Information Management and Business Review (ISSN 2220-3796)
Vol. 15, No. 3(SI), pp. 155-162, September 2023

Energy Efficiency of Kenaf Cultivation in Kelantan, Malaysia by using Data Envelopment Analysis

Rabiatul Munirah Alpandi[1*], Fatin Farazh Yaacob[2], Siti Mariam Melissa Abdullah[3], Siti Hawa Yusof[4], Muhammad Syafiq Mohd Salam[5]
[1]Faculty Business and Management, Universiti Teknologi Mara, Puncak Alam, Selangor, Malaysia
[2]Faculty Business and Management, Universiti Teknokogi Mara, Segamat, Johor, Malaysia
[3]Centre of Foundation Studies, Universiti Teknologi Mara, Dengkil, Selangor, Malaysia
[4]Faculty of Business, Taylors University, Subang Jaya, Selangor, Malaysia
[5]Maybank Investment, Malaysia
*rabiatulmunirah@uitm.edu.my, fatinfarazh@uitm.edu.my, mariammellisa@uitm.edu.my, sitihawa.yusof@taylors.edu.my

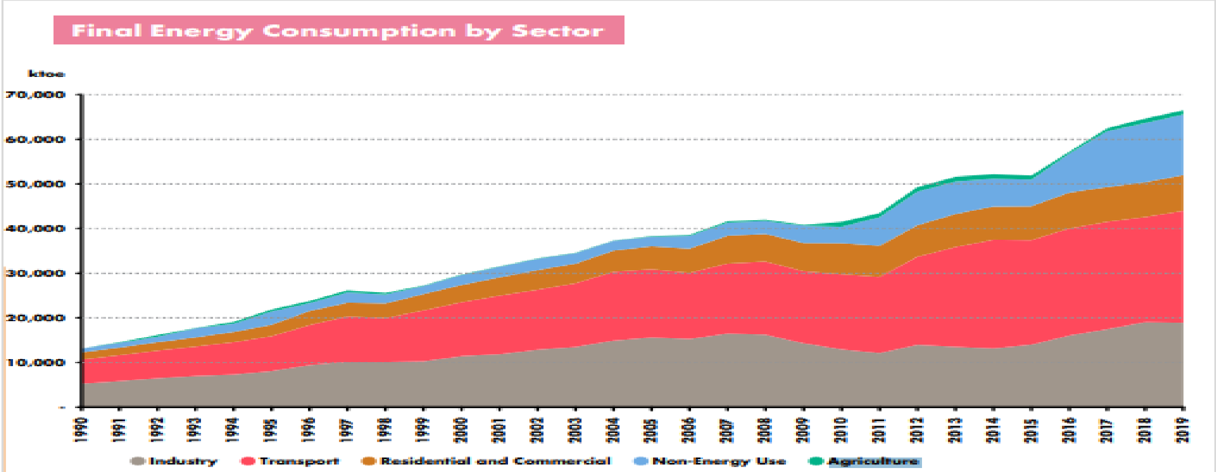
Abstract: Agricultural production has become aggressive energy concentrated in a determination to supply more food to the increasing population and provide sufficient and adequate essentials. The limited natural resources and the effect of the use of different energy sources on the environment and human health such as global warming, it is necessary to investigate energy consumption patterns in agriculture. In this study data envelopment analysis method approach has been used to determine the efficiencies of kenaf farmers concerning energy use in kenaf cultivation production activities in Kelantan, Malaysia. The study's empirical result will help to segregate the 15 most efficient farmers and inefficient ones. Other than that, the data envelopment analysis method also will help to identify wasteful uses of energy from different sources by inefficient farmers and to suggest reasonable savings in energy uses from different sources of inputs. The rank method and distribution of virtual inputs are used to get insights into the individual Kenaf farmer performance, rank efficient farmers and identify the improved operating practices followed by a group of truly efficient Kenaf farmers. The result of the analysis indicates the average value of technical efficiency (TE), Pure technical efficiency (PTE) and Scale efficiency (SE) scores of kenaf cultivation production were 0.854, 0.962 and 0.887 respectively. These results imply that all inefficient farmers operate at optimum scale size and management and 11.3% energy saving is possible without affecting the Kenaf yield level. The result also reveals the higher potential contribution to the total energy saving is from fertilizer (86.5%), Diesel (13%), Pesticides (0.3%) and human labor (0.2%).

Keywords: *Data envelopment analysis, kenaf production, Energy use efficiency, cultivation, agriculture.*

1. Introduction and Background

Agricultural production has become more energy intensive in a determination to supply more food to the increasing population and provide sufficient and adequate essentials (Amid et al., 2016). Considering the limited natural resources and the effect of the use of different energy sources on the environment and human health such as global warming, it is necessary to investigate energy consumption patterns in agriculture (Chopra et al., 2022). Measuring the energy efficiency of farming is required in both developing and developed countries (Sefeedpari et al., 2012). Energy is used in every form of input such as human labor, seed, fertilizer, pesticides, diesel, electricity and machinery to perform various operations for crop production. In Malaysia, energy consumption by sectors in Malaysia and agriculture is shown to have increasing trends in energy consumption from the year 1990 to 2019. This can be shown in Figure 1.

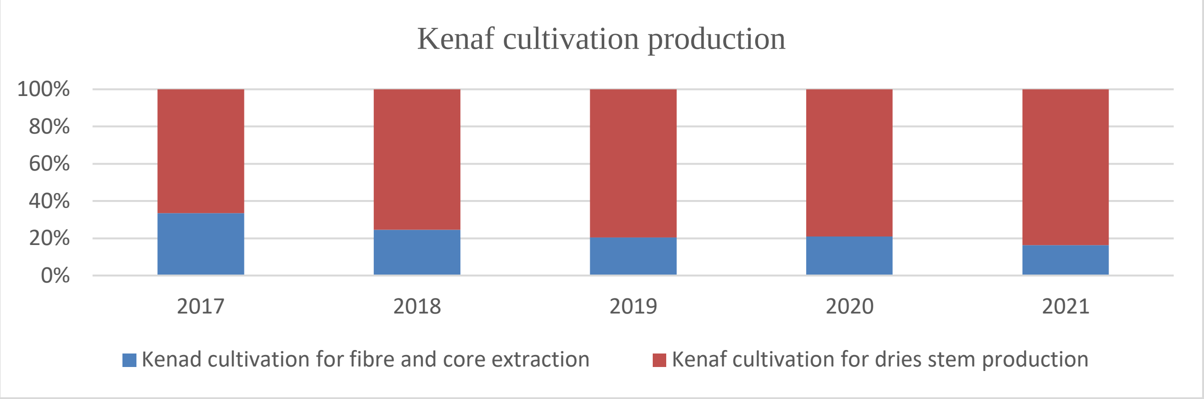
Figure 1: Energy Consumption by Sectors



(Sources: Malaysia Energy statistics, 2021).

Kenaf is an industrial crop with a high potential for cultivation in tropical climates. It is a main raw source production of fiber-based industries such as gunny sack, automotive components, yarn, textile, craft, non-woven and geotextile (MPIC, 2012). Otherwise, it's also important in the cordage and sacking manufacture as a substitute for jute. Kenaf also has been utilized as a part of car bodies which is seen as an effort to make vehicles sustainable, (Hassan et al., 2017) and has been used for building materials such as paneling, flooring, ceiling plaster, roofing, and fibreboard. The trend of kenaf production in Malaysia shows an increasing pattern. This can be shown in Figure 2 which shows the production of kenaf for fiber and dried stem (sources: Lembaga Kenaf dan Tembakau Negara (LKTN), 2022).

Figure 2: Kenaf Cultivation Production



(Sources: LKTN, 2022).

The increase in Kenaf production also causes an increase in energy consumption as well since Kenaf cultivation will utilize fertilizer, pesticides, human labor, and diesel to boost production in the market, (Abdul-Hamid et al., 2009). This is important for the farmers to make sure their kenaf farming is green which is forming ecological and environmentally friendly eco-farm to make sure there is no wastage in sources of input to maximize the production of Kenaf. Excessive use of energy in agriculture as well as reducing energy resources are the main reasons for optimizing energy consumption in agriculture. Therefore, efficient use of these energies is a necessary step toward reducing environmental hazards, preventing the destruction of natural resources, and ensuring agricultural sustainability, (Khoshroo et al., 2013).

2. Literature Review

Data Envelopment Analysis (DEA) has been widely used in energy efficiency-related literature in the agriculture sector. DEA also has been used for investigating efficiency evaluation as overall technical efficiency and energy saving target ratio to calculate the relative efficiency and energy potential saving and (Li, et al., 2018) used this method to see the potential for the Chinese agricultural sector for 30 provinces in China. DEA also has been used to analyze energy efficiency in Wheat Production (Haushyar et al., 2010), energy efficiency in Apple production in Japan (Masuda, 2018), energy efficiency in grape production (Alireza, 2013), energy efficiency improvement and input cost savings in Kiwifruit production (Mohammadi, 2011). In analyzing energy efficiency, the research empirical results show segregate efficient and inefficient of farmers based on how they manage their energy input and scale size of energy input to produce the output and the same time identify wasteful uses of energy from different sources by inefficient farmers and to suggest reasonable saving in energy uses from different sources of inputs (Amid et al., 2016). This DEA method has been used widely in various sectors however there is still a gap in the Kenaf cultivation sector.

3. Research Methodology

DEA is a linear programming-based technique developed to evaluate the relative efficiency of non-profit public-sector decision-making units (DMU) that use multiple inputs to produce multiple outputs. It is the optimization method of mathematical programming to generalize technical efficiency using a single input divided by a single output (Farrel, 1957) to multiple inputs divided by multiple outputs to construct a relative efficiency score as the ratio of a single virtual output to a single virtual input. Thus, DEA has become a new tool in operational research for measuring technical efficiency since it was introduced by Charnes, Cooper and Rhodes (1978). The authors proposed a model known as that had an input orientation and assumed constant returns to scale (CRS). However, the later study has considered an alternative set of assumptions that consider a variable return to scale (VRS). This model is known as BCC. DEA is also a method to measure the efficiency of decision-making units (DMUs), There are many articles published in journals or book chapters that have used variations of DEA in analyzing performance, (Emrouznejad, Parker and Tavares, 2008).

Up to now, the DEA has been used to evaluate and compare educational departments (schools, colleges, universities), health care institutions (hospitals, clinics), personality among individuals and in agriculture production, banking sectors, construction and many else. Besides the above-mentioned traits, the DEA method may help to identify possible benchmarks towards which performance can be targeted. The weighted combination of peer and peer themselves may provide benchmarks for the relatively less efficient organization and can be promulgated for the information of managers of organizations aiming to improve performance. The ability of DEA to identify the possible peer of role models as well as simple efficiency score gives it an edge over other measures, (Fried, Lovell and Schmidt, 1993). Many researchers have applied DEA in agricultural research, especially in energy use. Amid et al. (2016) investigated energy use patterns and optimization of energy required for broiler production using DEA while Nassiri et al. (2009) studied energy use efficiency for paddy crops using DEA in Punjab India.

Other than that, Alireza et al. (2013) also applied the DEA approach to determine the efficiency of farmers in energy use in grape production in the southern part of Iran. In this study, DMU refers to each Kenaf farm in Kelantan, Malaysia. For the assessment of units, an input-oriented slacks-based measure of efficiency CCR and BCC model was employed (Nassiri and Singh, 2009). The input-oriented model was assumed to be more suitable because there is only one output, while multiple inputs are used. Likewise, in farming systems, a producer has more control over inputs rather than output levels, and input conservation for given outputs seems to be more reasonable (Galanopoulos et al., 2006). In Kenaf cultivation, the inputs include fertilizer, pesticides, human labor, and diesel while the output is the Kenaf yield. The different inputs have distinct energy values. The input resources were transformed into energy terms by multiplying with the appropriate coefficient of energy equivalent (Narvendra et al., 2006, Nassiri et al., 2009, Khoshroo et al., 2013) as shown in Table 1.

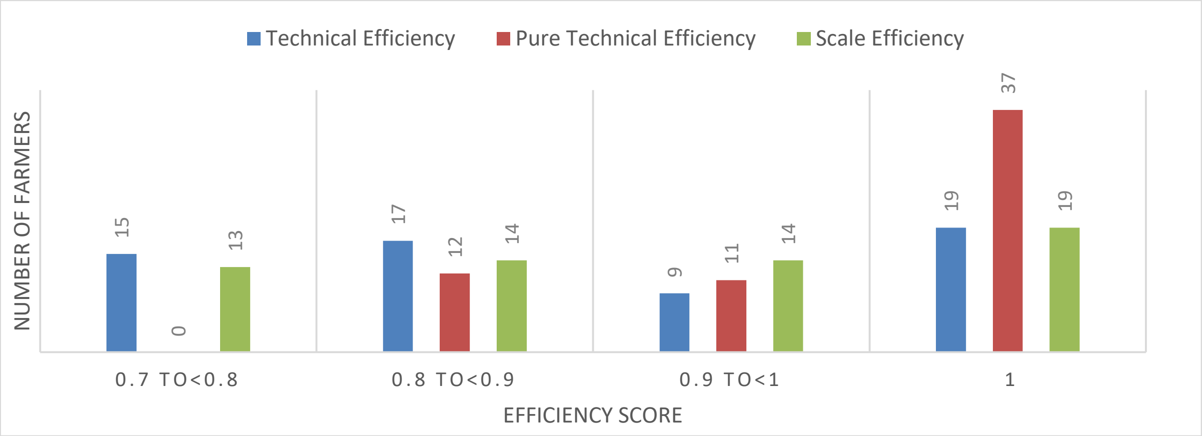
Table 1: Energy Coefficient of Different Inputs and Outputs Used

Items	Unit	Energy Equivalent (MJ unit^{-1})
Input		
Fertilizer	KG	60
Pesticides	Liter	120
Human Labour	Hour	1.96
Diesel	Liter	56.31

4. Results and Discussion

Identifying Efficient and Inefficient Farmers: The BCC model result indicates that a total of 60 Kenaf farmers were considered for the analysis. Of the 60 farmers, only 19 farmers gave an efficiency score of unity as shown in Figure 3. The management efficiency of farmers will be taken from technical efficiency (TE). On the other hand, the remaining 23 farmers who secured an efficient score of less than one are relatively inefficient in energy use from the different sources. It is proved from Figure 3 that the majority of inefficient farmers (9 of 23) were in the efficiency range of 0.9-0.99, followed by 17 and 15 farmers in the efficiency range of 0.8-0.89 and 0.7-0.79 respectively. However, the pure technical efficiency (PTE) estimation indicates only 37 farmers were efficient while scale efficiency (SE) estimation 19 farmers were efficient.

Figure 3: Efficiency Score Distribution of Kenaf's Farmers



The average values of the TE, PTE and SE are summarized in table 4. The summary statistical measures value (for all 60 farmers were considered) of TE, PTE and SE were shown in Table 2. The average values of TE, PTE and SE scores of kenaf farmers were 0.854, 0.962 and 0.887 respectively.

Table 2: Statistical Efficiency Measures in Kenaf Production

Efficiency Score	Min	Max	Average	Standard Deviation
Technical efficiency	0.700	1	0.854	0.119
Pure technical efficiency	0.833	1	0.962	0.056
Scale efficiency	0.700	1	0.887	0.104

The score of technical efficiency varies from 0.07 to 1 with a standard deviation of 0.119. The wide variation in the technical efficiency of kenaf farmers indicates a huge inefficiency between kenaf farmers in the studied area. The average scale efficiency of kenaf farmers was 0.887 which implies operation at optimal scale size with 11.3% energy saving without affecting the yield level.

Identifying Efficient Operating Practice: In this study benchmarking method was applied to rank efficient farmers. The results of ranking 15 superior efficient farmers are presented in Table 3. According to this table, DMUs 11, and 56 appear 56 times as benchmarks to other DMUs while DMUs ranking number 3 12 until 9 appear as a benchmark 53 times, followed by DMUs 39 which appear 39 times and DMUs ranking number 11 until 15 33 times and the last DMUs 15 which appear 26 times. Because of the high frequency, these ranchers can be selected as benchmarks to improve the performance of kenaf farmers.

Table 3: Ranking 15 Superior Efficient Ranchers in Kenaf Production in Kelantan

Rank	Rancher no.	Frequency in Benchmarking
1	11	56
2	56	56
3	21	53
4	27	53
5	32	53
6	44	53
7	48	53
8	49	53
9	53	53
10	39	39
11	14	33
12	33	33
13	51	33
14	57	33
15	12	26

Setting Realistic Input Levels for Inefficient Farmers: The technical efficiency score of farmers, which is less than one, indicates that at present the farmers use more energy from different sources. Therefore, they need to suggest realistic levels of energy without reducing the value of yield. Table 4 shows each inefficient rancher's pure technical efficiency, actual energy use, the recommended target energy use for each input and the percent saving in total energy use. Total saving energy can be shown in the evidence of present saving energy from 1% for rancher number 9 and 16 to 30% for rancher number 19. Table 5 shows the summarization of energy saving from different sources from Table 4. Using the information from Table 4 and Table 5, it's possible to advise the farmers to follow the better operation practices of their peers by reducing the input level to get their present yield.

Table 4: Actual and Potential Values of Energy Use from Different Sources for Inefficient Farmers (Based on the BCC model)

Farmer	TE Efficiency	Actual Energy Use				Target Energy Use				% Energy Saving				Total % Energy Saving
		Fertilizer	Pest	Labor	Diesel	Fertilizer	Pest	Labor	Diesel	Fertilizer	Pest	Labor	Diesel	
26	1	27600	120	16	10136	0	0	0	0	0	0	0	0	0
2	0.8	32829	139	27	8447	5811	29	22	0	15	17	45	0	19
4	0.7	30000	120	20	8447	4500	30	12	0	13	20	38	0	18
7	0.7	30000	120	20	8447	6000	24	12	563	17	17	38	6	19
8	0.7	31929	133	25	8447	11271	47	24	1126	26	26	50	12	28
19	0.7	31479	130	23	8447	12021	44	26	1689	28	25	52	17	30
24	0.9	30000	120	20	8447	0	0	0	0	0	0	0	0	0
31	0.8	31800	132	24	8447	7200	24	15	563	18	15	38	6	20
34	0.7	31479	130	23	8447	12021	44	26	1126	28	25	52	12	29
37	0.7	31479	130	23	8447	12021	44	16	1126	28	25	40	12	26
38	0.7	30000	120	20	8447	4500	18	12	1126	13	13	38	12	19
40	0.7	30000	120	20	8447	7500	30	20	1689	20	20	50	17	27
41	0.7	30000	120	20	8447	7500	30	20	0	20	20	50	0	23
42	0.8	29375	121	19	8752	865	5	1	258	3	4	3	3	3
43	0.9	33471	143	29	8447	3969	13	11	563	11	8	27	6	13

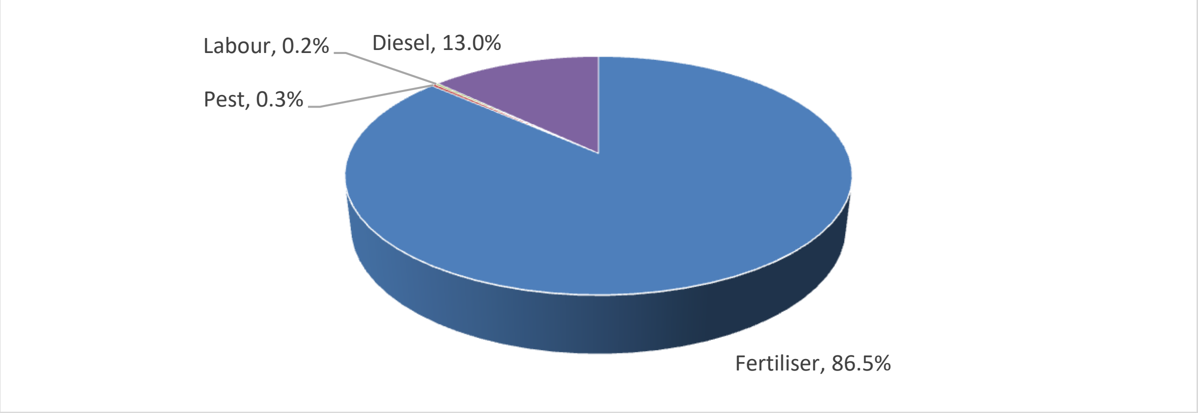
45	0.7	28125	120	18	9502	1875	0	1	633	6	0	6	6	5
50	0.7	29378	120	18	8928	2122	6	1	645	7	5	7	7	6
58	0.8	31420	131	23	8519	6020	25	16	1617	16	16	41	16	22
60	0.9	31736	132	24	8447	2764	6	15	0	8	5	38	0	13
23	1	30360	132	16	9573	0	0	0	0	0	0	0	0	0
55	1	38640	168	36	8607	1680	0	3	1528	4	0	9	15	7
5	1	38640	168	37	8447	0	0	12	563	0	0	24	6	8
13	0.8	30257	122	20	8447	2863	16	19	0	9	12	48	0	17
15	1	34500	150	31	8447	3000	0	8	1126	8	0	20	12	10
18	0.8	30771	125	22	8447	2349	19	18	0	7	13	45	0	16
20	0.8	30592	127	21	8579	6908	23	18	1557	18	15	47	15	24
22	1	34500	150	31	8447	0	0	0	0	0	0	0	0	0
25	0.7	31029	127	22	8447	10971	41	27	1126	26	24	55	12	29
35	0.8	33343	142	28	8447	10157	32	11	1689	23	18	28	17	21
36	1	31740	138	24	8728	0	0	16	1408	0	0	40	14	13
46	1	31740	138	24	8728	2760	0	8	282	8	0	25	3	9
52	0.9	34050	147	30	8447	4830	15	9	0	12	9	23	0	11
54	0.8	30257	122	20	8447	2863	16	19	0	9	12	48	0	17
59	0.8	30257	122	20	8447	4243	16	19	1126	12	12	48	12	21
1	1	28980	126	16	9010	0	0	0	0	0	0	0	0	0
3	0.9	28640	124	17	9146	3100	14	15	990	10	10	47	10	19
6	0.7	28014	122	16	9798	966	4	0	338	3	3	0	3	3
9	0.7	28980	126	16	9010	1260	0	0	0	4	0	0	0	1
10	0.9	28980	126	16	9010	0	0	0	0	0	0	0	0	0
16	0.8	28980	126	16	9010	1260	0	0	0	4	0	0	0	1
17	0.94	28980	126	16	9010	1380	6	0	0	5	5	0	0	2
28	0.8	29839	123	19	8624	3281	21	13	948	10	15	40	10	19
29	0.8	30607	125	21	8478	3953	19	10	1095	11	13	33	11	17
30	0.8	29757	121	19	8581	3243	11	1	429	10	8	5	5	7
47	0.8	29757	121	19	8581	3243	11	1	429	10	8	5	5	7

Table 5: Energy Saving from Different Sources

Inputs	Actual energy use	Target energy use	Energy Saving	Energy saving %
Fertilizer	1576560	1394290.5	182269.5	86.47
Pesticides	6528	5844.128	683.872	0.32
Labor	1454.32	981.931	472.389	0.22
Diesel	418383.3	391023.46	27359.85	12.98
Total Input energy	2002926	1792140.1	210785.6	100

Figure 4 shows the potential distribution of different sources in the total energy saving if the farmers followed the target energy. Results reveal that the highest contribution to total energy saving is 86.5% from fertilizer, 13.0% from diesel, 0.03% from pesticides and 0.2% from human labor.

Figure 4: Potential Distribution of Each Input to the Total Energy Saving



The input use pattern and yield obtained by the 15 most efficient and inefficient ranchers are compared in Table 6. The results reveal that inefficient farmers used higher quantities of fertilizer, pestilizer and human labor compared with efficient ones. In contrast, the yields obtained by inefficient farmers were about 20% lower than those of efficient farmers. It specifies that inefficient farmers did not use the resources efficiently.

Table 6: Comparison of Physical Inputs and Yield Use for Efficient and Inefficient Farmers

Units	Superior efficient ranchers (A)	Inefficient farmers (B)	% difference (B – A)/B *100
Yield (kg)	347.6	288.7	-20%
Fertilizer (MJ/kg)	528720	556620	5%
Pestilizer (MJ/liter)	12202	2280	3%
Human labor (MJ/h)	450.8	540.96	17%
Diesel (MJ/liter)	141338.1	138522.6	-2%

5. Conclusion

This paper describes the application of DEA in a basic way to study improving the energy use efficiency in the kenaf production system in Kelantan. Based on the result, Data Envelopment Analysis is very suitable to analyze these data and extracts many distinctive features of research practices and DEA helped in segregating efficient and inefficient farmers. It's also helped in finding the wasteful uses of energy by inefficient farmers, ranking efficient farmers by using the frequency/peer method and ranking energy sources by using the distribution of virtual inputs. The practices followed by the truly efficient farmers form a set of recommendations in terms of efficient operating practices for inefficient farmers. The empirical result indicates that the average value of TE, PTE and SE scores of kenaf production were 0.854, 0.962 and 0.887 respectively. These estimates for SE 0.887 imply that all inefficient farmers operate at optimum scale size and 11.3% energy saving is possible without affecting the yield level. Given the high cost of energy, this would be a substantial saving for the farmers. The higher potential contribution to the total energy saving is from fertilizer (86.5%), Diesel (13%), Pesticides (0.3%) and human labor (0.2%). This calls for the relevant authorities to educate farmers on energy waste or excessive use on the farms. Overall DEA can play a vital role in promoting energy efficiency in agriculture by providing insight into efficient practice and supporting decision-making processes.

References

Abdul-Hamid, H., Yusoff, M. H., Ab-Shukor, N. A., Zainal, B. & Musa, M. H. (2009). Effects of different fertilizer application levels on growth and physiology of Hibiscus cannabinus L. (Kenaf) planted on BRIS soil. *Journal of Agricultural Science,* 1(1), 121.

Amid, S., Gundoshmian, T. M., Shahgoli, G. & Rafiee, S. (2016). Energy use pattern and optimization of energy required for broiler production using data envelopment analysis. *Information Processing in Agriculture,* 3(2), 83-91.

Charnes, A., Cooper, W. W. & Rhodes, E. (1979). Measuring the efficiency of decision-making units. *European Journal of Operational Research*, 3(4), 339.

Chopra, R., Magazzino, C., Shah, M. I., Sharma, G. D., Rao, A. & Shahzad, U. (2022). The role of renewable energy and natural resources for sustainable agriculture in ASEAN countries: Do carbon emissions and deforestation affect agriculture productivity? *Resources Policy*, 76, 102578.

Emrouznejad, A., Parker, B. R. & Tavares, G. (2008). Evaluation of research in efficiency and productivity: A survey and analysis of the first 30 years of scholarly literature in DEA. *Socio-Economic Planning Sciences*, 42(3), 151-157.

Farrell, M. J. (1957). The measurement of productive efficiency. Journal of the Royal Statistical Society Series A: *Statistics in Society*, 120(3), 253-281.

Fried, H. O., Schmidt, S. S. & Lovell, C. K. (Eds.). (1993). The measurement of productive efficiency: Techniques and applications. Oxford University Press.

Hassan, F., Zulkifli, R., Ghazali, M. J. & Azhari, C. H. B. C. (2017). Kenaf fiber composite in the automotive industry: An overview. International Journal on Advanced Science, Engineering and Information Technology.

Li, N., Jiang, Y., Mu, H. & Yu, Z. (2018). Efficiency evaluation and improvement potential for the Chinese agricultural sector at the provincial level based on data envelopment analysis (DEA). *Energy*, 164, 1145-1160.

Houshyar, E., Sheikh Davoodi, M. J. & Nassiri, S. M. (2010). Energy efficiency for wheat production using data envelopment analysis (DEA) technique. *Journal of Agricultural Technology,* 6(4), 663-672.

Khoshroo, A., Mulwa, R., Emrouznejad, A. & Arabi, B. (2013). A non-parametric Data Envelopment Analysis approach for improving the energy efficiency of grape production. *Energy*, 63, 189-194.

Masuda, K. (2018). Energy efficiency of intensive rice production in Japan: An application of data envelopment analysis. *Sustainability*, 10(1), 120.

Mohammadi, A., Rafiee, S., Mohtasebi, S. S., Avval, S. H. M. & Rafiee, H. (2011). Energy efficiency improvement and input cost saving in kiwifruit production using the Data Envelopment Analysis approach. *Renewable Energy,* 36(9), 2573-2579.

Nassiri, S. M. & Singh, S. (2009). Study on energy use efficiency for the paddy crop using the data envelopment analysis (DEA) technique. *Applied Energy,* 86(7-8), 1320-1325.

Sefeedpari, P., Rafiee, S., Komleh, S. H. P. & Ghahderijani, M. (2012). A source-wise and operation-wise energy use analysis for corn silage production: A case study of Tehran province, Iran. *International Journal of Sustainable Built Environment*, 1(2), 158-166.