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Determinants of Sustainable Waste Management Behaviors (SWMB) in Palm Oil Mills: Literature Review

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Abstract*—In oil palm plantations, poor waste management has turned into a significant problem impacting daily operations. Using knowledge as a moderator and behavioral intention as a mediator, this study aims to determine the impact of attitude, subjective norms, and perceived behavioral control on sustainable waste management practices in palm oil mills. The Theory of Planned Behavior (TPB), the core theory in this study, is being adapted conceptually. In order to determine the elements that can affect the choice to implement sustainable waste management behavior (SWMB) in that particular field, this study gathered and consolidated evidence from more than 20 years of observational research on SWMB within the palm oil business. The understanding of the significance of context in determining the elements that may have an impact on SWMB in palm oil mills has been discussed as a result of this study. This information may be used by regulators to support the appropriate Standard of Procedure (SOP) and legislation, enabling them to reflect their best performance above all*.

***Keywords*—** *Theory of Planned Behavior (TPB), Sustainable waste management behavior (SWMB), attitude, subjective norms, perceived behavioral control, knowledge, behavioral intention*.

I. INTRODUCTION

Palm oil is the most extensively consumed edible vegetable oil on the earth and a source of chemicals and biofuels. Morever, palm oil also has become an important and necessary raw material. Regardless of the palm oil industry's potential sustainability, it has historically produced waste and wastewater. Hence, the release of excessive amounts of greenhouse gases has a negative influence on the environment. As a result, an essential requirement for the development of the bioeconomy is needed to provide an effective establishment of a sustainable palm oil sector (Sakai et al. 2022).

Thanks to the subtropical Asian monsoon and conditions of heavy precipitation, intense heat, and high sun intensity, which are optimal for tropical plant growth, oil palm plantations have increased dramatically across Southeast Asia during the past century. A 5-year-old oil palm tree has a 20-year active lifespan and can yield 40 to 60 kg of fruit in the duration of five to six times each year. The yield is 2.8 t/ha, or almost seven times more than the yield of soybean oil. After Indonesia, Malaysia is the second-largest exporter of crude palm oil (CPO), producing 17 106 t of CPO annually. Palm oil is a crucial part of the chemical industry as well as one of the most consumed edible vegetable oils in the world. According to Chimezie, Zhang, Djandja, Nonso, and Duan (2022), palm oil has lately acquired demand as a source of fatty-acid methyl-ester biofuels. In consequently, the biomass industry now pays attention to the palm oil industry.

According to research done in 2021 by Saravanan, Kumar, Jeevanantham, Karishma, Tajsabreen, Yaashikaa, and Reshma, a significant amount of methane was found to be emitted anaerobically from an improperly regulated oxidation lake. Secondary greenhouse gases called nitrous oxides are primarily generated after nitrogen fertiliser is applied to agricultural soil. In order to improve and implement the best biorefinery technologies, it is also necessary to analyse the full exploitation processes of biomass (together with all residual components) to decrease the environmental load. The remedies to these issues are covered in the following section.

Fresh fruit bunches were transformed into 151.2 million metric tonnes (MMT) of solid and liquid biomass within just one year (MPOB, 2019), with oil palm empty fruit bunch (OPEFB) contributing for about 33.3 MMT of that total (Thoe, Surugau, Chong, 2019). Due to the benefits, it offers as a considerably more ecologically friendly technique of managing and waste disposal of a waste produced by Malaysia's palm oil sector, carbonization of oil palm biomass has captured the attention of numerous research and development (Ibrahim, Tsubota, Hassan, and Andou, 2021).

The palm oil business produces large amounts of biomass waste, particularly empty fruit bunches (EFB), which are sometimes improperly treated or recycled. The purpose of the present research is to ignite public interest in effective waste management and the use of waste biomass. There are lots of product can be generated from this palm oil biomass. Many research has been conducted to investigate the potential product from oil palm biomass. There was a study conducted with framework of ecological EFB reuse, and the potential of such waste biomass for the production of bio-pellet fuel was examined (Brunerová et al. 2018).

Due to oil palm plantations' enormous waste generation and negative links to environmental contamination, the palm

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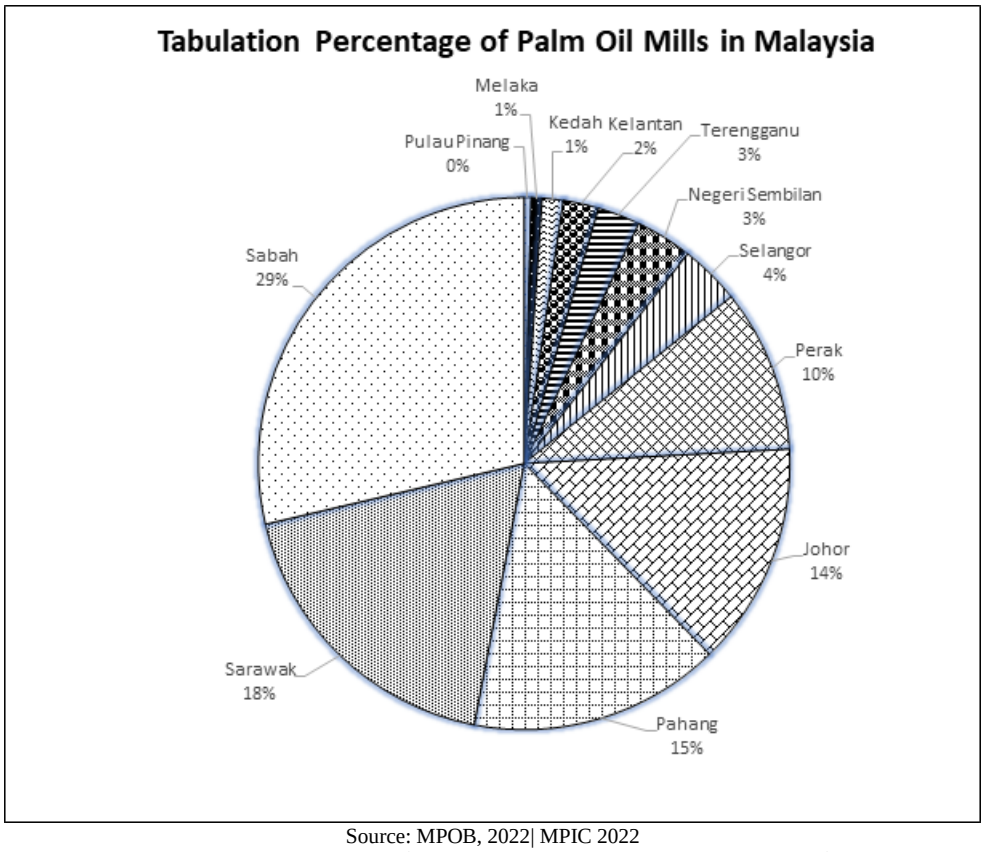
oil business in Malaysia has caused great worry. According to a study by Umar et al. (2018), just 23% of oil palm biomass is utilised as boiler fuel in a palm oil mill, with the rest 75% being disposed of onsite. The enormous number of the empty fruit bunches (EFB), which frequently created as a result of Malaysia's extensive production of crude palm oil, has constituted a serious environmental problem risk (Wen, Chew, Yiin, and Lock, 2022). Oil palm waste will have serious environmental repercussions if it is not properly handled and reduced (Dalton et al., 2022). In reality, to solve these issues, long-term palm oil management is required (Faridah et al., 2018).

Ineffective waste management has become one of the pollution's roots. Despite the aforementioned, the production process of palm oil has garnered widespread criticism due to the huge and undeniable environmental harm that this practise has caused. Oil palm plantations are to blame for deforestation and degradation of tropical and subtropical habitats, which have the most ecologically diversified terrestrial ecosystems in the world. (Mayes, 2004; MEA for the Millenium Ecosystem, 2018).

The excessive amount of useless biomass generated by the palm oil milling process has caused environmental concerns (Zamri et al., 2022). The empty fruit bunch and palm oil mill effluents (POME), in particular, are two types of biomasses that are still unharvested in the mills. According to Saritpongteeraka et al. (2022), empty fruit bunch (EFB) open decay results in the emission of non-CO2 greenhouse gases into the environment. Additionally, a study on the Air Pollution Index (API) in Sabah was published in 2022. Data for this study was gathered from 2010 to 2016. Tawau, in the Sabah Region, is classified as Unhealthy (API: 101-200), having the highest daily maximum mean API of 152.53. Despite this, Kota Kinabalu and Keningau both have the lowest overall mean API scores, with Kota Kinabalu's being 33.13 and Keningau's being 29.12. According to J. Sentian et al. 2022, daily API has shown high spatial fluctuation in this area, with coefficient variation varying from 29.87% to 36.06%. With the exception of Keningau Monitoring Station, all of the stations in the Sabah Region display notable patterns, with Kota Kinabalu exhibiting an increasing trend while the rest exhibited diminishing trends. As a result, from 2010 to 2016 the station with the worst air quality was Kota Kinabalu (J. Sentian, et al. 2022).

The incorrect handling of palm oil waste has had a significant influence on our biodiversity, and this frightening scenario has sparked public concern (Obidzinski et al. 2012). Millers did try to handle the palm oil biomass in a good way, but this practice needs to be investigated again to see how long it has been going on. Motel et al. (2009) says that these huge changes in oil palm plantations have had direct and indirect effects on the environment and pose a danger to it.

The palm oil business is growing quickly and needs a lot of research that focuses on this area to help and support it. So, this study was done to get more information from the oil palm industry from a social science point of view to help their management level understand the behaviour factors and enhance their company's performance at the same time.



Source: MPOB, 2022| MPIC 2022
Figure 1. Distribution percentage of palm oil mills by state in Malaysia in the year of 2022.

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The percentage of palm oil mills that are still expanding in each of Malaysia's states in 2022 has been showed in Figure 1. This data has been gathered by MPOB.

II. Literature Review

2.1 Theory of Planned Behavior

In recent years, the theory of planned behaviour (TPB) has been used a lot to study behaviour that beneficial for the environment. TPB is often used as a theoretical model in most studies because it is so good at explaining pro-environmental goals. The majority of scholars agree with the basic ideas behind TPB, but its limits have been questioned (Ajzen, 2011). In many TPB-based studies, researchers assume that goals and actions are interchangeable or very similar (Nguyen, Nguyen, and Hoang, 2019).

TPB says that people are more likely to do a behaviour if they have a positive attitude towards it, feel more social pressure and expectations to do it, see it as easy and convenient, and have the skills to do it (Xu, Wang, and Yu, 2020). TPB is a convincing and solid theory that has been utilised to clarify a wide range of character traits, including pro-environmental traits like using less energy, reducing PM2.5, sorting trash, buying green products, and travelling with less carbon (Wang, Wang, Zhao, and Yang, 2019b).

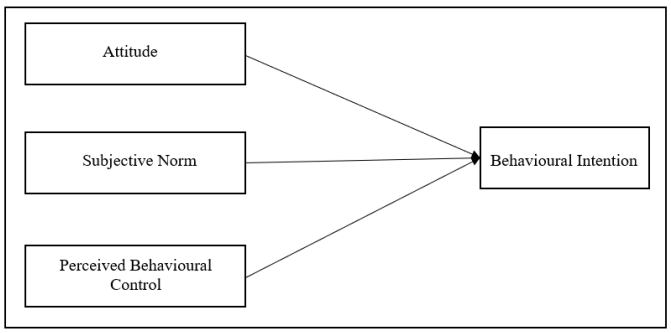

Figure 2. Theory of Planned Behaviour (Fishbein and Ajzen, 2010)

2.2 Palm Oil Waste

The palm oil business is growing, and at the same time it makes a lot of palm oil waste. To make oil from palm oil fruits, you have to go through a few steps. Salleh et al. (2018) stated that after the palm oil fruits are taken off the branches and the oil is extracted, about 72% of the fresh fruit bunch (FFB) mass is made up of a solid mass residue. This solid mass residue is made up of empty fruit bunches (EFB), palm mesocarp fibre (PMF), palm kernel shells (PKS), and palm oil mill effluent (POME). These are called biomass residues, and palm oil plants often make them. In conclusion, not more than 30% of the FFB will be turned into oil palm. This problem will cause a lot of consequences, such as issues with palm oil waste handling and disposal, as well as higher operating costs, which will affect oil palm mills in the long run.

Also, empty fruit bunches (EFB) are a by-product of oil palm plantations and are produced when palm oil is extracted. Singh et al. (2010) says that EFB is one of the most important waste products from the palm oil operation. EFB, which makes up about 22% of the weight of FFB, is the palm oil waste that is generated the most when oil palms are used to make oil. The general characteristics of palm oil biomass residue were taken from an earlier study (Salleh et al., 2018) and are shown below.

TABLE 1: General Characteristic of Palm Oil Biomass Residues per Ton of Processed FFB

Type of Biomass	**Empty fruit bunch (EFB)**	**Palm mesocarp fiber (PMF)**	**Palm kernel shell (PKS)**
Description	-fibrous type -utilised for mulching -dump on the field/ burnt	-fibrous type -solid fuel for steam boilers	-fibrous and solid type -more manageable in bulk -solid fuel for steam boilers
% of FFB (wet basis)	22.0	13.5	5.5
Gross CV (dry basis, MJ/kg)	18.88 ± 0.74	19.06 ± 0.32	20.09 ± 0.43
Moisture content (wt, %)	67.00 ± 1.41	37.09 ± 2.06	12.00 ± 1.08
Ash content	4.60 ± 0.50	6.10 ± 0.94	3.00 ± 1.27

Source: (Salleh et al. 2018)

2.3 Sustainable Waste Management Behaviour (SWMB)

SWMB is a set of patterns that include not making waste, buying green products, reusing and recycling, and getting rid of trash (Janmaimool, 2017). Past research has shown that the conceptual framework of SWMB has led to important results about how household residents plan to and deal with waste (Barr, 2007).

Researchers are very interested in learning more about the oil palm commodity because it is so useful and has been used in so many different ways. Their large amount of trash is also the main reason why most researchers are looking into how biomass can be used and changed into things like biofertilizers (Mahmud and Chong, 2021) and biochar (Ibrahim et al., 2021).

In this study, we will look into the SWMB by using the "3R" practises ("Reduce, Reuse, and Recycle"). The 3Rs are also called the order of waste control. Esmaeilifar, Iranmanesh, and Shafiei (2020) say that the 3R practises allowed them to set and align the SWMB approaches and put them into a number of groups, most of which were based on how willing people were to take care of waste. (Almasi, Mohammadi, Azizi, Berizi, Shamsi, Shahbazi, and Mosavi, 2019) This 3R technique is also very helpful, and it has been shown to give the community a lot of benefits, including more jobs, higher earnings, and more tax revenue.

SWMB research has also been conducted throughout the education area and in universities (Muniandy et al., 2021). As was said in the most recent study which was conducted by Muniandy et al. in 2021, they used the SWMB concept. The investigation found that a conceptual framework of SWMB can be employed to assess how Malaysian academics handle waste, and the researchers thought that the results of this study would help the management level in policy making.

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2.4 Factors That Influence the Sustainable Waste Management Behaviour (SWMB) In Palm Oil Mills.

2.4.1 Behavioural Intention

Intention is about how ready a person feels to do something and reflects how they think. Ajzen (2015) says that behavioural intentions are a strong predictor of action. The hypothesis says that intention has a good effect on how people handle food waste (Soorani and Ahmadv, 2019). People who act in ways that are good for the environment do things like employ less resources, generate fewer waste products, and recycle to lessen the negative affects they have on the environment (Kollmuss and Agyeman, 2002).

In recent years, the theory of planned behaviour (TPB) has been adopted a lot to study behaviours that have positive consequences for the environment. TPB is often used as a theoretical model in most studies because it is particularly effective at explaining pro-environmental goals. Many professionals agree with the basic ideas behind TPB, but its limitations have been questioned (Ajzen, 2011). In many TPB-based studies, researchers assume that goals and behaviours are interchangeable or very similar (Nguyen et al., 2019). Nevertheless, Fife-Schaw, Sheeran, and Norman (2007) say that changing a person's goal doesn't imply that the person's behaviour will shift as well. To close the gap between intentions and actions, researchers suggest looking at whether people have specific plans (called "implementation intentions") to change their behaviour.

2.4.2 Attitude

In general, an attitude is a response to something that happened, and it can be a good or unfavourable assessment of a person's behaviour over time (Ajzen, 1980). Attitude is also often defined as welcoming or rebuffing, warm or lukewarm, bad or good, or lukewarm. Many studies have used attitude as the major factor to measure SWMB because they know that this is an extremely important and crucial factor that affects human behaviour.

In waste management, a person's attitude will show how they feel about the way their actions affect the environment, such as recycling or saving energy (Norazah and Norbayah, 2016). The word "attitude" refers to a person's positive or bad feelings about others that affect how they act. Cash et al. (2022) thought that a person's attitude has the capacity to impact his or her behaviour, and that behaviour will shift in response to the person's attitude.

Despite that, Tam et al. (2018) has an opposing view on attitude. They say that people's attitudes and behaviours are very subjective and hard to predict. Because of this, it can be hard to figure out if these things have an effect on trash management. Also, they have done studies in the construction industry to find out how people in Australia feel about recycling. They looked at how people who work in the building industry feel about recycling and came to a good conclusion.

2.4.3 Subjective Norm

Subjective norms are the idea that an important person or group of people will encourage and approve of a certain behaviour. Ham, Jeger, and Frajman Ivkovi (2015) say that subjective norms are determined by a person's desire to agree with what other people think and their sense of social pressure from other people to act in a certain way. Previous study has shown that the effect of attitude is often stronger than the effect of subjective norms on deciding what to do.

Cheng (2020) did a study to look at the effect of subjective norm as one of the elements that affect how people sort trash at any waste sorting or disposal area. The households in Putrajaya, Malaysia, were the focus of the study, and researchers were able to get about 400 answers to perform the evaluation. Based on the results of this study, subjective norms have a moderate effect on and influence how households behave when it comes to waste segregation in sorting and disposal area.

Ham et al. (2015) suggests that the fact that the subjective norms attribute has different levels of significance could be because some of the data gathered through this variable is already in the acceptability for carrying out a certain behaviour variable. So, because the results of earlier studies seldom remain the same, we would like to investigate how oil palm plantation industry' subjective norms concerning SWMB affect their behaviour.

2.4.4 Perceived Behavioural Control

The belief of one's own capabilities and a sense of control over the circumstances can both be used to clarify perceived behavioural control, which is referred to as a combination of locus of control. Perceived behavioural control is defined as a person's opinion of their capacity to exhibit a particular behaviour and the ability to apply in the real life (Cheng, 2020). They ought to be inspired since they have the potential, resources, and skills needed to successfully execute waste segregation at the source. When exhibiting the perfect behaviour that is most likely to take place in this situation, they will no longer encounter any problem or inconvenience.

III. Methodology

This study collated and synthesised data from more than 20 years of observational research on SWMB across the palm oil industry in order to identify the factors that may influence the decision to carry out SWMB in that field. This study's findings have been explored in relation to the importance of context in identifying the variables that can affect SWMB in palm oil mills. Relevant data from academic papers has been gathered using a number of high-impact databases, including Emerald, Science Direct, and Social Science Database (Azam et al., 2021). The variables influencing sustainable waste management behaviors have been reviewed in more detail. Results from previous research on theoretical investigations have been incorporated into the discussion to enhance them.

IV. Discussion

SWMB was originally offered in a voluntary or institutional program roughly 20 years ago (Armijo de Vega et al., 2008). Despite the worrying scenario of increasing biomass waste disposal of oil palm at field, limited research has been undertaken towards oil palm mill in order to find the SWMB among millers in Malaysia. There have been studies on the conversion of oil palm biomass waste into valuable products such as biochar, feedstock, and so on. However,

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according to the study, not many oil palm plantation millers in Malaysia have implemented the advanced technology connected with this waste conversion practice in their mills. A large amount of oil palm waste, the most abundant waste created throughout the palm oil manufacturing process, EFB, is not effectively handled and processed. According to the study, this EFB is primarily disposed of directly to the field and is permitted to decay and decompose on its own without effective waste management being implemented by oil palm plantation millers nowadays.

Several studies have begun to use the SWMB conceptual framework in various sectors such as construction, to investigate human behavior toward waste disposal management (Begum et al. 2009; Wu, Yu, and Shen 2017). One of the investigations was conducted in 2009 and covered Malaysian building firms. Furthermore, this study discovered that the SWMB framework is capable of measuring contractors' attitudes and behaviors regarding waste management. Wu et al. (2017) did an additional investigation in China that used a construction site as a target industry to uncover the SWMB. However, the research indicated that the conclusion has little impact on contractors' adoption of waste management practices.

Additionally, there have also been SWMB studies conducted in the education or university fields (Muniandy et al. 2021). As previously stated, Muniandy et al. conducted a study in 2021 in which the SWMB concept was used, and the study discovered that a conceptual framework of SWMB is capable of measuring waste management behavior among Malaysian academics, and the researchers believed that the findings of this study will be able to aid the management level in the process of policy issuance.

According to Peng, Scorpio, and Kibert (1997), the six hierarchical disposal possibilities are reduced, reuse, recycle, compost, incinerate, and landfill, in that order. All these disposal options must be successfully coordinated in order to manage the generation of oil palm waste. However, Tam et al. (2018) concurred that the 3R principles of "Reduce, Reuse, and Recycle" are the most successful approach to manage waste.

Furthermore, according to the Report on Recycling Information, in order for a country to maintain its competitiveness in the economy, prosperity contribution, and environmental protection, citizens must practice less impacted material usage and integrate profitable behaviors. Nonetheless, applying 3R in SWMB towards industries, namely oil palm plantations, is a wonderful step, and this sector requires further examination given their lack of waste management in the field.

The various results of factors impacted SWMB across various sectors has led this research to be pursued. The limit study which focuses SWMB in palm oil industry has been a motivation to complete this research. And the curiosity of how behavioral intention will play a role in SWMB in oil palm mills Malaysia has been one of important driver in this research.

V. CONCLUSION

To the best of knowledge, no current research is concentrating especially on adoption behavior in the oil palm plantation industry. Malaysia's long-term implementation of sustainable waste management behavior has necessitated a broader and better understanding of the current situation in order to improve the policy's efficiency and efficacy. As a result, the goal of this study is to look at the effect of attitude, subjective norms, and perceived behavioral control on Malaysian oil palm millers' sustainable waste management behavior, as well as the incorporation of one antecedent which is behavioral intention. The findings of this study will provide updated current information about the factors that impact sustainable waste management behavior in Malaysia's Palm Oil Industry. The research will also help promote the development of sustainable waste management across Malaysian palm oil companies and support policymakers in understanding the holistic issue of implementing sustainable waste management for oil palm waste, particularly the EFB.

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