ERIA Research Project Report FY2025, No. 24

Natural Fibres Utilisation in ASEAN: Advancing Sustainability in Consumer Products and Green Manufacturing

Economic Research Institute for ASEAN and East Asia

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Chapter 1
Introduction

1.1. Research Background

Malaysia possesses a substantial yet frequently underutilised ecological resource in the form of lignocellulosic biomass, specifically Kenaf (Hibiscus cannabinus L.) and Jute (Corchorus spp.) fibres. Historically, these indigenous resources have been confined to low-value applications. However, recent advancements in material science and sustainability evaluations have highlighted their significant potential in mitigating the global issue of anthropogenic carbon emissions. The prevailing model of consumer goods production, which heavily depends on fossil-fuel-based synthetic polymers and energy-intensive additive manufacturing, results in a considerable carbon footprint and significantly contributes to atmospheric greenhouse gas accumulation.

In contrast, comprehensive Life Cycle Assessments (LCA) of Kenaf and Jute fibre production consistently demonstrate a markedly reduced environmental impact across various categories, particularly in terms of global warming potential (M. S. Islam and Ahmed, 2012; Puttegowda, 2025; Zhou et al., 2018). This advantage is attributed to several intrinsic factors. Firstly, as bast fibres, Kenaf and Jute exhibit rapid growth and require minimal synthetic inputs, such as fertilisers and pesticides, compared to many conventional industrial crops. Secondly, their cultivation serves as a significant carbon sink, with the plants actively sequestering atmospheric carbon dioxide (CO2) through photosynthesis, effectively offsetting emissions associated with downstream processing (Selvaraj et al., 2024). This biogenic carbon capture provides a viable pathway towards carbon neutrality and even negative emissions in material production.

Furthermore, from a material science perspective, the hierarchical structure and chemical composition (primarily cellulose, hemicellulose, and lignin) of Kenaf and Jute fibres confer desirable mechanical properties, including high specific strength and stiffness (Arjmandi et al., 2021; Iqbal et al., 2024). Advanced natural fibre engineering, which leverages these inherent attributes through optimised matrix selection and interfacial adhesion, can produce materials with performance characteristics suitable for a wide range of high-value applications, potentially replacing conventional, less sustainable materials. The strategic utilisation of these local resources aligns with circular economy principles, promoting the use of renewable feedstocks and the potential for end-of-life biodegradability or recyclability, thereby further minimising environmental impact.

Additionally, the development of a robust bio-based materials sector in Malaysia, centered on Kenaf and Jute, offers a viable pathway for regional economic diversification, the creation of skilled green jobs, and a reduced reliance on volatile global petrochemical markets. In this case, Midwest Composites' focus on engineering innovative natural fibre composites from these underutilised natural fibres represents a scientifically sound and economically prudent approach to sustainable materials development. By rigorously quantifying the environmental benefits through LCA and strategically optimising the material properties for targeted applications, they are not only contributing to decarbonisation efforts in the consumer goods sector but also fostering a paradigm shift towards a bio-based economy grounded in scientific understanding and environmental responsibility. This endeavor underscores the critical role of material science innovation in harnessing nature's inherent capacity to address global sustainability challenges.

1.2. Research Objectives

A) Analyse the Current Use of Natural Fibres in Consumer Products

Conduct a comprehensive review of how Kenaf and Jute natural fibres are currently utilised in consumer products across ASEAN, with a focus on identifying prevalent trends, practices, and gaps.

B) Examine Natural Fibre Composite Applications in Malaysia

Conduct a detailed case study on the use of natural fibre-based composites in Malaysia, exploring the development and proven effectiveness on natural fibre applications, and potential impact on green manufacturing.

C) Develop Recommendations for Enhancing Natural Fibre Utilisation

Provide actionable recommendations for policymakers, manufacturers, and stakeholders to promote the use of natural fibres in consumer products and foster green manufacturing practices in ASEAN.

1.3. Research Questions

A) What are the dominant applications, processing techniques, and market penetration levels of Kenaf and Jute natural fibres in current consumer products across the ASEAN region, and what are the key technological and market-related gaps hindering their broader adoption as sustainable alternatives to conventional materials?

B) How have natural fibre-based biocomposites been developed and implemented in Malaysia, what is the evidence of their technical efficacy and environmental performance in specific applications, and what is their demonstrated and potential contribution to the advancement of green manufacturing practices within the Malaysian industrial sector?

C) What evidence-based policy interventions, manufacturing process innovations, and stakeholder collaborations can be recommended to significantly enhance the utilisation of Kenaf and Jute natural fibres in consumer product manufacturing across ASEAN, thereby fostering the broader adoption of green manufacturing practices and contributing to regional sustainability goals?

Chapter 2
Literature Review

2.1. Jute

Jute is a natural fibre derived from the stem and outer skin of jute plants, primarily from two species – Corchorus capsularis (white jute) and Corchorus olitorius (tossa jute) (Zakaria Ahmed and Shuranjan Sarkar, 2022). The jute fibre is believed to have originated in the Indian subcontinent, particularly in regions of Bangladesh and India (Jahan et al., 2022). It is also hypothesised to have secondary centres of origin in South China and Indo-Burma (Jahan et al., 2022; Saba et al., 2015). Jute fibre is referred to as the 'golden fibre' due to its golden and silky lustre (Jahan et al., 2022; Moniruzzaman et al., 2024). It possesses several advantageous properties, including high tensile strength, and is considered one of the most economical natural fibre options (Ahmed and Miah, 2024). Its biodegradable and eco-friendly nature renders jute extensively utilised for various applications such as gunny sacks, geotextiles, and natural fibre composites. The global jute production landscape demonstrates the continued dominance of traditional producing countries like India and Bangladesh, while showing signs of potential expansion in other regions including Vietnam, Uzbekistan, and China (FAO, 2023).

Jute emerges as the most practical, economical, and accessible choice amongst natural fibres like kenaf, flax, and hemp. Its favourable reinforcing qualities enable the production of various intricate and planar shapes. The primary components of jute are a-cellulose, lignin, and hemicellulose. It is crucial to recognise that jute's mechanical and physical attributes can fluctuate considerably, affected by elements such as its physical state, chemical composition, cultivation conditions, and geographical origin. Moreover, the processing methods utilised contribute to determining these characteristics. Nevertheless, jute also exhibits certain shortcomings that render it suboptimal for reinforcement. These limitations encompass poor wettability, weak adhesion between fibre and matrix, inherent polarity due to hydroxyl and carboxyl groups in its structure, and low moisture resistance (Iqbal et al., 2024; S. Islam et al., 2024).

2.2. Kenaf

Kenaf, scientifically known as Hibiscus cannabinus, is an annual plant belonging to the Malvaceae family (Afzal et al., 2022; Norhisham et al., 2023). It is indigenous to Africa but has been cultivated in various regions globally, including Asia. The term 'Kenaf' originates from a Persian word 'kanab', which is derived from Cannabis sativa (hemp or marijuana) (Norhisham et al., 2023). However, Kenaf and hemp are not taxonomically related, despite having similar agricultural requirements. Kenaf belongs to the Malvaceae family, whereas hemp is classified under Moraceae (Graupner et al., 2023; Norhisham et al., 2023). Kenaf is known by various regional appellations, including mesta (Bengal, India), palungi (Madras, India), deccan hemp (Bombay, India), bimli jute (Andhra Pradesh, India), ambali (Taiwan), till, teel / teal (Egypt and Northern Africa), Java Jute (Indonesia), papoula de Sao Francisco (Brazil), stokroos (South Africa), dah, gambo and rama (West Africa) (Norhisham et al., 2023). Kenaf can attain a height of 8 to 20 feet with a maturation period of up to 150 days. It is hypothesised to have originated in east-central Africa or western Africa, where it has been utilised as a source of food and fibre for millennia. From these regions, the crop is believed to have disseminated to Asia via maritime routes or caravans through Mesopotamian territory.

In the ASEAN region, Kenaf is primarily cultivated for fibre production. The fibres are utilised in the manufacturing of natural fibre composites, biodegradable utensils, panels, bedding, livestock feed, and textiles. Additionally, kenaf is employed in paper production, construction materials, and biofuel (Austin et al., 2024; Saba et al., 2015). Kenaf fibres are characterised by their strength, soft handle, and low elasticity. They are composed of cellulose, lignin, hemicellulose, and pectin. The fibres exhibit robust and absorbent properties, rendering them suitable for various industrial applications. Global production of kenaf is estimated to be approximately 200,000 metric tonnes annually (Austin et al., 2024). However, specific data on annual production within the ASEAN region is limited. Major producers of Kenaf include China, Bangladesh, Thailand, and Myanmar. Malaysia is one of the leading producers of kenaf in the ASEAN region. The National Kenaf and Tobacco Board (LKTN) has been actively promoting kenaf cultivation as an alternative crop to tobacco, with the objective of developing it as a new economic resource.

2.3. Natural Fibre Composites

Natural fibre composites (NFCs) have emerged as a viable alternative to synthetic fibre-reinforced composites, offering sustainability, cost-effectiveness, and competitive mechanical properties. These materials consist of natural fibres embedded within a polymer matrix, resulting in lightweight yet durable structures suitable for various industrial applications. For instance, several extensive researches reported that natural fibre composites are 20 – 40% lighter than the conventional material made up of synthetic, steel and aluminum (Ahmad et al., 2015; Akampumuza et al., 2017; Ullah et al., 2025). The increasing interest in NFCs is driven by their biodegradability, renewability, and reduced environmental impact compared to petroleum-based composites (Gholampour and Ozbakkaloglu, 2020). Industries such as automotive, aerospace, construction, and consumer goods have increasingly adopted NFCs due to their favourable strength-to-weight ratio low cost, low density, high toughness, and good thermal properties properties (Ilyas et al., 2022; Ullah et al., 2025), (Ahmadi et al., 2024). However, challenges such as moisture absorption, fibre variability, and interfacial adhesion remain critical areas of research to improve their performance and reliability. Figure 2.1 shows the Lotus prototype car utilised natural fibre composites.

Figure 2.1. Lotus Eco Elise Prototype Incorporated Natural Fibre Composites for the Exterior and Interior Parts

Source: Akampumuza et al. (2017).

Natural fibres employed in composite manufacturing are predominantly sourced from plants and are categorised into bast, leaf, seed, fruit, and wood fibres. Bast fibres, such as flax, hemp, jute, kenaf, and ramie, are renowned for their high tensile strength and stiffness, rendering them suitable for structural applications (Puttegowda, 2025; Thapliyal et al., 2023). Leaf fibres, including sisal and abaca, demonstrate durability and resistance to wear, which contributes to their application in automotive and marine components. Seed fibres, such as cotton and kapok, offer softness and flexibility, making them ideal for cushioning and textile-based composites. Fruit fibres, like coir derived from coconut husks, provide excellent impact resistance and are frequently utilised in packaging and insulation materials. Wood fibres, obtained from softwood and hardwood species, function as reinforcements in bio-based composites, enhancing mechanical stability and dimensional integrity. The choice of fibre type is contingent upon the intended application, mechanical requirements, and environmental considerations.

The fabrication of natural fibre composites (NFCs) encompasses a variety of processing techniques that significantly affect fibre orientation, mechanical properties, and cost-effectiveness (Meinathan and Unni, 2017; Mursalin et al., 2018; Rabbi et al., 2021). Compression molding is extensively utilised for high-volume production, as it ensures uniform fibre distribution and consistent mechanical performance. Injection molding is particularly advantageous for complex geometries and mass production, as it allows precise control over fibre dispersion within the matrix. Vacuum infusion enhances fibre wetting and reduces void content, thereby improving structural integrity and mechanical strength. The hand layup process remains a cost-effective method for prototyping and small-scale production, offering customisation and flexibility in fibre arrangement. Pultrusion is another critical technique employed for continuous fibre reinforcement applications, yielding composites with high longitudinal strength and durability. The choice of fabrication method is contingent upon factors such as fibre type, matrix compatibility, intended application, and production scale.

Recent advancements in NFC research have concentrated on enhancing fibre-matrix adhesion, durability, and mechanical performance through innovative methodologies. A significant trend is the hybridisation of natural fibres with synthetic reinforcements, which augments strength and moisture resistance while preserving sustainability benefits (Puttegowda, 2025; Thomas and Balakrishnan, 2021). Furthermore, the integration of nanotechnology has facilitated the incorporation of nano-fillers, which improve fibre dispersion and mechanical properties by minimising defects and enhancing interfacial bonding. The development of bio-based resins has further bolstered the environmental appeal of NFCs, enabling fully biodegradable composites that align with circular economy principles. Machine learning applications have also gained prominence in NFC research, enabling predictive modeling for optimising fibre selection, processing parameters, and performance characteristics. These advancements address longstanding challenges such as moisture sensitivity and variability in fibre properties, thereby enhancing the viability of NFCs for large-scale industrial applications.

2.4. Jute and Kenaf Natural Fibre Composites

The increasing global emphasis on sustainable materials has led to extensive research on natural fibre composites (NFCs), particularly those reinforced with Jute and Kenaf fibres. These fibres offer biodegradability, lightweight properties, and cost-effectiveness, making them attractive alternatives to synthetic fibres in consumer goods. The integration of thermoset and thermoplastic matrices with Jute and Kenaf fibres has demonstrated promising mechanical and environmental benefits, yet challenges remain in optimising fibre-matrix compatibility and durability.

Thermoplastic matrices, including polypropylene (PP), polyethylene (PE), and polylactic acid (PLA), have been extensively investigated for their utilisation in Jute and Kenaf fibre-reinforced composites owing to their inherent recyclability and facile processability. Research has demonstrated that Kenaf fibre reinforcement in PP matrices can lead to composites exhibiting enhanced tensile strength and impact resistance, rendering them suitable for applications in packaging materials, furniture components, and various household items. Established processing methodologies such as injection molding, extrusion, and compression molding have been effectively employed for the fabrication of these thermoplastic natural fibre composites (NFCs). Notably, the interfacial adhesion between the fibre and the matrix is a critical factor governing the mechanical performance of these composite systems. Consequently, surface treatment techniques, such as alkali treatment and the application of silane coupling agents, have been explored to improve fibre wettability and promote robust interfacial bonding.

Despite the aforementioned advantages, thermoplastic-based Jute and Kenaf composites encounter several challenges that necessitate careful consideration. Firstly, the inherent hydrophilic nature of natural fibres leads to significant moisture absorption, resulting in dimensional instability of the composite and a subsequent reduction in its mechanical properties over time. Secondly, the processing temperatures typically required for thermoplastics can often exceed the thermal degradation threshold of the natural fibres, potentially causing fibre decomposition and a compromise in the final composite performance. Thirdly, achieving uniform dispersion of the natural fibres within the thermoplastic matrix remains a persistent challenge, which can negatively impact the efficiency of stress transfer within the composite material.

Thermoset matrices, encompassing epoxy, polyester, and phenolic resins, have been extensively investigated as matrices for Jute and Kenaf fibre-reinforced composites, primarily due to their inherent high strength and durability characteristics. Research has indicated that Kenaf fibre-reinforced epoxy composites exhibit superior flexural strength and impact resistance, positioning them as potential materials for applications such as consumer electronics casings, decorative panels, and sustainable utensils. Various processing techniques, including hand lay-up, vacuum-assisted resin transfer molding (VARTM), and compression molding, have been employed for the fabrication of these thermoset natural fibre composites (NFCs). It is noteworthy that the curing process plays a significant role in determining the crosslinking density of the thermoset matrix, which consequently influences the mechanical and thermal properties of the resulting composite material.

Despite their advantages, thermoset-based Jute and Kenaf composites present several challenges that warrant consideration. Firstly, thermoset matrices tend to exhibit inherent brittleness, which can limit the overall impact resistance of the resulting composite. Secondly, unlike thermoplastic composites, thermoset composites are generally non-recyclable via traditional melt-processing methods, posing significant challenges for end-of-life disposal and circular economy initiatives. While research explores chemical and thermal recycling methods for thermosets, these are not as widely established as thermoplastic recycling. Finally, achieving optimal interfacial adhesion between the natural fibres and the thermoset matrix remains a critical issue that can significantly affect the mechanical performance and overall durability of the composite material. Table 2.1 summaries the general comparative performance between thermoplastic and thermoset composites. Meanwhile, Table 2.2 tabulates several of the research findings done on both Jute and Kenaf natural fibre composites.

Table 2.1. General Performance of Thermoplastic and Thermoset Natural Fibre Composites

Property	Thermoplastic Based	Thermoset Based
Recyclability	High	Low
Processing Temperature	Moderate	High
Mechanical Strength	Moderate	High
Moisture Resistance	Moderate	Low
Impact Resistance	High	Moderate

Source: Author's data (2025).

Table 2.2. Summary of Research Works Done on Kenaf and Jute Fibre Composites

Types of Fibre	Types of Resin	Application	Optimum Fibre Loading %	Findings	Source
Kenaf	Thermoset	Exterior application	10–35	Provides excellent results for thermal degradation, tensile and flexural strengths	(Owen et al., 2022), (Ghori and Rao, 2021), (Suriani et al., 2021)
	Thermoplastic	3D printed component	2.5–10	Provides the best tensile and flexural strengths	(Han et al., 2022), (Dulina Tholibon et al., 2025)
Jute	Thermoset	Interior component	30	High tensile and flexural strengths	(Rahman et al., 2022),
	Thermoplastic	Consumer good	30	High tensile strength	(Ahmed and Miah, 2024)

Source: Author's data (2025).

2.5. Life Cycle Analysis (LCA)

The escalating global concern regarding greenhouse gas (GHG) emissions has prompted extensive research into sustainable materials, with a particular focus on natural fibre composites (NFCs). Amongst the most promising candidates are Kenaf and Jute fibres, which are noted for their biodegradability, lightweight characteristics, and reduced carbon footprint in comparison to synthetic fibres. Life Cycle Analysis (LCA) is employed as a scientific method to assess the environmental impact of these materials, encompassing the entire process from raw material extraction to end-of-life disposal. This review synthesises findings from recent LCA studies on Kenaf and Jute composites and examines their potential in mitigating global GHG emissions.

Kenaf fibre composites have been the subject of extensive research due to their minimal environmental impact. Life cycle assessment (LCA) studies demonstrate that Kenaf-based composites substantially decrease energy consumption and carbon emissions in comparison to synthetic alternatives. For instance, research on Kenaf-reinforced polypropylene composites reveals a reduction in life cycle energy consumption by 6.1% and greenhouse gas (GHG) emissions by 10.6% relative to conventional glass fibre composites (Zhou et al., 2018). Kenaf plants possess a high carbon sequestration capacity, absorbing CO_2 at a rate 1.5–2.0 times greater than traditional crops (Abdelrhman et al., 2023; Korol et al., 2020). This attribute positions Kenaf as an optimal candidate for carbon-neutral composite materials. Studies indicate that incorporating Kenaf fibres into automotive and construction applications could facilitate long-term carbon storage, thereby reducing overall GHG emissions. Additionally, Kenaf fibre composites offer biodegradability and recyclability, which mitigate landfill waste and environmental pollution. Nonetheless, challenges such as fibre degradation in humid conditions and the limited infrastructure for industrial-scale recycling remain areas requiring further development.

Conversely, jute fibre composites have exhibited notable environmental benefits, particularly in terms of energy conservation and emission reduction. Life cycle assessment (LCA) studies indicate that jute-reinforced polymer composites decrease life cycle energy consumption by 9.4% and greenhouse gas (GHG) emissions by 18.5% when compared to synthetic fibre composites (Gonzalez et al., 2023; Khan et al., 2023; Peças et al., 2019). These results underscore jute's potential as a sustainable alternative across various industries. Similar to kenaf, jute plants possess robust carbon sequestration capabilities, absorbing substantial amounts of CO_2 during their growth. Research indicates that jute-based composites could function as carbon-negative materials, especially in packaging, textiles, and automotive sectors. Jute fibre composites are biodegradable and compostable, rendering them suitable for short-lived consumer products. Nonetheless, challenges such as fibre-matrix compatibility and moisture sensitivity hinder their application in long-term structural uses. Both kenaf and jute fibre composites exhibit considerable potential in reducing GHG emissions, with jute demonstrating greater emission reductions and kenaf providing superior carbon sequestration.

2.6. Recent Trend in Jute and Kenaf Composites Application

Jute and Kenaf fibre composites have gained significant traction in Southeast Asia, particularly in Malaysia, due to their sustainability and mechanical performance. Malaysia has been actively promoting Kenaf as an industrial crop, with government initiatives supporting research and commercialisation. The Kenaf for the People Scheme (KUR) initiative, introduced by the Malaysian government, aims to enhance economic opportunities for local communities by fostering Kenaf fibre processing. Besides that, extensive research works have also conducted by local universities on mechanical strength and thermal performances.

Across the region, countries like Indonesia and Thailand are exploring Kenaf and Jute composites for eco-friendly applications, driven by environmental regulations and the push for biodegradable materials. Thailand, for instance, has integrated Kenaf fibre into packaging and furniture industries, leveraging its biodegradability and strength. Indonesia is also investigating Kenaf-based composites for automotive and aerospace applications, aligning with global sustainability trends. Driven by their inherent lightness, robust durability, and compelling environmental advantages, composites made from jute and kenaf fibres are being progressively integrated across a diverse spectrum of industries.

In the realm of consumer goods, these natural fibres are witnessing increased utilisation in the creation of biodegradable packaging solutions, sustainable furniture designs, and various household items, effectively serving as replacements for conventional synthetic materials. Notably, furniture panels crafted from kenaf fibres offer a compelling combination of enhanced durability and eco-conscious attributes.

Within the mass-transit sector, the unique properties of kenaf composites, including their fire resistance and lightweight nature, are being explored for applications in bus interiors. This includes the development of ceiling panels and seat backs. Highlighting this trend, Malaysian transportation companies are actively engaged in the testing of kenaf-based materials, signaling a commitment to improved sustainability within public transit systems.

The automotive industry is also embracing the benefits of kenaf and jute composites, incorporating them into components such as dashboards, door panels, and structural reinforcements. This strategic integration aims to achieve a reduction in overall vehicle weight, consequently leading to improved fuel efficiency. A notable example of this innovation is Toyota's pioneering use of kenaf-based door panels, demonstrating the practical viability of these materials in commercial vehicles.

The potential of kenaf fibre composites is also being actively investigated within the sports equipment domain. Initial testing suggests their suitability for applications such as bicycle frames and protective gear, where their inherent strength and impact resistance offer significant advantages. Ongoing research is specifically focused on evaluating kenaf's potential in the development of safer helmets and padding materials.

Looking towards the aerospace industry, significant research efforts are underway to explore the integration of natural fibre composites into aircraft interiors and non-structural components. The primary objective of this research is to achieve greater sustainability without compromising critical performance standards. Kenaf-based materials are currently under evaluation for their potential in creating lightweight cabin structures and effective insulation panels.

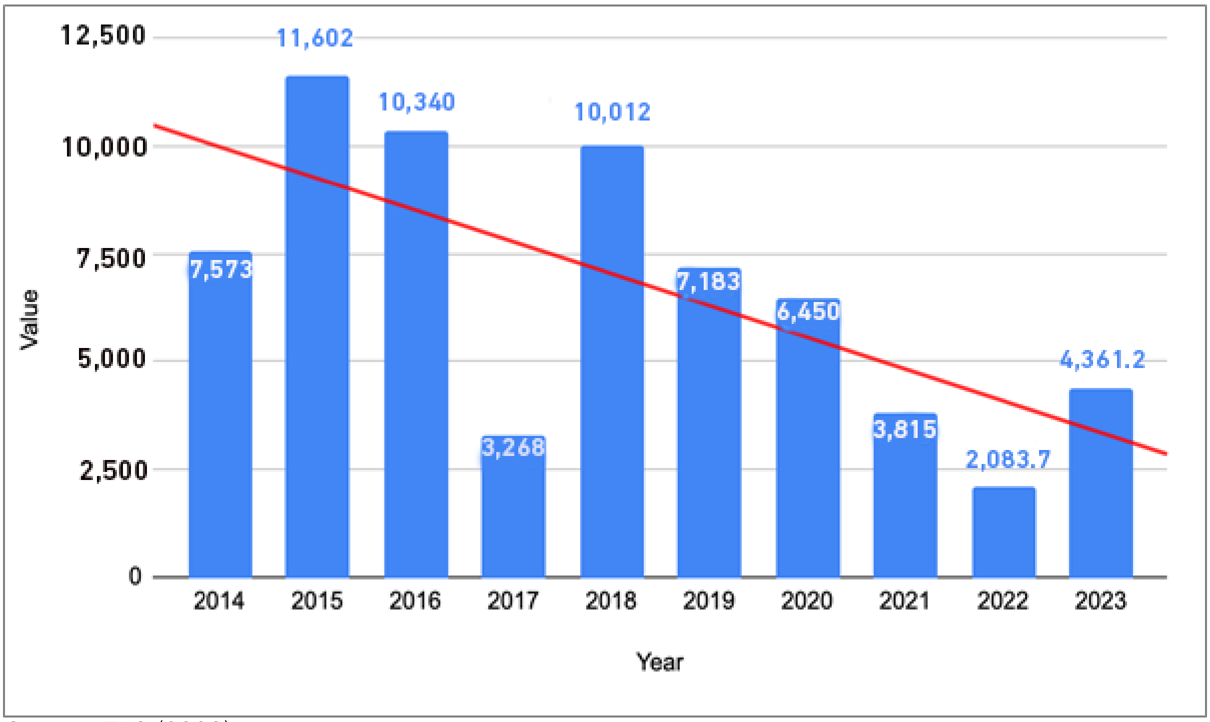
As previously highlighted, civil engineering is also benefiting from the unique characteristics of jute and kenaf composites. These materials are being utilised in the production of eco-friendly panels, insulation materials, and reinforcement structures. Their incorporation into cementitious composites has been shown to enhance the durability of construction materials while simultaneously contributing to a reduction in the overall environmental impact of construction activities.

2.7. Production of Jute and Kenaf Fibres in Malaysia, Indonesia, and Thailand

The increasing global focus on sustainability is driving demand for natural fibres like jute and kenaf as alternatives to synthetic materials. While synthetic fibres excel in strength and durability for high-performance applications, natural fibres offer lightweight, cost-effective, and eco-friendly solutions. Despite challenges in moisture and chemical resistance, the use of natural fibre composites is expanding, particularly in Europe. Kenaf, a versatile and sustainable fibre, finds applications in packaging, automotive components, and polymer composites, establishing its global value. Jute, the most produced natural fibre, offers significant tensile strength and modulus, making it crucial for reinforcing various composites, especially in the German automotive sector. Malaysia, Indonesia, and Thailand exhibit different levels of involvement in the cultivation, processing, and export of these important natural fibres.

2.7.1. Malaysia

Figure 2.2. Kenaf Production Volume in Malaysia
(in ton)

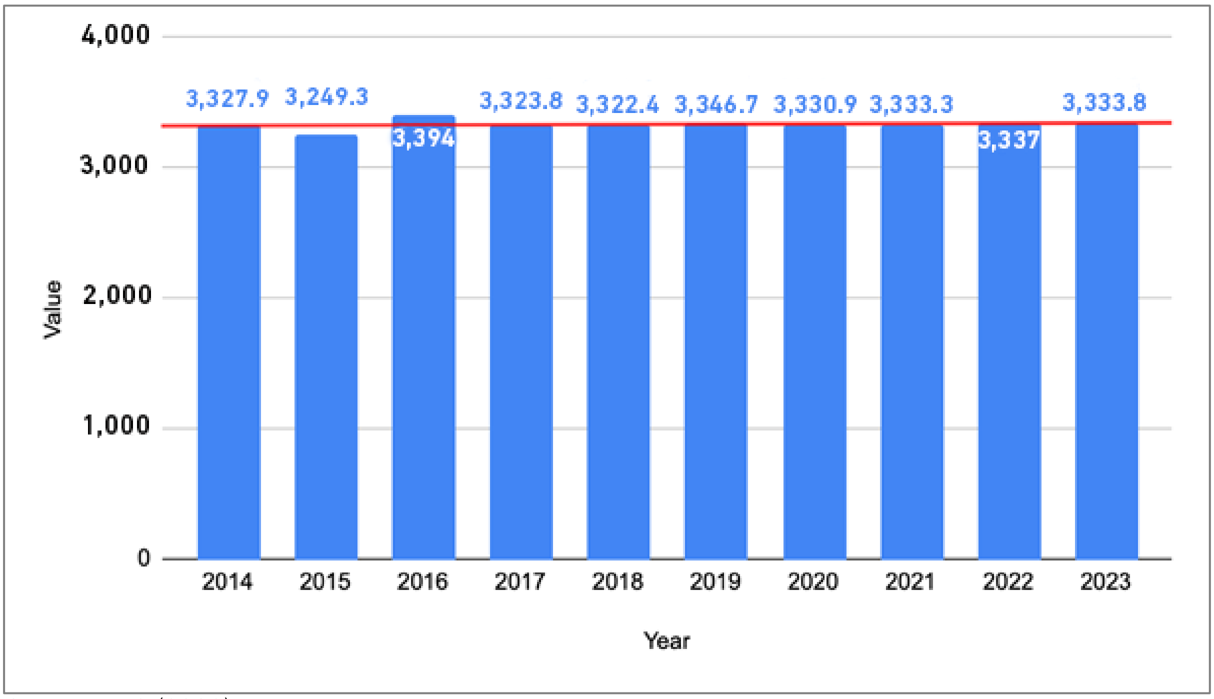


Source: FAO (2023).

Kenaf cultivation in Malaysia is primarily concentrated in Kelantan, Pahang, and Terengganu, with major locations in Pasir Puteh, Kelantan; Tebu Hitam, Rompin, Pahang; and Saujana, Setiu, Terengganu. These regions serve as the key hubs for kenaf farming due to their favourable climate and well-developed processing infrastructure. In 2023, the total harvested area for kenaf in Malaysia reached 1,640 hectares, showing a moderate yet steady presence in the country's agricultural sector. The yield of kenaf in Malaysia was recorded at 2,659.9 kg/ha, highlighting a relatively high productivity level compared to global standards. Over the past decade, Malaysia's kenaf production has experienced fluctuations, influenced by market demand and policy support. Production peaked at 11,602 metric tons in 2015 before experiencing a sharp decline in subsequent years. By 2022, production had dropped to 2,083.7 metric tons, marking its lowest point in the decade. However, in 2023, the industry showed signs of recovery, with total production increasing to 4,361.2 metric tons.

2.7.2. Indonesia

Figure 2.3. Kenaf Production Volume in Indonesia
(in ton)

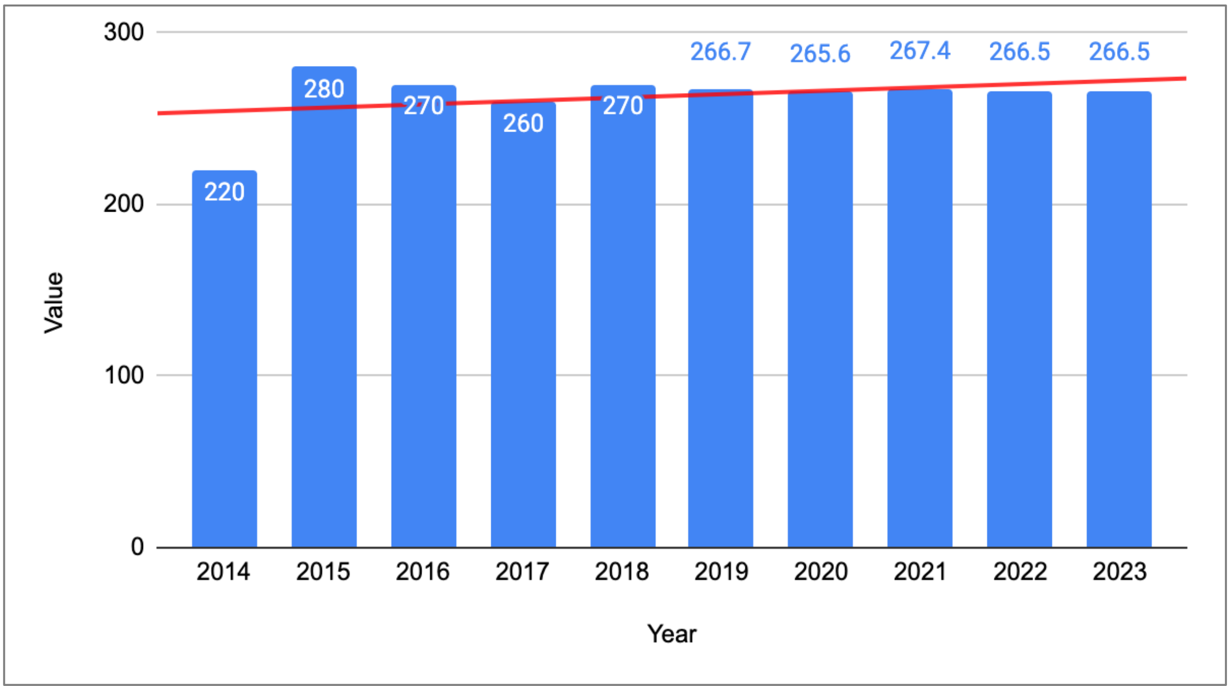


Source: FAO (2023).

Kenaf cultivation in Indonesia is primarily concentrated in Java, with significant production areas in Bonorowo, Laren, and Lamongan (Widyastuti et al., 2025). These regions have been the key hubs for kenaf farming due to their suitable climate and soil conditions. In 2022, the total plantation area for kenaf in Indonesia exceeded 3,300 hectares, indicating a stable yet relatively niche market presence within the country's agricultural sector. The yield of kenaf in Indonesia reached 853.8 kg/ha in 2023 reflecting consistent productivity levels. Over the past decade, kenaf production has remained relatively stable, fluctuating around 3,300–3,400 tons annually.

2.7.3. Thailand

Figure 2.4. Kenaf Production Volume in Thailand
(in ton)



Source: FAO (2023).

Thailand's kenaf production experienced significant fluctuations over the past decade. In 2014, production was relatively high at 2,452.8, but it dropped sharply to 1,397.2 in 2015, possibly due to reduced cultivation, market demand shifts, or unfavourable environmental conditions. However, production rebounded in 2016 to 2,478, the highest in the recorded period, before declining again to 2,109.3 in 2017 and 1,994.8 in 2018. From 2019 onward, production stabilised within the 2,094–2,194 range, suggesting a more consistent industry trend. In 2023, Thailand's kenaf production was 2,108.5, with a harvested area of 1,510 hectares and an average yield of 1,396.1 kg/ha.

2.8. Market Drivers

As global environmental concerns intensify, industries are shifting towards biodegradable and renewable materials. The global jute and kenaf market were valued at approximately US$2.4 billion in 2023 and is projected to reach US$3.6 billion by 2032, growing at a compound annual growth rate (CAGR) of 6%. This growth is driven by the increasing preference for eco-friendly alternatives to synthetic fibres and plastics.

Jute and kenaf are particularly favoured for their sustainability. Both fibres are characterised by rapid growth, low agricultural input requirements, and biodegradability. Jute matures within 120 days, requiring minimal pesticide and fertiliser use, thereby reducing its environmental impact. Similarly, kenaf matures in 100 to 200 days and requires fewer agricultural inputs, enhancing soil health while lowering production costs and overall environmental footprint (Sukri et al., 2024). Additionally, both fibres contribute to carbon sequestration by absorbing significant amounts of carbon dioxide during their growth. Studies indicate that their greenhouse gas emissions are negative due to this sequestration effect.

This increasing awareness of jute and kenaf environmental benefits is reflected in their adoption across various industries. In the automotive sector, kenaf fibres are being incorporated into vehicle components to reduce weight and reliance on synthetic materials. Meanwhile, the packaging industry is actively exploring jute-based materials as sustainable alternatives to plastics, aligning with global efforts to minimise plastic waste. As industries continue to seek environmentally responsible solutions, the demand for jute and kenaf is expected to grow, reinforcing their role in the transition to a more sustainable future.

Governments in these countries are actively promoting the cultivation and utilisation of jute and kenaf. In Malaysia, for instance, the government and research institutions are keenly interested in kenaf cultivation due to its promising market potential. They established a committee namely National Kenaf and Tobacco Board.

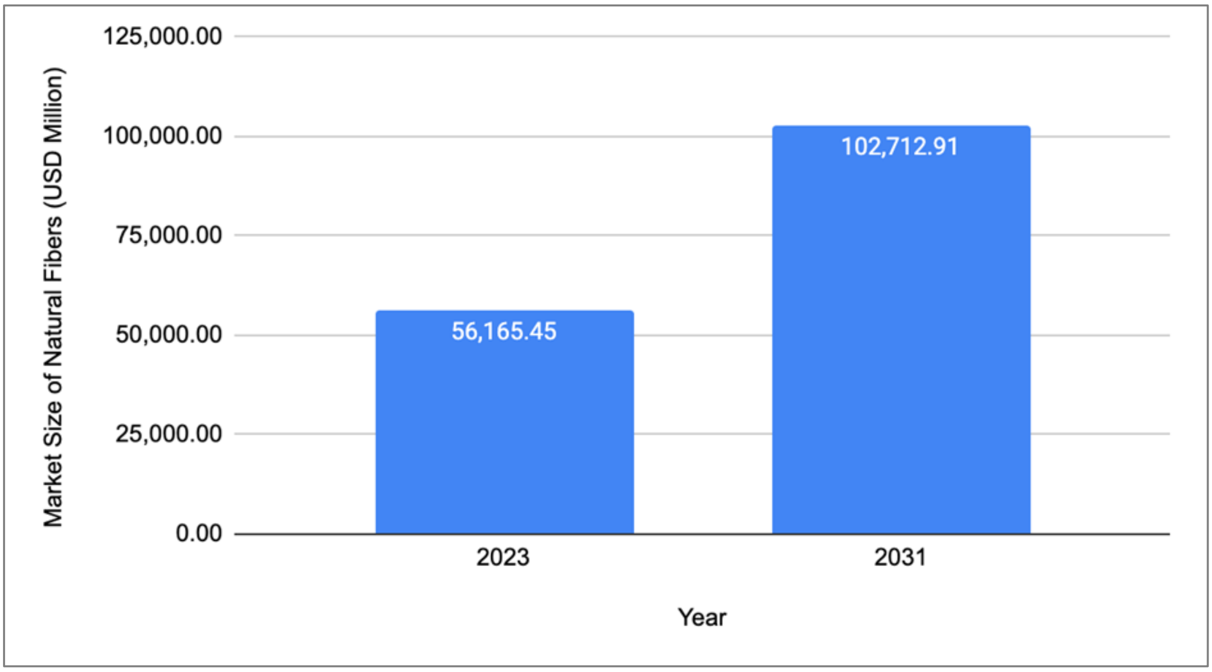
The market landscape of jute and kenaf in Malaysia, Indonesia, and Thailand highlights the growing significance of these natural fibres amid increasing global demand for sustainable materials. Each country exhibits distinct patterns in production, trade, and industry applications, with Malaysia showing a steady recovery in kenaf production, Indonesia maintaining stable output but facing declining exports, and Thailand experiencing market fluctuations. Despite these differences, the overarching trend points toward a rising need for jute and kenaf across multiple industries, including automotive, packaging, and construction.

Key market drivers, such as the push for eco-friendly products and supportive government policies, reinforce the long-term viability of these fibres. However, challenges such as market instability, import reliance, and production fluctuations must be addressed to ensure sustained growth. By fostering innovation, strengthening trade policies, and enhancing domestic production capabilities, Malaysia, Indonesia, and Thailand can further solidify their positions as key players in the global natural fibre industry.

2.9. Regulation and Policy of Jute and Kenaf in Malaysia, Indonesia, and Thailand

The cultivation, processing, and trade of jute and kenaf are influenced by government regulations and policies, which play a critical role in shaping the market landscape. This study compares the regulatory frameworks and policy initiatives for jute and kenaf in Malaysia, Indonesia, and Thailand. Additionally, this paper will discuss external sustainability regulations that impact the demand for natural fibres. The market size for natural fibres is projected to grow at a compound annual growth rate (CAGR) of 7.60% (Databridge, 2023).

Figure 2.5. Market Size of Natural Fibre, Projection
(in USD Million)



Source: Databridge (2023).

2.9.1. Regulatory Framework

Report published on the European Union Strategy for Sustainable and Circular Textiles states, 'By 2030, textile products placed on the EU market are long-lived and recyclable, to a great extent made of recycled fibres, free of hazardous substances, and produced in respect of social rights and the environment.' This indicates that the EU market will increase its consumption of natural fibres. Furthermore, key actions have been outlined, including the implementation of mandatory ecodesign requirements, the prohibition of the destruction of unsold or returned textiles, addressing microplastic pollution, the introduction of a 'Digital Product Passport' for textiles, ensuring green claims for genuinely sustainable textiles, and extending producer responsibility while enhancing the reuse and recycling of textile waste. These initiatives encourage businesses in countries engaged in international trade with the EU to adapt to these regulations. Consequently, these regulations promote government-driven demand for more sustainable natural fibres.

The National Kenaf and Tobacco Board (LKTN), operating under the Ministry of Agriculture and Agro-Based Industry, is responsible for overseeing the cultivation, research, and commercialisation of kenaf in Malaysia. As part of the country's agricultural diversification strategy, kenaf is actively promoted as a sustainable alternative to tobacco. To encourage this transition, the government provides various incentives for farmers to adopt kenaf cultivation, ensuring economic viability while supporting environmental sustainability. Under the National Kenaf and Tobacco Board Act 2009 (Act 692), LKTN is empowered to regulate, develop, and promote the kenaf industry through policy implementation, research and development (R&D), and market coordination. The Board facilitates financial assistance programs, including access to the National Kenaf and Tobacco Board Fund, to support farmers and industry players in transitioning to kenaf cultivation.

Additionally, licensing regulations ensure quality control, while market interventions, such as minimum price regulations, protect growers from price fluctuations. To strengthen the commercialisation of kenaf, LKTN actively supports product development, investment in processing infrastructure, and market expansion, both domestically and internationally. The Board also enforces strict environmental and quality standards for kenaf products, ensuring alignment with global sustainability goals. Furthermore, LKTN collaborates with other stakeholders, including government agencies, research institutions, and private companies, to enhance the competitiveness of Malaysia's natural fibre industry. By integrating regulatory measures with economic incentives, Malaysia aims to position kenaf as a key commodity in the natural fibre sector, providing an eco-friendly alternative to synthetic materials while ensuring long-term economic benefits for farmers and industry stakeholders.

Meanwhile for Indonesia, Kenaf and jute are included in the list of priority commodities under the supervision of the Indonesian Ministry of Agriculture, as stipulated in the Decree of the Minister of Agriculture of the Republic of Indonesia No. 104/KPTS/HK.140/M/2/2020. This designation reflects the Indonesian government's commitment to enhancing the production of kenaf and jute, demonstrating a strategic effort to develop and support these natural fibre industries.

On the other hand, Thailand does not have specific regulations governing the cultivation or processing of jute and kenaf. However, the country has implemented policies to promote the use of other natural fibres in the textile industry. In the broader context of natural fibres, Thailand's Board of Investment (BOI) offers incentives for the manufacturing of textile products, which include activities such as the production of natural or synthetic fibres, yarn spinning, fabric manufacturing, and garment production. Projects that meet specific criteria, such as being located in designated industrial estates and obtaining ISO 14000 certification, may benefit from exemptions on import duties for machinery and corporate income tax exemptions ranging from five to eight years, depending on the project's location (Toyota Boshoku Corporation, 2025). These incentives reflect Thailand's commitment to supporting the textile sector and promoting the use of natural fibres within the industry.

2.9.2. Government Incentives and Support

The Malaysian Agricultural Research and Development Institute (MARDI) has conducted extensive research on kenaf cultivation, harvesting, and mechanisation, as well as its downstream applications, including animal feed and bio-composites. Recognising the potential of kenaf as a sustainable crop, the Malaysian government allocated approximately MYR 100 million (US$32.41 million) for research and development (R&D) projects between 2006 and 2015 to enhance its production, processing, and commercial viability.

The Indonesian government has demonstrated its support for the kenaf industry through various policies and research initiatives. Government Regulation No. 7 of 2007 classifies raw or unspun processed fibres from plants such as jute, kenaf, and abaca as strategic agricultural products. It means that kenaf and jute are important plants for food security, economics, and environment. Additionally, the Ministry of Agriculture, through the Badan Penelitian dan Pengembangan (Balitbangtan), has been actively developing technologies to cultivate kenaf in suboptimal lands, including drylands, peatlands, and tidal areas. These efforts reflect the government's commitment to promoting kenaf as a valuable agricultural commodity while optimising land use in Indonesia.

There is no specific support directly aimed at jute and kenaf. However, the Thai government provides several forms of support in the agricultural sector, as follows:

a) The government has spent more than 100 billion baht to improve farmers' quality of life, including aid to farmers at a rate of 1,000 baht per rai of farming land, capped at a maximum of 20 rai or 20,000 baht. Recently, the Cabinet agreed to earmark 29.99 million baht to cover a fertiliser subsidy, capped at a maximum of 20 rai or 10,000 baht (Krisanaraj, 2024)

b) Thailand also supports sustainable farming, which is closely related to natural fibres. The Department of Agricultural Extension (DOAE) is working on the development of smart farming to observe its efficiency in maximising crop yields while reducing water and chemical use as well as greenhouse gas emissions (Krisanaraj, 2024).

Furthermore, the Thailand government offers various incentives to foreign investors, including tax breaks, grants, and land lease options, all aimed at encouraging investment in green technology and sustainable agriculture. These incentives not only attract investors but also contribute to Thailand's overall economic growth.

2.9.3. Export Taxation and Tariffs

According to the Guide on Proposed Sales Tax Rates for Various Goods (25.08.2018), the Malaysian government exempts kenaf seeds from sales tax, supporting the agricultural sector and industrial usage. Meanwhile, yarn of jute is subject to a 10% sales tax, ensuring standard taxation across imports. Additionally, based on data from the Royal Malaysian Customs Department, the following are the applicable export and import tariffs for these products in Malaysia:

Table 2.3. Export Taxation and Tariffs in Malaysia

HS Code	Description of Goods	PDK 2022 – Custom Duty Regulation 2022		PDK (ATIGA)– ASEAN Trade Goods Agreement (ATIGA) 2022	AKFTA - ASEAN Korea Free Trade Agreement	AJCEP–ASEAN Japan Comprehensive Economic Partnership
		Export Tariff	Import Tariff			
1209	Rubber seeds, kenaf seeds	0	0	0	0	0
5303; 5607; 5701; 5702; 6305	Jute and any type of Jute	0	0	0	0	0

Source: Malaysia National Trade Repository (2025).

In Indonesia, Minister of Finance Regulation No. 85 of 2023 stipulates several fees related to kenaf under non-tax state revenue applicable to the Ministry of Agriculture, including:

- Laboratory seed testing – Kenaf: IDR 25,705 per sample
- Physical analysis (fibre strength for kenaf, roselle, and vine): IDR 19,500 per sample

Additionally, Minister of Finance Regulation No. 75/PMK.011/2007 establishes tariff rates for kenaf and jute derivative products traded within the ASEAN and Korea region. Furthermore, Minister of Finance Regulation No. 50/PMK.010/2022 on the Determination of Import Duty Rates under the Agreement Between the Republic of Indonesia and Japan for an Economic Partnership stipulates that all jute products and their derivatives, as well as kenaf seeds, are exempt from export tariffs (0%). This policy aims to enhance trade relations between Indonesia and Japan while promoting the export competitiveness of natural fibre commodities.

Table 2.4. Export Taxation and Tariffs in Indonesia

HS Code	Description of Goods	Import Duty ASEAN–KOREA FTA (%)
1209.99.10.00	Rubber seeds, kenaf seeds	0
53.03	Jute and other textile bast fibres (excluding lax, true hemp and ramie), raw or processed; tow but not spun; tow and waste of these fibres (including yarn waste and garnetted stock)	5
5303.10.00.00	Jute and other textile bast fibres, raw or retted	0
53.07	Yarn of jute or of other textile bast fibres of heading 53.03	5
53.10	Woven fabrics of jute or of other textile bast fibres of heading 53.03	8
	Other Products from Jute Fibres	5–10

Source: EnterpriseSG.

Meanwhile, In Thailand, the import tariff for raw or retted jute and other textile bast fibres (HS Code 5303.10.00) is set at 30%. However, under the ASEAN Trade in Goods Agreement (ATIGA), ASEAN member countries are exempted from this tariff, with the exemption taking effect in 2017 and continuing indefinitely from January 1, 2022. Meanwhile, jute-based derivative products, such as yarn and fabric, are subject to significantly higher import tariffs ranging from 30% to 100%, indicating Thailand's preference for processing raw materials domestically rather than importing finished or semi-finished jute products. For kenaf seeds, Thailand applies a standard import tariff of 40%. However, similar to jute, ASEAN member countries benefit from a tariff exemption under ATIGA, allowing them to export kenaf seeds to Thailand without import duties. This exemption aligns with Thailand's trade policies within ASEAN, promoting regional cooperation and supply chain integration. Meanwhile, non-ASEAN countries must still adhere to the standard tariff rate when exporting kenaf seeds to Thailand.

Chapter 3
Research Methodology: Design of Experiment

The investigation of Kenaf and Jute fibres in the form of technical textile woven and non-woven mats were utilised to characterise and determine the thermoset natural fibre composites physical properties and strength performance. Both natural fibres were fabricated into composites via the Vacuum Assisted Resin Transfer Moulding (VARTM) method to ensure optimal outcomes. The physical characterisation tests will be conducted in accordance with the established American Society of Testing and Material (ASTM) standard procedures.

3.1. Material Preparation

Figure 3.1. Natural Fibre Samples Used in the Study (a) Jute Woven Mat, and (b) Kenaf Non-woven Mat

(a)	(b)

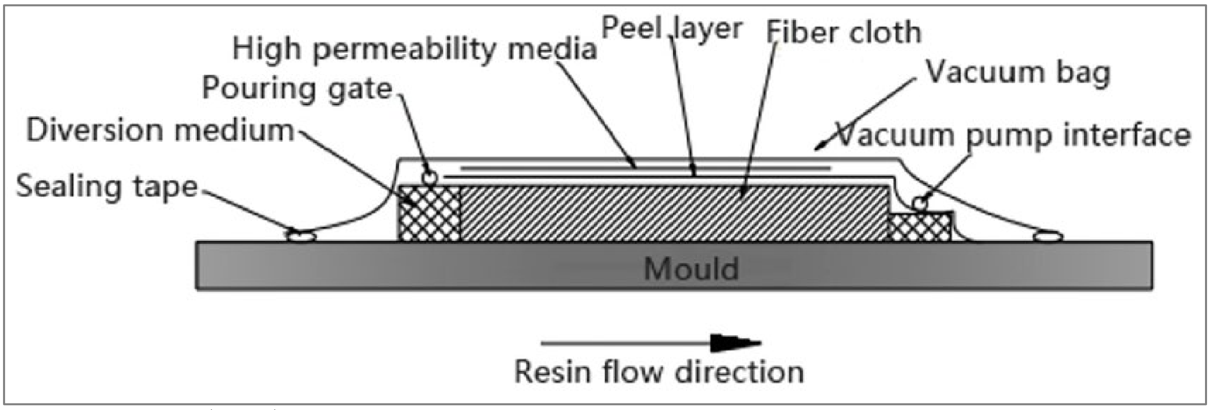
Source: Midwest Composites' documentation.

Two different types of natural fibres will be prepared for the study; Kenaf non-woven and Jute woven mats. Figure 3.1 presents the illustration of the actual technical textile mat samples.

3.2. Composite Fabrication

The natural fibre mats were fabricated into composites utilising a VARTM process with a thickness measurement of 2.5 mm. VARTM is a composite fabrication method wherein the process of resin distribution across the samples occurs simultaneously with compression under pressure. This technique ensures that the composite will possess an optimal fibre volume fraction percentage between fibre and resin within a single composite matrix. In this study, unsaturated polyester resin will serve as the resin matrix. Figure 3.2 illustrates the concept of the VARTM process.

Figure 3.2. VARTM Fundamental Reconfiguration Concept



Source: Liu et al. (2021).

3.3. Experimental Works

The experimental work will be conducted in accordance with the established ASTM standard procedure. Three types of physical analyses have been identified for implementation: fibre volume fraction, tensile strength, and flexural three-point bending.

3.3.1. Fibre Volume Fraction %

Fibre volume fraction is a physical analysis that will be conducted to determine the percentage of fibre and resin within a single matrix of composite. In the study, ASTM D 3171 of acid digestion method will be used to degrade the harden matrix. Initial weight of composite and the final weight of leftover fibres will be measured to calculate the fraction percentage.

3.3.2. Tensile Strength

The tensile strength reflects the composite strength capability to deform under tensile loading before it starts to break. The composite tensile test measures the maximum stress per cross-sectional area in the units of MPa, strain elongation in the units of %, and tensile modulus in the units of GPa. The test will be conducted based on the ASTM D638 standard.

3.3.3. Flexural Strength

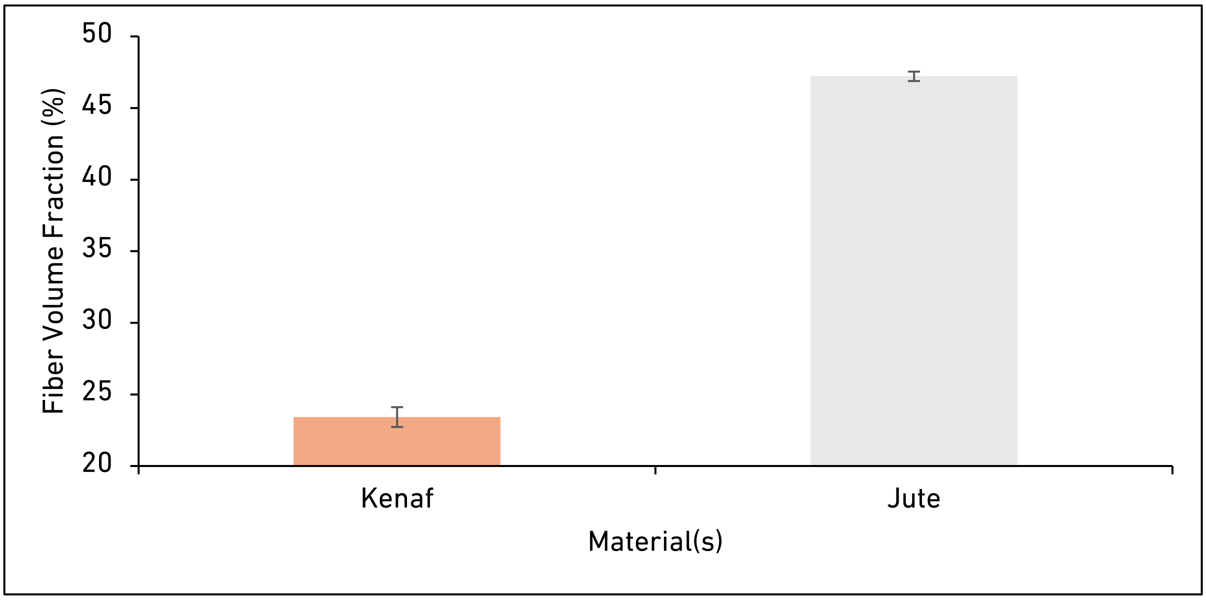
The composite flexural strength determines the maximum stress that a composite can withstand before it breaks when subjected to a bending force. The composite flexural measures the maximum flexural stress, flexural strain, and flexural modulus via a three-point bending approach. The composite flexural evaluation will be performed in compliance with the ASTM D790 standard.

Chapter 4
Research Findings

The section will delve into the experimental outcomes concerning kenaf and jute fibre composites fabricated using the Vacuum Assisted Resin Transfer Molding (VARTM) method. A comprehensive presentation and discussion of the physical and mechanical properties exhibited by these natural fibre composites will be provided, offering insights into their structural performance and potential applications.

4.1. Fibre Volume Fraction (FVF)

Figure 4.1. Fibre Volume Fraction Average Readings on Jute and Kenaf Composites



Source: Authors' data.

Figure 4.1 compellingly visualises the stark contrast in average fibre volume fraction between the two composite types. Kenaf non-woven composites exhibit a significantly lower average fibre content of approximately 23.41% within the composite matrix. Conversely, jute woven composites demonstrate a remarkably higher average fibre volume fraction of around 47.31%. This disparity likely arises from the higher resin absorption observed in the kenaf non-woven structure compared to the jute woven counterpart. Consequently, the lower fibre volume fraction in kenaf non-woven composites suggests a potential for diminished mechanical strength due to a higher proportion of the matrix material. In contrast, the substantially higher fibre volume fraction in jute woven composites is expected to yield excellent mechanical strength, as the increased fibre content provides more effective reinforcement within the composite matrix.

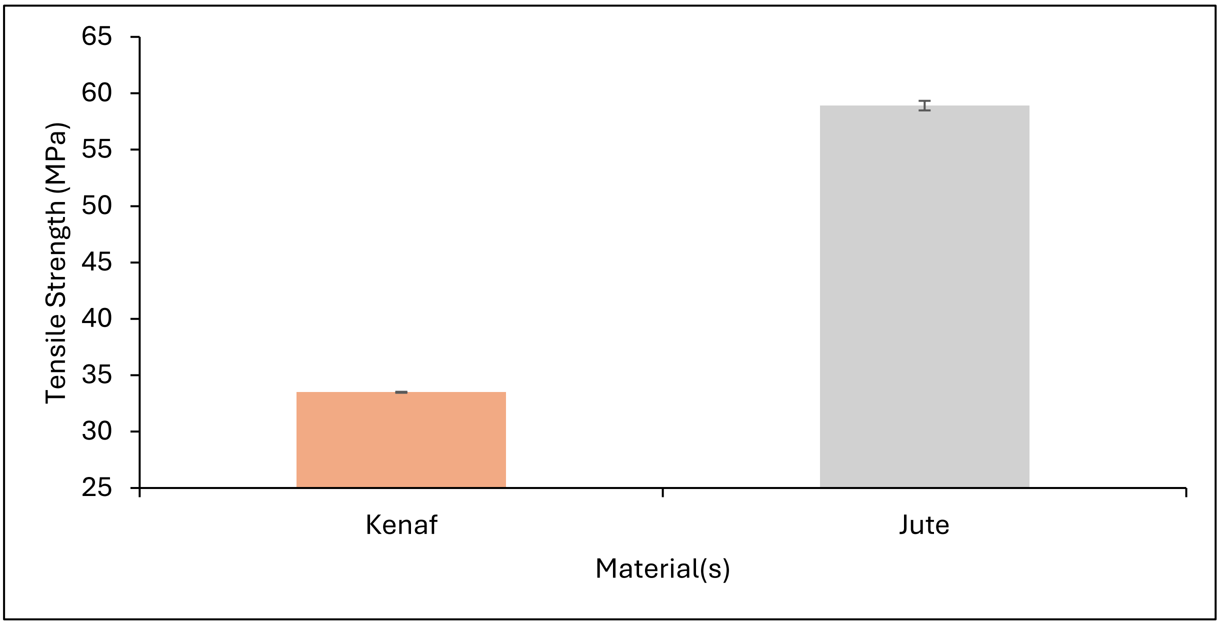
4.2. Tensile Strength

Table 4.1. Tensile Strength Readings between Kenaf and Jute Composites

	Kenaf Non-Woven			Jute Woven		
Reading	Stress	Strain	Modulus	Stress	Strain	Modulus
1	33.53	3.45	2.65	58.54	3.87	4.41
2	33.47	3.37	2.61	59.13	3.77	4.54
3	33.5	3.41	2.63	59.04	3.89	4.51
4	33.42	3.37	2.54	58.4	3.93	4.36
5	33.52	3.38	2.63	59.42	3.84	4.63
Average	33.49	3.40	2.61	58.91	3.86	4.49
Std Dev	0.04	0.03	0.04	0.42	0.06	0.11

Source: Authors' data.

Figure 4.2. Mechanical Tensile Strength Average Performances of Jute and Kenaf Composites



Source: Authors' data.

The bar graph in Figure 4.2 clearly illustrates a significant difference in tensile strength performance between kenaf and jute fibre composites. The kenaf composites exhibit an average tensile strength of approximately 33.5 MPa, while the jute composites demonstrate a substantially higher average tensile strength of around 59 MPa. This marked difference in tensile strength can be primarily attributed to the previously discussed disparity in fibre volume fraction. As established, the jute composites possessed a significantly higher fibre volume fraction (approximately 47.31%) compared to the kenaf composites (approximately 23.41%). Since the reinforcing fibres are the primary load-bearing component in a composite material, a higher fibre content directly translates to a greater capacity to withstand tensile forces before failure. Furthermore, the inherent mechanical properties of the individual fibres themselves play a crucial role. Jute fibres generally possess higher tensile strength compared to kenaf fibres. Therefore, even if the fibre volume fractions were similar, the intrinsic strength of jute fibres would likely contribute to a higher overall tensile strength of the resulting composite.

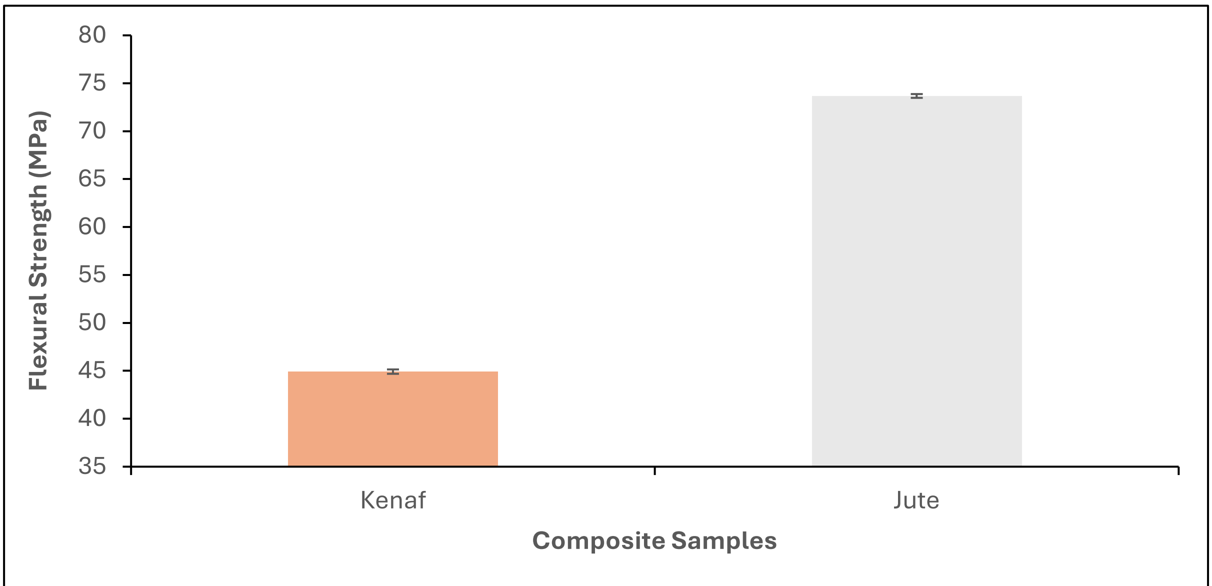
4.3. Flexural Strength

Table 4.2. Flexural Strength Readings of Jute and Kenaf Composites

	Kenaf Non-Woven			Jute Woven		
Reading	Stress	Strain	Modulus	Stress	Strain	Modulus
1	44.87	4.13	2.85	73.45	4.47	5.14
2	44.75	4.25	2.81	73.78	4.43	5.43
3	44.81	4.18	2.83	73.48	4.49	5.15
4	44.84	4.18	2.84	73.89	4.41	5.61
5	45.32	4.23	2.93	73.78	4.51	5.43
Average	44.92	4.19	2.85	73.68	4.46	5.35
Std Dev	0.23	0.05	0.05	0.20	0.04	0.20

Source: Authors' data.

Figure 4.3. Flexural Strength Average Performances of Jute and Kenaf Composites



Source: Authors' data.

Figure 4.3 illustrates a clear disparity in flexural strength performance between kenaf and jute fibre composites. The kenaf composites exhibit an average flexural strength of approximately 45 MPa, while the jute composites demonstrate a significantly higher average flexural strength of around 74 MPa. This substantial difference in flexural strength can be primarily attributed to the previously established variations in fibre volume fraction and the inherent properties of the fibres. The jute composites' significantly higher fibre volume fraction (around 47.31%) compared to the kenaf composites (around 23.41%) directly contributes to their superior flexural performance. A greater fibre content provides more reinforcement to resist bending forces and distribute stress more effectively throughout the composite structure. Furthermore, the higher tensile strength and stiffness generally associated with jute fibres also translate to better flexural strength. Flexural strength is a measure of a material's resistance to bending forces, and fibres with higher intrinsic strength and modulus contribute more effectively to this resistance. The woven structure of the jute fibres, as opposed to the non-woven arrangement of the kenaf fibres in this study, may also contribute to improved stress distribution and load transfer under bending, further enhancing the flexural strength.

4.4. Findings Discussion

The research demonstrates that leveraging the distinct advantages of both jute woven and kenaf non-woven composites can provide customised solutions for various industrial applications. Jute woven composites, characterised by a high fibre volume fraction of approximately 47.31%, exhibit notable tensile and flexural strengths, measuring around 59 MPa and 74 MPa, respectively. These attributes render them highly suitable for demanding structural applications, such as vehicle exteriors, where durability and safety are of utmost importance (Akampumuza et al., 2017; Iqbal et al., 2024; Rahman et al., 2022; Suriani et al., 2021). Conversely, kenaf non-woven composites, with a lower fibre volume fraction of approximately 23.41%, inherently display reduced tensile (approximately 33.5 MPa) and flexural strengths (around 45 MPa). Nonetheless, their performance adequately fulfills the requirements of non-structural applications, such as automotive interiors and consumer goods, where lighter weight and cost-effectiveness are prioritised over extreme load capacity (Jahan et al., 2022; Owen et al., 2022; Puttegowda, 2025). By integrating these complementary materials, manufacturers can design systems that capitalise on jute's strength where necessary, while also incorporating kenaf's advantages for components with lower load demands. This balanced strategy not only enhances overall performance and safety but also fosters innovative, sustainable design practices that align with both engineering excellence and practical manufacturing considerations.

4.5. Findings Summary

The study demonstrates that increasing the fibre volume fraction in natural fibre composites significantly enhances their tensile and flexural strengths. By optimising fabrication techniques, such as vacuum-assisted resin transfer molding (VARTM) and other advanced methods, it is possible to achieve higher fibre loading, which is crucial for producing composites with superior mechanical properties. In addition to fibre volume fraction, the research underscores the substantial impact of fibre architecture. A comparison between woven (jute) and non-woven (kenaf) composites revealed that the arrangement of fibres plays a critical role in determining performance characteristics. For instance, composites designed with specific weaving patterns may offer greater stiffness, whereas non-woven configurations could be more advantageous for applications requiring high impact resistance. This nuanced understanding encourages further exploration into diverse fibre arrangements and orientations, as well as systematic studies comparing various natural fibres. Furthermore, the observed performance differences – notably the disparity between jute and kenaf composites – highlight important avenues for material optimisation. Investigating surface treatments or chemical modifications on kenaf fibres could enhance interfacial adhesion with the matrix resin, thereby improving stress transfer and overall composite performance even when fibre volume fractions are lower. Establishing robust quality control measures throughout the manufacturing process is also essential to ensure that the final product meets industry standards in terms of consistency and reliability. Overall, these findings provide a solid foundation for future research aimed at refining composite manufacturing processes, optimising material properties, and broadening the application spectrum of sustainable natural fibre composites. By integrating innovative processing techniques, tailored fibre architectures, and targeted material enhancements, there is potential to develop eco-friendly composites that fulfill the diverse mechanical requirements of industries ranging from automotive and construction to packaging and consumer goods.

Chapter 5
Policy Recommendations

5.1. Benefits for Southeast Asian Countries (Particularly Malaysia) Transitioning to Green and Sustainable Material

Southeast Asian countries, including Malaysia, stand to gain significant economic, environmental, and social benefits by strategically transitioning from synthetic materials to jute and kenaf composites in their existing business solutions:

a) Economic Growth and Diversification: Cultivating and processing jute and kenaf can revitalise the agricultural sector, creating new income streams for farmers and rural communities. Establishing composite manufacturing industries will further diversify the economy, reducing reliance on traditional sectors and creating skilled jobs in processing, manufacturing, and research and development.

b) Reduced Environmental Impact: Jute and kenaf are renewable resources with a lower carbon footprint compared to synthetic materials derived from fossil fuels. Their biodegradability addresses the growing issue of plastic waste, reducing landfill burden and marine pollution prevalent in the region. Utilising these natural fibres contributes to national commitments towards climate change mitigation and a circular economy.

c) Enhanced Resource Security: Dependence on imported synthetic raw materials exposes Southeast Asian economies to price volatility and supply chain disruptions. Promoting locally sourced jute and kenaf enhances resource security and fosters self-reliance.

d) Improved Public Health: Reducing the production and use of certain synthetic materials, which can release harmful chemicals during manufacturing and disposal, can lead to improved air and water quality, benefiting public health.

e) Global Market Opportunities: The increasing global demand for sustainable materials presents a significant export opportunity for Southeast Asian countries. Establishing a strong domestic industry in jute and kenaf composites can position Malaysia and its neighbors as key players in this growing global market.

f) Alignment with Sustainable Development Goals (SDGs): Embracing jute and kenaf composites directly contributes to achieving several SDGs, including decent work and economic growth (SDG 8), industry, innovation, and infrastructure (SDG 9), responsible consumption and production (SDG 12), and climate action (SDG1 13)

5.2. Government Initiatives to Align with SMEs for Green and Sustainable Natural Fibre Solutions

Governments in Southeast Asia, particularly Malaysia, can implement the following initiatives to encourage and support Small and Medium Enterprises (SMEs) in adopting green and sustainable natural fibre solutions:

Financial Incentives:

i. Grants and Subsidies: Provide financial assistance to SMEs for research and development, pilot projects, and the adoption of new machinery and technologies for processing jute and kenaf.
ii. Tax Breaks and Rebates: Offer tax exemptions or rebates for businesses that utilise a significant percentage of natural fibres in their products or manufacturing processes.
iii. Low-Interest Loans: Facilitate access to affordable financing for SMEs investing in sustainable natural fibre technologies and infrastructure.

Technical and Capacity Building Support:

i. Research and Development Funding: Invest in research institutions to develop innovative applications and processing techniques for jute and kenaf composites, with a focus on solutions relevant to SME needs.
ii. Technology Transfer Programs: Establish programs to transfer knowledge and technologies related to natural fibre processing and composite manufacturing to SMEs.
iii. Training and Skill Development: Offer training programs to equip SME workforces with the necessary skills for handling and processing natural fibres and manufacturing composites.
iv. Incubation and Acceleration Programs: Support startups and SMEs in the green technology sector focusing on natural fibre solutions through mentorship, funding access, and market linkages.

Policy and Regulatory Framework:

i. Green Procurement Policies: Implement government procurement policies that prioritise products made from sustainable natural fibres, creating a domestic demand and encouraging SMEs to adopt these materials.
ii. Standards and Certifications: Develop national standards and certification schemes for jute and kenaf composites to ensure quality and build consumer trust.
iii. Streamlined Regulations: Simplify regulatory processes for SMEs involved in the cultivation, processing, and manufacturing of natural fibre products.
iv. Waste Management Policies: Implement policies that incentivise the use of biodegradable materials like jute and kenaf composites and discourage the use of non-biodegradable synthetics.

Awareness and Market Promotion:

i. National Campaigns: Launch national awareness campaigns to educate businesses and consumers about the benefits of using jute and kenaf composites.
ii. Trade Promotion: Support SMEs in participating in international trade fairs and exhibitions to showcase their sustainable natural fibre products.
iii. Market Linkage Programs: Facilitate connections between natural fibre producers, processors, and end-user industries (including SMEs).

5.3. Initial Initiatives for SMEs to Move Forward with the Green and Sustainable Natural Fibre Agenda Globally

SMEs in Southeast Asia can take the following initial steps to advance the green and sustainable natural fibre agenda on a global scale:

a) Focus on Niche and High-Value Applications: Instead of directly competing with established synthetic material producers in mass markets, SMEs can focus on developing innovative and high-value applications for jute and kenaf composites where their unique properties (e.g., biodegradability, specific strength-to-weight ratios, aesthetic appeal) offer a competitive advantage. Examples include eco-friendly packaging, sustainable textiles, bio-based furniture components, and niche automotive interior parts.
b) Emphasise Sustainability and Eco-Friendly Branding: SMEs should leverage the inherent sustainability of jute and kenaf in their branding and marketing efforts. Clearly communicating the environmental benefits and ethical sourcing of their materials can resonate with environmentally conscious consumers and businesses globally. Obtaining relevant eco-certifications can further enhance credibility.
c) Collaborate and Form Strategic Partnerships: SMEs can collaborate with research institutions, other SMEs, and even larger corporations to pool resources, share knowledge, and access wider markets. Forming partnerships with international distributors and retailers specialising in sustainable products can facilitate global market entry.
d) Invest in Research and Innovation: Even with limited resources, SMEs can invest in small-scale research and development to explore new applications, improve processing techniques, and enhance the properties of jute and kenaf composites. Collaborating with local universities or research centers can be a cost-effective approach.
e) Leverage Digital Platforms and E-commerce: Utilising online platforms and e-commerce can provide SMEs with direct access to global markets, bypassing traditional intermediaries and reducing market entry barriers.
f) Participate in International Sustainability Initiatives: Engaging with international organisations and initiatives focused on sustainability and the bioeconomy can provide

SMEs with valuable networking opportunities, market intelligence, and access to global best practices.

5.4. How Companies Like Midwest Composites Can Bring Value to Social and Government Policy

While 'Midwest Composites' might be a specific entity, the role of composite manufacturing companies in general, and those specialising in natural fibres in particular, can significantly contribute to social and government policy in Southeast Asia:

a) Demonstrating Economic Viability: Successful companies like a hypothetical 'Midwest Composites (Malaysia)' showcase the economic viability of utilising natural fibres, providing real-world examples of job creation, revenue generation, and potential for export earnings. This evidence can encourage governments to invest further in the sector and develop supportive policies.
b) Driving Innovation and Technological Advancement: Companies actively involved in R&D and the commercialisation of natural fibre composites contribute to technological advancements in processing, material properties, and new applications. This innovation can inform government strategies for promoting a bio-based economy.
c) Creating Skilled Workforce and Local Expertise: By establishing manufacturing facilities and investing in training, these companies contribute to the development of a skilled workforce and local expertise in the natural fibre composite sector, aligning with government goals for human capital development.
d) Promoting Sustainable Practices and Environmental Stewardship: Companies committed to sustainable sourcing and manufacturing practices can serve as models for environmental responsibility, influencing industry standards and supporting government efforts towards a greener economy. They can provide data and insights on the environmental benefits of natural fibre composites compared to traditional materials.
e) Contributing to Policy Formulation through Consultation: Companies with practical experience in the natural fibre composite industry can provide valuable input to government policy formulation through participation in industry associations, consultations, and pilot projects. Their insights on market challenges, regulatory hurdles, and opportunities for growth can help shape effective and practical policies.
f) Facilitating Public–Private Partnerships: Companies can collaborate with government agencies and research institutions on joint projects, leveraging their industrial capabilities to scale up research findings and implement government initiatives on sustainable development.
g) Raising Public Awareness and Consumer Demand: Through their marketing and product offerings, companies can play a crucial role in raising public awareness about the benefits of natural fibre composites and driving consumer demand for sustainable alternatives.

Chapter 6
Conclusions

This comprehensive analysis – spanning literature review, empirical findings on kenaf and jute composites, and targeted policy recommendations – sets out a clear pathway toward a more sustainable future for Southeast Asia, with Malaysia at the forefront. The research demonstrates the superior mechanical performance of jute composites, attributable to their higher fibre volume fraction, establishing a strong industrial benchmark for applications requiring high strength and stiffness. At the same time, the findings on kenaf composites point to promising opportunities for lighter and potentially more cost-effective solutions, meriting further optimisation and development.

The policy recommendations translate these technical insights into actionable strategies. By incentivising the adoption of jute and kenaf composites – particularly amongst SMEs – and by fostering a supportive ecosystem through financial incentives, technical assistance, and streamlined regulations, governments can drive economic growth, enhance resource security, and substantially reduce environmental impacts. The emphasis on global market integration, alongside the catalytic role of companies such as Midwest Composites, underscores Southeast Asia's opportunity to establish itself as a significant player in the expanding global bioeconomy.

The convergence of robust research findings with well-crafted policy measures promises wide-ranging benefits. Socially, these include rural economic revitalisation, improved public health through reduced pollution, and the creation of a skilled workforce. Industrially, it opens avenues for innovation, diversification, and greater competitiveness in response to global demand for sustainable materials. For governments, this framework provides a practical roadmap to align national development priorities with global sustainability agendas – paving the way for a greener economy and a more resilient, prosperous future for generations to come.

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