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Technology benchmarking of selected agriculture industries in Malaysia using Fuzzy Logic

(Penanda aras teknologi industri pertanian terpilih di Malaysia menggunakan Logik Kabur)

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Keywords: broiler, paddy, organic farming, Fuzzy Logic

Abstract

This study aimed to benchmark the production technology in Malaysia based on each commodity and to identify the potential technology that is suitable to be adopted in local environment. Benchmarking features and technologies applied in each industry were measured through survey and Fuzzy Logic system. This study was conducted on farmers involved in the production of paddy (268), broilers (312) and organic farming (53). The results showed technology applied in organic farming was still in average level. The application of technology/best practice in broiler farming was also in average level while technology in paddy production can be defined as among the best technology in terms of fertilisation and seed rate. There is a need to inject more catalysers to enable the best technology to be applied to increase more production and profit. It is also suggested that the role of technology transfer agencies to be strengthened and enhanced. Self-initiative, better training and effective technology transfer programme are needed by Malaysian farmers for impactful technological adoption.

Introduction

The history of benchmarking in agriculture was introduced by agricultural economists and has been extended by academics, farm management consultants and advisors, agricultural extension workers and farmers themselves over the course of a century. A significant part of benchmarking in the industry has been based on the comparative analysis of financial accounting records of farmer groups, complemented by physical stock and husbandry records. Benchmarking has had a very numeric feel to it in the industry, but there is also evidence that more tangible and process analysis elements are being incorporated into practices.

Techniques used in industrial applications, such as template matching and fixed object modelling are unlikely to produce satisfactory results in the classification or control of input from agricultural products. Therefore, self-learning techniques such as neural networks and Fuzzy Logic seem to represent a good approach.

Development of agricultural industries and agro-based industry in Malaysia shows progress and depends closely with the advancement of production technology. For this study, the selected agriculture industries such as paddy, broiler and organic farming were chosen because of the developments of

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these three industries are already saturated in terms of the technology in the field.

Problem statement

Broiler rearing system in Malaysia is divided into open house system and close house system. Almost 80% of the total broiler farms operating in Malaysia use open house system. Both systems use different technology. Generally, the close house system technology is better and more efficient than open house system. The advantages of close house system are comfortable environment in the chicken coop, controlled ventilation, optimised productivity, environmentally friendly farming and secured chicken quality. However, the weakness of the close house system compared to the open house system is the cost of providing infrastructure, repayments, electricity, water and higher maintenance. It is estimated that building a close house system would cost approximately RM12 – RM24 per chicken.

Organic farmers in Malaysia face challenges regarding land tenure, certification processes, hiring foreign workers, marketing, training and extension services, and governmental support. Despite the benefits that organic farming brings to farmers and environments, its adoption rate is still low among Malaysian farmers (Tiraieyari et al. 2014).

Based on historical data of paddy industry, farmers only applied 33% of the fertiliser requirement. The government subsidies fertilisers to help increase the fertiliser application to 41%. Physical loss is mitigated by the use of technology. The initial physical loss is estimated at 7.2% (Jafni et al. 2010) while the fraction of paddy area conversion is estimated at 0.2%. As for land fertility, the cumulative input used will affect fertility.

Objective

Technology practice among farmers is essential in improving the productivity of the country's production. Therefore, this technology benchmark study was conducted to identify the level of production technology among farmers in Malaysia. According to Kale and Karaman (2011), the benchmark study is one of the better methods to evaluate the performance of company or firm. This method includes a systematic framework for identifying, classifying and evaluating the processes, activities and firm performance. The main objective in this study was to determine the technology benchmarking in Malaysia in selected agricultural industries. The agriculture industries chosen in this study were broiler, organic farming and paddy.

Literature review

Bogan and English (1994) distinguish carefully between benchmarking for best practice and the practice of setting benchmarks for the performance analysis of an entity. This distinction is essential in understanding the use of benchmarks in the agriculture sector. In its widest sense, the migration of the terms 'benchmark' and 'yardstick' from surveying into business since the 1920s signifies the provision of a reference point or standard against which the performance of a business can be judged. Benchmarking is about improving competitive position by comparing performance against companies with best practice and implementing improvement programmes based on the results. Benchmarking helps minimise business complacency by challenging the acceptability of current performance and asking the question "where can we do better?" (Reed 1998).

Fuzzy Logic which was first introduced by Zadeh (1965), is used to handle uncertainty, ambiguity and vagueness. It provides a means of translating qualitative and imprecise information into quantitative (linguistic) terms. In recent years, more applications of fuzzy theory to agriculture have been reported. Simonton (1993) and, Chen and Roger (1994) used Fuzzy Logic in the classification of plant structures.

They found good agreement between the results from fuzzy prediction and human experts.

Methodology

This survey was conducted on 312 respondents for broiler, 268 respondents for paddy in granary and non granary areas and 53 respondents for organic farming throughout Peninsular Malaysia. Three main operations were applied in the Fuzzy Logic decision making process: selection of fuzzy inputs and outputs, formation of fuzzy rules and fuzzy inference. A trial and error approach was used to develop membership functions. Triangular and trapezoidal functions were used in establishing membership functions for high, moderate and low. The membership function developed was based on human expert or logical value based on situation. Each parameter was determined by a human expert based on the quality features of the three groups or membership functions (worst, moderate and best). Programming for fuzzy membership functions, fuzzification and defuzzification was done in Matlab.

For broiler production, a total of seven benchmark parameters were developed, namely accreditation, coop housing and infrastructure systems, cooling system technology, good husbandry practices in the field, technology disinfection, pest control technology and odour, and farm waste management technology.

For organic farming, six benchmarking parameters that have been set were accreditation, the use of legume crops, buffer zones, use of fertilisers, mulching and control of pests and diseases. Each respondent was given the fuzzy logic from 0 to 1 for each parameter depending on their benchmark performance. Based on the scores obtained from each parameter, benchmark indices are calculated and used to compare the performance of each entrepreneur.

For paddy production, eight benchmark parameters were selected, namely rate of seed, seed supply, land preparation, ploughing, water management, fertilisation, weed management and, pest and disease management. Simulation approach was used to build the eight benchmark parameters which include all the above parameters.

Analysis of the benchmark would be meaningful and be the basis for decision making only with data, accurate and adequate information. Each parameter was determined through in deep interviews using questionnaire which contained the information of production, technology used, yield and so on. Data were clarified based on the three categories, status or performance (low, medium and best).

The basic structure of the fuzzy inference system (FIS) consists of four components:

i. Fuzzification module which determines the membership degrees of the input values in the antecedent fuzzy rules
ii. Rule base with 'if–then' rules and related membership functions
iii. An 'inference engine' applying algorithms on the rule base and the input data to determine the degree of fulfilment of the output variable
iv. Defuzzification module which transforms the fuzzy output into a crisp output value in the fuzzy inference system

Determination of membership functions

It was stated by Shahin et al. (2000) that the lack of a systematic methodology for developing membership functions or fuzzy sets is a major limitation in designing a fuzzy system. Membership functions are in general developed by using intuition and qualitative assessment of the relations between the input parameters and output classes.

In the existence of more than one membership functions that is actually in the nature of the Fuzzy Logic approach, the challenge is to assign input data into one or more of the overlapping membership functions. These functions can be defined either by linguistic terms or numerical ranges or both.

Determination of membership functions in terms of shape and boundary has a clear effect on the result of classification performed by Fuzzy Logic. This situation greatly depends on experience and knowledge. Finding the right shape and the boundaries for the membership function will increase the accuracy of the Fuzzy Logic application. Statistics of the class populations, such as average, standard deviation and minimum-maximum values, could help the determination of membership functions.

Defuzzification

The centroid method, which is also known as the centre of mass, was used for defuzzification. In the defuzzification stage, the overall grade for a particular apple was found by taking the average of the weighted possible outputs using the weighted average method (Kartalopoulos 1996).

This method gives the output with the highest membership function. This defuzzification technique is very fast but is only accurate for peaked output. This technique is given by algebraic expression as:

$$\mu A^{(x^\circ)} \geq \mu A^{(x)} \text{ for all } x^2 \text{ X}$$

From each of the three output categories, trapezoidal areas were calculated for the parameters input being graded. Then, the weighted average of the three trapezoidal areas was calculated to find the final grade for the particular technologies applied.

Results and discussion

If the basic steps of Fuzzy Logic were followed, the result shows as index from 0 to 1. The index approaches close to 1 when the best approach of technology is applied by the commodity and the level of technology can be measured. But, if the index approaches to 0, worst technology is applied and there is a need for technology injection.

The benchmarking index for organic farming indicators was as follow:

- Technology applied >0.6: Best technology applied
- Technology applied 0.4 – 0.6: Moderate/ Average technology applied
- Technology applied <0.4: Worst technology applied

Organic farming

The first phase of this study involved over 53 respondents who were certified with Organic Certificate Malaysia (SOM). The respondents consisted of 26 people who undertake vegetables, 11 mushroom cultivators, 6 people working on vegetables and fruits, 3 fruit employers and the remaining 7 were working on other crops such as aloe vera, herbs and sandalwood trees. Based on the analysis, it was found that the use of buffer zones, leguminous crops and accreditation were high, while the use of fertilisers, mulching and, pest and disease control were still low (*Figure 1*).

The practice of farm technology is one of the important factors that can determine a parameter index and thus can improve the quality and value of a product. By using the highest = 1 and the lowest value = 0, the analysis found the average value of Fuzzy Logic for the use of the buffer zone is 0.587, followed by the use of leguminous

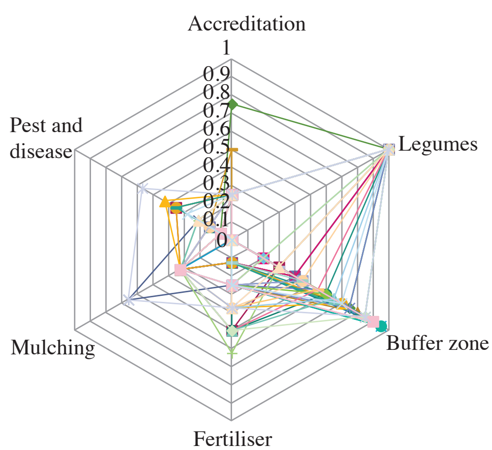

Figure 1. Organic farming Spider Web fuzzy index by parameters

crops (0.463), accreditation (0.268), the use of fertilisers (0.265), mulching (0.217) and, pest and disease control (0.148). The analysis also found that the technology gap between the lowest and highest practices for each technology is greater than 0.5 (the highest gap is 1 and the lowest 0.5). This shows that the technology gap between employers is very high. Some entrepreneurs are not using a technology directly in the parameter (*Figure 2*). The highest gap is the use of legume crop technology (1), followed by the use of buffer zones (0.75), mulching (0.66), the use of fertilisers (0.625), pest and disease control (0.571), and accreditation (0.5). On average, the benchmark index of organic farming in Malaysia remained moderate (0.445) with the lowest index value was 0.308 and the highest index was 0.601 (*Table 1*).

Organic farming is still new in Malaysia and majority of entrepreneurs do not have in-depth experience and knowledge in organic farming. From the analysis, the majority of respondents (73.2%) were at moderate level index between 0.4 and 0.5, followed by 17% who are at high level of more than 0.5% and 9.8% were at a low level which is below the index of 0.4. From the survey conducted, the benchmarking index of high technology usage exceeded 0.5 for the cultivation of vegetables and mushrooms (*Table 2*). Among these respondents, the use of legumes was the highest number of all seven respondents who had the same Fuzzy Logic 1, while the use of mulching was the lowest.

Broiler production

Fuzzy Logic analysis was applied in the technology parameters to determine the technology indices for both close and open house systems. The indices would exhibit the current farm situation in technology practices. The benchmarking index for broiler industry indicators was listed as below:

- Technology applied >0.6: Best technology applied
- Technology applied 0.3 – 0.59: Moderate/Average technology applied
- Technology applied <0.29: Worst technology applied

Based on the analysis result of Fuzzy Logic, there were three benchmark parameters, namely technology housing and infrastructure coop, disinfection technology

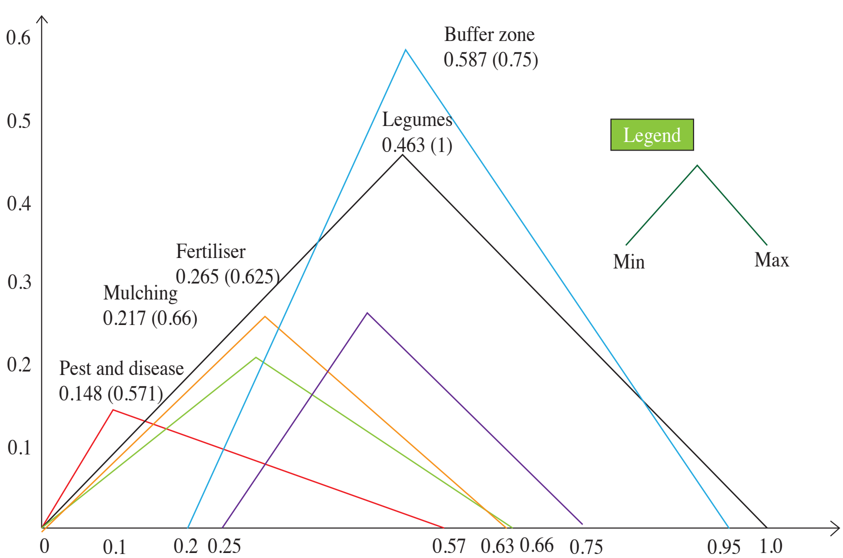

Figure 2. Sketch of technology gap among parameters in organic farming in Malaysia

Table 1. Benchmark index organic farming in Malaysia

	Average	Minimum	Maximum	Standard dev.
Benchmark index	0.445	0.308	0.601	0.055

Table 2. Fuzzy Logic value – respondents getting the best index

Respondents	1	2	3	4	5	6	7
Benchmarking index	0.601	0.552	0.517	0.513	0.513	0.509	0.504
Crops							
• Vegetable	√				√	√	√
• Mushroom		√	√	√	√		√
Fuzzy Logic index							
Accreditation	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Legumes	1	1	1	1	1	1	1
Buffer zone	0.85	0.85	0.85	0.55	0.85	0.75	0.65
Fertiliser	0.375	0.5	0.125	0.5	0.125	0.25	0.375
Mulching	0.66	0.33	0	0.33	0.33	0.33	0
Pest and disease	0.5712	0.0714	0.357	0.1428	0.0714	0.1428	0.0714

and pest control, and smell technology where the majority of broiler farms technology index reached a maximum value of 1. Broiler breeders need to emphasise the importance of these technologies to their companies. Meanwhile, the remaining benchmark parameters, which were cooling technology, good farming practices, management farm waste technology and accreditation, were below good practices.

The distribution of the benchmark index broiler production technology achieved an overall benchmark of seven parameter by each farm. These findings demonstrated the use of technology among the majority of broiler chicken farms in Malaysia was at a moderate level (*Figure 3*). The performance of a benchmark index broiler production technology as a whole in the open and close house systems is shown in *Figure 4*. About 13% of broiler farms reached a good level of technology, while 74% were moderate. This shows the majority of broiler farms reach the level of moderate technology index.

Figure 4 shows the technology gap for the close and open house systems. Technology gap index value means the differences of maximum and minimum technology applied. For the close house system, technology achievement index is at a moderate level of 0.595. The technology gap is 0.445. Meanwhile, open house system, achievement technology index is at a moderate level of 0.402 with the technology gap is 0.4 (*Figure 5*).

Close house system was found to have the technology gap larger than the open house system. This is due to the differences in the technology level in the field of the minimum and maximum is large. Furthermore, the use of technology in close house system is more than in open house system and it required a large capital costs to upgrade the existing technology. Most of the moderate scale farmers in the close house system were unable to bear the additional costs.

Paddy production

The classifications of the level of paddy production technology are as follows:

i. Technology practices with the best index (X ≥0.6)

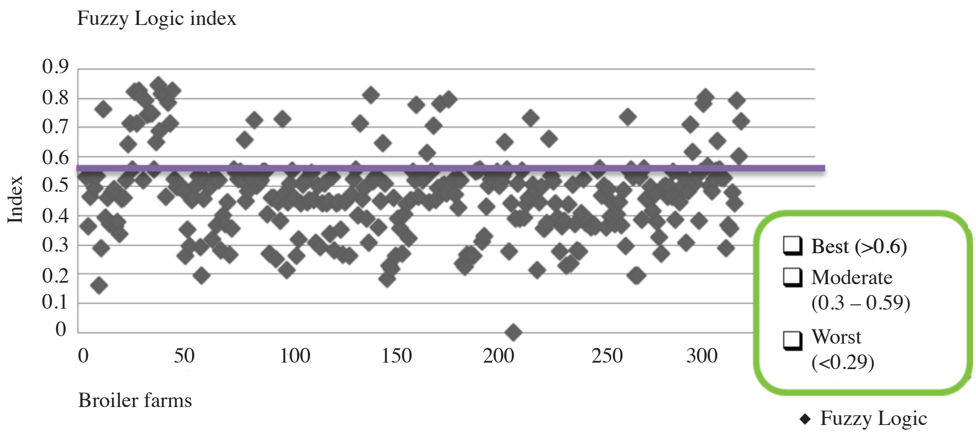

Figure 3. *Benchmark index broiler production technology*

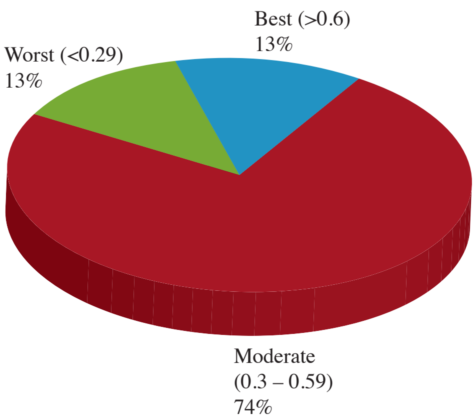

Figure 4. *Benchmark index broiler production technology (overall system)*

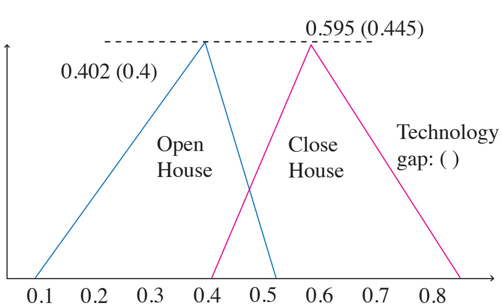

Figure 5. *Sketch technology gap of housing technology of broiler in Malaysia*

ii. The practice of simple technology index (0.5 ≤ X <0.6)
iii. Technology practices with the lowest index (X <0.5)

The benchmark index for the overall technology practices in paddy production was found to be at a moderate level of 0.52. Fuzzy Logic analysis shows that the best technology practices among farmers in Malaysia is the practice of fertilisation, seed rate and ploughing with the index value of 0.77, 0.69 and 0.67 respectively (*Figure 6*). Meanwhile, the weed management and seed preparation technologies were the lowest at 0.4 and 0.42 respectively for all respondents. There is a large technology gap exists for each technology practice among farmers. Therefore, these findings demonstrate that the role of development agencies is important to reduce the technology gap to ensure the productivity of the country's rice production is increased.

The Spider Web is a sketch of benchmark indices in rice production technology inside and outside the granary areas (*Figure 7*). The sketch shows the best technology practices was in PBLS granary areas, followed by the outside of the granary, MADA and lowest in the KADA. Tillage practices, water management, soil preparation and seed supply in the PBLS area were the best among the country's paddy cultivation area.

Conversely in KADA, fertiliser practices, weed management, management of R&D and seed rate showed the highest index among paddy growing areas. This

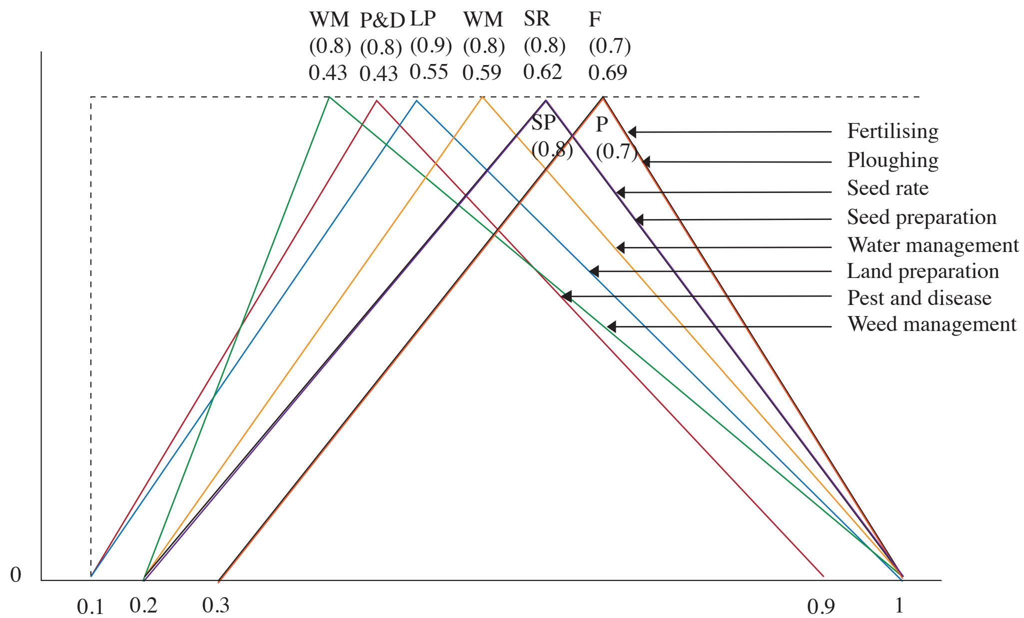

Figure 6. *Sketch of paddy production technology gap fuzzy index by parameters*

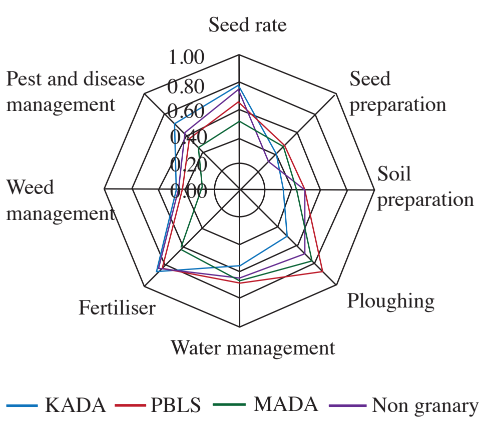

Figure 7. *Paddy production Spider Web fuzzy index by parameters*

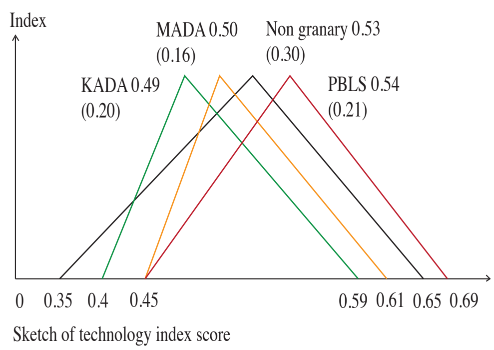

Figure 8. *Sketch of technology score between granary areas*

condition might be due to the low level of soil fertility in KADA which requires more fertiliser to enrich the soil and also high seed rate to ensure the growth of rice seedlings.

Further analysis was done to compare the technology practices in granary and non granary areas. Results showed that the index of technology for PBLS was 0.54, which was higher than the overall average (0.52) (*Figure 8*). Additionally, other analyses have been conducted to determine the technological gap between farmers in granary and non granary areas. This analysis was done by comparing the index with the lowest and best technology for each area. A lower value means the difference in technology gap is smaller and vice versa. Results of the analysis showed the value of the technology gap for MADA was 0.16, which was significantly lower than the rest of the granary, followed by KADA and PBLS. The analysis also shows that the technology gap between granaries is smaller compared with farmer's in non granary areas. This means farmers in non granary do not follow instructions compared with farmers in granary who have used the best technologies/practices and complied with the recommended technologies.

Conclusion

Fuzzy Logic was successfully applied to serve as a decision support technique in benchmarking of technology applied in selected agriculture industries. Based on the three industries, broiler and paddy production should have action plan to ensure the application of technology. From this benchmark index, the technology level in Malaysia was still in average level. Most of the farmers applied old technologies. Action should be taken to increase production by injecting more catalysers to ensure the best technology is applied by the farmers.

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Abstrak
Kajian ini bertujuan untuk mengukur penanda aras teknologi pengeluaran di Malaysia berdasarkan setiap komoditi dan mengenal pasti prospek teknologi yang berpotensi untuk diguna pakai dalam persekitaran tempatan. Ciri-ciri penandaarasan dan teknologi lain yang digunakan dalam setiap industri diukur melalui survei dan sistem Logik Kabur. Kajian ini telah dijalankan pada perusahaan padi (268), ayam pedaging (312) dan pertanian organik (53). Keputusan menunjukkan teknologi yang digunakan untuk pertanian organik masih dalam tahap purata. Bagi penternakan ayam pedaging, amalan terbaik teknologi juga pada tahap yang sederhana manakala dalam pengeluaran padi, teknologi boleh ditakrifkan antara teknologi yang terbaik dari segi membaja dan kadar benih. Lebih pemangkin perlu disuntik untuk menjadikan amalan teknologi yang terbaik dan meningkatkan lagi pengeluaran dan keuntungan. Dicadangkan juga peranan agensi pemindahan teknologi diperkukuhkan dan dipertingkatkan. Oleh itu, inisiatif diri, latihan yang lebih baik dan program pemindahan teknologi yang berkesan diperlukan oleh petani Malaysia untuk menjadikan amalan teknologi lebih berkesan.