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# A SYSTEMATIC LITERATURE REVIEW ON ENVIRONMENTAL ISSUES AND CHALLENGES TOWARDS THE PALM OIL INDUSTRY

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**Abstract:** Environmental, social, and policy issues have presented numerous obstacles affecting the production, product quality, development, and business operations of the palm oil industry. This paper presents a systematic review of past literature to identify significant environmental issues and challenges faced by the palm oil industry to comprehend their impact on palm oil production, quantity, and quality. The PRISMA protocol was used, which resulted in eight articles for further review. These articles reported that climate change, a lack of land resources, and palm oil plantation diseases have been hampering the operation and production processes within the palm oil industry. These environmental issues have resulted in negative effects, such as decreased palm oil quantity and quality, deteriorated palm oil grade, and reduced annual production volume. Addressing these environmental threats requires joint efforts from the government, non-governmental organisations (NGOs), and the community.

Keywords: Climate change, palm oil industry, natural resources, plantation diseases, sustainable development.

## Introduction

Palm oil is mainly produced in Southeast Asian countries, with Malaysia and Indonesia being the two largest producers that account for the majority of global palm oil production and supply (RSPO, 2021). The palm oil industry plays a crucial role in the economies of producing countries by providing employment opportunities and contributing to government revenues. However, it is also associated with concerns regarding labour practices and income inequality. One of the major challenges associated with the palm oil industry is its environmental impact, particularly deforestation (Meijaard *et al.,* 2020). Large-scale conversion of forests into palm oil plantations has led to habitat loss for many endangered species, such as orangutans and tigers, and further contributes to greenhouse gas emissions (Nantha *et al.*, 2009; Meijaard *et al.,* 2020; Poor *et al.,* 2020). While sustainable practices and efforts to reduce deforestation have gained increasing attention in recent years (MPOB, 2020), effects from the natural environment on the palm oil industry should also stand as a concern since it has a huge impact on the industry.

The accelerated commercialisation of palm oil stems from its status as a beneficial product. Primarily, the antioxidant-rich oil is known to have a lowering impact on cholesterol levels (Thoenes, 2006). According to Hannah & Max (2020), palm oil production has increased rapidly over the past 50 years. In 1970, the world produced only 2 million tonnes of palm oil; the number is now 35 times higher, with 71 million tonnes of palm oil produced globally in 2018. Furthermore, palm oil is USD 200 per tonne less expensive than rapeseed, groundnut, sunflower, and soybean oil (Cheng, 2019). In 2011, palm oil met the demands of 3 billion people across 150 nations, with countries like Australia, China, and India accounting for 31.3% of the world's oil and fat consumption (Mark *et al.,* 2018). Apart from food applications, palm oil is also used for a variety of other products, such as cosmetics and

motor lubricants. It has become an increasingly significant agricultural commodity for tropical nations across the globe, particularly since crude oil prices have risen to unprecedented levels. Therefore, it is hardly surprising that palm oil plantations occupy millions of hectares throughout Malaysia, Indonesia, and Thailand (Peatlands, 2005; Dennis *et al*., 2021). In 2014, palm oil plantations spanned 6.78 million hectares of land in Indonesia, which is currently the world's biggest producer of palm oil (Hannah & Max, 2020).

Numerous environmental variables have caused a reduction in the productivity, quality, and efficiency of palm oil's production and distribution processes. The Sustainable Development Goals (SDGs) established by the United Nations (UN) propose a total of 17 goals that serve as a road map for the world to achieve a sustainable future (United Nations, 2020). In particular, SGDs Goal 12 "Responsible Consumption and Production" seeks to address and manage any food production issues, such as palm oil products, that arise as a result of human activities or environmental challenges. However, the goal is yet to be met due to a lack of a sustainably managed system and environmental factors that significantly reduce the quality and production of palm oil products.

Past research posits that natural disasters, such as droughts, floods, and wildfires, can disrupt palm oil production by damaging plantations, reducing yields, and causing supply chain disruptions (RSPO, 2023). Furthermore, climate change also poses significant challenges to the industry as palm oil cultivation is sensitive to specific climatic conditions and can be affected by rising temperatures or changes in rainfall patterns (UNEP, 2021, 2022). Climate variability can result in decreased yields and lower oil extraction rates, thus impacting productivity and profitability. Additionally, changing climate patterns can increase the frequency and intensity of extreme weather events, further exacerbating the industry's vulnerability to natural disasters (RAN, 2022). Also, the expansion of palm oil plantations has been a major driver of deforestation in several tropical regions, resulting in habitat loss, declined biodiversity, and increased carbon emissions (Greenpeace, 2018). The availability and allocation of land resources are therefore critical for the expansion of the palm oil industry; however, the environmental impact associated with the land-use change has drawn significant attention and criticism (RAN, 2023).

The Malaysian palm oil industry has been experiencing a tropical climate, which high temperatures, high humidity, and consistent rainfall can characterise. However, climate variability, including changes in rainfall patterns and extreme weather events, can impact palm oil production (MPOB, 2021). Adverse weather conditions such as droughts and excessive rainfall can have a considerable impact on the yield of palm oil plantations, resulting in reduced fruit development and increased susceptibility to diseases and pests. In Malaysia, periodic flooding, especially during the monsoon season, is a common occurrence that can cause significant damage to the plantations, disrupting harvesting and processing operations and leading to crop losses (Ferdous *et al.,* 2022). Additionally, the excess water can negatively impact soil fertility and facilitate the spread of diseases, exacerbating the situation (See Too & Narimah, 2021). Additionally, pests (e.g., red palm weevil) and diseases (e.g., Fusarium wilt and basal stem rot) can cause significant damage to palm oil plantations and reduce yields (MPIC, 2023). These arguments hence denote that the local palm oil industry is facing the challenges of managing pests and diseases that can affect oil palms.

Therefore, it is imperative for the Malaysian palm oil industry to explore solutions that can address these environmental challenges continuously. Sustainable plantation certification programmes like the Roundtable on Sustainable Palm Oil (RSPO) and Malaysian Sustainable Palm Oil (MSPO) have been introduced to ensure sustainability in oil palm cultivation while preventing environmental challenges from affecting its production activities and

sustainable practices. Thus, this study aims to assess the impact of environmental issues and challenges on the production and quality of palm oil products. The study outcomes aim to offer valuable inputs towards addressing challenges related to the domestic palm oil sector that arise from environmental factors.

## Materials and Methods

### *Reference Resources*

This study employed the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) to conduct a systematic study on the environmental difficulties and challenges faced by the palm oil industry. PRISMA is a publication standard with 27 components that are applicable to the Systematic Literature Review (SLR) creation procedure (Moher *et al*., 2009). It is commonly used in the fields of medicine and public health; however, its usage can be extended into social sciences following its efficiency in creating research questions and its methodical process for source searches. Moreover, PRISMA reduces prejudice and performs well in research synthesis (Sadie *et al.,* 2019).

### *Development of Research Questions*

This study used PICo as a research question development tool to identify the problem, interest, and context of the SLR. PICo is a mnemonic of three concepts, P (Problem), I (Interest), and Co (Context), that is used for the development of SLR research questions based on qualitative synthesis as well as to obtain the important elements and aspects required in developing the research questions (Lockwood *et al*., 2015). Following these concepts, the research questions for this SLR were constructed by determining (P) as Environmental Issues and Challenges, (I) as Palm Oil Sector, and (Co) as Impacts of Environmental Issues. This study specifically focused on identifying various environmental issues and challenges that have impacted oil palm cultivation in the palm oil sector.

### *Systematic Search Strategy*

Figure 1 provides an overview of the steps done in the application of SLR through the PRISMA protocol. It began with the formulation of the research questions, followed by identification, screening, eligibility, quality appraisal, as well as data abstraction and analysis. A total of 12 articles were selected for this study.

#### *i. Identification*

All resources for this study were gathered from the Scopus and Web of Science (WoS) databases. These databases were selected following their rigorous reviewing process. Ensuring the quality of the articles published on Scopus and WoS is of utmost importance to support the purpose of literature studies. This quality check guarantees that the articles meet the highest standards of excellence and credibility.

Numerous studies have been conducted to explore the problems faced by the palm oil industry. Thus, the thematic methodology was used in this study to search, screen, select, and filter existing articles to obtain the most relevant articles from the search engines. This process was utilised as it is an eligible and systematic way to ensure that the reviewed articles meet the quality standards and suitability as a source for SLR.

This study utilised string searching as its search strategy (Table 1). The advanced search approach was done by entering the codes and keywords that could lead to relevant articles. Additionally, string searching was employed to avoid irrelevant items. A list of articles was compiled using the search terms as shown in Table 1.

#### *ii. Screening*

The scope of the search results was limited to articles published between 2013 and 2022. In order to maintain consistency and standardise our article sources, the results were filtered to include only English-language articles. These filtering techniques were necessary to ensure that irrelevant articles were excluded, English-written content was included for

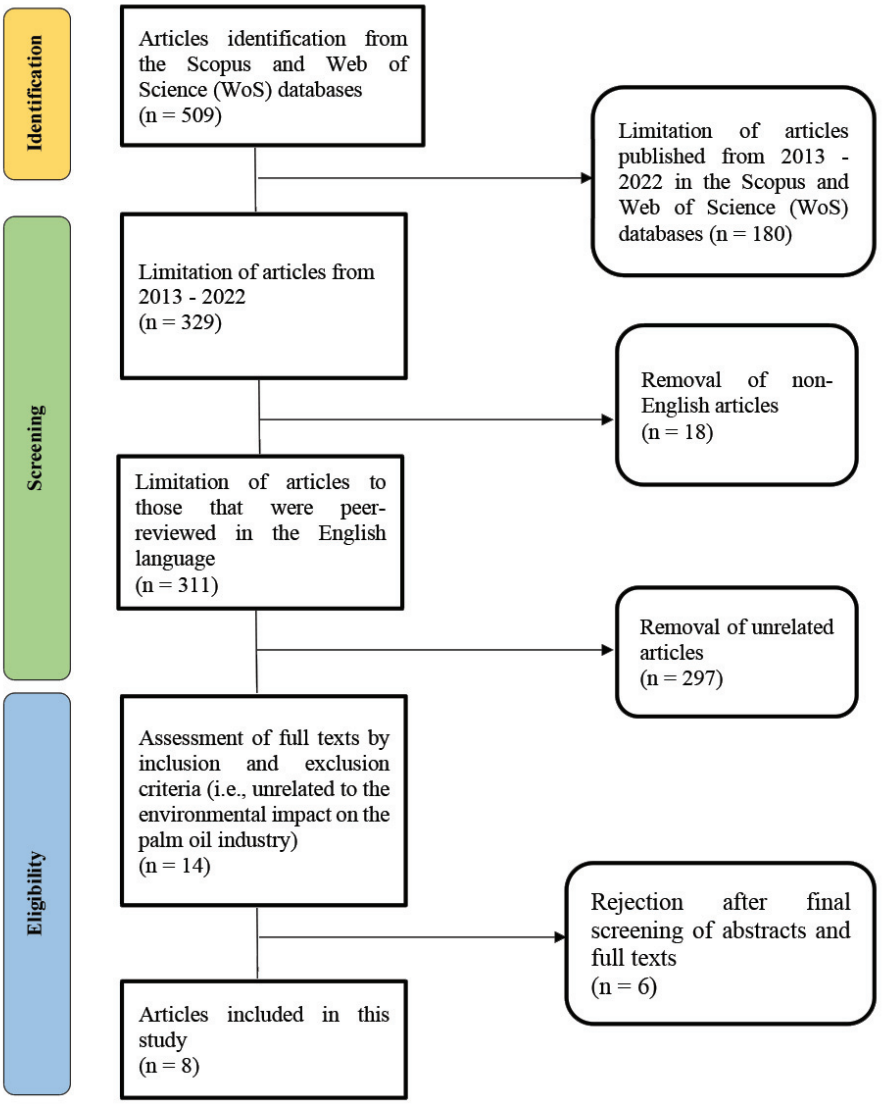


Figure 1: PRISMA Protocol Flow Diagram of the Systematic Literature Review (SLR) Process

uniformity purposes, and obsolete materials were eliminated. This study was not country-specific due to the scarcity of papers related to environmental issues and challenges faced by the palm oil industry.

The search results served as the foundation for the subsequent screening procedure. Relevant items were rejected according to the criteria specified throughout the screening procedure (Table 2). The screening procedure began by reviewing the title and abstract of every article. A total of 509 articles were associated with this study; however, only 311 articles were deemed appropriate for this SLR.

### *iii. Eligibility*

Following the screening process, a total of 311 articles underwent the eligibility phase to ensure that all resources found in the search engine were indeed relevant to the scope and topic of this study. The eligibility phase involved reading

Table 1: *Search string* to search articles from WoS and Scopus

| | |
|---|---|
| **Scopus** | TITLE-ABS-KEY("environmental challenges") AND ("palm oil industry") |
| | TITLE-ABS-KEY("environmental problems") AND ("palm oil sector") |
| | TITLE-ABS-KEY("nature challenges") AND ("palm oil industry" OR "palm oil sector") |
| **Web of Science** | TI ("environmental challenges") AND ("palm oil industry") |
| | TI ("environmental problems") AND ("palm oil sector") |
| | TI ("nature challenges") AND ("palm oil industry" OR "palm oil sector") |

Table 2: Screening criteria

| Criteria | Specifications |
|---|---|
| Type of Publication | Articles (review articles were excluded) |
| Language | English only |
| Timeframe | Nine years (2013-2022) |
| Type of findings | Empirical data |
| Focus of findings | Environmental issues and challenges faced by the palm oil industry |

the full texts of the selected articles to exclude any irrelevant articles. This would scrutinise the existence of any issues regarding the appropriateness of the articles' titles, abstracts, methodologies, results, and commentaries. Such a phase led to the rejection of 303 papers as the scope of these studies was limited to the effects of environmental challenges related to oil palm farming in the palm oil industry, which would jeopardise production and product quality. A final count of eight articles was found suitable for the review and used for the quality appraisal phase.

### *Quality Assessment of Articles*

All selected articles from the databases must undergo a quality assessment to minimise bias and to detect any articles with weak methodology (Edward *et al.,* 2019). Due to the various techniques employed by these articles, a Mixed Method Appraisal Tool (MMAT) was utilised to evaluate their quality. Additionally, these articles were evaluated using several standard criteria, in which (1) the research questions must correspond to the research topic and (2) the presented data must correspond to the research purpose. The evaluation using these criteria is known as a matrix or theme analysis. It was conducted by two field experts where all MMAT questions were addressed by either "Accept", "Reject", or "Not Relevant" if there was any ambiguity. Only articles that met the evaluation requirements were included as samples for this SLR. Following the quality appraisal, all eight articles underwent an in-depth review to extract relevant data and information.

### *Data Extraction and Analysis*

The article review phase began by reviewing the abstract and discussion of each article. A thorough examination of the articles' outcomes was done, if necessary, to obtain additional information from the sources of this SLR. The next step was to analyse the extracted data using qualitative synthesis, which is one of the best analyses for an integrative review (SLR) that combines multiple

research designs (Whittemore & Knafl, 2005). Several analysis techniques can be used for SLR; however, theme analysis is one of the best data analysis techniques for multiple research designs (Flemming *et al*., 2019). The utilised analysis technique is deemed appropriate for identifying research patterns from the extracted data. In order to acquire the most suitable theme(s) in line with the objectives of the SLR, the extracted data was segregated into three sub-themes, namely: i) Climate Change; ii) Land Use Degradation; and iii) Plantation Disease. Subsequently, these themes were summarised and validated to establish the final results.

## Results and Discussion

### *Description of Review Samples*

The present study reviewed eight (8) articles to accomplish the research objectives. Figure 2 shows the distribution of these articles by country concerning palm oil-related challenges caused by environmental factors.

### *i. Frequency of Issues Per Country*

Table 3 shows a list of articles selected for this SLR. A thorough review of the findings revealed that four articles ascribe environmental concerns as being problematic for the Malaysian palm

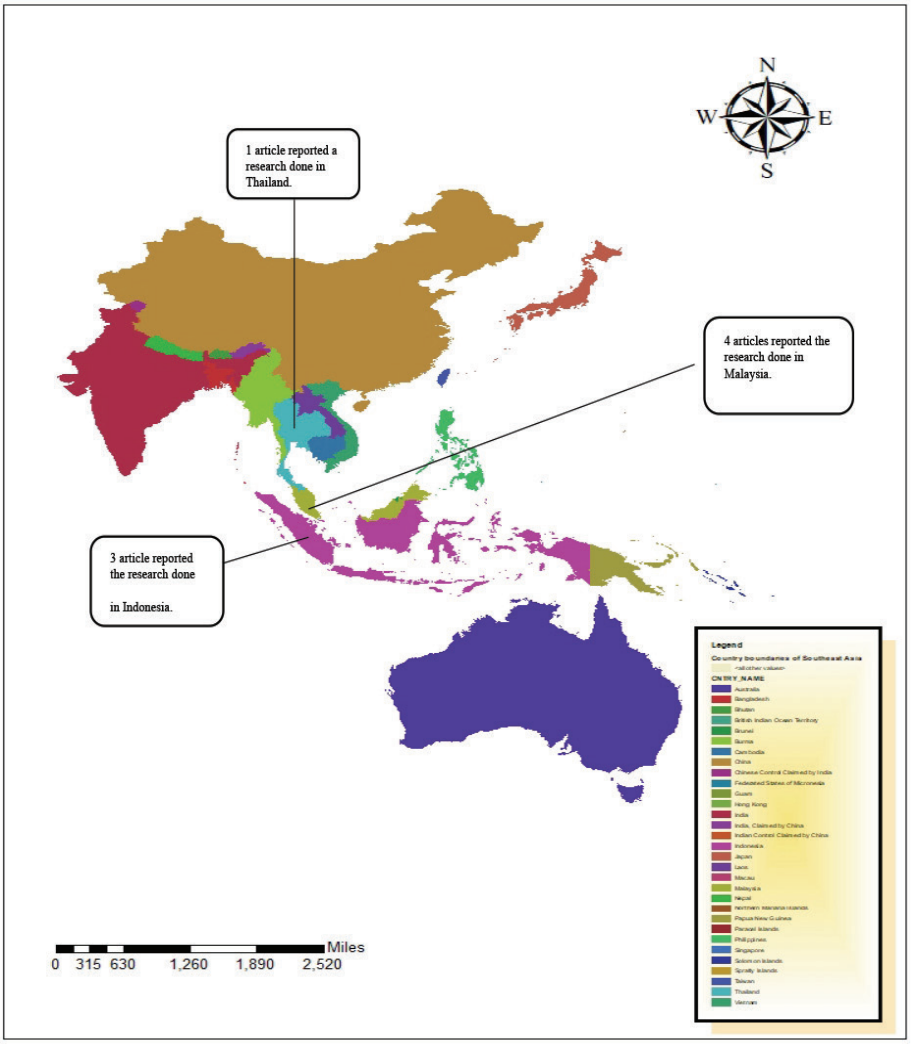


Figure 2. Distribution of articles by country

Table 3: List of selected articles for SLR

| Article | Year | Main Findings |
|---|---|---|
| Basyuni *et al*. | 2015 | Drought and flood |
| Peng *et al*. | 2018 | Land use issue<br>Land use prohibition policy towards the palm oil industry |
| Surahman *et al*. | 2018 | Forest fires<br>Transboundary haze pollution |
| Barthel *et al*. | 2018 | Palm oil plantation disease issue<br>Reduction of the palm oil production's quantity and quality |
| Sarkar *et al*. | 2020 | Palm oil disease due to environmental habitat changes |
| Santika *et al*. | 2020 | Climate change |
| Zamri *et al*. | 2022 | Scarcity of high-quality disease-resistant palm seeds<br>Plantation diseases outbreak<br>Decline in productivity |
| Nupueng *et al*. | 2022 | Plantation diseases due to soil contamination |

oil industry (Peng *et al*., 2018; Mark Barthel *et al*., 2018; Sarkar *et al*., 2020; Mohd Zamri *et al*., 2022). Environmental concerns include the scarcity of high-quality disease-resistant palm seeds, which consequently leads to plantation disease outbreaks (Mohd Zamri *et al*., 2022). Although it does not occur frequently, disease outbreaks have led to a decline in productivity. According to Abdul Hair (2019), one of the issues confronting the palm oil industry's long-term supply is the prevention of plantation disease. Resolving such problems can therefore increase productivity. Furthermore, three papers stated that environmental challenges affect palm oil cultivation and production in Indonesia (Basyuni *et al*., 2015; Surahman *et al*., 2018; Santika *et al*., 2020). Forest fires are a common phenomenon in many Indonesian plantations, which can sometimes spiral out of control, resulting in detrimental effects on the surrounding areas (Basyuni *et al*., 2015). Furthermore, this has contributed to the transboundary haze pollution. On the other hand, Thailand is grappling with land space constraints when constructing new palm oil plantations (Nupueng *et al*., 2022). This is because cultivating palm seeds for palm oil production requires arable land, which is further compounded by the scarcity of adequate land resources. As a result, the economic production of palm oil presents a significant challenge.

***Thematic Analysis***

This study used the thematic analysis technique to extract relevant data from the selected articles. The analysis allowed the present study to narrow the research topic by presenting the data in an organised manner.

***i. Climate Change***

Climate change has been reported to have a negative impact on sustainable palm oil production as climatic appropriateness declines, thus resulting in increased economic and social challenges across producing countries (Santika *et al.,* 2020). It can also lead to changing weather patterns, including more extreme weather events such as droughts and floods. This may impose a significant impact on palm oil production, particularly if it occurs during critical phases of the palm oil production cycle, such as flowering and fruit development. Extreme weather can also result in reduced yields, which can affect the profitability of the palm oil industry. Poleward shifts in climate-related plant ranges are by far the most often documented with minimal observations on whether poleward shifts in regions are suited for oil palm development (Santika *et al.,* 2020). The influence of future climates on the adaptability of oil palm cultivation in a global context has

been observed, as well as how species may respond to climate change. Palm oil cultivation requires specific temperature ranges for optimal growth and production; hence, temperature changes can affect the growth and yield of oil palms. For example, a temperature that is too high or too low can prompt reduced growth and lower yields.

Furthermore, climate change can affect water availability, which is a critical factor in the cultivation of palm oil. Therefore, both floods and droughts are believed to have significant impacts on the industry. Droughts can have a particularly severe impact on palm oil production due to the extensive water requirement of oil palms. The absence of sufficient water will reduce the growth and yield of these trees, leading to lower productivity and profitability. Additionally, droughts can exacerbate soil erosion, which can damage the root systems and reduce the trees' ability to absorb water and nutrients. It can also cause wildfires that destroy palm oil plantations and further reduce yields. These arguments highlight the prominence of drought and changes in rainfall patterns that can reduce the amount of water available for the irrigation of oil palms, subsequently reducing yields and lowering productivity.

Floods also have significant impacts on palm oil production, particularly if they occur during critical phases of the production cycle, such as flowering and fruit development. The occurrence of floods can potentially damage the root systems of oil palms and reduce their ability to absorb water and nutrients while also promoting soil erosion and decreased soil fertility, subsequently further reducing yields (Basyuni *et al*., 2015). Additionally, floods can increase the incidence of pests and diseases, which will reduce yields and increase the costs associated with pest and disease management.

Suitable oil palm climate impact data was used to develop mortality schemes based on the hypothesis that large degrees of unsuitable and marginal climates, in particular, were likely to result in high levels of mortality. Furthermore, reductions in highly suitable and/or better-suited crops would not affect oil palm mortality. In order to estimate the potential impact of climate change on the growth of oil palm, simulation modelling was employed to estimate the mortality rate resulting from unsuitable climatic conditions. Suitable climate scenarios for oil palm growth were determined to estimate changes in climate suitability and anticipate potential impacts (Santika *et al*., 2020). The percentage of oil palm mortality predicted in Southeast Asia and Latin America was calculated and extrapolated to Malaysia and Indonesia (Santika *et al*., 2020). Because of the large numbers grown in these countries, these percentages represent large numbers of oil palms in Malaysia, Indonesia, Thailand, and Papua New Guinea.

Santika *et al.* (2020) forecasted climate suitability losses in nearly all regions where palm trees occur in Africa, and CLIMEX modelling revealed that Africa would have less favourable climatic conditions for oil palm farming. However, clear longitudinal trends to prospective refugees from West to East Africa were discovered, which could allow oil palm to persist naturally or through the establishment of new plantations in the continent's east, with environmental concerns being of crucial importance (Sarkar *et al.,* 2020). The study predicted an increase in the appropriate climate over time, which implied a more unfavourable climate for the cultivation of oil palms in the central part of South America (Sarkar *et al.,* 2020). Increasing longitudinal trends in favourable climates for oil palm cultivation were found from the present year to 2050 and 2100 from west to east in Southeast Asia. According to Sarkar *et al.* (2020), an enhanced model for predicting the appropriate environment for oil palm cultivation in Africa is imperative to validate the west-to-east trend and it can be applied to other regions, such as South America and Southeast Asia.

Meanwhile, a significant negative relationship was found between annual average temperature and sea level rise with oil palm production in Malaysia, with rises of 1°C to

4°C potentially causing oil palm production to decrease by 10% to 41% (Sarkar *et al.,* 2020). Future changes to suitable climates for growing oil palm worldwide were considered using modelling based on temperature, soil moisture, and wet stress data (Sarkar *et al.,* 2020). The general predictions were focused towards a reduced level of suitable climatic regions by 2050 and further reductions by 2100. The projections indicate serious consequences for the oil palm industry generally. In Africa, the climate is predicted to be less suitable for growing oil palm at the same rate or faster than in Malaysia and Indonesia, except for Uganda where increases in climatic suitability are predicted. Paraguay appears to be gaining a suitable climate for growing oil palm in South America, whereas Venezuela will have a particularly low level of suitability in its climate.

Moreover, countries like French Guiana, Suriname, and Guyana appear to maintain suitable climates and large losses will be determined in west Brazil by 2100. The Western countries of Colombia, Peru, and Ecuador will suffer severe losses in suitability due to climate. Furthermore, there was a three-phase trend in suitable climates rather than a single direct longitudinal change. By 2050, Vietnam, the Philippines, Papua New Guinea (PNG), and Malaysian islands will have increased their suitable climate. In particular, large decreases in suitable climates are predicted by 2050 for the west of Southeast Asia, particularly Thailand, Laos, and Cambodia (Santika *et al.,* 2020).

These findings suggest that climate has an important role in defining the range limits of oil palm distribution by exerting eco-physiological constraints (Santika *et al.,* 2020). However, factors such as soil properties and biotic interactions may prevent plants from colonising sites that are otherwise suitable. Climate change can exacerbate these impacts by altering the distribution and abundance of species that are important for biodiversity conservation. This can have long-term impacts on ecosystem services that are vital for the sustainability of palm oil production.

### *ii. Land Use Limitation*

Land use limitation can have a significant impact on the palm oil industry as it requires large areas of land for cultivation. According to Peng *et al.* (2018), 1.37 billion hectares of land are suitable for oil palm development across the world, with those from twelve tropical nations accounting for 84% of all suitable lands. However, not all of these prospective lands can be used for palm oil cultivation as land use policies often require federal governments' approval in addition to the plantation areas quota imposed by the urban planning departments of certain nations. Aside from that, palm oil plantations may degrade soil quality and cause land degradation. This prompts many governments to regulate land use quotas for the palm oil industry closely.

Such limitation of land use may cause a significant reduction in the overall production of palm oil, ultimately affecting the profitability of the industry. It will also impact smallholder farmers because many of them depend on palm oil production as a source of income. Moreover, land use limitations due to government policies may force the industry to resort to forest clearing to expand their plantation areas. This will lead to severe deforestation that can cause habitat and biodiversity loss and further contribute to climate change. Ultimately, limiting land use for the expansion and cultivation processes in the palm oil industry will affect the economies of countries that heavily rely on the palm oil trade.

### *iii. Palm Oil Plantation Diseases*

Diseases (e.g., fungal, bacterial, viral, pests) stand as a major challenge for the palm oil industry as they can cause significant damage to oil palms, reduce yields, and increase production costs (Barthel *et al*., 2018). A common palm oil disease is Basal Stem Rot (BSR), which is caused by the *Ganoderma boniness* fungus and can lower yields by 50% to 80%. Recent decades have seen faster dissemination of BSR as a result of foci infection following repeated cycles of crop planting in contaminated locations. In Malaysia, BSR has been found in young plants and seedlings where previously only old oil

palms had been affected (Barthel *et al.,* 2018). The disease may kill up to 80% of plants by the time an oil palm tree stands halfway through its 25-year economic lifetime. Furthermore, the greatest level of illness was found in Sumatra, which shows a link between the length of time for palm trees' cultivation and greater disease concentrations.

According to Barthel *et al.* (2018), BSR is becoming more common in interior Peninsular Malaysia and Sabah, and it has been identified at high levels in regions where it has never existed before. Regardless of cropping history, significant concentrations of BSR were found in oil palms planted on inland lateritic and peat soils, despite the fact that such soils had previously been disease-free. In other areas, 40% to 50% of palm trees had died at the time of replanting (every 25 years), with the bulk of standing palm trees displaying disease signs. This data points to a rise in BSR as a result of expected climate change. On the other hand, the climate is currently ideal for cultivating oil palms. The previously observed rise in illness was attributable to enhanced fungal virulence rather than increased sensitivity of oil palms owing to a less suitable environment. Natural selection of more virulent strains may boost BSR further, and oil palms cannot always quickly adapt and respond to changes in pathogen virulence.

Over half of its economic life period, the BSR pathogen is capable of infecting oil palms at a rate of up to 80% incidence (Barthel *et al.,* 2018). Ganoderma is a diverse genus with a lack of clearly defined species and it will adapt to climate change more quickly than oil palms through the natural selection of more virulent strains (Sarkar *et al.,* 2020). BSR is less severe in Kalimantan than in Sumatra, Indonesia, owing to younger crop rotations. The prevalence of BSR in Thailand is quite low with a reported rate of 1.53%, but it is more prevalent in the south (Basal stem rot of oil palm in 2020). The closeness of Peninsular Malaysia, where illness rates are equally high, may impact BSR incidence in Southern Thailand (Nupueng *et al.,* 2022).

In Papua New Guinea, the incidence of Basal Stem Rot (BSR) is relatively low as compared to other Southeast Asian regions, yet some locations have reported infection rates as high as 50%. However, given the lower initial incidence than in Malaysia and Indonesia, there is a possibility of a 25% infection rate in this nation. The country of Myanmar, on the other hand, is likely to have a rare occurrence of BSR due to the newer plantation setup and greater distances between them. Additionally, the country's unique climate conditions differ significantly from other Southeast Asian regions, making it less suitable for oil palm cultivation (Nupueng *et al.,* 2022). Furthermore, Peninsular Malaysia and Sabah have a substantially higher disease incidence than Sarawak. As a result, Sabah may be a more sustainable location in terms of BSR incidence. On the other hand, both Sumatra and Java have an unusually high prevalence as n compared to other places in Indonesia, such as Sulawesi and Papua. These scenarios reveal probable places that could be suited for the industry's long-term viability.

Researchers have also reported acute and chronic wilt of oil palm caused by *Fusarium Oxysporum elaeidis* (FOE), which is found primarily in Africa (Mohd Zamri *et al.,* 2022). Quarantine mechanisms have been successful in keeping FOE out of Malaysia and Indonesia, while native strains may infect oil palms in vitro. Avoiding importation from endemic areas is crucial to prevent FOE in locations where it is not commonly found. However, breeding materials from Africa must be imported to promote genetic variety in Malaysia and Indonesia, subsequently posing a danger of contaminated seeds and pollen. Although quarantine protocols are implemented in Malaysia and Indonesia, there is still a possibility of illness spreading, especially because climate change may exacerbate the problem (Mohd Zamri *et al.,* 2022).

In the Ivory Coast, vascular wilt signs were seen in 20% of oil palms planted between 1964 and 1967, with certain crosses reaching 70% (Mohd Zamri *et al.,* 2022). However, 2% of vascular wilt rate was documented from 1976 to

1983, and symptoms in plantations were difficult to locate in the 1990s. These decreases were ascribed to resistance breeding. FOE infection of oil palms was common in Ghana with infection rates of 10.4% and 8.3%, respectively, and FOE was present in approximately 11% of symptomless palms in plantations. Additionally, Mohd Zamri *et al.* (2022) found that Malaysian oil palms were susceptible to infection from the African FOE strains.

*Phytophthora palmivora* is a fungus-like oomycete that causes serious damage to oil palms in Latin American nations such as Colombia (Barthel *et al.,* 2018). The illness has recently ravaged more than 30,000 hectares in South West Colombia and more than 10,000 hectares in the Central Zone, with its fast spread linked to climate change. *Phytophthora palmivora* has acute and chronic variants, and multiple separate diseases have likely been labelled with the same term. For instance, countries like Colombia and Ecuador were reported to have the acute types, whereas Brazil has the chronic versions (Barthel *et al.,* 2018). Although a comparable spear rot of oil palms with a possible trace of *phytophthora palmivora* has been documented in Africa and Thailand, no reports of the disease have been made in Malaysia or Indonesia. Many additional oomycete hosts occur in Malaysia and Indonesia (e.g., durian) and *phytophthora palmivora* poses a danger to Malaysian and Indonesian plantations, especially in light of a recent major epidemic in Colombia. Given that the outbreak of *phytophthora palmivora* may pose serious issues for large Southeast Asian oil palm businesses, further infectivity analyses are therefore required. Fungi from other oil palm species are also affected by several minor fungal infections (Barthel *et al*., 2018).

Bunch failure is a disease caused by the basidiomycete *Marasmius palmivorus* that causes oil palm fruit bunches to fail to grow from anthesis to harvest. *G. philippii*, a closely related basidiomycete to *G. boninense*, is a trunk rot of Acacia trees that is also recognised as an oil palm disease (Barthel *et al*., 2018). Due to climate change, this species may become more separated from oil palms. *Phellinus noxius* is a basidiomycete that causes upper stem rot in oil palms and, in certain circumstances, co-occurs with *G. boninense*.

## Discussion

### *Palm Oil Sustainable Management*

The palm oil industry relies heavily on environmental conditions for the growth, production, and distribution of oil palm plantations (Cheah *et al.,* 2023). According to previous studies, climate change, land use restrictions, and palm oil plantation illnesses are among the challenges for the palm oil sector. These environmental concerns led to a deterioration in the quality of palm oil seeds, while uncertain weather conditions affected palm oil plantations. Such a problem may also reduce the quality and quantity of palm oil products. Nur Hafiza *et al.* (2021) reported that climate change is one of the challenges confronted by oil palm smallholders in operating their palm oil plantations. The monsoon season often witnesses the occurrence of floods that create challenges to harvesting palm seeds and planting palm trees. This climate calamity has made it impossible for them to regularly collect palm oil fruits, resulting in fewer fruits being processed in mills. The lack of palm oil crops will result in price increases due to the market deficit of palm oil.

Land use change is another issue to consider following the lack of suitable lands for palm plantations given the current rate of expansion (Hor, 2022). The optimum soil for planting oil palms is peat soil; however, peak development has shifted the land use pattern and less appropriate lands can now be designated as palm plantation zones. For instance, Johor has numerous peat soil types that are excellent for palm growing, but the state government decided to develop the strategic regions due to the high population density (Azima *et al.,* 2018). This can lead to a lack of suitable areas for palm oil crops.

Furthermore, environmental or natural variables, such as plant diseases, may cause

significant difficulty to the palm oil sector. Various diseases can negatively impact palm oil plantations and fruit quality. For instance, defoliation by bagworm and limacodids was found to affect crop production by more than four tonnes of fresh fruit bunches (FFB) per acre in Johor Bharu, Malaysia (Wood *et al.,* 1973). The expansion of plantation viruses in a given region due to modifications in the biology of the soil, plants, and animals is a common natural cause of palm disease. Consequently, the absence of effective disease management to curb the rapid spread of such illness will impose the palm oil industry with significant challenges. Past studies reported that low-quality palm oil products have become increasingly pertinent due to the prevalence of certain diseases. A survey conducted in North Sumatra found that between 40% to 50% of oil palms were infected after five years of replanting and resulting in a 35% drop in yield production, with the illness having the potential to reach approximately 65% to 75% in the next seven years (Subagio *et al.,* 2003).

The current research has the potential to address an existing research gap by highlighting the environmental aspects that are of utmost importance to the palm oil industry. The study found only eight relevant papers from the Scopus and Web of Science (WoS) databases, indicating a significant gap in the existing literature on the subject. Therefore, conducting this study could help identify and bridge the gap, enhancing the relevance of the subject matter and paving the way for future research in this direction. Past studies were mainly focused on climate change, land use limitation, and diseases; these three issues have formed the thematic results and findings of this study. However, the fact remains that there are numerous other environmental factors, such as the La-Nina and El-Nino phenomena, that may impose adverse effects on the palm oil industry, including its stakeholders like oil palm smallholders and industry players.

Existing evidence discovered that climate change is a major challenge for the palm oil industry, as it is for many other agricultural sectors. To address such issues, the industry is currently focusing on sustainable practices that can promote climate resilience, including the use of drought-resistant palm oil varieties and the implementation of agroforestry systems to promote soil health and biodiversity (Cheah *et al.,* 2023). The palm oil industry is also working to reduce greenhouse gas emissions associated with palm oil production through means like the use of renewable energy sources and improved waste management practices (MPOB, 2023).

Limitations on land use also carry a major commodity to the global palm oil industry. However, various strategies can be pursued to promote sustainable palm oil production, such as improving land management practices, exploring alternative crops, and promoting sustainable land use policies (RSPO, 2023). All stakeholders, including governments, companies, civil society, and consumers, must work together to ensure that palm oil production is sustainable and does not come at the expense of the environment and communities.

Furthermore, federal governments and other stakeholders play an important role in addressing the impacts of climate change on the palm oil industry (RSPO, 2023). This includes implementing measures to promote sustainable land use practices that can reduce greenhouse gas emissions, such as reforestation and improved land management practices. Governments can also promote the development and use of sustainable palm oil production practices through policy incentives and regulations, as well as increasing their support for the research and development of new technologies and practices (Nanthan & Tisdell, 2011). These initiatives can promote sustainable practices and mitigate the impacts of climate change, thus ensuring that the palm oil industry remains a sustainable and vital source of livelihood for millions of people around the world (Poor *et al.,* 2019).

Another major challenge to the palm oil industry is diseases, which can affect both the growth and yield of oil palms and the overall productivity and profitability of the industry. To address such challenges, more palm oil

producers are opting for sustainable and integrated pest management practices, which emphasise the use of natural enemies, crop rotation, and cultural practices to control pests and diseases. Additionally, the development of disease-resistant varieties of oil palms is an important area of research as well as the use of biological control agents, such as Trichoderma and Bacillus species, to control soil-borne diseases.

This comprehensive literature review has revealed significant evidence regarding natural influences that exert significant impacts on the oil palm smallholder community as well as the production process. The findings of this study are valuable for future researchers to make informed decisions aimed at reducing negative environmental impacts on smallholders. Furthermore, this study provides policymakers with crucial insights and fundamental ideas to consider before formulating any policies or guidelines addressing this issue.

This study found that natural disasters not only have negative impacts towards the Malaysian palm oil sector but also on other countries such as Indonesia and Thailand. Previous studies have investigated the effect of the palm oil sector on the natural environment; however, there is a lack of research investigating how the environment affects the palm oil sector. The main objective of this study is to compile relevant research that can serve as a reference for the government, local stakeholders, smallholders, and the community. It will also increase general awareness towards these problems and provide a clearer understanding of the challenges posed by the natural environment to the palm oil sector, subsequently reducing financial losses, safeguarding community income, and addressing plantation issues in the palm oil industry.

## Conclusion

Palm oil has established itself as a valuable worldwide commodity, with its production and commercialisation being vital to the economies of the producing nations. The oil is high in antioxidants, has a low cholesterol impact, and costs less to produce than rapeseed, peanut, sunflower, or soybean oils. However, several obstacles may deteriorate the industry's productivity and product quality: (i) climate change, (ii) land use restrictions, and (iii) plantation or crop illnesses. This study summarises the environmental challenges that may cause a reduction in the output and product quality of the palm oil industry. The findings hope to provide insights for relevant stakeholders to apply sustainable approaches or practices that can reduce the impact of these environmental challenges towards the industry. Additionally, it is recommended that all players in the palm oil industry participate in certification schemes, such as the Roundtable on Sustainable Palm Oil (RSPO), to promote sustainable palm oil production and reduce the risk of these unsustainable impacts.

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