International Journal of Latest Engineering Research and Applications (IJLERA) ISSN: 2455-7137

Volume – 02, Issue – 07, July – 2017, PP – 46-53

Carbon Stored in Kenaf Fiber Utilization of Biocomposite Applications into Automotive Components

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Abstract: The aim of this research is to assess the environmental impacts of the carbon dioxide sequestration and emission of kenaf cultivation and stored carbon in kenaf fiber used for automotive components; The data was collected through an interview as well as the data on kenaf' cultivated area in the four states (Pahang, Kelantan, Terengganu and Perak) in 2014 which were obtained from the (National Company for Kenaf and Tobacco-Malaysia). The three scenarios of kenaf production (10, 12& 15) ton per hectare has been assumed. The kenaf production ton/hectare has been converted to fibre. Then, the carbon which has been stored in the fiber for use in automotive components has been calculated. The data were analysed using Microsoft Excel software13 while some of the data were analysed using SPSS22. The results depicted that, the Pahang state has the highest contributor to environmental performance.In addition, the investigation has concluded that the usage of kenaf core and bast altogether as composite materials with other fillers for automotive components will enhance in mitigating the pressure to the environment by storing much carbon in the auto body. Also, this will give a superior industrial product through the lifetime of the automobile when the percentage of the fiber in the manufactured components was increased.

Key words: Kenaf production, fibre conversion, environmental performance, automotive components & stored carbon

1. Introduction

Governments and civil society groups are endeavouring to mitigate global warming by reducing the concentration of greenhouse gases (GHG) through "reforestation" activities, as forests are to serve as effective sinks absorbing the excess carbon dioxide (CO_2) from the atmosphere. A viable strategy in this regard is carbon sequestration through forestry activities. The Kyoto Protocol of 2005 sets mandatory targets for industrialised countries to reduce GHG emissions by an average of 5.2% below their current levels by the year 2012 (Jindal etal, 2006).However, the cost of carbon sequestration in tropical countries ranges from $0.10 to $20 per ton of carbon, whereas in industrialised countries the cost ranges between $20 and $100 per ton of carbon. This difference in costs will entice industrialised countries to invest in carbon sequestration in the developing world due to the low price. In order to encourage a reduction in the actual carbon emissions at home, the Kyoto Protocol limits the use of carbon sinks from forestry and other land-based activities to only 1% of the base year emissions for each of the five years (Jindal et al., 2006).

The investigation by (Lasco et al., 2002) led to the conclusion that the assessed rate of carbon sequestration based on plant biomass changes in vegetation is indicative of the optimum land use. Thus, plants have different abilities to absorb emitted carbon dioxide, as shown below:

1/ Species of tree plantations (10.09 ton Carbon/10^4 m^2/year)
2/ Coconut (4.78 ton Carbon/10^4 m^2/year)
3/ Brushland (4.29 ton Carbon/10^4 m^2/year) and
4/ Natural forest plantation cover (0.92 ton C/10^4 m^2/year).

The problem of greenhouse gases has been discussed and dealt with for many years, but it appears to still persist in the present. Transportation and human activities, such as manufacturing, agriculture etc., are the main contributors and causes of greenhouse gas emissions. The percentage of carbon dioxide emissions of the EU is almost 20%, in North America it is almost 30%, while the percentage in Asia is around 10%, and most of the above-mentioned percentage originates from transportation (Mandell, 2011). Moreover, the society's need for fossil fuels has rapidly increased in recent years. Hence, renewable crops and tree plantations have come into the focus as energy resources, allowing an effective management of GHG emissions (Thimothias & Ranasinghe, 2012).Researchers often note that the replacement of fossil fuels with renewable energy will create significant opportunities or at least, diminish gas emissions (Monti & Alexopoulou, 2013). In addition, the adoption of a mandatory Greenhouse Gas Emissions Reduction Programme, with high-priced carbon dioxide credits, will improve the income opportunities for farmers, leading to an enhancement of the agricultural sector, which will reasonably increase the participation rates of farmers and ranchers. In other words, it will also benefit society, specifically communities related to soil carbon sequestration by means of their farms, who will receive these carbon credits as "charismatic" welfare (Rice & Reed, 2007).

In addition, (Hashim et al., 2015) concluded that more thorough data regarding carbon emissions will assist planners when adopting a green industry. However, there are few records on how to deal with these issue. Therefore, it is necessary to mitigate or delay CO_2 emissions when planning to produce industrial products (Vogtländer, van der Velden, & van der Lugt, 2014). As the issues of anthropogenic CO_2 emissions on a global scale are reviewed, the following three main flows can be considered:

1- Carbon emissions per year caused by burning fossil fuels: 6.4 Gt/year
2- Carbon emissions per year caused by deforestation in tropical and sub-tropical areas (Africa, Central America, South America, South and Southeast Asia): 1.93 Gt/year
3- Carbon sequestration per year by re-growth of forests on the Northern Hemisphere (Europe, North America, China): 0.85 Gt/year.

1.1 Environmental Impact and carbon storage in Kenaf fibre and other natural fibre composite

In the last few decades, ecological concern and global warming have begun by adopting the Kyoto protocol which highlighted the carbon dioxide emission issues in many countries including Canada who has committed to reducing a combination of CO_2, CH_4 and N_2O emissions to below 6% by the year 2012. Moreover, this opens a door to investigate the environmental performance of natural fibre products such as hemp fibre mat thermoplastic; the study was conducted by Pervaiz and Sain, (2003) to evaluate carbon storage potential and carbon dioxide emissions and to compare the results of the commercial glass fibre composites; The investigation of a comparative life cycle analysis which concentrates on the non-renewable energy consumption of natural and glass fibre composites illustrates that a net saving of 50 000 MJ equivalent to (~3 ton CO_2 emissions) tons of thermoplastic can be achieved by substituting 30% of glass fibre reinforcement with 65% hemp fibre. It is further estimated that 3.07 million ton CO_2 emissions (4.3% of total USA industrial emissions) and 1.19 million m^3 crude oil (1.0% of total Canadian oil consumption) can be saved by substituting 50% fibre glass plastics with natural fibre composites in auto components (Pervaiz and Sain, 2003).

The environmental and energy aspects of kenaf plant are diverse and complicated. The usage of kenaf for manufacturing composite materials can contribute towards substituting fossil fuels. The evaluation of the energy consumption of kenaf fibre in every application produced is fewer when compared with synthetic or mineral products. The energy consumption is assessed through kenaf cultivation, fibre production, and transportation as well as manufacturing which indicated that the energy and chemical to process kenaf for paper is fewer when matched with wood fibre (Rettenmaier N, 2010b), (Monti and Alexopoulou, 2013). According to Cherubini F (2009) the use of electricity in kenaf cultivation can keep up to 85–180 GJ/ha/year, which is lesser than (160–295 GJ/ha/year) when the heat was used.

1.2 Carbon storage potential in kenaf fibre and other natural fibre composites

The estimated Carbon dioxide emissions for material and manufacturing in ton/ton of composite for both natural and glass fibres was evaluated by converting energy into CO_2 emissions using standard conversion factors for different fossil fuels. Oil is assumed as a base fuel for this study, which emits 75% of CO_2 emissions, compared to coal (Greenhouse gases, global climate change, and energy). The average value of carbon dioxide emission for coal in 1999 was estimated at 208 pounds per million Btu (Carbon dioxide emission factors for coal). The heat energy released by incinerating of hemp fibre and PP was also added in as non-renewable energy requirements to calculate the released energy. The results revealed that a net reduction in emissions of cubic ton CO_2/ton of the product if glass fibres are substituted by hemp fibres and consequently 1.16 m3 (1160 l) of crude oil is saved for the same amount of product. Moreover, it was concluded that all these savings on energy are based on 1 ton of composite only. Now if we consider the projected consumption of all natural fibres (excluding wood) by 2005 which is 45 million kg of auto sector and assuming more or less the same amount of biomass in all fibres produced from (hemp, flax, kenaf) 65% of fibre ratio in thermoplastic then the annual CO_2 possible reduction is 0.135 million tons (Pervaiz and Sain, 2003).

1.3 Developing Composites from Natural Fiber

Natural fibre composites are used as replacements for glass-reinforced composites for several industrial usages. Natural fibre composites, for example, hemp fibre-epoxy, flax fibre-polypropylene (PP), and china reed fibre-PP are mostly used by the customers in automotive applications due to their lower price and lower density. Glass fibres used for composites have a density of 2.6 g/cm3 and cost between $1.30 and $2.00/kg. In comparison, flax fibres have a density of 1.5 g/cm3 and cost between $0.22 and $1.10/kg (Foulk, etal 2000).

Joshi, etal (2004) concluded that natural fibre composites environmentally seem to be better than the glass fibre composites because of the following subsequent advantages: (1) when produced natural fibre has a lower impact on the environment when compared to glass fibre production; (2) natural fibre composites contain higher fibre, which decreases more of the littering base polymer content; (3) the light-weight of natural fibre composites mend the fuel efficiency and lessen emissions in the used phase of the component, particularly in automobile applications; and (4) the end of life burning of natural fibres results in healthier energy and carbon esteems.

1.4 Automotive parts manufacturing from natural fibre as lightweight material

The researchers and policymakers are more concerned with the usability of natural fibres for the development of greener solutions in the production, consumption and disposal of automotive products. The work of (Ali, etal, 2015) concluded that the natural fibre composite material can be used as conventional materials for the automotive components industrialists. The economic aspect and environmental benefit of using natural fibre have not been undervalued. For instance, as bio-based materials, the natural fibre products are lighter than the conventional fibre and for that, they can reduce the cost of production and their production is costly effective (Holbery and Houston, 2006). However, the use of natural fibres may be the answer for many ecological problems, such as End-of-Life vehicles (ELV), waste reduction and for economic development projects. To achieve the goal of lightweight construction in the vehicle, the automakers have substituted the steel with aluminium, magnesium, composites, and foams. The recycling of the end-of-life vehicles, which targeted up to 85%, are recovered from the auto industry to opt for lightweight materials technology to meet these recovery targets. The research conducted by (Shuaib and Mativenga, 2016) recommended that the quantifying of the environmental benefit of industrial products such as glass fibre reinforced thermoset plastic composites is a crucial issue which we should be aware of when conducting future work.

The competition in the marketing of lightweight materials for the automotive is large. This is because of the demanding nature of the vehicle. In addition, recently the environmental concern has opened the need for a lighter vehicle with low fuel consumption; and therefore the need for recycling (Uddin and Kalyankar, 2011). These pressures have opened the door for the introduction of new materials to the automotive market as an alternative to steel. However, there are many barriers to the large scale use of these materials mainly due to the cost of the raw materials. Consequently, there is a need for further research for suitable processes in the properties provision. This research and innovation can open up the possibility of having lighter and more environmentally friendly future vehicles (Pandey, etal, 2010). Moreover, the study conducted by Barth, (2015) illustrated that the percentage of kenaf natural fibres is an alternative to glass and mineral fibres for automotive manufactured products and has dramatically increased in the percentage when compared with other fibre crops.

2. Methodology

2.1 Environmental assessment and Co_2 stored estimation of kenaf fibre utilised in automotive components.

The data used in this study consists of the following:

1- The data collected through an interview and group discussion with the kenaf farmers in Bachok-Kelantan and kampong Mercong-Pahang cultivated the kenaf using several inputs to know the productivity of kenaf cultivation per hectare.

The interview focused on environmental performance data such as (the eco-friendly plantation of kenaf crop, the input used to produce kenaf such as pesticides, herbicides, fertilisers and the effect of kenaf in the purity of water during the cultivation season).

2- The kenaf production in the year 2014 which was cultivated in four Malaysian States (LKTN, 2014) was used to quantify the carbon storage potential of the kenaf processed fibre used for producing composite for automotive components.

3- The percentage of converted kenaf to fibre when using (the kenaf decorticator high power1 and 2, Kenaf Processing and Marketing Centre (CMPC)) to convert the cultivated kenaf in the four Malaysian

States to fibre; In this section, we interviewed the LKTN staff in the Kenaf processing factory about the quantitative data such as the percentage of kenaf stem when converted to fibre, and the daily data of 30 days of kenaf processing by the two above mentioned decorticators used to estimate how much can one ton produced core, fibre, and waste when processed with machines.

4- To convert the processed fibre into stored CO_2, the whole processed raw material of kenaf into fibre multiplied by 1.27 which is equivalent to carbon dioxide stored by kenaf fibre $kgco_2/kg$ as revealed in the works of (Barth, 2015). However, the kenaf core is similar to the tree hardwood (Lips and van Dam, 2013), therefore the sequestrated carbon of the kenaf core has been included in this investigation which followed the assessment as revealed by Oliver (2014) to estimate the carbon stored in kenaf fibre product using the equation below.

Carbon stored in fibre = (kenaf production ton/ha*percentage of processed fibre output)* (1.27+1.835).The three assumed scenarios of kenaf production (10; 12 & 15 ton/ha) depended on the average weight of dry matter of kenaf production in the Kenaf Malaysian States used to estimate the fibre production per region.

3. Results and Discussions.

3.1 Environmental Assessment and Estimation of CO_2 Stored in Kenaf Fibre Utilized in Automotive Components

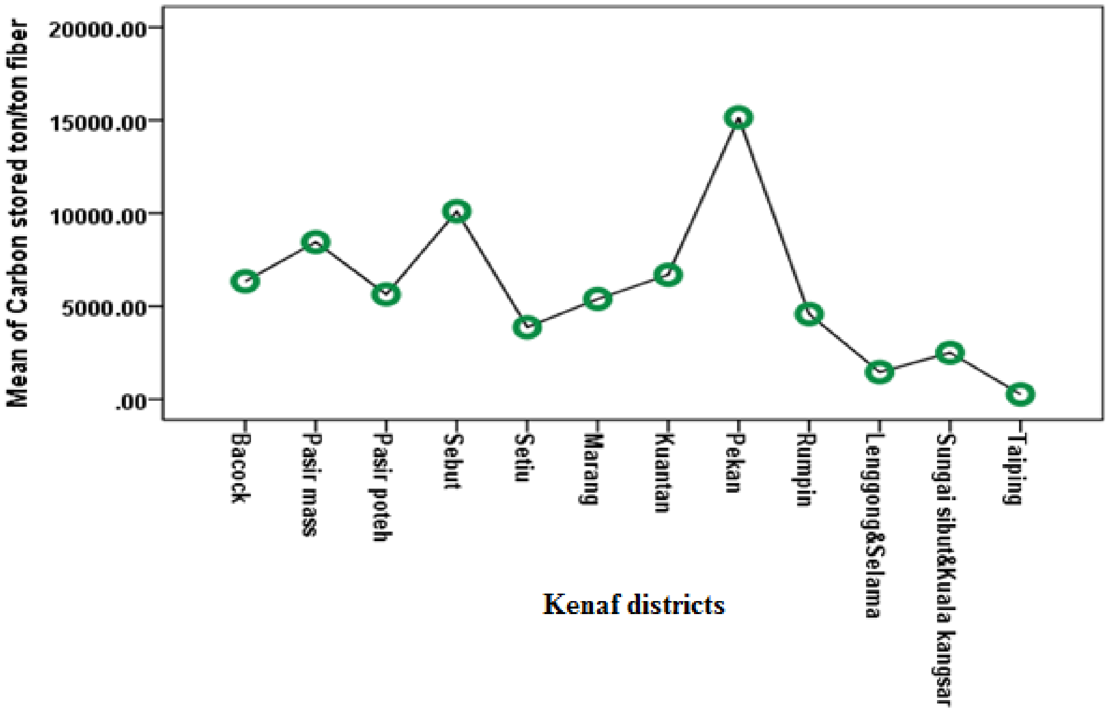
The mean separation test of the carbon stored in the kenaf cultivated in individual states is depicted in table 3.1. The results illustrate that there is a significant difference between the Pahang state and the other three states. However, considering the production of kenaf in all the states, it may be concluded that the results strongly depend on kenaf cultivation per hectare. The analysis of the carbon stored in the processed fiber reveals that there are no significant differences between the Terengganu and Kelantan states, while there is a great disparity between three states, namely Pahang, Terengganu, and Kelantan, and the fourth – Perak. The investigation concluding that the highest carbon amount stored by the vehicle components found in the kenaf fiber cultivated in the Pahang state, with the maximum and minimum amounts of 15149.50 and 4580.08 t/t, respectively. The explanation to this is that in Pahang more land is dedicated to the cultivation of kenaf, and thus the production in this state is the highest. It is followed by the Terengganu and Kelantan states, while Perak contributes the least to kenaf cultivation and thus has the least environmental performance. The research conducted by (van Dam, 2008) revealed that the cultivation of fibrous crops results in CO2 fixation in biomass through photosynthesis, which has a positive effect on the CO2 balance, in addition to further advantages obtained when valorizing the biomass to produce materials with properties that are less harmful to the environment. The results revealed by (Pervaiz and Sain, 2003) exhibit the total savings of CO2 emissions is 4.13 million ton/year when the natural fiber used in the automobile components.

Table3.1 A comparison of Carbon dioxide stored in kenaf fibre among the states ton CO2/ton fiber

States	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Pahang	8807.85	5592.81	3229.01	4580.08	15149.50
Terengganu	6459.09	3252.44	1877.79	3875.45	10111.41
Kelantan	6811.40	1466.80	846.86	5637.02	8455.54
Perak	1409.26	1117.65	645.28	267.76	2501.43

3.2 Carbon Stored in Kenaf Fibre among the Kenaf Districts

Further analysis was carried out to distribute kenaf production by districts. The results depicted in figure 3.2 indicate the situation of the carbon stored in the kenaf fiber cultivated in the fourteen districts under study. The investigation reveals that the farmers of the Pekan district (Pahang state) are the largest contributor to kenaf production in Malaysia; this indicated by the highest share of carbon storage obtained when kenaf is converted to the fibre using the decorticator processing machine. This district is followed by Sebut in the Terengganu state. Also, the analysis demonstrates significant differences between Pekan and Sebut compared with the rest of the regions, (Stockmann, etal., 2014) clarifies that the assessment of covered areas by plant at the regional level with the estimation of ecosystem carbon and the determining of stored carbon can be used to inform decision makers and used as guides of climate change adaptation and alleviation efforts of greenhouse gasses emission.



Figer3.2 A comparison of stored carbon in kenaf fibre among the districts in four states.

4.16 A comparison of Carbon stored in kenaf fibre among the districts in four states

The comparative analysis of the carbon stored in the kenaf fiber cultivated in the districts of the four states under study is illustrated in Figures 3.3a , 3.3b, 3.3c and 3.3d, which depict a dependence between carbon storage and kenaf production in ton/hectare. Pasir Mas, Sebut, Pekan and Kuala Kangsar have a significant environmental performance due to their better share in kenaf cultivation, which contributes to the production of a reasonable quantity of processed fiber. At present, these districts provide factories with the highest quantity of kenaf fiber used for several industrial products in Malaysia. Generally, it can be concluded that when the kenaf productivity per hectare increases, the sequestrated and stored quantities of carbon also increase which will lead to better environmental performance, as well as the saving of carbon in the vehicle body due to the addition of kenaf fiber will help in saving carbon dioxide emission. According to (Alves et al., 2010), the opportunity to use jute fibers to design buggy vehicle for the environmental improvements to the substitution of glass fibers, to produce a structural frontal bonnet; recommended with the best advantages of applying jute fiber composites in buggy components. Their research revealed that for environmental aspects, the jute fiber indicates an increase of about 15% of the performance of the produced bonnet, while on the economic issues, jute fibers cost about seven times less than glass fibers; in their study they noted that jute fibers have many advantages in the replacement of glass fibers to reinforce composite materials. It is possible to observe that jute composites related to the four aspects, present the better overview performance than glass composites. This will encourage to produce sustainable vehicle industry, with more environmentally friendly consumption behavior of natural fiber for automotive components. Thamae and Baillie (2008) conducted an environmental research to compare Natural Fibre Composite for car door panels (manufactured from wood fiber and polypropylene) with conventional glass fiber reinforced panels; their results indicated that the part which is made of a Natural Fibre Composite material could reduce the environmental impacts of the panels.

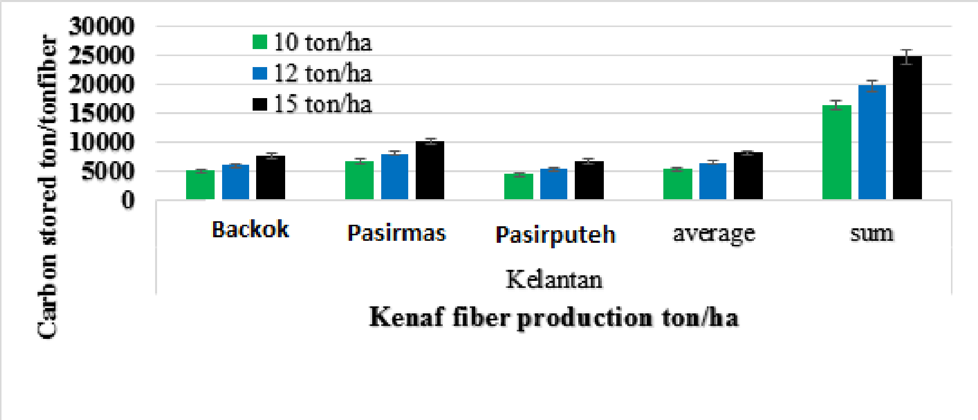


Figure3.3a A comparison of carbon stored in kenaf fiber among Districts- Kelantan state

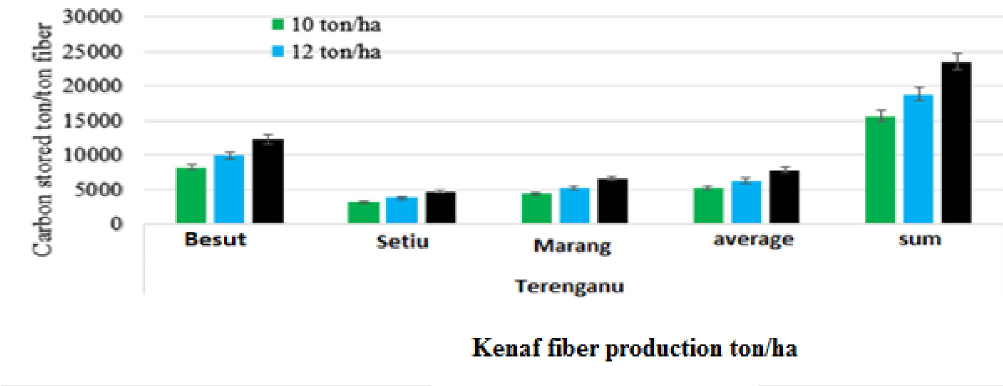


Figure 3.3 b A Comparison of Carbon Stored in Kenaf Fiber Among Districts-Terengganu State

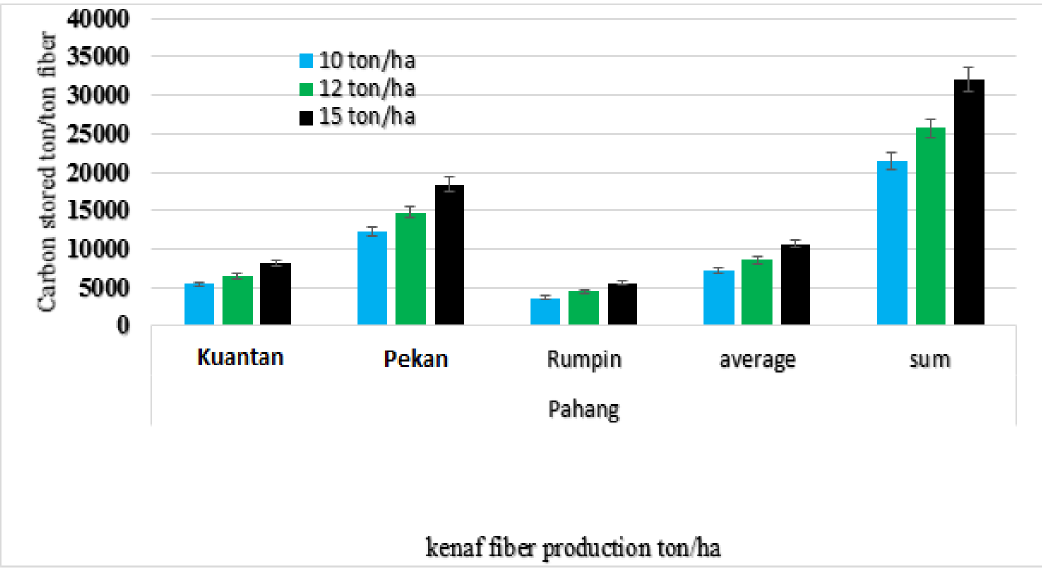


Figure 3.3 c A Comparison of Carbon Stored in Kenaf Fiber Among Districts-Pahang State

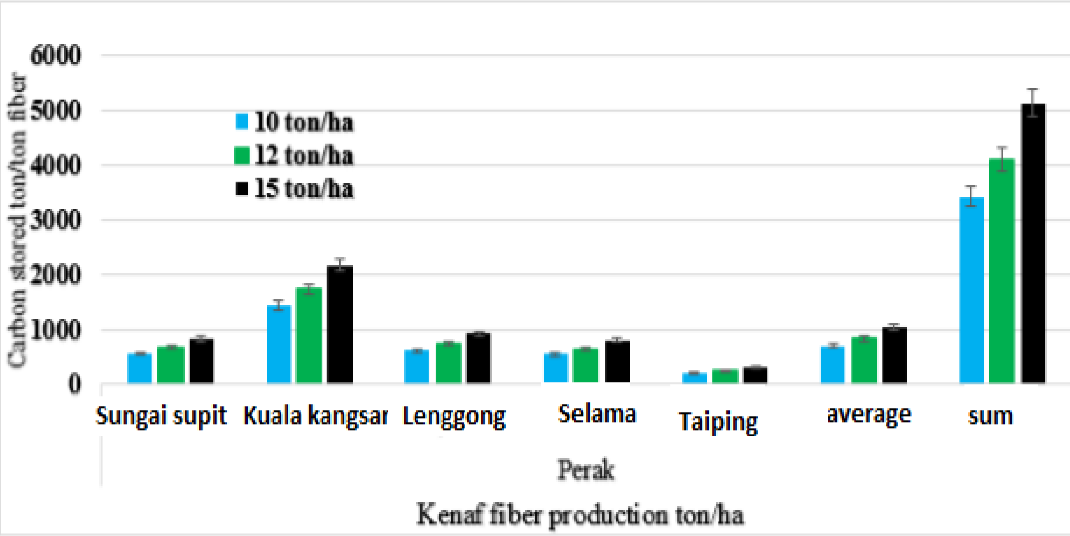


Figure3.3d A comparison of carbon stored in kenaf fiber
Among Districts-Perak state

Conclusion

Finally, the investigation of environmental assessment indicated that the kenaf stem could absorb in its fiber more than twice the quantity of carbon stored in other bast fibers, such as flax and hemp. Also, these fibers can be efficiently used to manufacture automotive components or in any other applications for composite materials.

The study concluded that kenaf has a vital environmental performance when it is cultivated more than once a year, recommending to consider it as a great plant, which can be grown to mitigate global warming. Also, the investigation recommends that to increase the environmental impact, the large area of kenaf cultivation should be encouraged, which can lead to better environmental impact.

Acknowledgement

The author would like to express his warm gratitude to Long Research Grant Scheme project (LRGS) for the financial support received. **Also, the author appreciated the financial support received from project vote 6382200 (Increased production in small holder product. System for specific industrial applications)**; many thanks also to LKTN staff for their assistance in providing information. Furthermore, the author would like to extend his deepest thanks to LKTN inspector, Mr. Bakhir for his help in conducting the survey. In addition the author would like to thank Mr. Bahron, technician in the Laboratory of Bioresource Management-INTROP for his help to facilitate various areas of the data collection.

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