

# Assessment of Falcata as Biomass Feedstock: A Thermochemical and MCDA-based Evaluation

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**Abstract.** This study presents an assessment of *Paraserianthes falcataria* (Falcata) as a biomass feedstock for decentralized energy systems in Mindanao, Philippines. A Multi-Criteria Decision Analysis (MCDA) framework was employed to evaluate five candidate species using availability (40%), cost (30%), and energy content (30%) as decision criteria. Falcata emerged as the top-ranked feedstock, driven by its dominant regional availability (449,515.02 m<sup>3</sup>), moderate cost range (PHP 2,600–4,300/m<sup>3</sup>), and competitive heating value (17.92 MJ/kg). Thermogravimetric analysis revealed a peak decomposition temperature of 348 °C and a total mass loss of 84.43%, indicating high thermal reactivity. Proximate and ultimate analyses confirmed favorable characteristics, including low ash content, high volatile matter, and desirable elemental composition. These results establish Falcata as a technically viable and regionally abundant feedstock for small- to medium-scale thermal energy applications, supporting waste valorization and rural energy self-sufficiency in Mindanao.

## 1 Introduction

Biomass has long been recognized as a critical component of the renewable energy mix in the Philippines, particularly in rural and off-grid areas where centralized infrastructure remains limited. Mindanao, the second largest island group in the country, generates substantial volumes of agricultural and forest biomass residues each year. In 2021, crop-based wastes such as corn residues (1.75 million MT), rice husks (906,073 MT), and sugarcane bagasse (1.54 million MT) collectively held an estimated energy potential of 17.3 TWh [1]. Despite this, Mindanao's installed biomass power capacity remains low—only 84 MW—yielding an annual output of 0.736 TWh, which represents less than 5% of its theoretical potential [1], [2]. This resource-utilization gap is primarily due to fragmented feedstock supply chains, seasonal availability of biomass, and the absence of enabling systems for rural biomass collection and preprocessing [3].

While agricultural residues are often emphasized, forest-based biomass, especially from plantation species, offers stable and high-volume supply potential. Among these, *Paraserianthes falcataria* (commonly known as Falcata) has emerged as a strategic resource.

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It is fast-growing, widely cultivated, and dominates Mindanao's log production, particularly in regions such as Caraga and Northern Mindanao [4].

Despite its prominence in regional forestry and wood-processing industries, Falcata's role in energy-focused biomass utilization has received comparatively less systematic attention.

A study employing the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method evaluated various biomass feedstocks for sustainable energy production in the Philippines [5]. Sugarcane bagasse emerged as the top choice due to its high calorific value and substantial annual volume. Falcata ranked second, indicating its potential as a biomass source, albeit with certain limitations. However, strategic considerations and economic factors currently favor other biomass sources for energy generation, than Falcata is currently favored. Moreover, Falcata's value chain is highly waste-generating, with estimates showing that up to 76.5% of the harvested volume ends up as bark, slabs, cut-offs, and sawdust. These residues are typically underutilized or discarded, despite possessing favorable energy characteristics such as high volatile matter, low ash content, and heating values comparable to other woody biomass. Harnessing these residues in decentralized thermal energy systems presents an opportunity to reduce waste, generate clean energy, and support energy self-reliance in rural communities.

Further, despite extensive studies on biomass characterization and utilization, regional feedstock assessments in the Philippines commonly treat availability, cost, and fuel properties separately and rarely integrate thermochemical characterization with structured decision analysis for feedstock selection. In particular, Falcata remains underrepresented in region-specific bioenergy consideration despite its dominance as an industrial tree plantation species (ITPS) in Mindanao. This study addresses this gap by combining Mindanao log production-based availability analysis, proximate and ultimate characterization, thermogravimetric analysis (TGA), and a weighted MCDA framework to identify the most suitable biomass feedstock for decentralized energy applications.

## **2 Methodology**

### **2.1 Biomass Feedstock Assessment**

#### *2.1.1 Feedstock Availability and Resource Mapping*

To quantify the availability of *Paraserianthes falcataria* (Falcata) as a biomass feedstock, a systematic collection and analysis of production data was undertaken. Regional log production records from 2019 to 2023 were retrieved from the official annual publications titled "Philippine Forestry Statistics" of the Department of Environment and Natural Resources – Forest Management Bureau (DENR-FMB). These records provided verified data on harvested log volumes (in m<sup>3</sup>) for all administrative regions of Mindanao, with a focus on Regions 9 to 13, where forest-based industries and plantation forestry are most active.

The procedure involved aggregating five years of log production data for each region, computing annual averages, and ranking them by total Falcata volume. This multi-year span was selected to minimize the effects of seasonal variability, market fluctuations, and external disruptions. Average production values were treated as representative indicators of sustained biomass availability over time.

### 2.1.2 Energy Yield and Proximate/Ulimate/Thermogravimetric Analysis

To evaluate the energy content of Falcata and its biomass characteristics as a feedstock, proximate analysis, ultimate analysis, and thermogravimetric analysis (TGA) were conducted on Falcata wood in two different forms: chips and pellet.

- Proximate Analysis: The moisture content, volatile matter, fixed carbon, and ash content of Falcata following ASTM D3172-13 standards were determined.
- Ultimate Analysis: The elemental composition (C, H, O, N, S) using ASTM D3176-15 standards were measured.
- Thermogravimetric Analysis (TGA): The thermal decomposition behavior of Falcata under controlled heating conditions was assessed.

These analyses provided critical data on fuel properties, combustion characteristics, and thermal behavior, supporting the selection of Falcata as a viable biomass feedstock for energy applications. Both proximate and ultimate analysis were conducted in the Department of Energy while the TGA was performed in DOST-FPRDI. See Appendix E for results.

## 2.2 Multi-Criteria Decision Analysis

The criteria for selection were adopted from this study [5]. However, only 5 criteria were identified and applicable as follows:

- Geographical Location and Condition
- Biomass Feedstock Availability
- Satisfaction of Demand
- Costs of Feedstocks
- Energy Content

### 2.2.1 Scoring and Weighting

The Multi-Criteria Decision Analysis (MCDA) procedure applied in this study evaluated the viability of biomass feedstocks using three quantifiable criteria: Availability, Cost, and Energy Content, with respective weights of 40%, 30%, and 30%. Availability was assigned a higher weight (40%) to reflect feedstock security considerations in Mindanao, while cost and energy content were equally weighted (30%) to balance economic feasibility and fuel quality.

Availability was assigned the highest weight in the MCDA framework due to its critical role in ensuring a sustainable and secure biomass supply chain [5], [6]. Measured in total cubic meters (m<sup>3</sup>) of log production in Regions 9–13 for the year 2019-2023, this criterion reflects the physical abundance and regional consistency of feedstock availability. In decentralized energy systems, especially in rural or off-grid areas, logistical feasibility and continuity of supply are paramount. High availability reduces dependence on long-haul transport, enhances resilience to seasonal fluctuations, and supports continuous system operation, making it the most influential factor in the feedstock selection process.

The cost of biomass was weighted at 30%, recognizing its substantial impact on the economic feasibility of the energy system, particularly for communities with constrained resources [5]. Cost was averaged based on regional price ranges expressed in Php/m<sup>3</sup>. While not as decisive as availability, cost determines the operational sustainability and affordability of fuel procurement. Lower feedstock costs increase competitiveness with other energy sources and reduce the levelized cost of energy (LCOE), which is crucial for rural adoption where subsidies and infrastructure support are often limited.

Also weighted at 30%, energy content, expressed in Megajoules per kilogram (MJ/kg), serves as an indicator of thermal efficiency and overall energy yield per unit mass. Although

secondary to availability, high energy content can significantly reduce feedstock volume requirements, improve system efficiency, and minimize emissions per unit energy output. This makes it an essential technical criterion in identifying superior-performing feedstocks, particularly for systems that integrate heat recovery or hybrid thermal-electric outputs [5], [7].

### 2.3 Final Ranking and Interpretation

The Multi-Criteria Decision Analysis (MCDA) applied in this study involved two main steps: normalization of criteria values and weighted aggregation to determine a composite score for each biomass feedstock.

Normalization was performed to scale the raw data (availability, cost, and energy content) into a comparable [0–1] range. The approach differed depending on whether higher or lower values were more desirable:

The availability and energy content were directly normalized using:

$$N_i = (x_i - x_{min}) / (x_{max} - x_{min}) \quad (1)$$

where  $N_i$  is the normalized value,  $x_i$  is the value of criterion for species  $i$ ,  $x_{min}$  and  $x_{max}$  are the minimum and maximum among all feedstocks.

The cost was inversely normalized (since lower cost is preferable) using:

$$N_i = (x_{max} - x_i) / (x_{max} - x_{min}) \quad (2)$$

Each normalized value was then multiplied by its assigned weight: Availability as 40%, Cost as 30%, and Energy content as 30%.

The final composite score  $S$  for each feedstock was computed as:

$$MCDA_i = \sum_{j=1}^n w_j N_{ij} \quad (3)$$

where  $w_j$  is the weight of criterion  $j$  and  $N_{ij}$  is the normalized value of criterion  $j$  for biomass species  $i$ .

Biomass species were then ranked based on their total composite scores, with higher scores indicating more favorable feedstock characteristics for decentralized thermal and gasification applications.

## 3 Results and Discussions

Falcata (*Paraserianthes falcataria*) was examined in terms of its geographical distribution, availability, waste yield, cost and energy potential. It was further assessed using multi-criteria decision analysis (MCDA) to determine its suitability as a feedstock among available biomass resources in the region, the following criteria were considered:

### 3.1 Biomass Feedstock Assessment

#### 3.1.1 Geographical Location and Condition

Falcata is a dominant forest commodity, with over 24,839.63 hectares of plantations recorded in 2020. The provinces contribute significantly to Falcata-based wood processing industries, mainly for plywood and veneer production. A 4-year-old Falcata can yield 177.3–220 m<sup>3</sup> per

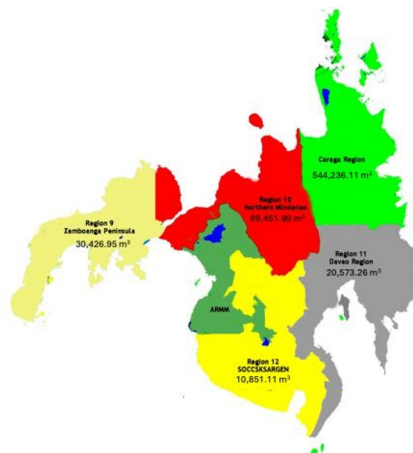
hectare. The average growth rate is 30 cm<sup>3</sup>/year, making it a fast-growing and high-yield species. It is classified as an industrial tree plantation (ITP) species due to its fast growth rate, high wood yield, and commercial importance in the wood processing and biomass energy sectors. Being an ITP species means that *Falcata* is intensively cultivated in managed plantations to supply raw materials for industrial applications, rather than being harvested from natural forests [8].

According to the latest report of the Department of Environment and Natural Resources-Forest Management Bureau (DENR-FMB), *Falcata* (*Paraserianthes falcataria*) dominates log production in the Philippines. It contributes 77.00% of the total log production in the Philippines, with 613,821.88 cubic meters out of 797,192.27 cubic meters nationwide. This makes *Falcata* the most widely harvested species for industrial and biomass applications.

**Table 1.** Top Log-producing Regions in the Philippines in 2019-2023 [4]

Region	Administrative Region Name	Production (m <sup>3</sup> )				
		2019	2020	2021	2022	2023
13	Caraga	607,959.00	573,782.08	642,678.59	533,771.07	362,989.79
10	Northern Mindanao	92,202.00	127,535.39	45,793.99	54,711.80	127,016.80
11	Davao Region	24,534.00	11,942.06	12,125.38	21,730.92	32,534.43
12	SOCCSKSARGEN	15,496.00	11,432.37	19,866.38	2,690.12	4,770.69
9	Zamboanga Peninsula	97,706.00	16,812.31	20,335.53	490.27	16,790.66

Geographically, the top five (5) log-producing regions for *Falcata* in the Philippines are all located in Mindanao as shown in Table 1. *Falcata* thrives in the tropical climate of the Philippines, particularly in Mindanao. The species grows best in warm, humid environments with well-drained soil [9], making Caraga, Northern Mindanao, and Davao Region ideal locations for large-scale plantations, as shown in Fig. 1. The average log production over the last five years (2019-2023) was 572,018.53 m<sup>3</sup>.



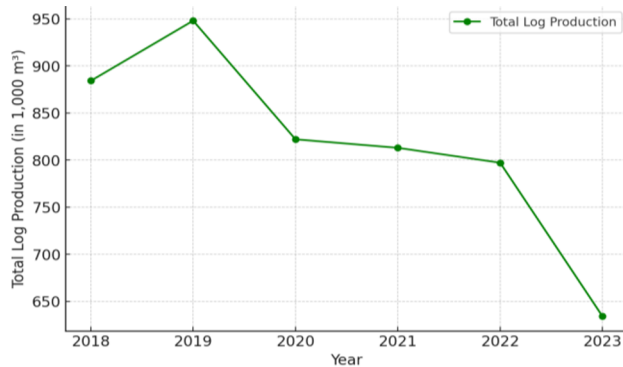
**Fig. 1.** Mindanao Map with Average Log Production per Region (2019-2023)

The Geographical Location and Condition criterion highlights Mindanao's strategic advantage in *Falcata* production, supported by favorable environmental conditions and extensive plantations. However, the declining production trend necessitates sustainable

forestry practices to ensure the continued availability of biomass feedstock and industrial raw materials.

### 3.1.2 Biomass Feedstock Availability

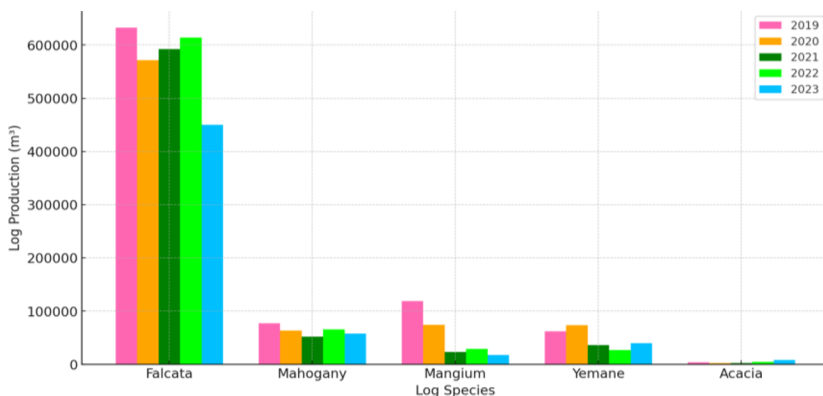
Based on the report [4], Philippines produced a total of 634.03 thousand cubic meters of logs in 2023. This volume was slightly lower compared to previous years' production, marking a declining trend that began in 2020. The peak production was in 2019, with 948.10 thousand cubic meters, and the average production from 2018 to 2022 was 852.92 thousand cubic meters.



**Fig. 2.** Philippines Log Production Trend (2018-2023)

The decline in the Philippines' log production from 2019 to 2023 can be attributed to several interrelated factors such as stringent conservation policies, deforestation, natural disasters, and economic challenges. The reduction in log production has led to an increased reliance on imported wood products to meet domestic demand.

Fig. 2 illustrates the log production trends of the top-producing regions in the Philippines from 2019 to 2023, which directly affects biomass feedstock availability for industrial applications such as bioenergy production, wood processing, and pulp manufacturing. Recent reports highlight the Philippine government's ongoing efforts to implement conservation policies aimed at mitigating deforestation and promoting sustainable forest management such as the National Greening Program (NGP).



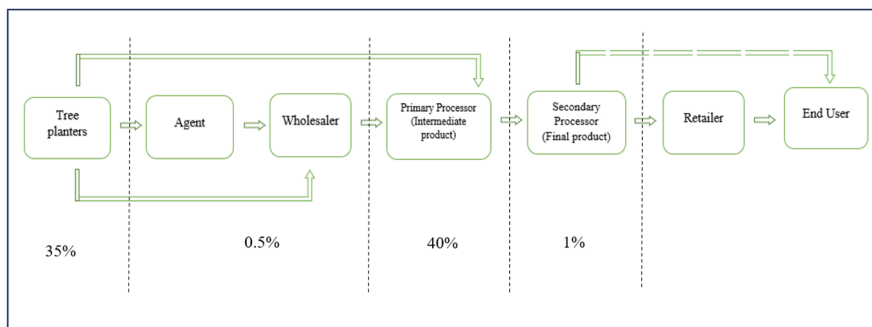
**Fig. 3.** Comparison of Top 5 Log Species in the Philippines (2019-2023)

In Fig. 3, from 2019 to 2023, Falcata remained the dominant log species in the Philippines but declined by 28.8%, from 632,574 m<sup>3</sup> to 449,928.75 m<sup>3</sup>, indicating challenges in plantation expansion and market demand. Mahogany production remained relatively stable despite a decrease, sustaining demand in the furniture and construction industries. Mangium experienced the sharpest decline, dropping 85.3% due to shifting plantation priorities. Yemane initially declined but rebounded in 2023, suggesting renewed interest in pulpwood and reforestation. Meanwhile, Acacia, the least produced species, showed an increasing trend, more than doubling its output, indicating growing market viability.

In terms of availability of the Falcata as biomass feedstock, it remains the dominant log species in the Philippines, despite a declining trend in overall log production. Optimizing Falcata waste for biomass energy presents a sustainable opportunity for energy production.

### 3.1.3 Satisfaction of Demand

Wood waste generation from Falcata processing is substantial, with approximately 35% of waste produced at the farm level and an additional 40% lost during primary processing [10], particularly in veneer log cutting (Fig. 4). Based on a study, residue types as wood wastes include tops, branches, leaves, stumps and roots which constitute approximately 40%. There is a potential for recovery depending on site-specific and technological factors.



**Fig. 4.** Percent Wood Waste in the Value Chain of Falcata-Plywood

During the processing of Falcata wood, logs are classified into high and low grades. Top-quality logs, such as sawlogs and veneer log flanges, are either sent to major wood processing facilities or exported. In veneer processing, approximately 47–53% of Falcata log volume becomes waste depending on whether gross or net recovery is considered. Further, lower-grade logs are further categorized into low-quality logs, low-grade logs, and pulpwood. Low-quality logs are utilized as poles and piles for fish pens and electrification posts. Other low-grade logs, despite their inferior quality, are still processed by secondary wood manufacturers into various wood products.

**Table 2.** Falcata Wood Wastes Across Value Chain

Stage in the Value Chain	Percentage (%)	Waste Amount (m <sup>3</sup> )
1. Tree Planters	35	200,206.55
2. Agent & Wholesalers	0.5	2,860.09
3. Primary Processor (Intermediate Product)	40	228,807.49
4. Secondary Processor (Final Product)	1	5,720.19
	Total	437,594.33

In Table 2, based on the average log production of 572,018.53 m<sup>3</sup> over the last five years (2019-2023), the total estimated wood waste generated across the Falcata value chain amounts to 437,594.33 m<sup>3</sup>, accounting for a waste rate of approximately 76.5% of total production. The total energy potential from 437,594.33 m<sup>3</sup> of Falcata wood waste, given a wood density of 500 kg/m<sup>3</sup> and a lower heating value (LHV) of 17 MJ/kg, is approximately 3,719,551.81 GJ (or 3,719.55 TJ). A biomass power plant operating at 33% efficiency can generate approximately 38.93 MW of power using said Falcata wood waste over a year of continuous operation (8,760 hours).

Given these volumes, sawdust and wood trimmings as wastes from Falcata processing can be effectively repurposed as feedstock for biomass gasification, providing a renewable energy source while simultaneously mitigating waste.

This criterion on Satisfaction of Demand presents an opportunity that with recoverable wood wastes to become biomass feedstocks, it can generate a substantial amount of renewable energy.

### 3.1.4 Costs of Feedstocks

Market prices of Falcata logs depend on log diameter, ranging from PHP 2,800 to 4,200 per m<sup>3</sup> in 2024. In 2020, the buying price of Falcata ranged from PhP 3,300 to PhP 4,300, depending on size (Table 3). In recent years, by 2024, the price has decreased due to factors such as the rapid increase of imported products from China. High price variations were also dependent on the quality of Falcata delivered by growers or farmers.

**Table 3.** Market Prices of Falcata (2020-2024)

Size	2020 Price (PhP)	2024 Price (PhP)
26 cm up	3,300.00	2,800.00
30 cm up	3,800.00	3,200.00
40 cm up	4,100.00	3,600.00
50 cm up	4,200.00	4,200.00
60 cm up	4,300.00	4,200.00

Despite the well-documented pricing for Falcata logs, there remains no published cost data for Falcata wood waste, which represents a significant gap in the valuation of its biomass energy potential. Given that Falcata waste accounts for up to 76.5% of total production, establishing a pricing model for sawdust, trimmings, and residual biomass could support investment in bioenergy applications and optimize the economic potential of Falcata-based industries.

## 3.2 Energy Yield and Proximate/Ulimate/Thermogravimetric Analysis

This section evaluates the proximate analysis, ultimate analysis, and thermogravimetric analysis (TGA) being conducted on Falcata in two different forms: chips and pellet.

### 3.2.1 Ultimate and Proximate Analyses

Table 4 presents the results of the ultimate and proximate analyses of Falcata Wood Pellet (FWP) and Falcata Wood Chips (FWC) conducted by the Department of Energy (DOE).

Referring to the ultimate analysis, both FWP and FWC have similar carbon and hydrogen contents, with FWC showing slightly higher values. This indicates that both forms of Falcata wood have comparable potential for energy production from their carbon and hydrogen content. The oxygen content is almost identical for both FWP and FWC, suggesting that the oxidizing potential during gasification is similar for both forms. FWP has a higher ash content (1.9%) compared to FWC (1.0%). Higher ash content can lead to more residue and may affect the efficiency and maintenance of the gasification system.

**Table 4.** Ultimate and Proximate Analyses of FWP and FWC and other Biomass

Analysis Type	Component	FWP Value (%)	FWC Value (%)	Wood Range (%)	Agricultural Residues Range (%)	Grasses & Herbaceous Range (%)
Ultimate Analysis	Carbon (C)	45.4	46.0	45-50	35-45	40-45
	Hydrogen (H)	6.44	6.58	5-6	4-6	5-6
	Nitrogen (N)	0.32	0.28	0.1-0.5	0.2-1	0.5-1
	Sulfur (S)	N.D.	N.D.	<0.1	<0.1	<0.1
	Oxygen (O)	45.94	46.14	40-45	35-50	40-50
	Ash	1.9	1.0	0.5-1	10-20	5-20
Proximate Analysis	Moisture Content	11.42	6.0	10-15	10-20	10-20
	Volatile Matter	79.82	84.29	70-80	65-75	70-80
	Fixed Carbon	18.20	14.97	15-25	10-20	10-20
	Ash Content	1.98	0.74	0.5-1	10-20	5-20
	Heating Value MJ/kg.	16.61	17.92	18-20	15-18	15-18

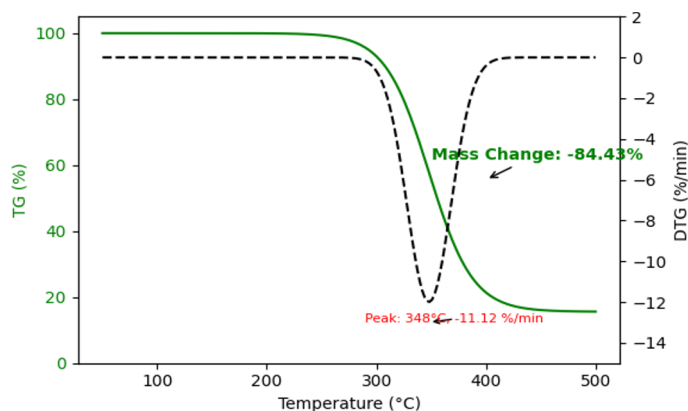
FWP has a higher moisture content (11.42%) compared to FWC (6.0%). Lower moisture content in FWC is advantageous as it requires less energy for drying and enhances gasification efficiency [11]. FWC has higher volatile matter content (84.29%) compared to FWP (79.82%). Higher volatile matter can enhance the gasification process, leading to better syngas production. FWP shows a higher fixed carbon content (18.20%) than FWC (14.97%). Fixed carbon is important for the sustained production of syngas [33], indicating FWP might provide a more consistent fuel source. The ash content in FWP (1.98%) is significantly higher than in FWC (0.74%). Lower ash content in FWC is beneficial as it results in less residue and potentially lower maintenance requirements [18]. FWC has a higher heating value (17.92 MJ/kg) compared to FWP (16.61 MJ/kg). A higher heating value suggests that FWC could produce more energy per kilogram of biomass, making it a more efficient feedstock in terms of energy output.

Referring to Table 4, in ultimate analysis, FWP (45.4%) and FWC (46.0%) have carbon content comparable to wood biomass (45–50%), but higher than agricultural residues (35–45%) and grasses/herbaceous biomass (40–45%). Also, the hydrogen content in FWP (6.44%) and FWC (6.58%) were slightly higher for wood. The nitrogen content was within the range. The oxygen content FWP (45.94%) and FWC (46.14%) was within the typical range for most biomass types. FWP (1.9%) and FWC (1.0%) have very low ash content compared to agricultural residues (10–20%) and grasses/herbaceous biomass (5–20%), making them more desirable as they produce less residual waste and require less frequent system maintenance.

In terms of the proximate analysis, the moisture content of both Falcata forms were within the typical range for all biomass. This is obvious since both were sun-dried during feedstock preparation. FWP (79.82%) and FWC (84.29%) are at the higher end of the range

compared to wood (70–80%), agricultural residues (65–75%), and grasses/herbaceous biomass (70–80%). FWP (18.20%) and FWC (14.97%) fall within the expected range for wood (15–25%) and agricultural residues (10–20%). Higher fixed carbon typically results in a longer burning time and better energy yield. Red hot char reacts with carbon dioxide and water to produce hydrogen gas (water-gas shift reaction) and carbon monoxide (Boudouard reaction), both valuable components of syngas. The ash contents for both Falcata forms in both analyses were consistent and are advantageous compared to agricultural residues (10–20%) and grasses/herbaceous biomass (5–20%). Finally, The heating value of FWP (16.61 MJ/kg) and FWC (17.92 MJ/kg) is comparable to wood (18–20 MJ/kg) but higher than agricultural residues (15–18 MJ/kg) and grasses/herbaceous biomass (15–18 MJ/kg). This suggests Falcata biomass is a promising alternative fuel with a good balance of combustion efficiency and energy output.

### 3.2.2 Thermogravimetric Analysis



**Fig. 5.** TGA of Falcata

Thermogravimetric analysis (TGA) of Falcata wood revealed a peak decomposition temperature of approximately 348 °C, corresponding to a maximum mass loss rate of  $-11.12\% \text{ min}^{-1}$ , indicating rapid devolatilization, as shown in Fig. 5. The total mass loss of 84.43% reflects the high volatile content of the biomass and its efficient thermal degradation behavior. These characteristics are favorable for thermochemical conversion processes, as they support enhanced gas release and reduced residual char formation, particularly in fixed-bed and fluidized-bed systems.

### 3.3 Multi-Criteria Decision Analysis

The Multi-Criteria Decision Analysis (MCDA) results in Table 5 highlight Falcata as the most suitable biomass feedstock among the top five species assessed.

With an MCDA score of 0.70, Falcata ranked highest due to its vast availability of 449,515.02 m<sup>3</sup> (normalized score: 1.00), moderate cost (PHP 2,600–4,300/m<sup>3</sup>, normalized: 1.000), and competitive absolute energy content (17.92 MJ/kg, normalized: 0.00). Although Falcata exhibits a competitive heating value (17.92 MJ/kg), it represents the lowest energy content among the evaluated species; therefore, under min–max normalization for benefit-type criteria, it receives a normalized energy score of 0.0. This outcome reflects relative ranking within the dataset rather than absolute fuel inadequacy. Moreover, its dominant

volume in all regions in Mindanao strongly influenced its top rank despite having lower calorific value compared to others.

**Table 5.** MCDA Table based on the PFS 2023 Report [4]

Rank	Species	Availability (m <sup>3</sup> )	Cost* (Php/m <sup>3</sup> )	Energy Content (MJ/kg)	Norm_Availability	Norm_Cost	Norm_Energy	MCDA Score
0	Falcata	449,515.02	2,600 – 4,300	17.92**	1.0	1.0	0.0	0.70
1	Yemane	30,059.97	2,510 – 5,100	20.35	0.06	0.74	1.0	0.55
4	Acacia	4,161.31	2,000 – 7,200	18.33	0.0	0.18	0.17	0.10
2	Mahogany	13,315.76	2,000 – 5,500	18.0	0.02	0.79	0.03	0.25
3	Mangium	13,367.44	1,100 – 8,600	19.54	0.02	0.0	0.67	0.21

\*The cost values were reported across different log grades (e.g., sawlog, veneer) and diameters (e.g., <30 cm to >60 cm) from Regions 9 to 13. No cost data was found for wood waste or by-products like sawdust, which remains a data gap in assessing full economic potential.

\*\*From Table 4

Yemane followed with a score of 0.55, influenced by its high energy content (20.35 MJ/kg, normalized: 1.000) and moderate availability (30,059.97 m<sup>3</sup>, normalized: 0.065), making it a favorable alternative.

Mangium and Mahogany, while having respectable energy contents (normalized: 0.67 and 0.03, respectively), are constrained by moderate availability (normalized: 0.02 and 0.02) and higher or more variable cost ranges (normalized: 0.0 and 0.79), thus yielding lower scores of 0.21 and 0.25, respectively.

Finally, Acacia, though showing decent energy value (18.33 MJ/kg, normalized: 0.17), scores the lowest (0.10) due to its very limited availability in Regions 9–13 (4,161.31 m<sup>3</sup>, normalized: 0.00), which limits its viability as a regional feedstock despite potential competitiveness elsewhere.

Overall, the MCDA indicates that availability remains the most decisive factor in ranking biomass feedstock options in the Philippine context, especially when sourcing from specific regions, particularly in Mindanao.

## 4 Conclusion

This study established *Paraserianthes falcataria* (Falcata) as the most suitable biomass feedstock among five candidate species for decentralized energy systems in Mindanao. Using a Multi-Criteria Decision Analysis (MCDA) framework with weighted parameters: availability (40%), cost (30%), and energy content (30%), Falcata achieved the highest composite score (0.70), primarily due to its dominant regional availability (449,515.02 m<sup>3</sup>), moderate cost range (PHP 2,600–4,300/m<sup>3</sup>), and favorable heating value (17.92 MJ/kg). Thermochemical characterization through proximate, ultimate, and thermogravimetric analyses further validated Falcata's suitability by confirming its low ash content, high volatile matter, and efficient thermal decomposition behavior. These attributes make Falcata a technically and economically viable feedstock for small- to medium-scale biomass-based energy applications in rural and off-grid contexts.

Future work should extend the present assessment by incorporating life-cycle analysis and techno-economic evaluation to quantify the environmental and economic performance of Falcata-based energy systems. Such analyses would enable a more comprehensive comparison of decentralized biomass utilization pathways, including emissions, logistics, and cost competitiveness. Additionally, system-level studies integrating Falcata residues into specific thermochemical conversion technologies may further support informed deployment in rural and off-grid applications.

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