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Market based valuation of bamboo's carbon sequestration in Magtabid, Caranan, Pasacao, Camarines Sur

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Abstract

Bamboo, a fast-growing and versatile plant, plays a crucial role in climate change mitigation through its capacity to absorb and store atmospheric carbon dioxide. This study investigates the market-based valuation of bamboo's carbon sequestration potential in Magtabid, Caranan, Pasacao, Camarines Sur. Using a descriptive quantitative research design, biometric characterization and vegetational analysis were conducted within five 10 × 10 m quadrats to identify bamboo species, measure diameter at breast height (DBH), culm height, and density, and estimate above-ground biomass. The carbon content was calculated following IPCC guidelines, applying a 0.5 conversion factor to biomass values. The market price approach was employed to assign monetary value to the estimated carbon stock, integrating local carbon credit prices and bamboo product market data. Findings highlight bamboo's ecological significance in soil stabilization, biodiversity conservation, and climate resilience, while also demonstrating its economic potential through carbon trading and ecosystem service valuation. Results provide valuable insights for agencies such as DENR, LGUs, and the Forest Management Bureau in formulating policies on carbon markets, reforestation, and sustainable land management. Ultimately, this research emphasizes bamboo's viability as a natural climate solution, aligning with Sustainable Development Goals 13 (Climate Action) and 15 (Life on Land), while promoting community-based livelihood opportunities and environmental stewardship.

Keywords: bamboo, carbon sequestration, market-based valuation, ecosystem services, climate change mitigation

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1. Introduction

Bamboo is a versatile and rapidly growing plant belonging to the grass family, known for its unique physical and mechanical properties, strong and sustainable material used structurally for thousands of years. In Caranan a coastal barangay in Pasacao, Camarines Sur, located at low elevation (around 10 m above sea level) along the shore to Magtabid Beach. Historically, parts of this area appear to have been more heavily forested, over time, beach resorts, community, and agricultural and coastal development (including resorts and roads) have transformed much of the landscape. The bamboo forest that exists in Magtabid, Caranan Pasacao Camarines Sur likely consists of scattered patches, possibly along streams, edges of water or less-disturbed backshore or hillside zones rather than an extensive continuous bamboo grove. The bamboo species present in Magtabid include native types such as kawayan-tinik, a local bamboo with woody perennial grass features which is used locally in crafts and construction. Recent studies have quantified bamboo's remarkable tensile strength (350-500 MPa) and elasticity modulus (18-20 GPa), surpassing many conventional construction materials (Ghavami et al., 2017).

It serves as an aesthetically pleasing and low-cost alternative to conventional materials like timber, with various suitable species and relevant physical characteristics for structural design (Kaminski et al., 2016). Bamboo forests contribute to both local and global ecological benefits, enhancing biodiversity and supporting community resilience against environmental changes (Thokchom & Yadava., 2023). The market valuation of bamboo's carbon sequestration is essential to study because it demonstrates bamboo's significant role in climate change mitigation by showing its economic benefits alongside its ecological advantages. This can draw in investment and encourage the widespread use of bamboo for both environmental preservation and financial gain. This valuation provides a basis for including bamboo in national climate strategies and international carbon markets, allowing farmers and communities in bamboo endemic regions to benefit from carbon credits and generate new income streams from degraded lands.

By assigning monetary value under the market price approach per sequestered amount of carbon by the bamboo stand including forest area, the valuation of natural bamboo forests also means rehabilitation that aims to help alleviate environmental issues while promoting ecological stability, biodiversity conservation, climate change mitigation, and healthy community well-being. Ecosystems Research and Development Bureau under SDG number 13, the climate action, which provides a sustainable solution focusing on regulating and conserving the environment. This is also aligned with the Sustainable Development Goal 15, Life on Land as the bamboo forests help restore land, prevent desertification, and protect biodiversity. Their fast growth and strong roots prevent erosion and stabilize slopes (International Bamboo & Rattan Organization, 2023).

The study of market valuation of bamboo carbon sequestration is crucial in advancing knowledge on sustainable forestry and climate change mitigation. By quantifying the economic benefits and carbon storage potential of bamboo, researchers can inform policy and investment decisions that promote bamboo as a viable solution for carbon offsetting. It improves knowledge of market dynamics, farmers income, and carbon price, which helps to improved carbon sequestration project implementation. In the Philippines, bamboo is one of the most economically important non-timber forest products. According to PCAARRD's Industry Strategic Science and Technology Programs (2023), the total area of bamboo stands in the Philippines ranges from 39,000-53,000 ha. A recent nationwide assessment revealed that 78% of these stands show significant potential for carbon credit projects due to their growth characteristics (Lasco et al., 2022). Due to its versatility, bamboo is widely accepted as an alternative to wood for furniture, handicrafts, construction material and chemical products that has contributed to rural employment and foreign exchange. The Philippine bamboo industry generates approximately ₱2.3 billion annually, supporting over 1.2 million livelihoods (DTI, 2023).

Bamboo's role extends beyond carbon sequestration. Its extensive root system prevents soil erosion and enhances water retention, making it a valuable tool in disaster risk reduction, especially in flood-prone and drought affected areas. Studies in Southeast Asia have documented bamboo's effectiveness in reducing soil erosion by up to 70% compared to bare slopes (Vogt et al., 2020). It is estimated that one hectare of bamboo can sequester up to 60 tonnes of CO2 per year (Climate Change Commission, 2024), with new findings showing this capacity persists for over 50 years in well-managed stands (Zhou et al., 2022). Bamboo has a strong potential for sequestering carbon, and when carbon revenues are taken into account, it becomes more appealing commercially. According to Hou et al. (2019) carbon credits can often offset opportunity costs of alternative land uses, enhancing the market valuation of bamboo in afforestation projects.

Despite their significant ecological contributions, these services such as carbon sequestration, preventing soil and sediment loss, and landscape restoration get less attention. Recent economic valuations indicate natural bamboo forests provide ₱1.8 million/ha/year in unaccounted ecosystem services (Moreno et al., 2023). The bamboo industry is also beset with problems and challenges. The benefits it provides has not received the attention it deserves, particularly when it comes to the non-market ecological services provided by natural bamboo forests in the Philippines. Investment has focused more on planting bamboo than on allowing it to grow naturally in forests (DENR's Ecosystems Research & Development Bureau, 2024). To enhance the understanding of these advantages, especially the indirect use value of natural bamboo forests like carbon sequestration, a monetary value must be assigned to the projected amount of stored carbon. By quantifying these qualities, payment systems for the ecological use of natural bamboo forests that sustain the species' population and improve the management and conservation of natural resources. These could enhance bamboo's contribution to climate strategies and market valuation.

Objectives of the Study - The primary aim of the research is to identify the total economic value of bamboo's carbon sequestration potential and its prevalence in Magtabid, Caranan, Pasacao, Camarines Sur. Furthermore, this study aims to: identify the different bamboo species in the area; determine the ecological status of the bamboo forest through biometric characterization and vegetational analysis; calculate the Total Economic Value (TEV) of the estimated carbon stock of the natural bamboo forest in terms of above-ground biomass and estimated monetary value.

Significance of the Study - This study primarily benefits the residents of Magtabid, Caranan, Pasacao, Camarines Sur, and the barangay LGU. Specifically, the following groups and agencies may find this research valuable. The Department of Environment and Natural Resources (DENR) can use the market-based valuation of bamboo's carbon sequestration capacity to guide policies related to carbon trading programs, forest management, and biodiversity conservation, thereby integrating bamboo ecosystems into national sustainability efforts. Local Government Units (LGUs), working with agencies such as the DENR, Department of Agriculture (DA), Department of the Interior and Local Government (DILG), and Department of Science and Technology (DOST), may use the results to develop programs that support reforestation, carbon reduction, climate action, and livelihood projects while exploring carbon market opportunities. The Philippine Forest Management Bureau (FMB), under the DENR, can apply the study's data to sustainable forestry policies, particularly regarding bamboo's ecological and financial benefits as a viable carbon sink in reforestation efforts. The Department of Agriculture (DA) can benefit by integrating bamboo-based carbon sequestration into agroforestry initiatives and rural development programs, helping farmers adopt sustainable land-use practices and climate resilience strategies. Future researchers may use this study as a foundation for further work on ecosystem service valuation, refining methodologies to assess bamboo's ecological and economic contributions across different contexts. Students studying environmental science, agriculture, or economics can learn how bamboo supports environmental protection and offers real-world climate solutions, as well as gain ideas for projects or future research. The manuscript is divided using numbered sections, with second-level section numbering following the upper level's number automatically; this numbering should also be used for internal cross-referencing, and any subsection should be given a brief heading.

Scope and Delimitation - This study is confined to the natural bamboo stands located in Magtabid, Caranan, Pasacao, Camarines Sur. The research area was selected due to its accessibility, ecological significance, and the willingness of the property owner to allow fieldwork. While the findings provide valuable insights into bamboo's carbon sequestration potential, they may not fully represent other bamboo ecosystems in neighboring sitios or barangays with different ecological conditions, soil types, or management practices.

The scope of the study is limited to above-ground biomass (culms, branches, and leaves), excluding below-ground biomass such as roots and rhizomes, which also contribute to carbon storage but were not measured due to methodological constraints and time limitations. Additionally, the study does not account for carbon stored in long-term bamboo products (e.g., furniture, housing materials), even though these extend sequestration beyond the forest ecosystem. The valuation framework applies the market price approach, relying on current voluntary carbon market rates and available bamboo product market data. These prices are subject to fluctuations due to global economic trends, policy changes, and demand variability, which may affect the precision of the valuation. The study also assumes a constant carbon conversion factor (0.5) based on IPCC guidelines, which may vary across species and ecological contexts.

In terms of temporal scope, the research was conducted within a single season and therefore does not capture seasonal variations in bamboo growth, biomass accumulation, or carbon sequestration rates. Long-term monitoring would provide more accurate insights into the sustainability of bamboo's carbon storage capacity. Institutional and policy limitations also shape the study. While the research highlights bamboo's potential for integration into carbon markets, the actual implementation of carbon trading schemes depends on government regulations, verification protocols, and international market participation. These external factors were beyond the control of the researchers but remain critical for translating ecological valuation into economic opportunities. Finally, the study is limited by logistical constraints such as the number of quadrats sampled (five 10 × 10 m plots), availability of measuring instruments, and reliance on secondary data for national bamboo statistics. Despite these limitations, the research provides a strong foundation for understanding bamboo's ecological and economic contributions, offering practical insights for local communities, policymakers, and future researchers.

Theoretical Framework - The multi-layered theory called the Bio-Economic Displacement Carbon Leverage Theory, which integrates several foundational concepts to show how carbon markets can drive conservation and community benefits. Ecosystem Services Theory forms the broadest foundation. This theory states that natural ecosystems (like forests, wetlands, and oceans) provide essential, valuable services to humanity for free. These include provisioning services (food, water), regulating services (climate control via carbon storage, flood prevention), cultural services (recreation), and supporting services (soil formation). Recognizing and quantifying these services is the first step in arguing for their protection, as it transforms nature from a passive backdrop into a critical form of "natural capital."

Ecological Economics Theory builds upon this by providing the philosophical and economic lens. Unlike traditional economics, which often treats the environment as an external subset, ecological economics sees the human economy as a fully contained subsystem of the finite global ecosystem. It argues that economic activity is bound by ecological limits and emphasizes sustainability, justice, and the need to account for the real value of natural capital in decision-making, thus justifying market interventions for conservation. Carbon Market Theory provides the specific financial mechanism. It creates a tradable commodity—a carbon credit—representing a verified reduction or removal of one tonne of carbon dioxide from the atmosphere. By putting a price on carbon, this theory uses market forces to incentivize emission reductions where they are most cost-effective. In this framework, it directs financial value toward activities that protect or restore carbon-storing ecosystems.

The integration of these theories leads to a practical pathway Market-Based Valuation assessing the Carbon Credit Feasibility of a conservation project. If feasible, the sale of credit provides the financial Incentive for Conservation & Sustainable Land Management (e.g., avoiding deforestation, regenerative agriculture). The resulting revenue, in turn, can fund Enhanced Community Livelihoods & Environmental Stewardship, creating a virtuous cycle where economic and ecological benefits reinforce each other, leveraging carbon finance to achieve broader bio-economic and social goals.

2. Methodology

This chapter describes the methodology used to collect data for the study. The methodology of the study consists of research design, research method, population and sampling design, data gathering procedure, and statistical treatment.

2.1 Research Design

The study used a descriptive quantitative method to identify different bamboo species present in the study area. Recent taxonomic studies had demonstrated the effectiveness of morphological characterization combined with DBH measurements for accurate bamboo species identification, particularly in fragmented forest stands (Alam et al., 2022). The researcher measured biometric parameters including the diameter at breast height (DBH) at 1.3m above ground level and total height of bamboo individually, following standardized protocols established by the International Network for Bamboo and Rattan (INBAR, 2021). For economic valuation, the researcher employed a market price approach method. This method aligned with contemporary ecosystem service valuation frameworks that emphasized market-based mechanisms for natural capital accounting (Costanza et al., 2017). Recent applications in Southeast Asia had successfully used this approach to value carbon sequestration services in mixed bamboo forests, with adjustments made for local market conditions (Tao et al., 2020). The market price approach provided a real-world perspective on the value of an entity by analyzing market data and transactions involving comparable assets (Walton, 2024). The valuation process incorporated findings from recent studies on bamboo carbon markets in the Philippines, which suggested that localized pricing models yielded more accurate valuations than global carbon price indices (Lasco et al., 2023). The researcher determined the economic value of the carbon sequestered bamboo stands using both current market prices for carbon credits and the projected value of bamboo products in local markets.

2.2 Research Method

The study employed a descriptive quantitative method to identify bamboo species within the study area, measuring biometric parameters such as diameter at breast height (DBH) and total height of each bamboo stand. To determine the fair value of bamboo resources, the researchers applied the market price approach, which assesses worth by analyzing market data and comparable transactions, thereby providing a real-world perspective on asset valuation (Walton, 2024). Data collection was conducted in collaboration with the local community, who assisted in locating bamboo stands, measuring growth, and sharing traditional knowledge, ensuring that the findings reflected actual conditions. A random sampling design was implemented by establishing five (5) quadrats, each measuring 10 × 10 meters, to analyze density, frequency, and relative abundance. Within these quadrats, biometric parameters, including DBH measured at 1.3 meters from the ground, total height, culm count, and species identification—were recorded. The collected data were processed using validated allometric equations, typically derived from destructive sampling of representative culms, to estimate oven-dry biomass. These biomass estimates were then converted into carbon content to assess the economic value of carbon sequestration (Black et al., 2022).

2.2.1 Vegetational parameters (density, frequency, relative abundance)

In the study area, five sampling quadrats measuring 10 × 10 meters were marked with plastic poles and ropes, as shown in Figure 1. The vegetation assessment followed standard methodologies outlined in Braun-Blanquet's cover-abundance scale (Braun-Blanquet, 2023), integrating statistical measures for species characterization. In vegetation analysis, density measured the number of individuals per unit area, frequency indicated the proportion of sampling units in which a species was found, and relative abundance compared the abundance of a species to the total abundance of all species in a community. Density, frequency, and relative abundance are key measures used to describe the structure of plant or animal communities. Density represents the numerical strength of a species, calculated by dividing the total number of individuals of that species across all sampled plots by the total area of those plots. Frequency reflects the degree of dispersion of a species within a study area, determined by randomly sampling multiple locations and recording the presence of species in each unit. Relative abundance, on the other hand, indicates the proportion of individuals of a given species compared to the total number of individuals of all species in the community, expressed as a percentage by dividing the species count by the overall count and multiplying by 100. Together, these metrics provide a comprehensive picture of how species are distributed, how dominant they are, and how they interact within an ecosystem.

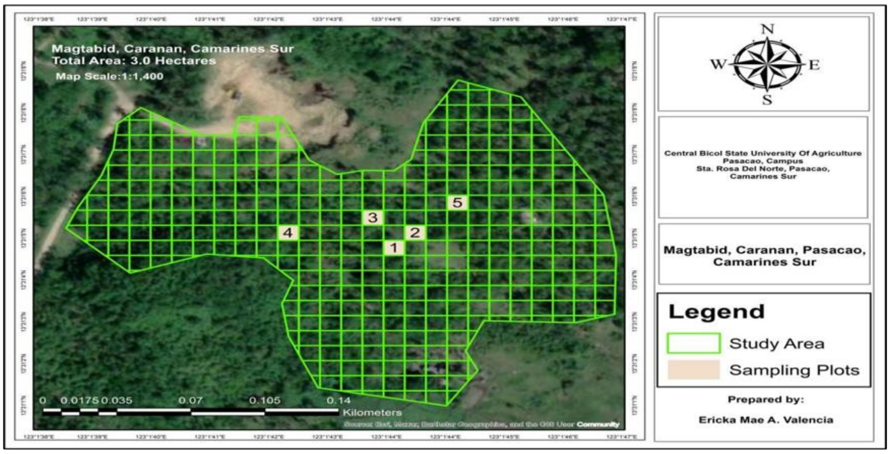

Figure 1. Five quadrats conducted in study area

2.2.2 Biometric Characterization of Bamboo

For biomass estimation, bamboo culms within quadrats were measured for both diameter at breast height (DBH) and total height. DBH was recorded using measuring tape in accordance with standard bamboo measurement protocols (Huy and Long, 2025), while total height was determined using telescoping height poles as per carbon sequestration study guidelines (IPCC, 2025). These biometric values served as essential inputs for carbon stock estimation models, enabling a quantitative assessment of bamboo's contribution to atmospheric CO_2 absorption (Nath et al., 2025).

2.2.3 Carbon Sequestration by the Bamboo Forest

The researcher estimated the total carbon sequestration of the natural bamboo forest using established allometric equations for biomass conversion. The above-ground biomass (AGB) was calculated based on diameter at breast height (DBH), a key biometric measurement used for bamboo biomass estimation. The converted biomass values were used to determine the total carbon content stored in the natural bamboo forest.

2.2.4 Above Ground Biomass

The diameter at breast DBH served as a critical parameter in computing bamboo biomass through allometric equations. Following the formula adapted from (Yen et al., 2017).

2.2.5 Total Carbon Content from Above Ground Biomass

The total carbon content was calculated by aggregating carbon sequestration per bamboo species and scaling it to the entire study area. The carbon stored in above-ground biomass (AGB) was derived by multiplying the summed AGB per species by the total number of culms across the sampled area, then applying a carbon conversion factor. Following the IPCC Guidelines for National Greenhouse Gas Inventories (2019), a conversion factor of 0.5 (50%) was used to account for the proportion of carbon in bamboo biomass.

2.2.6 Calculating the estimated monetary value

The economic valuation of carbon stock sequestered in natural bamboo forests is influenced by several factors, including forest size, geographic location, bamboo species diversity, and the quantity of carbon sequestered per ton. The computation of carbon sequestration value (CSV) is based on the estimated amount of carbon stored per hectare, multiplied by the prevailing carbon market price. As reflected by the formula to compute the carbon sequestration value (CSV), the amount of estimated sequestered carbon (tons/ha) is multiplied by the current market price of carbon credits as of May 17, 2024, amounting to $155.86 (PHP 9,016.50) based on the study of Black et al. (2022) as the carbon market price global average. The carbon market price reflects the cost of avoiding carbon emissions, which is equivalent to the economic value of sequestering carbon.

2.3 Data Gathering Procedure

This section discussed the procedures that were used in gathering the data needed for the study. First, to gather the data, the researchers used a random sampling method in plotting a quadrat measuring 10 x 10 meters. Along with it, they established geotags for location and layout coordinates, which were used in mapping to show the study area through the Geocam tool. Second, the researcher identified the bamboo species using the five quadrats and utilized bamboo characterization such as diameter at breast height (DBH) and total height during bamboo identification as parameters of the developed allometric formula for biomass conversion, as well as its vegetational analysis such as density, frequency, and relative abundance. Lastly, the researcher calculated the economic value of the bamboo forest using a market price approach by converting the natural bamboo forest's carbon sequestration value (CSV).

2.4 Statistical Treatment of Data

In this study, data were analyzed using both descriptive and basic inferential statistics. Means, percentages, and standard deviation were used to summarize the vegetational analysis (density, frequency, relative abundance) and biometric data (DBH, height). The Importance Value Index was calculated for each bamboo species to determine its ecological dominance. To test significant differences in species distribution and carbon stock across the study area, a One-Way Analysis of Variance was employed. The relationship between bamboo diameter (DBH) and height was analyzed using Pearson's Correlation. The total carbon stock was converted to its economic value using the prevailing carbon market price.

3. Results and Discussion

This chapter presents the result of the study, which were discussed according to the objectives, specifically the identified bamboo species vegetation analysis, biometric characterization, carbon stock calculation, and economic valuation.

3.1 Bamboo Species in Magtabid, Caranan, Pasacao, Camarines Sur

Three bamboo species were identified in the study area within Magtabid, Caranan, Pasacao, Camarines Sur. The three species are *Gigantochloa levis* (Bolo) ninety-three (93) individuals, *Bambusa blumeana* (kawayan tinik) thirtyfive (35) individuals and *Bambusa vulgaris* (kawayang kiling) thirty-three (33) individuals. The total number of identified bamboos in the plantation within five (5) quadrats are one hundred sixty-one (161).

Gigantochloa levis (bolo) is a sympodial, highly tufted bamboo that is 5–10 cm in diameter and 13–20 meters tall. It has the greatest number of individuals found in the study area. The green, upright culms have walls that are 1.0–1.2 cm thick. The culms are erect, woody, and thin-walled, often producing aerial roots from nodes. On the outside, it has a thick layer of dark brown hair. It usually grows in the province of Laguna, Quezon, Bicol, Iloilo and Leyte. It is frequently seen growing around cities and villages, along riverbanks and creeks (Razal & Palijon., 2020).

Bambusa blumeana (Kawayan tinik) is one of the most commonly used bamboo in the Philippines. It is the species with the widest distribution. It is present in nearly all parts of the country, with the exception of high elevation areas. It is characterized by its thick-walled culms and dense, thorny lower clumps. At the base of the culms, wall thickness is mostly solid, especially in dry areas or poor soils. Lower culm nodes show a ring of aerial roots, with a gray or brown ring below and above the sheath scar (Schröder, 2025).

Bambusa vulgaris (Kawayan kiling) is an erect, evergreen, clump-forming bamboo that typically reaches heights of 10–20 meters (Astiti et al., 2018; Latha et al., 2023). The culms are characteristically yellowish or yellowish-green, often featuring green stripes, and are known for being free of thorns (Latha et al., 2023). Its leaves are narrow and lanceolate, growing up to 35 centimeters in length (StuartXchange, 2023). While it shares the "Kauayan" name with *Bambusa spinosa*, it is distinguished by its thinner-walled culms and the absence of spiny branches (StuartXchange, 2023).

a b c

Figure 2. Image of three (3) bamboo species found within the five quadrats in Magtabid, Caranan, Pasacao, Camarines Sur, (a) *Gigantochloa levis* (b) *Bambusa blumeana (c) Bambusa vulgaris*

3.2 Biometrics Description

The biometric description of the identified bamboo species in the study area is presented in Table 1. The table shows the average and range of diameter at breast height (DBH) and total height of the identified bamboo species, namely Bolo (Bambusa blumeana), Kawayang Kiling (Bambusa vulgaris), and Kawayang Tinik (Gigantochloa levis). These values are compared with the standard range of DBH and height of erect bamboo species based on the handbook Erect Bamboo Species Found in the Philippines by Christina A. Roxas.

3.2.1 Diameter at Breast Height (DBH)

The table 1 shows that the largest diameter at breast height (27.00 cm) was observed in Bolo, while the smallest diameter at breast height (2.87 cm) was also recorded in the same species. Kawayang Kiling showed a DBH range of 3.82 cm to 8.92 cm, while Kawayang Tinik ranged from 4.78 cm to 9.55 cm. In terms of average DBH, Kawayang Tinik recorded the highest value (6.81 cm), followed by Bolo (6.34 cm) and Kawayang Kiling (6.13 cm). The findings show that the highest DBH values of the identified bamboo species fall within the standard DBH range, indicating normal and healthy growth. However, the smallest DBH values in the standard range were not fully attained, which may be influenced by stand density and age structure of the bamboo clumps. The presence of smaller DBH values suggests continuous regeneration, while larger DBH values indicate mature culms. This implies that the identified bamboo species, particularly Bambusa vulgaris, are not extinct, are cultivated, and are continuously growing in the study area.

In terms of height, Bolo showed the widest height range (2–9 m) and the highest average height (7.025 m). Kawayang Kiling had a height range of 3–7 m with an average height of 5.4 m, while Kawayang Tinik ranged from 2–8 m with an average height of 6.04 m. These results indicate variation in vertical growth among the species, which may be influenced by species characteristics and site conditions. Overall, the DBH and height distribution of the identified bamboo species suggest that areas with less disturbance tend to have larger and taller bamboo culms, while areas closer to human activity may have smaller average DBH due to harvesting pressure. This pattern indicates sustainable bamboo growth and continuous regeneration within the study area.

Table 1

Biometric description of the identified bamboo species (Bambusa bluemeana, Bambusa vulgaris, Gigantochloa levis)

Species	Min DBH	Max DBH	Average DBH (cm)	Height Range (m)	Average height (m)
Bolo	2.87	27.00	6.34	2-9	7.025
Kawayang kiling	3.82	8.92	6.13	3-7	5.4
Kawayang tinik	4.78	9.55	6.81	2-8	6.04

3.3 Vegetation Analysis of the Bamboo Species

The identified bamboo species are presented in the Table 2. below as their family name, scientific name, common name, local name, and number of individuals per species with their density, frequency, and relative abundance. The vegetation analysis method is essential for determining species composition and ecological structure to guide sustainable management (Mahajan & Fatima, 2015). Of the 161 culms recorded*, Gigantochloa levis* emerged as the most ecologically significant due to its high density (0.186) and relative abundance (5.003554), contributing substantially to biomass and carbon storage at approximately 9.55 kg of carbon per culm (Pongon, Camacho, & Carandang, 2015; Tongco et al., 2016). While *Bambusa blumeana* and *Bambusa vulgaris* exhibited lower densities, *B. vulgaris* was found to be the most widely distributed species with a frequency of 0.8, serving as a vital carbon sink and a primary resource for local construction and food (Islam et al., 2015; Maroma, 2015). Despite the localized distribution of *Bambusa blumeana*, its durability makes it culturally important for housing (Salzer et al., 2018). Collectively, these species form a bamboo-rich ecosystem where ecological dominance directly supports community livelihoods, ranging from fishing gear and construction to household uses (Mendoza et al., 2019).

Table 2

Vegetation Analysis of the Bamboo Species.

Family name	Scientific name	Common name	Local name	Total (N)	Density	Frequency	RA
Poaceae	Bambusa bluemeana	Kawayang tinik	Marurugi	35	0.07	0.2	1.863354
	Bambusa vulgaris	Kawayang kiling	Butong	33	0.066	0.8	
	Gigantochloa levis	Bolo	Boloncena	93	0.186	0.4	
Total (N)				161	0.322	1.4	1.863354

3.4 Total biomass, above-ground biomass, and carbon content ton/ha

The table 3 shows the Total biomass, above-ground biomass, and carbon content ton/ha of the species per quadrat. Based on measurements from five quadrats in Magtabid, 161 bamboo culms yielded 15.3 kg of biomass, which translates to 7.66 kg of carbon content using the standard IPCC conversion factor (IPCC, 2019). When scaled per hectare, this storage is valued at ₱2,367.57, illustrating how small bamboo plots contribute significantly to climate mitigation (Shrestha et al., 2020). The high productivity and rapid biomass accumulation in these stands reflect strong ecological health and an efficient capacity for carbon sequestration (Kaushal et al., 2016). Because most carbon is locked within the visible above-ground structures, such as the culms and leaves, bamboo serves as a more effective sequestration tool than many tropical tree species (Singh et al., 2018). With a potential exceeding 2 tons of carbon per hectare, the Magtabid stands are comparable to other major Asian bamboo forests (Yiping et al., 2017; Pan et al., 2023). Ultimately, these active carbon sinks provide both environmental benefits and economic value through carbon credits, establishing bamboo as a strategic asset for sustainable environmental management and local livelihoods (INBAR, 2021; Gupta et al., 2019; Li et al., 2022).

3.5 Monetary value of natural bamboo carbon sequestration

Based on the data in Table 4 the carbon storage assessment of the natural bamboo forest in Magtabid, Pasacao, reveals a total sequestration of 0.246402 t/ha across the 3-hectare site, valued at ₱7,102.08 based on a carbon price of ₱9,016.50 per ton. This measurable economic value highlights bamboo's potential in nature-based climate finance (Griscom et al., 2017), with its valuation reflecting the high end of voluntary carbon markets that reward biodiversity and community benefits (Donofrio et al., 2023). Analysis of individual quadrats shows significant spatial variability: the highest values in Quadrats 3 and 5 (₱553.32 each) indicate dense, mature bamboo that should be prioritized for protection (Yuen et al., 2017; Pongon et al., 2016), while the lower value of Quadrat 4 (₱282.52) suggests a need for restoration due to past disturbances or younger growth (Mendoza et al., 2019; Razal, 2022). Middle-value areas like Quadrats 1 and 2 represent growing stands that could increase in sequestration capacity if preserved (Tongco et al., 2016; Lantican et al., 2017). This uneven distribution necessitates tailored management strategies that align with national programs such as those from the DENR (DENR, 2021). Furthermore, while the Philippines currently lacks a national carbon tax despite high transportation emissions (World Bank, 2022), the integration of carbon pricing could provide essential public investment for sustainable development under the Climate Change Act (Climate Change Commission, 2015). If implemented thoughtfully to protect low-income households, such mechanisms could effectively incentivize cleaner energy and support nature-based solutions like bamboo forests.

Table 3
Total biomass, above-ground biomass, and carbon content ton/ha

Number of quadrats	Number of culms	Total diameter at breast height (cm)	Biomass (kg)	Carbon Content (kg)	Total Carbon content (ton/ha)
Q1	35	6.81	3.11	1.56	$491.50
Q2	36	6.07	3.00	1.50	$486.71
Q3	40	6.59	3.07	1.53	$553.32
Q4	20	6.97	3.13	1.57	$282.52
Q5	30	6.04	2.99	1.50	$553.32
TOTAL	161	32.48	15.3	7.66	2367.57

Table 4
Monetary value of natural bamboo carbon sequestration

Total Carbon Stock (To/Ha)	Carbon Market price/ton as of May 17, 2023	Total Area of the Study Site (Ha)	Total Price of Carbon Stock (Peso)
0.246042	9,016.50	3	7102.08

4. Summary, Findings, Conclusions and Recommendations

Summary - This study, entitled "Market-Based Valuation of Bamboo's Carbon Sequestration Potential in Magtabid, Caranan, Pasacao, Camarines Sur," was conducted to assess the ecological and economic value of bamboo as a carbon sink. The research employed a descriptive quantitative design, using five 10 × 10 m quadrats to perform biometric characterization and vegetational analysis. Measurements of diameter at breast height (DBH), culm height, and density were taken to estimate above-ground biomass. Carbon content was calculated using IPCC guidelines with a 0.5 conversion factor, and the market price approach was applied to translate carbon stock into monetary value. The results revealed that bamboo species in the study area contribute significantly to carbon storage, soil stabilization, and biodiversity conservation. The valuation showed that bamboo forests are not only ecologically important but also profitable, with the potential to generate income through carbon trading and ecosystem service markets. These findings provide valuable insights for government agencies, local communities, and policy makers in designing climate strategies and livelihood programs. Overall, the study demonstrated that bamboo can serve as a sustainable resource for both environmental protection and economic development. By quantifying its carbon sequestration capacity and assigning market value, the research highlights bamboo's role in climate change mitigation, ecosystem restoration, and community resilience.

Findings - The study identified three bamboo species in Magtabid, Caranan, Pasacao, Camarines Sur. These are Kawayan Tinik (Bambusa blumeana), Kawayan Kiling (Bambusa vulgaris) and Bolo (Gigantochloa Levis). These species differ in their growth characteristics, culm structure, and ecological roles. Their presence highlights the diversity of bamboo in the study area and provides a strong basis for evaluating carbon sequestration potential. Biometric characterization, including measurements of diameter at breast height (DBH), height, and culm count, demonstrated bamboo's rapid growth and high biomass accumulation. These parameters highlight bamboo's strong potential for carbon storage. Vegetational analysis showed that bamboo species dominate the sampled quadrats, with high density and frequency values. This indicates ecological resilience and the ability of bamboo to thrive in varied environmental conditions. The carbon sequestration assessment confirmed that bamboo stands in Magtabid have substantial carbon storage capacity. The results align with national and international studies that recognize bamboo as an effective carbon sink. The market-based valuation revealed that bamboo's carbon sequestration can be monetized through carbon credits. This finding emphasizes the potential of bamboo to generate sustainable income streams for local communities while contributing to climate change mitigation.

Conclusions - The study concludes that bamboo is a powerful natural climate solution, combining ecological resilience with economic potential. Its rapid growth, high biomass accumulation, and adaptability make it an effective carbon sink, while its market valuation shows its capacity to support carbon trading initiatives and sustainable livelihoods. The findings emphasize the importance of integrating bamboo into national climate strategies, carbon market frameworks, and reforestation programs. Agencies such as DENR, LGUs, FMB, and DA can use these results to promote bamboo-based projects that reduce greenhouse gas emissions, restore degraded lands, and provide alternative income sources for rural communities. Beyond its ecological role, bamboo offers opportunities for industries such as construction, handicrafts, and bioenergy, further enhancing its economic value. Recognizing bamboo's role in ecological restoration and livelihood generation aligns with Sustainable Development Goals 13 (Climate Action) and 15 (Life on Land). Bamboo's carbon sequestration potential and market valuation demonstrate its potential as a cornerstone of sustainable forestry and climate resilience in the Philippines. This research contributes to advancing scientific knowledge, guiding policy development, and strengthening community-based environmental stewardship.

Recommendations - The findings of this study reveal that bamboo in Magtabid, Caranan, Pasacao, Camarines Sur, has significant carbon sequestration potential and market-based value. However, to fully realize this potential and ensure sustainability, the following recommendations are proposed based on the key areas identified in the study:

- Policy Development: Integrate bamboo carbon sequestration into DENR and LGU climate action plans, reforestation programs, and carbon trading frameworks to formally recognize bamboo as a viable carbon sink.
- Community Awareness: Educate local residents, including non-teaching personnel and barangay stakeholders, about bamboo's dual ecological and economic benefits through seminars, information campaigns, and demonstration farms.
- Sustainable Management: Promote proper propagation techniques and avoid overharvesting to ensure long-term ecological stability, soil conservation, and continuous carbon storage capacity.
- Carbon Market Access: Establish mechanisms for farmers and communities to participate in voluntary carbon markets, including technical assistance for carbon credit measurement, registration, and emission reduction verification.
- Expanded Research: Include below-ground biomass, soil carbon, and biodiversity assessments in future studies to provide a more complete valuation of bamboo's ecosystem services and climate mitigation potential.

Implications for students -This study provides students with a practical example of how theoretical concepts in environmental science are applied in actual field research. Students can learn from the methodologies employed, particularly the use of quadrat sampling, biometric measurements, and carbon stock calculations following IPCC guidelines. The research demonstrates that undergraduate theses can contribute meaningful data to local environmental management and climate action efforts. Furthermore, students may find inspiration in how the researchers transformed simple field observations—measuring bamboo diameter and height—into an economic valuation with potential policy applications.

Implications for educators - This study serves as an instructional resource for educators teaching environmental science, forestry, ecology, or natural resource economics. The research provides a concrete case study of how to conduct a market-based valuation of an ecosystem service, which can be used to illustrate abstract concepts such as natural capital, ecosystem services valuation, and carbon markets in a local Philippine context. Educators may also use the findings to initiate discussions on integrating climate change mitigation into classroom instruction.

Implications for schools and academic institutions - Academic institutions, particularly those offering environmental science programs, can make several insights from this study. The research demonstrates that meaningful undergraduate research is possible within local communities without requiring extensive funding or sophisticated equipment. This may encourage schools to support more community-based research initiatives that simultaneously advance student learning and serve local needs. Moreover, the study highlights the value of partnerships between academic institutions, local government units, and private landowners, a model that institutions may replicate for future research and extension projects. Finally, the alignment of the research with Sustainable Development Goals 13 and 15 reflects how the study can contribute to broader institutional commitments to sustainability.

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