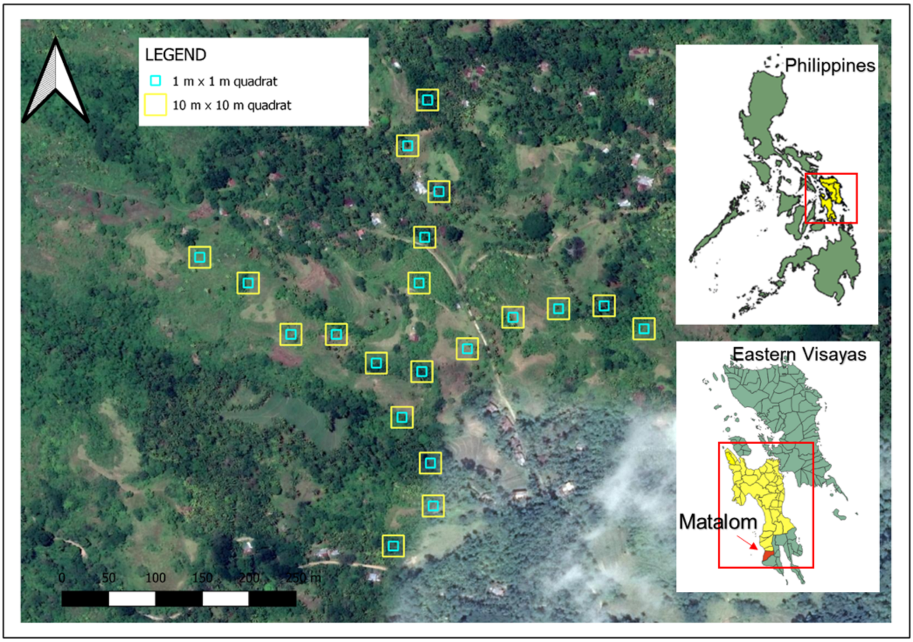


**Figure 1**. Study sites in Jubilee Cross Hill, Matalom, Leyte, Philippines.

### *Ethics Statement*

The researcher asked for consent and informed the owner of the land and officials of the barangay before the study was conducted. Personal information remains anonymous and confidential.

### *Data Collection*

A stratified random sampling technique was used in this study to establish 20 plots of 10 m x 10 m for trees and 20 subplots of 1 m x 1 m for understorey to determine plant species diversity and aboveground carbon stocks. A 250 metre transect line on each side (North, South, East, West) was established using a tie straw, and for every 50 metres, plots were allocated randomly in the study area. In the established 10 m x 10 m representative sampling plots, all trees with a diameter at breast height (1.3 m aboveground) of at least 10 cm were identified, measured using a diameter- tape (D-tape), and recorded. Photos were also taken from each tree species (Bobon-Carnice & Lina 2017; 2021). The diameters were measured separately above the swelling for tree species that branched at breast height, and the average measurements were recorded. For trees that forked below 1.3 m, the individual stem was separately measured and treated as two trees (Sintayehu et al., 2020).

All understorey plant species within 1 m x 1 m sub-plots were recorded, counted, photographed, and clipped to 1 cm stubble height using scissors. The clipped understorey was put in the paper bags and brought to the washing area. The understorey plant species were thoroughly washed with tap water and distilled water. Then, it was air-dried until there was no more water dripping. Fresh weight was recorded using a digital weighing scale. The collected understorey materials were put into the oven and dried at 65 degrees Celsius for approximately 24 hours until constant weight. Finally, the dried materials of understorey plant species were weighed and recorded (Sintayehu et al., 2020; Bobon-Carnice & Lina, 2017; 2021). Sampling was done between September and October 2021 for tree species and from January 22 to 31, 2022, for understorey plant species, after Typhoon Odette.

Books on Weeds in Irrigated and Rainfed Lowland Ricefields in the Philippines (Donayre et al., 2018), Weeds of Vegetables and other Cash Crops in the Philippines (Donayre et al.,2019), Ecosystems Research and Development Bureau. Common Weed Species with Medicinal Uses (2012), Forest Management Bureau-Department of Environment and Natural Resources (2007) Greenbook 2: Procedures and Technique in Planting, Forest Tree Species with Medicinal Uses (2002), and website www.phytoimages.siu.edu were utilized and serve as instruments for the initial identification of plant species scientific names. We also consulted with experts in plant taxonomy from DENR Region 8, Tacloban, City, to validate the initial identification of plant species.

### *Data and Statistical Analysis*

Plant species richness was obtained as the number of species in the study site. Species abundance was obtained as the number of individuals per species in the study area (Locey and White, 2013). Plant species diversity was calculated using the Shannon - Wiener Diversity Index (H') (Whittaker, 1960; Sintayehu et al., 2020).

$$H' = -\sum_{i=1}^{S} pi\, ln\, pi$$

Where *pi* is the proportion of species *i*, *ln* is the natural log, and *S* is the number of species in a specified area. A greater value of the Shannon-Weiner Diversity index (H') indicates a higher species diversity. A computed result of the Shannon - Wiener Diversity Index (H') was interpreted using the modified Fernando Biodiversity Scaling System (Fernando 1998) as cited by Aureo et al. (2020) where diversity levels 3.50 – 4.00, 3.00 – 3.49, 2.50 – 2.99, 2.00 – 2.49, and 1.99 and below was interpreted as very high, high, moderate, low, and very low respectively. Plant species evenness was estimated using Pielou's index (Pielou, 1966; Sintayehu et al., 2020):

$$J' = \frac{H'}{ln\, S}$$

Where: H' is the Shannon-Weiner Diversity index, and S is the total number of species. The interval of this index ranges from 0 to 1, where 0 is degenerate distribution, and 1 is complete evenness (uniform) (Pielou, 1966; Sintayehu et al., 2020; Kvålseth, 2015):

The relative abundance of plant species in the study site was calculated using the equation described by Garg et al. (2020):

$$\text{Relative abundance (\%)} = \frac{\text{Abundance of indidual species}}{\text{Total abundance of all species}} \times 100\%$$

***Aboveground carbon assessment of trees***

The allometric equation was used to estimate carbon stocks in each tree species within 10 m x 10 m representative sampling plots. The aboveground biomass of all trees with DBH ≥ 10 cm was calculated with the following equation by Brown (1997) (as cited by Cairns et al., 2003):

$$Y = \exp\,[-1.996 + 2.32 * \ln\,(dbh)]$$

Where Y is aboveground per tree biomass (kg), dbh is the diameter at breast height (cm). And the results were converted to tons per hectare (1 ton =1,000 kg, 1 ha = 10,000 $m^2$) (Sintayehu et. al., 2020). And the carbon content was calculated through the following the equation also (Bobon-Carnice, 2017):

$$\text{C storage (t } ha^{-1}) = \text{Total biomass/ha} \times 0.45$$

***Understorey plant species aboveground carbon assessment***

The carbon content was calculated as 50% on the dry biomass of understorey species. The carbon stock of dry biomass of understorey species was calculated with the following formula:

$$W_c = W_o \times 0.5$$

Where $W_c$ is the weight of carbon in understorey biomass (g), $W_o$ is the oven-dry weight of aboveground biomass, and 0.5 is the estimated carbon percentage in dry plant biomass. Moreover, the results of the samples were converted to tons per hectare (1 ton = 1,000,000 g) (Bobon-Carnice, 2017; Sintayehu et al., 2020).

For the statistical analysis, an independent t-test was used to determine if there were significant differences in the diversity and C-stocks between trees and understorey plant species since the two samples (trees and understoreys) under comparison are independent of each other. The non-directional (two-tailed) deviation was used as the null hypothesis does not specify in which the two samples differ. The alpha level used was 0.05. Wherein if the t-test result in the statistical analysis of data is larger than 0.05, the null hypothesis will be accepted, and if the t-test result is less than 0.05, then the null hypothesis will be rejected (Kim, 2015).

## Results

### *Plant Species Diversity*

**Table 1** shows the different tree species found in the study sites and their relative abundance. The total number of individuals in all species of trees is 98. The most abundant species is *Swietenia macrophylla* (Mahogany), which has 44 individuals and has 44.90% relative abundance from the total number of individuals in all species of trees. While the least abundant species of trees found in all quadrats with the lowest relative abundance were also recorded for *Parishia insignis* (Badbad), *Mangifera indica* (Mangga), *Artocarpus blancoi* (Tipo), and *Melicope triphylla* (Tonggamos) with only one (1) total number of individuals found in each species and 1.02% relative abundance.

Aside from that, **Table 2** also presents the different species of understoreys in the study area and their relative abundance. The total number of individuals in all species is 2814. The most abundant understorey plant species with the highest relative abundance was also recorded for *Urochloa mutica* (Miligoy), with 590 individuals and 20.97% relative abundance. In comparison, the least abundant species of understorey with the lowest relative abundance were recorded for *Phaius tankervilleae* (Banti), *Convolvulus arvensis* (Bagon-Bagon), *Colocasia esculenta* (Gabi-Gabi), *Mimosa pudica* (Hibi-Hibi), *Alternanthera sessilis* (Banwa), and *Ambrosia psilostachya* (Korhito), both with one (1) total number of individuals and with the relative abundance of 0.04%.

.

**Table 1.** Tree species and relative abundance in the study area.

| Species Name | | Total Number of Individuals per species (Abundance) | Relative Abundance (%) |
|---|---|---|---|
| Local Name | Scientific Name | | |
| Mahogany (Mahogany) | *Swietenia macrophylla* | 44 | 44.9 |
| Hambabawd (Leichhard Tree) | *Nauclea orientalis* | 19 | 19.39 |
| Lagnob (Hauili) | *Ficus septica* | 10 | 10.2 |
| Gemelina (White teak) | *Gmelina arborea* | 9 | 9.18 |
| Abgaw (Fragrant premna) | *Premna odorata* | 4 | 4.08 |
| Nangka (Jackfruit) | *Artocarpus heterophyllus* | 3 | 3.06 |
| Baganga (Bagalunga) | *Melia dubia* | 2 | 2.04 |
| Tugas (Molave) | *Vitex parviflora* | 2 | 2.04 |
| Badbad "Layang-layang (Red Dhup) | *Parishia insignis* | 1 | 1.02 |
| Lubi (Coconut) | *Cocos nucifera* | 1 | 1.02 |
| Mangga (Manggo) | *Mangifera indica* | 1 | 1.02 |
| Tipo (Atipolo) | *Artocarpus blancoi* | 1 | 1.02 |
| Tonggamos (Philippine box-orange) | *Melicope triphylla* | 1 | 1.02 |
| **Total** | | **98** | **100** |

**Table 2.** Understorey plant species and relative abundance.

| Species Name | | Total Number of Individuals per species (Abundance) | Relative Abundance (%) |
|---|---|---|---|
| Local Name | Scientific Name | | |
| Miligoy (6) (Buffalo grass) | *Urochloa mutica* | 590 | 20.97 |
| Lukdo-lukdo (1) (Fern) | *Gleichenia japonica* | 310 | 11.02 |
| Cogon (Cogon grass) | *Imperata cylindrica* | 267 | 9.49 |
| Kunsinsi (Tick clover) | *Desmodium triflorum* | 250 | 8.88 |
| Miligoy (1) (Bristle basketgrass) | Oplismenus hertillus | 241 | 8.56 |
| Morio-morio (Bitter bush) | *Chromolaena odorata* | 177 | 6.29 |
| Lukdo-lukdo (2) (Giant sword fern) | *Nephrolepis biserrata* | 131 | 4.66 |
| Goob (Spike Moss) | *Sellaginella delicatula* | 103 | 3.66 |
| Miligoy (5) (African Bermuda-grass) | *Cynodon nlemfuensis* | 78 | 2.77 |
| Miligoy (7) (Indian crabgrass) | *Digitaria longiflora* | 67 | 2.38 |
| Miligoy (2) (Hilo grass) | Paspalum conjugatum | 65 | 2.31 |
| Sagbot (4) (Milk weed) | *Veronica perigrina* | 65 | 2.31 |

| | | | |
|---|---|---|---|
| Bogang (Wild sugarcane) | *Saccharum spontaneum* | 51 | 1.81 |
| Onod-onod (Bearded flatsedge) | *Cyperus squarrosus* | 48 | 1.71 |
| Disaplina (Blue porter weed) | *Stachytarpheta jamaicensis* | 43 | 1.53 |
| Miligoy (8) (Eastern African couchgrass) | *Digitaria abyssinica* | 39 | 1.39 |
| Kudsot (Blue wiss) | *Teramnus labialis* | 35 | 1.24 |
| Dawpang (Caesar weed) | *Urena lobata* | 26 | 0.92 |
| Kampisaw (Yellow star-thistle) | *Centaurea solstitialis* | 24 | 0.85 |
| Miligoy (3) (Southern crabgrass) | *Digitaria ciliaris* | 24 | 0.85 |
| Hagupit (Sal leaved desmodium) | *Desmodium gagenticum* | 19 | 0.68 |
| Bosikad (Purple leaved button weed) | *Borreria ocymoides* | 16 | 0.57 |
| Hakopaw (Ogiera) | *Eleutheranthera ruderalis* | 16 | 0.57 |
| Talikod (Chamber bitter) | *Phyllantus urinaria* | 16 | 0.57 |
| Tagbak (Garden ginger) | *Zingiber phumiangense* | 15 | 0.53 |
| Eping-eping (Round-leaved tick trefoil) | *Desmodium rotundifolium* | 13 | 0.46 |
| Sagbot (2) (Tilo) | *Justicia pectoralis* | 13 | 0.46 |
| Kokog banog (Dog's-tongue) | *Pseudelephantopus spicatus* | 11 | 0.39 |
| Hilba-hilba (Tall fleabane) | *Erigeron sumatrensis* | 8 | 0.28 |
| Kotocola (Lawn marshpennwort) | *Hydrocotyle sibthorpioides* | 6 | 0.21 |
| Rolio (Blood lily) | *Scandoxus multiflorus* | 6 | 0.21 |
| Lukdo-lukdo (3) (Interrupted Fern) | Osmunda claytoniana | 5 | 0.18 |
| Alibhaka (Pignut) | *Hyptis suaveolens* | 4 | 0.14 |
| Sagbot (3) (Red clover) | *Trifolium pratense* | 4 | 0.14 |
| Bagon-bagon (Black bindweed) | *Fallopia convolvulus* | 3 | 0.11 |
| Hakopaw (Shaggy soldier) | *Galinsoga quadrira* | 3 | 0.11 |
| Nito (Climbing Fern) | *Lygodium circinnatum* | 3 | 0.11 |
| Toway-toway (Beggar's Tick) | *Bidens pilosa* | 3 | 0.11 |
| Vietnam (Bitter vine) | *Mikania micrantha* | 3 | 0.11 |
| Kanaka (Milkweed) | *Euphorbia heterophylla* | 2 | 0.07 |
| Miligoy (4) (Kikuyu grass) | *Pennisetum clandestinum* | 2 | 0.07 |
| Tawa-tawa (Garden spurge) | *Euphorbia hirta* | 2 | 0.07 |
| Bagon-bagon (Bindweed) | *Convolvulus arvensis* | 1 | 0.04 |
| Banti (Greater swamp-orchid) | *Phaius tankervilleae* | 1 | 0.04 |
| Gabi-gabi (Taro) | *Colocasia esculenta* | 1 | 0.04 |

| | | | |
|---|---|---|---|
| Hibi-hibi (Sensitive plant) | *Mimosa pudica* | 1 | 0.04 |
| Korhito (Cuman ragweed) | *Ambrosia psilostachya* | 1 | 0.04 |
| Sagbot (1) (Sessile joyweed) | *Alternanthera sessilis* | 1 | 0.04 |
| Talampay (Black nightshade) | *Solanum nigrum* | 1 | 0.04 |
| | **Total** | **2814** | **100** |

**Table 3.** Diversity of Trees and Understorey Plant Species in Jubilee Cross Hill.

| Plant Species | Species Richness | Species Abundance | Species Abundance Density | Species Evenness | H' |
|---|---|---|---|---|---|
| Trees | 13 | 98 | 4,900 / ha | 0.69 | 1.76 |
| Understorey | 49 | 2814 | 1,407,00 / ha | 0.73 | 2.83 |

The variation of species richness of trees and understorey is 13 and 49, respectively. Additionally, the abundance of species or the total number of individuals per species of trees and understorey is 98 and 2814. The variation of diversity index in trees and understorey plant species is 1.76 and 2.83. Trees and understorey plant species' evenness also are 0.69 and 0.73, respectively.

### *Aboveground Carbon Stocks*

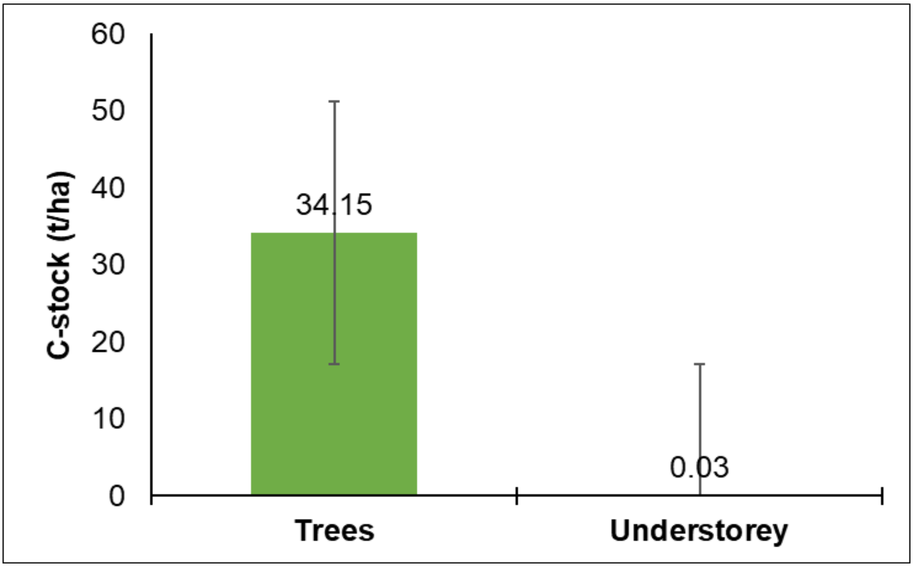


**Figure 2.** Total Aboveground Carbon Stocks of Trees and Understorey.

Aboveground trees have a total mean of 34.15 t C $ha^{-1}$ of aboveground carbon stocks, whereas understorey plant species only have a total mean of 0.03 t C $ha^{-1}$. In determining if there are significant differences in the diversity and C-stocks between trees and understorey plant species, an independent t-test was used to analyze the data since trees and understorey plant species were independent. The computed t-test in the diversity of trees and understorey resulted in 0.0043. Furthermore, the significant difference in C-stocks between trees and understorey plant species t-test also resulted in 0.0064.

## Discussion

This study shows the importance of plants in our ecosystem as they play a significant role in ecosystem diversity and the carbon cycle. Trees and understorey plant species are just one of the critical elements of our ecosystem. In this study, understorey plant species have a higher species richness and abundance. Trees also have a low diversity value in the diversity index, whereas understorey plant species have a moderate diversity value based on the Modified Fernando Biodiversity Scale (Fernando, 1998), as cited by Aureo et al. (2020). Both trees and understorey plant species also have unequal distribution of plant species in the study area based on the interval, according to Kvålseth, 2015. However, despite having a smaller species richness, abundance, and diversity value, trees could contribute higher carbon stocks than understorey plant species.

The study revealed that species richness is higher for understorey plant species than tree species, which is 49 and 13, respectively. The abundance of species or the total number of individuals per species of trees and understorey is 98 and 2814. For the diversity index, the result was 1.76, interpreted as very low, and 2.83, which is moderate based on the Modified Fernando Biodiversity Scale (MBFS) led by understorey species than tree species. Similarly, the species evenness, which is 0.69 and 0.73, led by understorey plant species, both signify unequal distribution of plant species in the study area. The implications of a moderate biodiversity index of trees and understorey based on the MFBS can be significant for ecosystem functioning, carbon storage, and wildlife habitat. Firstly, a moderate biodiversity index of trees and understorey can affect ecosystem functioning. Studies have shown that increasing tree and understorey biodiversity can increase the productivity and stability of ecosystem processes such as carbon sequestration and nutrient cycling (Watson et al., 2019; Jucker et al., 2020). Therefore, a moderate biodiversity index may limit the potential for these ecosystem functions to function optimally.

Secondly, a moderate biodiversity index of trees and understorey can also impact carbon storage. Trees and understorey vegetation play an important role in carbon sequestration, and studies have found that higher tree and understorey biodiversity can enhance carbon storage (Cavender-Bares et al., 2019; Xu et al., 2019). Therefore, a moderate biodiversity index may limit the potential for forests to store carbon effectively. Lastly, a moderate biodiversity index of trees and understorey can also impact wildlife habitats. A high biodiversity of trees and understorey vegetation can provide a habitat for a diverse range of wildlife species (Gehring et al., 2019; Walters et al., 2020). Therefore, a moderate biodiversity index may limit the potential for forests to support a diverse range of wildlife species.

It further implies that the growth of trees in Jubilee Cross Hill was significantly affected by the unintended fire and converting some areas into croplands. It is also supported by the study that the occurrence of a single fire event significantly affects the diversity and regeneration of trees (Verma et al., 2017). Anthropogenic activities have shaped and influenced species diversity (Giliba et al., 2011). Fire reduces the covering of trees, slows the advance of trees, and maintains the dominance of understorey species (Limb et al., 2011). One of the disadvantages of understorey dominance is that it may expose the hill to erosion. Given that understorey plant species can also yield or hasten the growth of trees if it dominates the hill entirely, this may result in a low abundance of trees. Hence it will cause damage to the environment and the population underneath the hill (Bruelheide et al., 2018).

The result also expressed that the area may have an unstable and unproductive ecosystem due to very low diversity of trees and moderate diversity of understorey plant species which contrasts with the study of Lillo et al. (2019), where an area with high species diversity results in a more stable and productive ecosystem. The result of the study was also supported by the statement that low species richness and unequal distribution of trees or a high relative abundance of a single species in the area resulted in low diversity which may be due to natural processes or human disturbances (Gadow et, al., 2012).

Research shows that the main driver of the richness of plants in the said biodiversity in Jubilee Cross Hill, Matalom, Leyte is the resource availability in which an estimated 50-90 per cent of life in the rainforest exists in the trees above the shaded forest floor. The primary tropical rainforest is divided into at least five layers: the overstorey, the canopy, the understorey, the shrub, and the forest floor. Each layer has unique plant and animal species interacting with the ecosystem (Royo & Carson, 2022). Hence, it is crucial to promote and protect biodiversity in forest ecosystems to maintain the health and sustainability of these ecosystems.

On the other hand, comparing trees and understorey plant species with the accumulation of the carbon stocks shows that their contribution to overall aboveground carbon (AGC) storage was due to species richness and unequal distribution of plant species. Cutting trees and converting them into croplands potentially reduce aboveground carbon stocks and affect plant species diversity. Trees were the most likely affected by the disturbances regarding diversity level. It was further found that large trees play a significant role in the accumulated carbon stock of the forests in Jubilee Cross Hill, Matalom, and Leyte. It is because the large-diameter trees store massive amounts of carbon and are a significant driver of carbon cycle dynamics in the forest.

**Figure 2** further indicates that tree species resulted in a higher carbon stock with a mean of 34.15 t C $ha^{-1}$ compared to understorey plant species, which only contributed a mean of 0.03 t C $ha^{-1}$. It was also presented that there are significant differences in the diversity of trees and understorey plant species based on an independent t-test result of 0.0043. The computed t-test in the C-stocks between trees and understorey plant species also resulted in 0.0064, which shows a significant difference. Comparing the carbon stocks of trees and understorey plant species indicates that tree species resulted in higher carbon stocks than understorey plant species. Since understorey has a higher species richness than trees, trees have fewer relative abundances than the understorey. It indicates a higher value of C-stocks of trees, which implies that trees play a vital role in the global carbon cycle and has a great potential to increase carbon stocks, as it means that trees need more conservation strategies. (Henry et al., 2011; Gebrewahid et al., 2018; Coritico et al., 2020).

Several studies have investigated the comparative analysis of carbon stocks in trees and understorey vegetation. For example, Bobon-Carnice and Lina (2017) found in a study on carbon storage and nutrient stocks distribution in three adjacent land use patterns in Lake Danao National Park, Ormoc, Leyte, Philippines, that the carbon stocks of trees in the old-growth forest were the highest, followed by the agroforestry area and the grassland as the lowest. In a subsequent study by the same authors in 2021, Bobon-Carnice and Lina found that carbon stocks in trees were significantly higher in the old-growth forest compared to the secondary forest.

Additionally, Yang et al. (2019) conducted a study in a subtropical forest in China and found that carbon stocks in understorey vegetation were significantly lower than in trees. However, the study also found that carbon stocks in understorey vegetation were highest in forests with diverse understorey communities. Similarly, Fuentes et al. (2020) found in a Peru tropical forest study that carbon stocks in trees were significantly higher than in understorey vegetation. Still, the contribution of understorey vegetation to total ecosystem carbon stocks increased with forest disturbance.

In contrast to this study's result, in temperate forests in China by Zhang et al. (2015), trees had significantly higher carbon stocks than understorey vegetation, with tree carbon stocks averaging 101.6 Mg/ha and understorey vegetation carbon stocks averaging 5.8 Mg/ha. The literature suggests that trees generally have significantly higher carbon stocks than understorey vegetation. However, the contribution of understorey vegetation to total ecosystem carbon stocks can vary depending on forest disturbance, understorey diversity, and other factors.

To determine if there are significant differences in the diversity and C-stocks between trees and understorey plant species, independent t-test was used to analyze the data. The computed result shows a significant difference in the diversity of trees and understorey plant species. Correspondingly, the computed t-test result of C-stocks between trees and understorey plant species shows a significant difference since trees and understorey plant species are independent.

This study shows that trees should be given further attention since they play a crucial role in the global carbon cycle (Salunkhe et al., 2017), despite their very low diversity index. Trees also stand an indispensable role in environmental protection, particularly soil erosion, since the dominance of understorey plant species exposes the hill to erosion (Bruelheide et al., 2018). Hence, there should be conservation and enhancement of trees in Jubilee Cross Hill to protect the area and maintain its beauty for tourist attractions. It is highly suggested that strong coordination from local communities, local government units, and concerned government agencies should arise to create programs to enhance and protect the study area.

## Conclusion

The diversity levels of trees and understorey plant species in terms of species richness and abundance were led by understorey plant species. For the diversity index, understorey plant species still have a higher value, interpreted as moderate, and trees have a very low value, based on the Modified Fernando Biodiversity Scale. Both trees and understorey plant species signify unequal distribution in the study area. Despite trees' deficient diversity level, they still contribute to higher carbon stocks as trees tend to contribute more carbon to the ecosystem due to their larger diameter at breast height (DBH) compared to other plants, which have great potential for the global carbon cycle. Comparatively, there are significant differences in the diversity and c-stocks between trees and understorey based on the independent t-test. Furthermore, more conservation strategies are needed to protect and manage plant species in the study site, particularly trees.

## Acknowledgment

The authors are thankful to our colleagues in reviewing the paper, namely Dr. Elisa C. Operario, Prof. Adorne Y. Madera, Ma'am Joanna Fatima A. Bergado, Ma'am Lilibeth B. Peliño, and Sir Julius Ken P. Badeo, for their essential contribution, comments, and suggestions to establish this research study—equally, the Department of Environment and Natural Resources, Philippines for validating our plant species.

## References

**Aureo WA, Reyes TD, Mutia FCU, Jose RP, Sarnowski MB. 2020.** Diversity and composition of plant species in the forest over limestone of Rajah Sikatuna Protected Landscape, Bohol, Philippines. *Biodiversity Data Journal, **8.***

**Bendimerad, Fouad & Rizal, Ma & Bergonia, Ma & Borinaga, Moses & Beroya-Eitner, Mary Antonette & Tirkey, Nancy & Barba, Marivic & Padao, Ishtar & Padilla, Michael & Perez, Ma & Zayas, Jerome & Villa, Paolo & Dakis, Kristoffer & Valera, Annie. 2014.** The Mw7.2 October 15, 2013, Bohol, Philippines Earthquake. 10.13140/RG.2.2.23010.76485/1.

**Bobon-Carnice PA, Lına S. 2017.** Carbon Storage and Nutrient Stocks Distribution of Three Adjacent Land Use Patterns in Lake Danao National Park, Ormoc, Leyte, Philippines. *Journal of Science, Engineering and Technology, **5:*** 1–14.

**Bobon-Carnice PA, Lina SB. 2021.** Changes in Carbon and Nutrient Stocks of Secondary Forest Transformations Under Ultisol in Leyte Island, Philippines. *Mindanao Journal of Science and Technology, **19*** (1).

**Bruelheide H, Dengler J, Purschke O, Lenoir J, Jiménez-Alfaro B, Hennekens SM, Botta-Dukát Z, Chytrý M, Field R, Jansen F, Kattge J. 2018.** Global trait-environment relationships of plant communities. *Nature ecology & evolution, **2*** (12): 1906–1917.

**Cairns MA, Olmsted I, Granados, J, Argaez J. 2003.** Composition and aboveground tree biomass of a dry semi-evergreen forest on Mexico's Yucatan Peninsula. *Forest Ecology and Management, **186*** (1–3): 125–132.

**Cavender-Bares J, Keen A, Miles B, Quesada T. 2019.** Biodiversity and ecosystem services in a climate context. *Frontiers in Ecology and Evolution, **7***: 464.

**Coritico FP, Lagunday NE, Galindon JMM, Tandang DN, Amoroso VB. 2020.** Diversity of trees and structure of forest habitat types in Mt. Tago Range, Mindanao, Philippines. *Philippine Journal of Systematic Biology, **14*** (3): 1–11.

**Corlett R. 2016**. Plant Diversity in a Changing World: Status, Trends, and Conservation Needs. *Plant Diversity, **38:*** 10–16.10.1016/j.pld.2016.01.001.

**Donayre DKM, EC Martin, SE Santiago, JT Lee. 2018.** *Weeds in Irrigated and Rainfed Lowland Ricefields in the Philippines. 2nd Edition.* Philippine Rice Research Institute, Maligaya, Science City of Muñoz, Nueva Ecija, Philippines. 197 p.

**Donayre DKM, Santiago SE, Martin EC, Lee JT, Corales RG, Janiya JD, Kumar V. 2019.** *Weeds of Vegetables and other Cash Crops in the Philippines.* Philippine Rice Research Institute, Maligaya, Science City of Muñoz, Nueva Ecija, Philippines. 141p.

**Ecosystems Research and Development Bureau**. Common Weed Species with Medicinal Uses Vol. 24 No.1, January-April 2012 Research Information Series on Ecosystems ERDB, College 4031, Laguna. Retrieved from: http://erdb.denr.gov.ph/files/publications/rise/r_v24n1.pdf

**Forest tree species with medicinal uses.** Ecosystems Research and Development Bureau, Department of Environment and Natural Resources, 2002. Retrieved from: https://erdb.denr.gov.ph/wp-content/uploads/2015/06/denr_v11.pdf

**Forest Management Bureau-Department of Environment and Natural Resources.** 2007. Greenbook 2: Procedures and Technique in Planting. Visayas Avenue, Diliman Quezon City 1100 Philippines. 33 pp. Retrieved from: https://forestry.denr.gov.ph/pdf/ref/greenbook1.pdf

**Fuentes M, Malhi Y, Lloyd J, Vega RM. 2020.** Above- and below-ground carbon stocks in lowland Amazonian and Andean forests: Implications of deforestation and forest degradation. *Global Change Biology, **26*** (10): 5422–5437.

**Gadow KV, Zhang CY, Wehenkel C, Pommerening A, Corral-Rivas J, Korol M, Myklush S, Hui GY, Kiviste A, Zhao XH. 2012.** Forest structure and diversity. *Continuous cover forestry*: 29–83.

**Gebrewahid Y, Gebre-Egziabhier TB, Teka K, Birhane E. 2018.** Carbon stock potential of scattered trees on farmland along an altitudinal gradient in Tigray, Northern Ethiopia. *Ecological processes, **7*** (1): 1–8.

**Gehring TM, Swihart RK, Dey DC. 2019.** Understorey plant communities influence habitat use by small mammals in managed forests. *Forest Ecology and Management, **432:*** 633–641.

**Henry M, Picard N, Trotta C, Manlay R, Valentini R, Bernoux M, Saint-André L. 2011.** Estimating tree biomass of sub-Saharan African forests: a review of available allometric equations. *Silva Fennica, **45*** (3): 477–569.

**Jucker T, Bongalov B, Burslem DF, Nilus R, Dalponte M, Lewis SL, Phillips OL, Qie L, Coomes DA. 2020.** Topography shapes the structure, composition and function of tropical forest landscapes. *Ecology Letters, **23*** (3): 459–469.

**Kim TK. 2015.** T test as a parametric statistic. *Korean journal of anesthesiology, **68*** (6): 540–546.

**Kvålseth TO. 2015.** Evenness indices once again: critical analysis of properties. *Springer Plus, **4*** (1): 1–12.

**Locey KJ, White EP. 2013.** How species richness and total abundance constrain the distribution of abundance. *Ecology letters, **16*** (9): 1177–1185.

**Li W, Li J, Liu S, Zhang R, Qi W, Zhang R, Knops JM, Lu J. 2017.** Magnitude of species diversity effect on aboveground plant biomass increases through successional time of abandoned farmlands on the eastern Tibetan Plateau of China. *Land Degradation & Development, **28*** (1): 370–378.

**Lillo EP, Fernando ES, Lillo MJR. 2019.** Plant diversity and structure of forest habitat types on Dinagat Island, Philippines. *Journal of Asia-Pacific Biodiversity, **12*** (1): 83–105.

**Limb RF, Fuhlendorf SD, Engle DM, Kerby J D. 2011.** Growing-season disturbance in tallgrass prairie: evaluating fire and grazing on *Schizachyrium scoparium*. *Rangeland Ecology & Management, **64*** (1): 28–36.

**Pielou EC. 1966.** The measurement of diversity in different types of biological collections. *Journal of theoretical biology, **13:*** 131–144.

**Pomeroy RS. 1987.** The role of women and children in small scale fishing households: a case study in Matalom, Leyte, Philippines. *Philippine Quarterly of Culture and Society*: 353–360.

**Salunkhe O, Khare PK, Kumari R, Khan ML. 2018.** A systematic review on the aboveground biomass and carbon stocks of Indian forest ecosystems. *Ecological processes, **7*** (1): 1–12.

**Sintayehu DW, Belayneh A, Dechassa N. 2020.** Aboveground carbon stock is related to land cover and woody species diversity in tropical ecosystems of Eastern Ethiopia. *Ecological Processes, **9*** (1): 1–10.

**Sorecha EM, Deriba L. 2017.** Assessment of Plant Species Diversity, Relative Abundances and Distribution in Haramaya University, Ethiopia. *Journal of Physical Science and Environmental Studies, **3*** (3): 30–35.

**Rahayu S, Lusiana B, van Noordwijk M. 2005.** Above ground carbon stock assessment for various land use systems in Nunukan, East Kalimantan. *Carbon Stock Monitoring in Nunukan, East Kalimantan: A Spatial and Modelling Approach. World Agroforestry Centre, SE Asia, Bogor, Indonesia*: 21–34.

**Rahman B, Karmilah M, Kautsary J, Ridlo MA. 2021.** The Tidal Flooding Causes in the North Coast of Central Java: A Systematic Literature Review. *Journal of Southwest Jiaotong University, **56*** (6).

**Royo AA, Carson WP. 2022.** Stasis in forest regeneration following deer exclusion and understory gap creation: A 10-year experiment. *Ecological Applications*, ***32*** (4): p.e2569.

**Walters JR, Derrickson SR, Michael Fry D, Haig SM, Marzluff JM, Wunderle Jr JM. 2020.** Status of the California condor (Gymnogyps californianus) and efforts to achieve its recovery. *The Auk: Ornithological Advances, **137*** (1): 1–18.

**Watson R, Baste I, Larigauderie A, Leadley P, Pascual U, Baptiste B, Demissew S, Dziba L, Erpul G, Fazel A, Fischer M. 2019.** Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. *IPBES Secretariat: Bonn, Germany*: 22–47.

**Whittaker RH. 1960.** Vegetation of the Siskiyou mountains, Oregon and California. *Ecological monographs, **30*** (3): 279–338.

**Xu X, Medvigy D, Powers JS. 2019.** Diversity and structural complexity of understory vegetation are key predictors of carbon stocks in human-modified tropical forests. *Environmental Research Letters, **14*** (10): 105008.

**Yang Y, Zhang W, Li Y, Yu S, Ding Y, Wang H. 2019.** Biomass and carbon stocks of understory vegetation in subtropical forests of China. *Forest Ecology and Management, **446:*** 149–156.

**Zhang W, Yang Y, Yu S, Li Y, Ding Y, Wang H. 2015.** Biomass and carbon stocks of understory vegetation in temperate forests in China. *Forest Ecology and Management, **346***: 16–22.