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TREE DIVERSITY AND CARBON SEQUESTRATION POTENTIAL IN FORESTRY EXPERIMENTAL FOREST OF THE UNIVERSITY OF MINDANAO, DAVAO CITY, PHILIPPINES

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Abstract

Forests play a crucial role in mitigating climate change through carbon sequestration. This study assessed tree diversity and the carbon sequestration potential of the Forestry Experimental Forest of the University of Mindanao, Davao City, Philippines, aligned with the Sustainable Development Goals (SDGs) of the United Nations, which promote global environmental sustainability, particularly SDG Goals 13, Goal 13: Climate Action, and Goal 15: Life on Land. Tree diversity and carbon stock were analyzed using descriptive, quantitative, and correlation methods. A rectangular plot method with a 10% sampling intensity was established to measure the aboveground biomass in trees. Shannon-Weinner was used to determine the species diversity of the area, and the General Allometric Equation developed by Chave et al. (2014), was used to estimate the carbon stock. The study found 51 species, dominated by *Pinus kesiya* (Royle ex Gordon, 1840), with a moderate diversity index of 2.83, a high carbon stock of 62.51 Mg/ha, and a high species richness and evenness. *P. kesiya* (Royle ex Gordon, 1840) has the highest importance value index and a positive correlation between tree diversity and carbon stock. The drawn results encourage academic institutions and local communities to conserve and plant diverse trees to increase biodiversity. These findings are valuable for policymaking, symposiums, and future research.

Keywords: species diversity, carbon stock, aboveground biomass, allometric equation

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INTRODUCTION

Forests are important in mitigating climate change by acting as carbon sinks, absorbing carbon dioxide (CO_2) through photosynthesis, and storing it in biomass and soil (Nunes et al. 2020). Reforestation, particularly with native species, enhances carbon sequestration while promoting biodiversity and ecosystem stability (Di Sacco et al. 2021). Anthropogenic activities, such as fossil fuel combustion, contribute to rising greenhouse gas emissions, leading to severe climate impacts, including ice cap melting, extreme weather, and biodiversity loss (Khosroabadi et al. 2021, Zhumadilova et al. 2023). The UN Sustainable Development Goals (SDGs), particularly Goals 13 (Climate Action) and 15 (Life on Land), emphasize the need for environmental conservation and sustainable management (Saini et al. 2022). Tropical rainforests, covering less than one-fifth of the Earth's land area, support 1.5 billion people and over half of global biodiversity (Pillay et al. 2021). However, human activities threaten their carbon storage potential, despite forests sequestering more carbon than any other terrestrial ecosystem (Yimer et al. 2023). This study assesses tree diversity and carbon sequestration potential in the Forestry Experimental Forest of the University of Mindanao, Davao City to address these concerns. Specifically, it examines species composition, importance value, richness, evenness, and carbon storage in trees, and explores the relationship between tree diversity and sequestration capacity. Grounded in the theory that species richness enhances biomass carbon storage (Baul et al. 2021), this research utilizes a non-destructive sampling method (Upadhyaya 2023) to quantify carbon stock. The study aims to provide data for sustainable forest management, inform policy-making, and contribute to local and global climate change mitigation efforts.

MATERIAL AND METHODS

The study was conducted in the Forestry Experimental Forest of the University of Mindanao, located in Barangay Bayabas, Toril, Davao City (7.0197° N, 125.4173° E). The 55-hectare area contains distinct forest patches and is a research extension site. The study focused on assessing tree diversity and carbon sequestration, measuring trees ≥10 cm DBH at 1.3 m height following FMB Technical Bulletin No. 3. In the conduct of the study, a 20 × 50 m plot method (Verly et al. 2023) was used, with plots randomly generated through QGIS (Umar et al. 2023). The area was assessed regarding species diversity, importance value, richness, and evenness. A total of 55 plots were established at 55 hectares using 10% sampling intensity. The number of plots was determined using:

$$\mathrm{NP}= \frac{As}{\mathrm{Ap}} \times \mathrm{SI}$$

Where:

As = forest stand area
Ap= plot area
SI= sampling intensity

GPS and DENR GEOCAM were used for mapping. Tree diversity was analyzed using the Shannon Diversity Index (Pramudita et al. 2023, Carnice et al. 2023):

$$H' = \sum_{i=1}^{8} piInpi$$

Where:

H'= diversity index
pi= species proportion

It was categorized based on the Modified Fernando Diversity Scale. Species richness was calculated as:

$$\text{Richness}= \frac{\text{Number of species}}{\log(\text{Number of individuals})}$$

Species evenness was obtained following this equation:

$$e = \frac{H'}{\ln S}$$

Where:

e= species evenness
H'= Shannon-Wiener Diversity Index
S= total number of species.

The Importance Value (IV) was computed as:

$$IV = RD+RF+RBA$$

Where:

RD= relative density
RF= relative frequency
RBA= relative basal area.

For Carbon Stock Calculation, a non-destructive equation was used to estimate tree biomass and aboveground carbon content, developed by (Chave et al. 2014, Upadhyaya et al. 2023):

$$AGB \text{ (kg or mg)} = 0.0559 \times (\rho D^{2H)}$$

Where:
AGB= aboveground biomass (kg)
D= diameter at breast height (cm)
H= tree height (m)
For carbon content:

$$AGC=0.47\times AGB$$

Where:
AGC= Above ground Carbon (kg or Mg)

Biomass density (Mg/ha) and Above Ground Carbon (Mg/ha) content per hectare were calculated by dividing its value by sampling area which is 5.5 has.

Table 1. The Modified Fernando diversity scale as a reference for the analysis of the study area diversity.

Relative values	Shannon-Wienner (H') values
Very high	3.5-4.00
High	3.0-3.49
Moderate	2.5-2.99
Low	2.0-2.49
Very Low	1.00-1.99

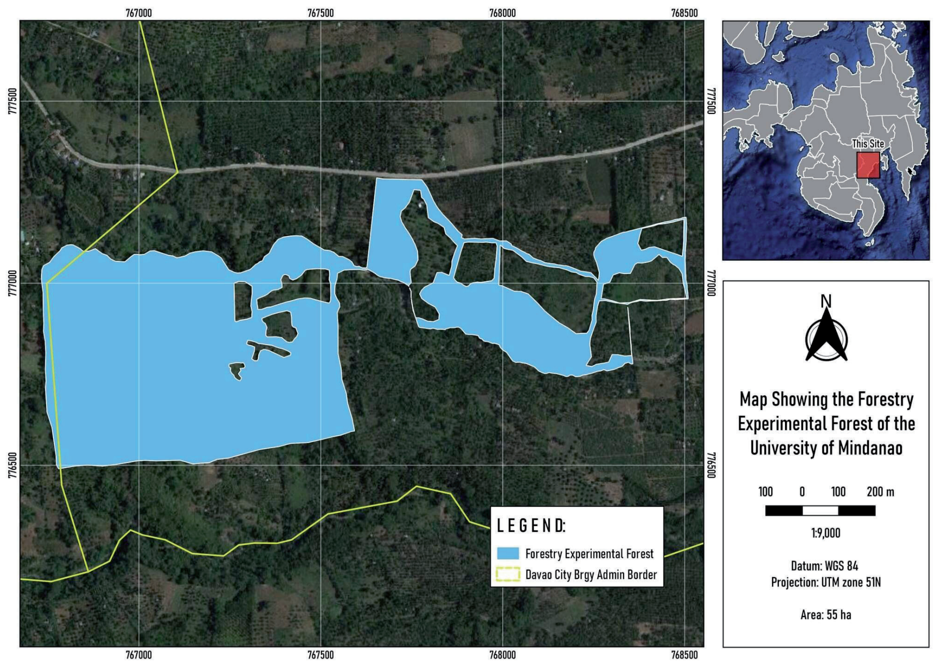

Figure 1. Location of the study.

RESULTS AND DISCUSSION

Species composition of Forestry Experimental Forest of the University of Mindanao, Davao City

The species composition of the Forestry Experimental Forest of the University of Mindanao at Eden, Brgy. Bayabas, Toril, and Davao City are comprised of 736 individual trees comprising 51 species belonging to 25 families. The study area was dominated by *Pinus kesiya* (Royle ex Gordon, 1843), *Swietenia macrophylla* (King, 1886), and *Gmelina arborea* (Roxburgh ex Smith, 1810). The least species were also determined, among of them such as *Melanolepis multiglandulosa* var. *multiglandulosa* (Reinwardt ex Blume, 1826), *Lagerstroemia speciosa* (Linnaeus, 1753), *Alstonia scholaris* var. *scholaris* (Linnaeus, 1767), *Cassia fistula* (Linnaeus, 1753) and *Falcataria falcata* (Linnaeus 1753). A total of 736 individual tree species comprising 51 species belonging to 25 families were recorded in the 55 sampling plots. Among the 736 species, *Pinus kesiya* (Royle ex Gordon, 1843), *Swietenia macrophylla* (King, 1886), and *Gmelina arborea* (Roxburgh ex Smith, 1810) were the dominant species in the area. Whereas *Melanolepis multiglandulosa* var. *multiglandulosa* (Reinwardt ex Blume, 1826), *Coffea arabica* (Linnaeus, 1753), *Litsea philippinensis* (Merrill, 1905), *Lagerstroemia speciosa* (Linnaeus, 1753), *Alstonia scholaris* var. *scholaris* (Linnaeus, 1767), *Cassia fistu*

Species diversity (H')

Table 1 shows the diversity of tree species in the study area. The Shannon-Weiner Diversity Index method was used to determine the diversity of tree species. The result shows that the study area has a diversity index of 2.83. The diversity index of 2.3445, based on the Modified Fernando Diversity scale, indicates moderate diversity of tree species in the study area, similar to the findings of Saka et al. (2024). This index reflects a moderately diverse group of species denoting a healthy mix that contributes to the biodiversity and richness of the environment. They also added that to preserve the diversity of trees and avoid their total eradication, the fewer tree species in the research area should be appropriately protected. (Linnaeus, 1753), *Annona muricata* (Linnaeus, 1753), *Ceiba pentandra* (Linnaeus, 1753), *Viticipremna philippinensis* (Turcz, 1863), *Aleurites moluccana* (Linnaeus, 1753), *Mangifera indica* (Linnaeus, 1753), *Falcataria falcata* (Linnaeus 1753), *Ficus benjamina* var. *bracteata* (Corner, 1960), *Bridelia insulana* (Hanse, 1877), *Ficus ruficaulis* (Merrill, 1904), T *Pterocymbium tinctorium* (Blanco, 1837), and *Ficus variegata* var. *variegata* (Blume, 1825) were the less tree species found in the area.

Table 2. Species with individual frequency and computed diversity indices.

Species	Frequency	Species Diversity
Melanolepis multiglandulosa var. *multiglandulosa* (Reinwardt ex Blume, 1826)	1	0.01
Coffea arabica (Linnaeus, 1753)	2	0.01
Litsea philippinensis (Merrill, 1905)	1	0.01
Lagerstroemia speciosa (Linnaeus, 1753)	1	0.01
Pinus kesiya (Royle ex Gordon, 1843)	164	0.33
Swietenia macrophylla (King, 1886)	100	0.27
Alstonia scholaris var. *scholaris* (Linnaeus, 1767)	1	0.01
Cassia fistula (Linnaeus, 1753)	1	0.01
Annona muricata (Linnaeus, 1753)	1	0.01
Ceiba pentandra (Linnaeus, 1753)	1	0.01
Viticipremna philippinensis (Turcz, 1863)	1	0.01
Aleurites moluccana (Linnaeus, 1753)	1	0.01
Mangifera indica (Linnaeus, 1753)	1	0.01
Gmelina arborea (Roxburgh ex Smith, 1810)	92	0.25
Falcataria falcata (Linnaeus 1753)	1	0.01
Artocarpus heterophyllus (Lamarck, 1789)	2	0.01
Hevea brasiliensis (Humboldt, Bonpland, & Kunth, 1817)	38	0.15
Ficus benjamina var. *bracteata* (Corner, 1960)	1	0.01

Species	Frequency	Species Diversity
Bridelia insulana (Hanse, 1877)	1	0.01
Ficus ruficaulis (Merrill, 1904)	1	0.01
Pterocymbium tinctorium (Blanco, 1837)	1	0.01
Ficus variegata var. *variegata* (Blume, 1825)	1	0.01
Total	736	2.83

Importance Value Index

The Importance Value Index (IVI) provides a broad understanding of the ecological significance of a species within a community (Mustapha et al. 2022). The parameters used to measure the importance value index include Relative density (RD), Relative Frequency (RF), and Relative Basal Area (RBA). The result shows that among 51 species, the species that has the highest importance value is *Pinus kesiya* (Royle ex Gordon, 1843) with a 62.30 importance value index, followed by *Swietenia macrophylla* (King, 1886) *with* 34.31 and *Gmelina arborea* (Roxburgh ex Smith, 1810) with 26.79, *Artocarpus odoratissimus* (Blanco, 1837), *Nephelium lappaceum* (Linnaeus, 1767) with 13.59. Based on the frequency of species, these indicate that the most important tree species in the study have been the dominant species.

Table 3. Tree species with the highest value in terms of relative density, relative frequency, relative basal area, and importance value.

Species	RD	RF	RBA	IVI
Pinus kesiya (Royle ex Gordon, 1843)	22.2	9.3	30.6	62.3
Swietenia macrophylla (King, 1886)	13.5	7.5	13.2	34.3
Artocarpus odoratissimus (Blanco, 1837)	6.5	7.0	5.6	19.1
Gmelina arborea (Roxburgh ex Smith, 1810)	12.5	5.6	8.6	26.7
Nephelium lappaceum (Linnaeus, 1767)	3.5	6.5	3.4	13.5

Recalis et al. (2017), reported that Pinus kesiya (Royle ex Gordon, 1843) is a fast-growing, coniferous species that grows well at high elevations and on relatively poor soils. Moreover, based on the study of Danquah et al. (2020), Swietenia macrophylla (King, 1886) is a crucial element and has been employed in reforestation efforts and the rehabilitation of degraded woodland environments. Its comparatively quicker growth rate allows it to sequester considerable amounts of carbon over the years, and its strong capacity to collect carbon in its biomass (Dinesha et al. 2023). The quick growth of Gmelina arborea (Roxburgh ex Smith, 1810) makes it a valuable timber species employed in plantations and reforestation. Gmelina arborea (Roxburgh ex Smith, 1810) has a potential capacity to store carbon, making it a desirable plant for sequestering CO_2 during climate change (Hakamada et al. 2023).

Species richness (D) and species evenness (e)

Table 4 shows the Species Richness and Evenness Index of the Forestry Experimental Forest of the University of Mindanao. The study area has 736 individual trees comprising 51 species. The species richness index of the study area is 7.72 whereas the species evenness index of the study area is 0.71. Prumadita et al. (2023) state that the Margalef species index helps count the number of species in a community. They also explain that when there is a high number of species in the area, the value of the Margalef species richness index is also high. Conversely, the Margalef species richness index is also low if fewer species exist in the area. Based on the level of criteria Margalef Species Richness Index of Wardhana et al. (2022), the Margalef Species Richness Index of the study area is more than 4, which indicates that the area's species richness is in the high category. It also implies that the area is in good condition. The analysis of species evenness of the study area shows that the species evenness index (e) is E= 0.71. This result indicates that the value of E >0.6 means that the evenness distribution of individuals in the Forestry experimental forest is high or in the high category. Based on the criteria of the Evenness index by Rudianto et al. (2022), an evenness index greater than 0.6 implies that the area exhibits high population uniformity.
Similar to the study of Joshi et al. (2023), their research yielded an evenness index of 0.83, indicating a more equal dispersion of species and greater forest diversity. Moreover, Pramudita et al. (2023) elaborated that the Evenness Index value ranges or falls between zero and one. The more uneven the number of individuals in each species, the lower the value. On the other hand, a more excellent value indicates an even distribution of individuals across species (Pramudita et al. 2023).

Table 4. Species Richness and Evenness Index of Forestry Experimental Forest of the University of Mindanao, Davao City.

Number of Species	Number of individual trees	Species Richness Index	Species Evenness Index
51	736	7.72	0.71

Amount of aboveground carbon stock in the study area

The General Allometric Equation developed by Chave et al. (2014) was used to estimate the amount of aboveground carbon stock stored in trees at the Forestry Experimental Forest of the University of Mindanao, Davao City.
Table 5 revealed the biomass density and carbon stored in trees in the study area. The total biomass density and Carbon stored of 736 individual trees were 132.99 mg/ha and 62.51 mg/ha, respectively. The aboveground carbon stocks of the Forestry Experimental Forest of the University of Mindanao (62.51 mg/ha) is lower than those of PT KOJO's forest area in Indonesia (190.69 mg/ha) (Pebriandi et al. 2024), and the forest in Mt. Malindawag, Lubilan, Naawan, Misamis Oriental, Philippines (273.70 mg/ha) (Origenes & Lapitan 2021). The tree species having the highest biomass density and carbon stored was Benguet Pine (*Pinus kesiya (Royle ex Gordon, 1840)*) with 43.33 mg/ha and 20.37 mg/ha, followed by Big-Leafed Mahogany (*Swietenia macrophylla* (King, 1886)) with 15.82 mg/ha and 20.37 mg/ha.
The Benguet Pine is a medium- to large-sized

tree that grows fast. It has a diameter of as much as 140 cm and a maximum height of 40 meters. Based on the tree's biomass partitioning pattern, most aboveground biomass, which is 60–77%, is found in the main trunk (Poclis et al. 2023). Given that it is the dominant species in the area, most of the carbon in the forest is likely contained in this tree. Moreover, tropical forests make a significant contribution to mitigating climate change by absorbing, sequestering, and storing carbon from the air (Yimer et al. 2023). A similar study also reported, according to Upadhyaya et al. (2023), which state that trees play a crucial part in reducing a significant portion of carbon dioxide (CO_2) and Greenhouse Gas (GHG) by absorbing and storing the carbon in their central parts in the form of carbon.

The study's results align with those of Saka et al. (2024), who noted that significant carbon stock implies the area's ecological significance and suggests that it can sequester carbon dioxide and provide a range of ecosystem services, including nutrient cycling and habitat provision. However, according to Saka et al. (2024), when the vegetation or forest is cleared and burned, the amount of carbon in the form of CO_2 can be emitted into the atmosphere. This highlights that the 62.51 mg/ha carbon stored in the study area can be released into the atmosphere if the area is removed or burned. It illustrates that maintenance and safeguarding of the study area is essential.

Table 5. The amount of carbon stored in trees in Forestry Experimental Forest of University of Mindanao.

Species	Biomass Density (Mg/ha)	Carbon Stored (Mg/ha)
Spathodea campanulata (Palisot de Beauvois, 1805)	0.70	0.33
Melanolepis multiglandulosa (Reinwardt ex Blume, 1826)	0.02	0.01
Trema orientalis (Linnaeus, 1753)	0.30	0.14
Artocarpus blancoi (Elmer, 1915)	3.94	1.85
Senna spectabilis (de Candolle, 1825)	0.62	0.29
Coffea arabica (Linnaeus, 1753)	0.02	0.01
Eucalyptus deglupta (Blume, 1850)	0.96	0.45
Litsea philippinensis (Merrill, 1905)	0.10	0.05
Homalanthus populneus var. *populneus* (Geiseler, 1807)	0.08	0.04
Ficus balete (Merrill, 1912)	5.34	2.51
Lagerstroemia speciosa (Linnaeus, 1753)	0.74	0.35
Pinus kesiya (Royle ex Gordon, 1843)	43.33	20.37
Swietenia macrophylla (King, 1886)	15.82	7.44
Alstonia scholaris var. *scholaris* (Linnaeus, 1767)	0.21	0.10
Durio zibethinus (Murray, 1774)	2.62	1.23
Bauhinia purpurea (Linnaeus, 1753)	0.03	0.02
Cassia fistula (Linnaeus, 1753)	0.06	0.03
Flacourtia jangomas (Loureiro, 1790)	0.08	0.04

Species	Biomass Density (Mg/ha)	Carbon Stored (Mg/ha)
Eucalyptus tereticornis (Smith, 1795)	5.39	2.53
Annona muricata (Linnaeus, 1753)	0.02	0.01
Artocarpus sericicarpus (Jarrett, 1959)	0.78	0.37
Leucaena leucocephala (Lamarck, 1783)	0.10	0.05
Gliricidia sepium (Jacquin, 1760)	0.06	0.03
Ceiba pentandra (Linnaeus, 1753)	0.15	0.07
Lansium domesticum (Corrêa, 1807)	0.35	0.17
Viticipremna philippinensis (Turcz, 1863)	0.09	0.04
Aleurites moluccana (Linnaeus, 1753)	0.01	0.01
Polyscias nodosa (Blume, 1826)	1.23	0.58
Ficus congesta var. *congesta* (Roxburgh, 1832)	0.06	0.03
Mangifera indica (Linnaeus, 1753)	0.03	0.02
Garcinia mangostana (Linnaeus, 1753)	1.03	0.48
Artocarpus odoratissimus (Blanco, 1837)	6.52	3.07
Gmelina arborea (Roxburgh ex Smith, 1810)	8.10	3.81
Vitex parviflora (Jussieu, 1806)	0.27	0.13
Falcataria falcata (Linnaeus 1753)	0.94	0.44
Artocarpus heterophyllus (Lamarck., 1789)	0.27	0.13
Cratoxylum sumatranum ssp. *sumatranum* (Jack, 1820)	0.24	0.11
Hevea brasiliensis (Humboldt, Bonpland, & Kunth, 1817)	1.85	0.87
Nephelium lappaceum (Linnaeus, 1767)	5.51	2.59
Ficus benjamina var. *benjamina* (Linnaeus, 1753)	0.89	0.42
Ficus benjamina var. *bracteata* (Corner, 1960)	0.07	0.03
Sandoricum koetjape (Burman, 1768)	1.90	0.89
Pterocarpus indicus forma *indicus* (Willdenow, 1806)	2.10	0.99
Chrysophyllum cainito (Linnaeus, 1753)	3.43	1.61
Bridelia insulana (Hanse, 1877)	0.34	0.16
Ficus ruficaulis (Merrill, 1904)	0.05	0.02
Terminalia catappa (Linnaeus, 1767)	0.48	0.23
Pterocymbium tinctorium (Blanco, 1837)	0.01	0.00
Ficus variegata var. *variegata* (Blume, 1825)	0.33	0.16
Ficus nota (Blanco, 1837)	0.14	0.07
Tabebuia pallida (Lindley, 1827)	15.26	7.17
Total	132.99	62.51

CORRELATION BETWEEN TREE DIVERSITY AND CARBON SEQUESTRATION POTENTIAL IN FORESTRY EXPERIMENTAL FOREST

Spearman Correlation Coefficient

Assessed the correlation between tree diversity and carbon sequestration potential at the ordinal level. The result of the analysis of the Spearman correlation coefficient of the study area between tree diversity and carbon sequestration potential was r = 0.72 (Tab. 6).

The Spearman Correlation Coefficient reveals that the relationship between tree diversity and carbon sequestration potential in the Forestry Experimental Forest of the University of Mindanao, Davao City has a positive correlation. Therefore, the null hypothesis is rejected, which states that no significant correlation exists between tree diversity and carbon stock in the Forestry Experimental Forest of the University of Mindanao, Davao City.

Table 6. Spearman Correlation Coefficient between tree diversity and carbon sequestration potential of Forestry Experimental Forest of the University of Mindanao, Davao City.

	Carbon stock	Species diversity
Carbon stock	1	
Species diversity	0.72	1

The results agree with the findings of Obonyo et al. (2023) that there is a positive correlation between aboveground carbon and tree species diversity. Di Sacco et al. (2021) reported that a high species diversity in trees promotes forest biomass and carbon above ground by improving ecosystem stability and health. The results further align with those of Kothandaraman et al. (2020), which stated a positive correlation between aboveground carbon and tree diversity. However, the results contradict the findings of Khan et al. (2024), which their study showed a weak correlation between tree diversity and carbon stock. The study's results also contradict the findings of Manaye et al. (2021), which revealed no significant relationship between carbon stock and species diversity. Moreover, in a comparative study conducted by Obonyo et al. (2022), findings showed a positive correlation and weak relationship between aboveground carbon and species diversity in different study areas. Thus, this difference in results is likely to be explained by other factors that significantly affect carbon stock, which includes tree size, age, density, height, and site efficiency in production (Gebrewahid et al. 2020).

The result of this study revealed a positive correlation between carbon stock and tree diversity, which implies that a diverse forest has good carbon sequestration potential. Thus, putting conservation efforts into tree diversity together with improving the carbon stock of forestry experimental forests is vital. Additionally, the current study highlights the significance of tree diversity and the capacity of forests to store carbon as a vibrant carbon sink that, through biomass accumulation and forest carbon, helps mitigate climate change's effects (Luong et al. 2023).

Forests and their vegetation are the most significant carbon and biodiversity pools. Consequently, preserving already-existing forest patches or extending and improving forest areas by planting indigenous tree species can reduce anthropogenic impact on forest resources; the importance of managing forests effectively, like preventing forest fires, results in "double benefits" as it protects the forest and benefits the entire environment (Luong et al. 2023).

CONCLUSIONS

The Forestry Experimental Forest of the

University of Mindanao, Davao City has a moderate diversity index, the *Pinus kesiya* (Royle ex Gordon, 1843) has the highest importance value index among the abundant tree species studied, the study area has a high species richness and a high evenness index. On the other hand, the experimental forest has a moderate amount of carbon stored in trees, amounting to 62.51 mg/ha. Lastly, there is a positive correlation between tree diversity and carbon stock in the Forestry Experimental Forest of the University of Mindanao, Davao City. The study's findings encourage the administration of academic institutions to engage in improved forest management, focusing on preserving the diversity of the forest and implementing regular monitoring to adapt to environmental changes, ensuring the role of the forest in mitigating the effects of climate change. The study also provides helpful information for policymaking, which helps the management develop policies that support conservation and sustainable land use practices and environmental protection.

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