

Oil Palm Industry Economic Journal

O P I E J

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CHALLENGES AND OPPORTUNITIES FOR INTENSIFYING OIL PALM CULTIVATION IN WEST-CENTRAL AFRICA, USING A CASE STUDY OF GHANA

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ABSTRACT

The global demand for palm oil, an economically important product in tropical regions, continues to rise rapidly. To meet this demand, there is a focus on expanding oil palm production, particularly in Latin America and Africa. However, in West and Central Africa, biophysical constraints, such as sub-optimal climate conditions and poor management practices, limit yields. Socioeconomic issues, including a lack of skilled labour and disorganised industry expansion, further hinder production. Opportunities for intensification are thus considerable in West Africa, where fresh fruit bunch (FFB) yields are ~56% lower than those of major producers in Southeast Asia and ~47% lower than in Latin America. This study reviewed opportunities for yield intensification in oil palm cultivation, using Ghana as a case study, while considering both agronomic and socio-economic factors. Findings suggest that increases in palm oil production may result from increased fruit supply from smallholders, who are the dominant producers in Ghana (~95%) and promoting specific practices for yield intensification, such as improved harvesting and nutrient management. Increasing average yields to a biophysically achievable 21 t ha⁻¹ could significantly boost national FFB production, potentially eliminating the need for additional land, and meeting Ghana's current annual demand for crude palm oil without expansion. Yield intensification strategies could therefore underpin effective strategies for agricultural intensification in Ghana and the broader West-Central Africa region. Achieving this requires collaborative efforts between industry stakeholders, including plantations, smallholders and government intervention.

Keywords: land sparing, plantation, smallholder, yield gap, yield intensification.

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INTRODUCTION

Oil palm (*Elaeis guineensis* Jacq.) is an important crop for food production globally and for economic development in tropical regions. More than

80% of palm oil is produced in Indonesia and Malaysia where 90% of the area under oil palm cultivation occurs within 10° of the Equator (Food and Agriculture Organization [FAO], 2023; Lim *et al.*, 2011; Paramanathan, 2003; Rhebergen, 2019). The crop contributes 35%-40% of global vegetable oil production and plays a key role in driving economic development in many tropical regions (Corley, 2009; FAO, 2024; Griffiths *et al.*, 2002; Hansen *et al.*, 2015; Rhebergen, 2019; World Wildlife Fund [WWF], 2022). It is a highly efficient crop in terms of input use, and delivers the highest oil yield among oil-producing crops (De Vries *et al.*, 2010).

Driven by rising global demand for vegetable oil (Corley, 2009), there has been a rapid expansion of the area under oil palm, with the cultivated area expanding from 3.6 million hectares in 1961 to

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28.7 million hectares by 2020 (FAO, 2023). Using FAO data, the rate of oil palm expansion over the 2000-2020 period was 983,000 ha yr⁻¹, greater than cocoa (258,000 ha yr⁻¹), rubber (285,000 ha yr⁻¹) and rice (782,000 ha yr⁻¹), but less than soybean (2,707,000 ha yr⁻¹). While the FAO data on vegetable oil production may have various limitations, such as data gaps and inconsistencies, they remain a valuable point of reference (Jannot, 2013). With a continued projected increase in demand for palm oil in the coming decades and limited undeveloped land in Southeast Asia, the industry is expected to expand mostly in Latin America and Africa (Jannot, 2013; Laurance *et al.*, 2014; Rhebergen, 2019; Sayer *et al.*, 2012). In Africa, expansion is encouraged not only by the availability of low-cost land but also by relatively cheap labour, low taxes and proximity to key markets in Europe and the Middle East (Jannot, 2013). Increases in production to date have been achieved mostly through the expansion of the cultivated area, and average yields remain far below the potential (Donough *et al.*, 2009; Rhebergen, 2019; Sayer *et al.*, 2012).

Improvements in productivity are critical for addressing challenges including a rapidly changing climate, growing competition for good quality agricultural land and the growing imperative for environmental stewardship (Bryan *et al.*, 2014; Rhebergen, 2019; Sayer *et al.*, 2012; Tilman *et al.*, 2017). Intensification and improvement in resource use efficiency are considered two of the most promising approaches for increasing agricultural productivity (Bryan *et al.*, 2014; Khatun *et al.*, 2017; Rhebergen, 2019; Sayer *et al.*, 2012; Wessel & Quist-Wessel, 2015; Woittiez *et al.*, 2017). Such intensification entails bridging the yield gap between current farmer output and the potential yields attainable through best practices and existing technology in a specific environment (Guilpart *et al.*, 2017; Lobell *et al.*, 2009; Rhebergen, 2019; Sayer *et al.*, 2012).

There are considerable opportunities to intensify palm oil production, which will provide net benefits for production and the environment. Although some expansion of the cultivated area may be justified (Corley, 2009), closing 'yield gaps' on land already planted to oil palm will contribute to production whilst avoiding negative environmental impacts associated with expansion (Griffiths & Fairhurst, 2003; Griffiths *et al.*, 2002; Rhebergen, 2019; Sayer *et al.*, 2012). Yield intensification, together with concomitant conservation of large reserves ('land sparing'), provides greater net production and biodiversity benefits than efforts to maintain biodiversity (apart from that directly beneficial to productivity) within plantations (Phalan *et al.*, 2011; Soliman *et al.*, 2016). This is contingent upon the implementation of measures related to habitat connectivity

(Grass *et al.*, 2019). Ecological intensification aims to increase yield per unit of land, approaching the potential yield of farming systems, while maintaining acceptable standards of environmental stewardship (Fairhurst & Griffiths, 2014).

Opportunities for intensification are likely to be large in West and Central Africa, due to low current productivity (Figure 1). Despite the Gulf of Guinea in West Africa being considered the centre of origin for oil palm (Simmonds, 1976; Zeven, 1964), the region's current fresh fruit bunch (FFB) yields (average ~8.0 t ha⁻¹) are considerably lower than those in Southeast Asia (average ~18.0 t ha⁻¹) and Latin America (15.0 t ha⁻¹), due to less suitable climatic conditions and suboptimal management practices, particularly among smallholder farmers (FAO, 2023; Paramanathan, 2003; Rhebergen, 2019). Ghana is typical of the West African countries in which oil palm is grown, and distinctly different from the main producing countries, Indonesia and Malaysia (Jannot, 2013; Ruml *et al.*, 2022). In Ghana, the oil palm sector is predominantly characterised by smallholder-driven production systems, in contrast to Southeast Asia, where large-scale industrial plantations dominate. The scale of industrial operations in Ghana is comparatively limited, with plantations being significantly smaller. For instance, the largest industrial oil palm plantation in Ghana, the Ghana Oil Palm Development Corporation (GOPDC), spans approximately 15,000 ha across two estates (<https://www.gopdc-ltd.com/>). By comparison, SD Guthrie in Malaysia operates on a much larger scale, managing nearly 310,000 ha across 121 estates (<https://www.sdguthrie.com/>).

This review focuses on Ghana as a case study to explore the concept of yield intensification in oil palm through a systems approach that integrates both agronomic and socio-economic perspectives. The results of a four year yield intensification project, implemented by the International Plant Nutrition Institute (IPNI) and Solidaridad West Africa, are synthesised to identify factors limiting palm oil production in the country. Using the yield gap concept, opportunities for increasing production are examined. This article aims to highlight the significance of yield intensification in enhancing the sustainability of oil palm production systems and the livelihoods of those involved.

YIELD GAPS IN OIL PALM

Yield gap analysis has been applied to systematically assess food security and opportunities for increasing production of various crops at various scales (Guilpart *et al.*, 2017; Van Ittersum *et al.*, 2013). It identifies the factors responsible for yield gaps, and how they might be mitigated, in a two-step process.

The first step is to quantify the yield gap, which is the difference between the potential yield and the actual yield. Potential yield may be 'non-water-limited' (where sufficient irrigation water is available) or 'water-limited' for rainfed crops. The next step is to identify the factors contributing to the yield gap, which allows remedial measures to be devised and implemented (Lobell, 2013).

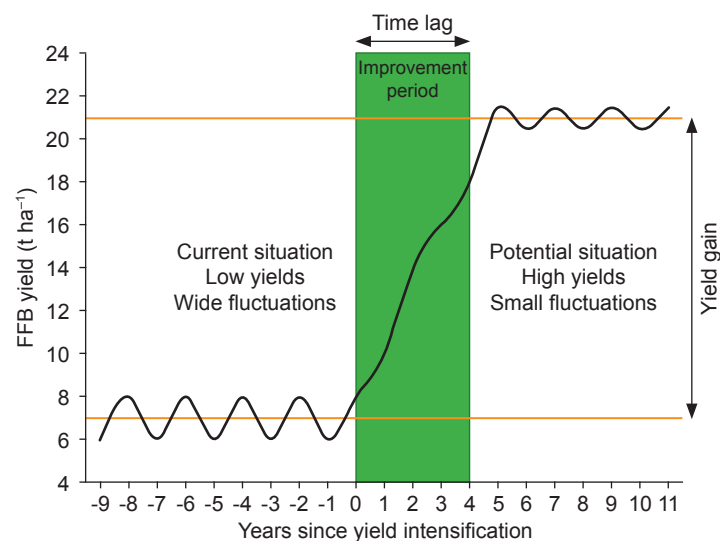
Yield gap analysis in oil palm is challenging for several reasons (Hoffmann *et al.*, 2017). Most yield gap analyses have been for annual crops such as cassava (Fermont *et al.*, 2009), wheat (Aggarwal & Kalra, 1994; Anderson, 2010; Bell *et al.*, 1995), rice (Laborte *et al.*, 2012; Yang *et al.*, 2008) and other cereals (Neumann *et al.*, 2010). By comparison, perennial crops have received little attention (Euler *et al.*, 2016; Hoffmann *et al.*, 2017; Woittiez *et al.*, 2017). A modified approach is required because perennial crops are structurally different to annual crops (Rhebergen, 2019; Rhebergen *et al.*, 2018). For instance, annual crops allow growers to benefit from new seeds each growing season, while perennial crops have a fixed genetic yield potential for their crop cycle, which lasts at least 25 years for oil palm (Woittiez *et al.*, 2017). Additionally, similar to other perennial crops such as rubber, cocoa and coffee, oil palm experiences 6-36 months delay between stressful events and a negative impact on yield (Breure, 2003; Fairhurst & Griffiths, 2014; Rhebergen, 2019). This delay makes it challenging to identify and quantify the effects of specific factors (Rhebergen, 2019; Woittiez *et al.*, 2017). For example, a period of water or nutrient stress at any time during flower and fruit development may drastically reduce eventual yield. These time-lagged effects must be accounted for when assessing yield gaps (Hoffmann *et al.*, 2017). Moreover, deficiencies

in management practices such as incomplete, infrequent, or incorrect harvesting (*i.e.* harvesting unripe or overripe bunches) directly translate to lower yields (Donough *et al.*, 2010; Fairhurst & Griffiths, 2014; Rhebergen, 2019). Yield gap assessment in oil palm is further complicated by the disparity in practices among farm types, which range from smallholder farms of <10 ha to large-scale plantations of >10,000 ha (Rhebergen, 2019).

When assessing yield gaps and devising interventions, it is crucial to differentiate between annual and perennial crops. In annual crops, opportunities to close the gaps generally arise between crop cycles. For perennial crops, yield gaps can be addressed within a cropping cycle, though there may be time lags between implementing corrective agronomic measures and observing their effects on yield (Figure 1). Additionally, yield gaps might be reduced between crop cycles by using improved germplasm and improving practices employed to establish the crop and manage it during the immature stage (Rhebergen, 2019).

Management regimes that integrate yield intensification with environmental goals are commonly called "Best Management Practices" (BMPs). These are practical and cost-effective agronomic means to reduce the yield gap, while minimising detrimental environmental impacts on production through efficient allocation of resources (Donough *et al.*, 2009; Rhebergen, 2019).

In oil palm plantations, considerable work has been carried out to quantify the effect of applying BMPs. To achieve this, a set of site-specific BMPs is identified and applied across several fields or 'blocks' within a mature plantation. These BMPs are evaluated based on agronomic, economic, and environmental criteria compared to reference



Source: Fairhurst *et al.* (2019).

Figure 1. Opportunities to increase palm oil production in Ghana, a country typical of West and Central Africa, are substantial through the implementation of yield intensification strategies.

(or control) fields (REF), where current standard practices are used (Rhebergen, 2019). The yield gaps between BMPs and REF can thus be directly attributed to differences in management practices including crop recovery, pruning, drainage, and use of fertilisers and mill by-products (Oberthür *et al.*, 2012). Implementing and evaluating BMPs involves a trial-and-error approach, where various agronomic practices are modified until the most effective combination for a specific site is determined. It is then scaled up to become standard practice, and the cycle of BMPs identification and assessment begins again (Donough *et al.*, 2009, 2010; Rhebergen, 2019). This process involves close collaboration and active participation from farmers, field staff and managers.

THE SITUATION IN GHANA

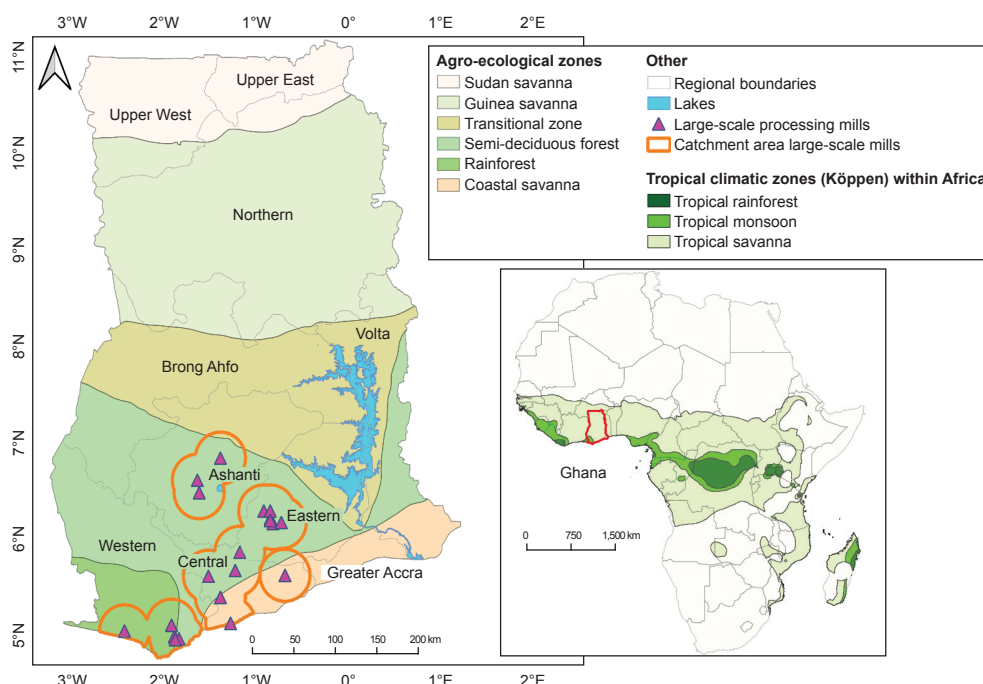
Environment

Ghana is biophysically similar to West and Central African countries along the Gulf of Guinea. Its climate is strongly influenced by the inter-tropical convergence zone and its seasonal north-south fluctuation with a dry continental air mass coming from the north and a tropical, maritime air mass from the south (Hayward & Oguntuyinbo, 1987; Rhebergen, 2019). Consequently, the Northern and Southern Regions of Ghana experience distinctly different climates (McSweeney *et al.*, 2010a, 2010b).

In order of increasing aridity from south to north, six agro-ecological zones have been identified: Rainforest, semi-deciduous forest, coastal savanna, forest-savanna transition, Guinea savanna and Sudan savanna (Antwi-Agyei *et al.*, 2012) (Figure 2).

Oil palm is predominantly cultivated in Southern Ghana, particularly in the tropical rainforest and moist semi-deciduous forest areas, which provide the essential ecological conditions for its growth (Gyasi, 1992; Rhebergen, 2019). Within the oil palm belt, rainfall distribution is bimodal. Long rains occur from March to July, while short rains take place from September to November, with a brief and consistent dry spell in August. The dry season extends from December to February, during which rainfall is typically less than 100 mm in December to February and less than 50 mm in January (Rhebergen, 2019).

Mean annual precipitation is highest in the southwest (~2,400 mm yr⁻¹) and lowest in the north. Relative humidity averages around 80%. The mean monthly temperature rarely falls below 25°C, and the daily variation in temperature is 5°C-9°C. The region's topography is mainly undulating (2°-9°), with rolling to hilly terrain (>20°) in the southwest (Rhebergen, 2019). The primary soil types in the oil palm belt are light texture, highly weathered and leached acrisols and ferralsols (World Reference Base or Ultisols and Oxisols, US Soil Taxonomy), characterised by low pH and poor soil fertility (Buringh, 1979; Rhebergen, 2019; Swaine, 1996).



Source: Rhebergen *et al.* (2016) and Peel *et al.* (2007).

Figure 2. Regions and agro-ecological zones of Ghana, and locations of large-scale oil palm processing mills. The area suitable for oil palm cultivation corresponds more-or-less with the 'Rainforest' and 'Semi-deciduous forest' zones. Inset shows the location of Ghana and tropical climatic zones within Africa.

Palm Oil Production Systems

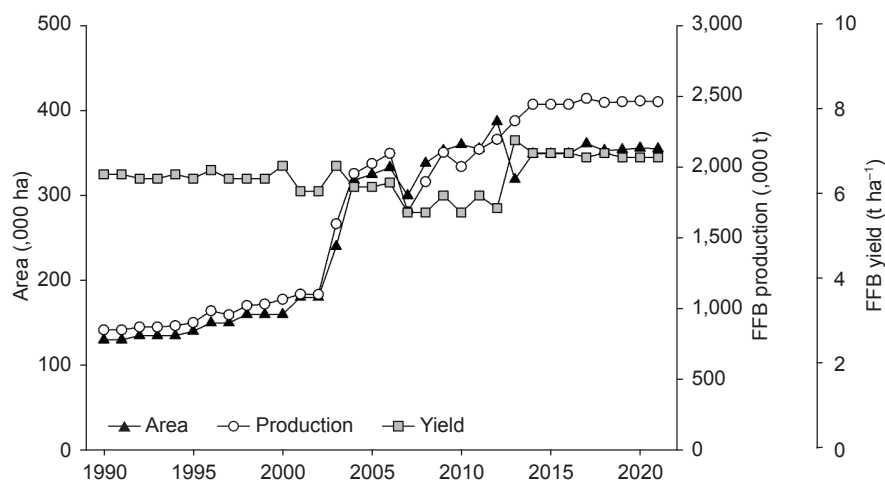
In Ghana and the rest of West and Central Africa, oil palm has been encouraged, spread and cultivated for a long time. The first commercial plantations were established in the 1800s (Gilbert, 2013; Smith *et al.*, 1992), but complex land tenure constrained the development of industrial-scale production (Gyasi, 1996; Jannot, 2013). Consequently, smallholder farmers have historically dominated the oil palm sector in Ghana, serving as the primary drivers of its expansion. However, since the early 2000s, the oil palm sector in Ghana experienced a tremendous surge, partly due to increasing interest from investors in expanding and developing the cultivated area (Rhebergen, 2019). Recent expansion has mostly been due to an increase in the area of large plantations (Ofosu-Budu & Sarpong, 2013), largely at the expense of off-reserve forest patches and food cropland (Asubonteng *et al.*, 2018), but deforestation in reserves by smallholders has also occurred (Acheampong *et al.*, 2019). Although there have been large increases in production over the past 20 years, yield per hectare has remained low (Figure 3).

Oil palm is the second largest income-earning crop in Ghana after cocoa (Ofosu-Budu & Sarpong, 2013), and provides a major source of employment (Gilbert, 2013). Although Ghana is the third largest producer of palm oil in sub-Saharan Africa, with an annual production of 2.5 million tonnes in 2021 (next to Nigeria [10.1 million tonnes] and Cameroon [2.6 million tonnes]) (FAO, 2023), it has an annual crude palm oil (CPO) production deficit of ~140,000 t (for 2020), which is partly compensated by costly imports (FAO, 2023). A similar production deficit has developed in other West and Central African countries since the 1990s (Jannot, 2013). Hence, there is a considerable opportunity in Ghana to increase production to meet the high demand for palm oil.

The Ghanaian palm oil industry has three main components: (i) Large corporate plantations ($\geq 1,000$ ha) with substantial processing mills (capacity >15 t hr⁻¹ of FFB), (ii) smallholder farms of up to 100 ha, and (iii) small-scale processors utilising semi-mechanised mills (capacity of <1 t hr⁻¹ of FFB) (Adjei-Nsiah *et al.*, 2012; Rhebergen, 2019). While several censuses show contrasting results (FAO, 2023; MASDAR, 2011; Ofosu-Budu & Sarpong, 2013), it is believed that smallholder farms comprise about 95% of the total area under oil palm in Ghana (~327,600 ha), with the majority of the farms <5 ha, and account for most of the FFB production nationally ($>80\%$) (Rhebergen, 2018, 2019). The remainder of the land area and production is accounted for by large industrial plantations.

Industry Structure

Corporate plantations in Ghana are defined by their large size, monoculture plantings and organised layout (Gyasi, 1996), while the smallholder sector mainly consists of a highly fragmented mosaic of low-yielding small farms amongst other land uses. Moreover, smallholders in Ghana are not well integrated within the whole industry (Dzanku & Hodey, 2022; Fold & Whitfield, 2012; Rhebergen, 2019) compared with the main producing countries such as Malaysia and Indonesia (Jannot, 2013; Rhebergen, 2019; Ruml *et al.*, 2022; Shamsul Bahrin & Lee, 1988). In Ghana, some smallholders are associated with corporate plantations in nucleus-smallholder or out-grower arrangements (5%), but the majority are independent farmers without formal ties to a plantation-milling company (90%) (Adjei-Nsiah *et al.*, 2012; Osei-Amponsah *et al.*, 2012; Ruml *et al.*, 2022). Smallholders affiliated with companies are obliged to sell all their produce to the company mill, and obtain technical support and inputs (*e.g.*, hybrid seedlings and fertilisers) on credit from the company (Rhebergen, 2019).



Source: FAO (2023).

Figure 3. Changes in the area under oil palm, total FFB production and FFB yield in Ghana from 1990-2017.

In contrast, independent smallholders are self-reliant and can sell their FFB to the processing mills either directly or via middlemen, sell on the open market, or process their own FFB into palm oil. Smallholder farmers who are better educated and operate larger farms tend to earn better returns because their scale allows them to overcome the set-up costs required to transport FFB to the mills (Dzanku & Hodey, 2022). In regions with multiple mills nearby, competition for FFB is high, leading to price wars between plantations and local buyers in the domestic consumption market. Additionally, the uncoordinated establishment of new mills near existing ones has exacerbated the competition for FFB, highlighting the need for improved planning within the industry (Fold & Whitfield, 2012) (Figure 2).

CURRENT PRODUCTION CONSTRAINTS AND FUTURE OUTLOOK

Biophysical Constraints and Opportunities

Unlike regions in Southeast Asia, such as parts of North Sumatra, Indonesia and Sabah, Malaysia which receive high annual rainfall evenly distributed throughout the year, West Africa experiences lower annual rainfall and regular dry seasons (Carr, 2011). These dry seasons can significantly impact crop yields. Multiple studies have demonstrated that a yield reduction of 10%-15% occurs with each 100 mm increase in water deficit (Corley & Tinker, 2003; Olivin, 1968). However, yield results from a trial conducted at three locations with varying annual water deficits in Ghana indicate that the reduction could be even larger (>20%), as supported by yield simulations using PALMSIM (Hoffmann *et al.*, 2014) (Figure 4).

This reduction could reach 40%-50% of palms experienced severe water stress the previous year (Caliman & Southworth, 1998). Water deficits exceeding 400 mm yr⁻¹ are considered unsuitable for economic oil palm cultivation due to their severe impact on floral initiation, which reduces growth and yield (Danso *et al.*, 2008; Manorama *et al.*, 2024; Olivin, 1968; Paramanathan, 2013; Van Der Vossen, 1969). These deficits affect nearly 70% of the total land area in Ghana (Rhebergen *et al.*, 2016). Oil palm in Ghana is primarily cultivated in areas with annual water deficits of 100-150 mm ("Optimal" zone), and to a greater extent in areas with 150-250 mm annual water deficit ("Favourable" zone) (Rhebergen *et al.*, 2016). These zones have a FFB yield potential of approximately 25-30 and 20-25 t ha⁻¹ respectively (Figure 4). Thus, water deficit largely determines both the maximum achievable yield at a specific location and the cultivable area, serving as a critical constraint to

oil palm production in Ghana and across much of West and Central Africa (Jannot, 2013; Rhebergen *et al.*, 2016). This may be exacerbated in the future due to climate change-induced droughts driven by increased temperatures, reduced annual rainfall and prolonged dry seasons. However, modelling suggests that anticipated climate changes, marked by rising temperatures and an earlier onset of the rainy season, could lead to improved yields in the Niger Delta Region of Nigeria (Okoro *et al.*, 2017). Nonetheless, although there is broad agreement among climate projections concerning regional changes in temperature, there are large uncertainties about future changes in the monsoon system, which drives precipitation in the region (Niang *et al.*, 2014; Okoro *et al.*, 2017).

Water stress reduces oil palm yield and affects its distribution throughout the year. In regions with well-distributed rainfall, yields remain relatively steady year-round. However, in areas with pronounced dry seasons, such as Ghana, yield peaks are more pronounced, impacting harvesting and processing. To counteract the effects of water stress, irrigation is often recommended and is expected to become increasingly important due to the anticipated rise in drought frequency and intensity, as well as the expansion of oil palm into drier regions (Okoro *et al.*, 2017; Woittiez *et al.*, 2017).

While the impact of drought on oil palm is well-documented, research on yield responses to irrigation remains limited, particularly in West Africa. Under well-watered conditions, crop evapotranspiration (ET_c) for mature oil palm is estimated at 4-5 mm day⁻¹ or 1,461-1,829 mm yr⁻¹, equivalent to 280-350 L palm⁻¹ day⁻¹ for a stand density of 143 palms ha⁻¹ (Carr, 2011; Dufrene, 1989). In Malaysia, irrigation in oil palm cultivation is considered viable only if it increases yields by at least 4 t ha⁻¹ (Lee & Izwanizam, 2013), with reported gains of 5-6 t ha⁻¹ achieved through its implementation (Afandi *et al.*, 2022).

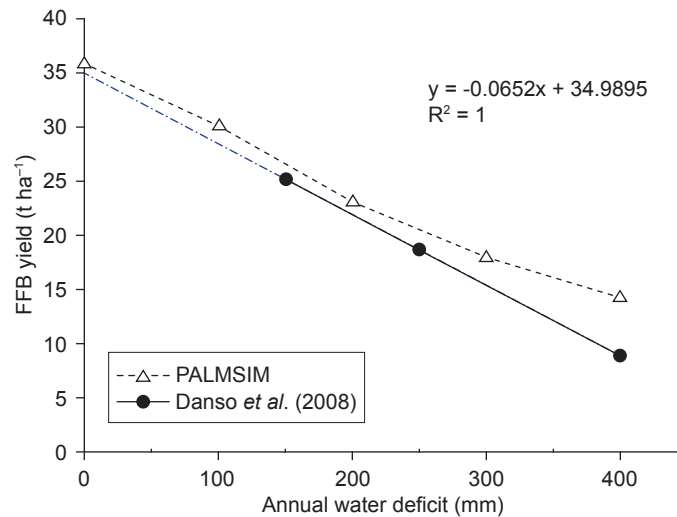
Similarly, a trial conducted in Ghana's Western Region reported a yield increase of approximately 5.0 t FFB ha⁻¹ over three years when irrigation was combined with ample nutrition (Rhebergen *et al.*, 2019). In contrast, irrigation alone resulted in a much smaller yield increase of just 0.6 t ha⁻¹. Notably, both treatments received similar amounts of water: 1,796 mm in year 1 (37% from irrigation), 1,803 mm in year 2 (39% from irrigation) and 1,712 mm in year 3 (29% from irrigation) indicating that water availability alone was not the primary limiting factor. These results underscore the critical role of adequate nutrition in maximising the benefits of irrigation (Rhebergen *et al.*, 2019).

While the Ghanaian trial's scale was insufficient for a comprehensive cost-benefit analysis, irrigation alone may not be profitable, due to high

capital costs (USD2,500 ha⁻¹) and operating costs (USD150 ha⁻¹ yr⁻¹ for 450 L palm⁻¹ day⁻¹) associated with sprinkler irrigation (Tittinutchanon *et al.*, [2008] adjusted for inflation). However, combining irrigation with fertiliser could lead to significant profit increases. Optimum fertiliser rates are likely to be higher with irrigation due to higher attainable yields (Tittinutchanon *et al.*, 2008), and the optimum fertiliser and irrigation practices will vary based on environmental conditions (Woittiez *et al.*, 2017). In cases where irrigation is not economically viable or logistically feasible such as when water sources like rivers are limited or insufficient to sustainably support oil palm cultivation alternative drought mitigation strategies should be considered. These include selecting soils with good water-holding capacity, using organic mulches and reducing plant density (Carr, 2011).

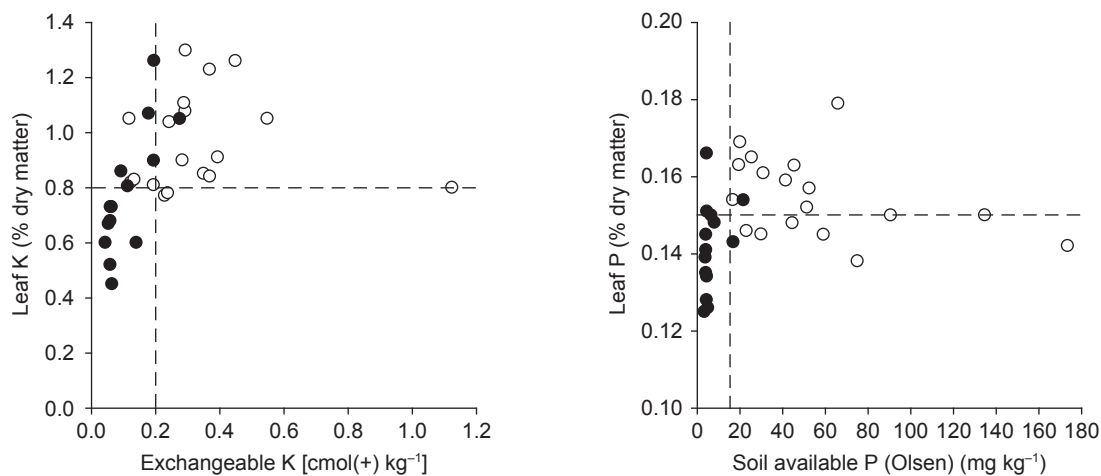
Another challenge for oil palm production in Ghana is inadequate nutrient supply. Soil and leaf analyses reveal significant nutritional constraints, particularly in phosphorus (P) and potassium (K) (Figure 5), primarily due to historically low fertiliser applications in plantations and minimal use on smallholder farms.

To sustainably intensify production, these deficiencies must be alleviated. Response to K is likely to be particularly important in Ghana due to its role in mitigating water-stress (Taulya, 2013). Site-specific fertiliser recommendations are currently lacking for oil palm in Ghana and developing them is essential to increase yields. Their development requires fertiliser response trials in different environments and crop phases, as well as consideration of all the other inherent and management factors influencing soil fertility (Nelson, 2023).



Source: Danso *et al.* (2008), Hoffmann *et al.* (2014) and Rhebergen *et al.* (2014).

Figure 4. Relationship between the annual water deficit and yield at three trial sites, and yield simulations using PALMSIM under various water deficit regimes for the oil palm plantation Norpalm Ghana Ltd.



Source: Rhebergen *et al.* (2018).

Figure 5. Low leaf and soil concentrations for K and P indicate considerable nutritional constraints, particularly at smallholder farms (black circles; open circles for plantations). The leaf and soil critical values for K and P are represented by dashed horizontal and vertical lines.

Management Constraints and Opportunities with Yield Intensification

In Ghana, potential (*rainfed*) FFB yields are around 21.0 t ha⁻¹, yet actual yields average approximately 11.0 t ha⁻¹ on large corporate plantations and 6.0 t ha⁻¹ on smallholdings, resulting in yield gaps of 9.0 and 14.0 t ha⁻¹, respectively (Rhebergen, 2019; Rhebergen *et al.*, 2018). These low yields are linked to several challenges, including unfavourable climate conditions, poor soil fertility and inadequate field management (Rhebergen, 2019). Additionally, small-scale processors achieve oil extraction rates (OER) as low as 12%, primarily due to poor processing practices and equipment (*e.g.*, a digester combined with a separate hand-operated screw press [Donker, 1979]), compared to 21% achieved by large-scale processors (Figure 6). These inefficiencies further reduce productivity, resulting in potential annual CPO losses of over 5.0 and 3.0 t ha⁻¹ yr⁻¹ for smallholder and large corporate systems, respectively, during peak production (Rhebergen *et al.*, 2018).



Figure 6. Workers operating a hand-press for palm oil extraction, commonly used in small-scale processing systems, achieve lower oil extraction efficiency than large-scale mills.

The potential to increase yields in Ghana by implementing BMPs was thus considerable and led to a four year study that commenced in 2013. Production constraints were identified for twenty smallholder farms and three large-scale plantations (full project description and locations provided in Rhebergen [2019]). Yield improvement with BMPs compared to REF occurred in two distinct phases: i) A short-term effect (≤ 1 year) resulting from improved operational management, such as maximising crop recovery through harvesting all suitable crops ('yield taking') and ii) a longer-term effect (>1 year) driven by enhanced agronomic practices ('yield making') (Rhebergen *et al.*, 2020).

To evaluate the impact of BMPs implementation, various measurements related to crop production (such as bunch count and weight), field maintenance (field audit scores), palm nutrition (fertiliser usage, chemical analysis of leaves and soil) and labour allocation (including man-days dedicated to harvesting and field upkeep) were conducted at regular intervals. A comprehensive depiction of the BMPs process and its associated measurements can be found in Rhebergen (2019).

Results of the study indicated an overall increase in yield of ~ 7 t ha⁻¹ for large plantations and ~ 12 t ha⁻¹ for smallholders, of which $\sim 30\%$ and $\sim 40\%$ were attributed to crop recovery, respectively. Improvements in crop recovery were achieved by implementing more frequent harvesting (with intervals of 7-10 days) and enhancing field access (through better roads, paths and weeded circles), which led to more efficient production (*i.e.*, higher bunch weight harvested per harvester, from a smaller area). Since oil palm produces bunches continuously, it is crucial to maintain complete crop recovery over the whole year. If harvest intervals exceed 10 days, some of the crops may become over-ripe or rotten, leading to losses (Fairhurst & Griffiths, 2014).

The larger yield response on smallholdings was partly due to poor initial field conditions, resulting in a lower baseline yield compared to plantations (5.3 *vs.* 11.1 t ha⁻¹). Most smallholder farms were severely neglected; the absence of harvesting paths and weeded circles restricted access to palms, while poor pruning and frond management hindered workers from harvesting ripe FFB (Figure 7). Consequently, the potential for improvement and benefits of crop recovery were greater than in plantations.

Long-term yield increases were more challenging to explain due to the delayed impact of improved agronomic practices on yield. However, an analysis of fertiliser use, leaf nutrients and soil chemistry identified significant nutritional constraints, especially in P and K, which need careful management to build and maintain soil fertility and enhance production, particularly on smallholder farms. Yield increases with improved agronomy were thus substantial, even though fertiliser recommendations were not fully implemented. Fertiliser applications were larger at both plantation and smallholder sites; however, they were not adequately balanced to align with BMPs program recommendations. This led to significant nutrient gaps between the recommended and applied rates, resulting in notable leaf nutrient deficiencies, particularly for P and K. Among smallholder farmers, limited access to credit and the delayed return on investment from fertilisers were the major barriers. For plantations, financial constraints, such as insufficient budgets for fertiliser inputs,

or conflicts with BMPs program priorities, were cited as the primary reasons for these discrepancies (Rhebergen, 2019).

The largest yields recorded in the study were 27.3 t ha⁻¹ at a plantation site, 25.0 t ha⁻¹ at a smallholder farm, and 32.6 t ha⁻¹ at an irrigation trial (Rhebergen *et al.*, 2019). These results demonstrate the immense production potential that can be achieved by minimising agronomic and biophysical constraints through various yield intensification techniques.



Figure 7. The greatest yield improvements in rehabilitating smallholder oil palm farms were achieved by facilitating unrestricted access for harvesting and palm maintenance. This was accomplished through the creation of weeded harvest paths and circles and the pruning of unproductive fronds. a) Before rehabilitation and b) after rehabilitation.

Socioeconomic Constraints and Opportunities at the Farm Scale

Smallholdings are typically family-operated (Mensah-Bonsu *et al.*, 2009). In these households, economically active members work on the farm for an average of only 61 days yr⁻¹ (Dzanku & Hodey, 2022). A significant portion of household income is derived from non-crop activities, as off-farm employment often offers better financial returns, albeit with limited opportunities. Labour allocation

is heavily influenced by commercialisation levels, with more commercialised smallholder households dedicating a higher proportion of their labour to farm activities (Dzanku & Hodey, 2022). However, the financial barriers to adopting advanced practices and technologies remain a major constraint for most smallholders, limiting their potential to improve productivity (Rhebergen, 2019).

In contrast, plantations in Ghana rely heavily on hired labour (Gyasi, 1996). To raise productivity, the importance of improved crop recovery, through frequent harvesting and good access, was highlighted earlier. However, sustaining these operations presents several challenges for plantations:

Insufficient skilled workers. While oil palm plantations provide numerous employment opportunities, the work (particularly harvesting) is often perceived as physically demanding and hazardous (Ismail, 2013; Rhebergen, 2019). Unattractive working conditions, such as isolation and low wages, combined with competition from alternative sectors like large-scale agribusiness and mining, may lead to high turnover rates. Frequent workforce changes and the need for continuous training result in skill shortages, hindering the consistent implementation of BMPs, particularly in maintaining high harvesting standards (Rhebergen, 2019).

Seasonal labour mismatches. Labour demand fluctuates with seasonal crop cycles. During periods of low FFB production, fewer workers are required and piece-rate payments lead many labourers to seek alternative employment. Conversely, during peak production months, the increased demand for harvesters often exceeds supply. Poor planning and recruitment exacerbate these shortages (Panyin, personal communication, 2024), leading to extended harvest intervals and significant crop losses (Figure 8). Seasonal production variations also strain milling operations, resulting in underutilisation during the lean season and insufficient capacity during peak periods (Rhebergen, 2019).

Mechanisation offers a way to address some of the labour challenges by reducing the physical burden of field operations and improving productivity (Rhebergen, 2019). Devices designed to collect and transport FFB such as mechanical grabbers, compact transporters, mechanical buffaloes, battery-powered wheelbarrows and loose fruit collectors along with the development of lighter, more ergonomic and powered FFB cutters, could enhance efficiency while improving worker health and safety (Abd Rahim *et al.*, 2010; Anon, 2004; Jayaselan & Ahmad, 2011; Leng, 2002; Murphy, 2014).

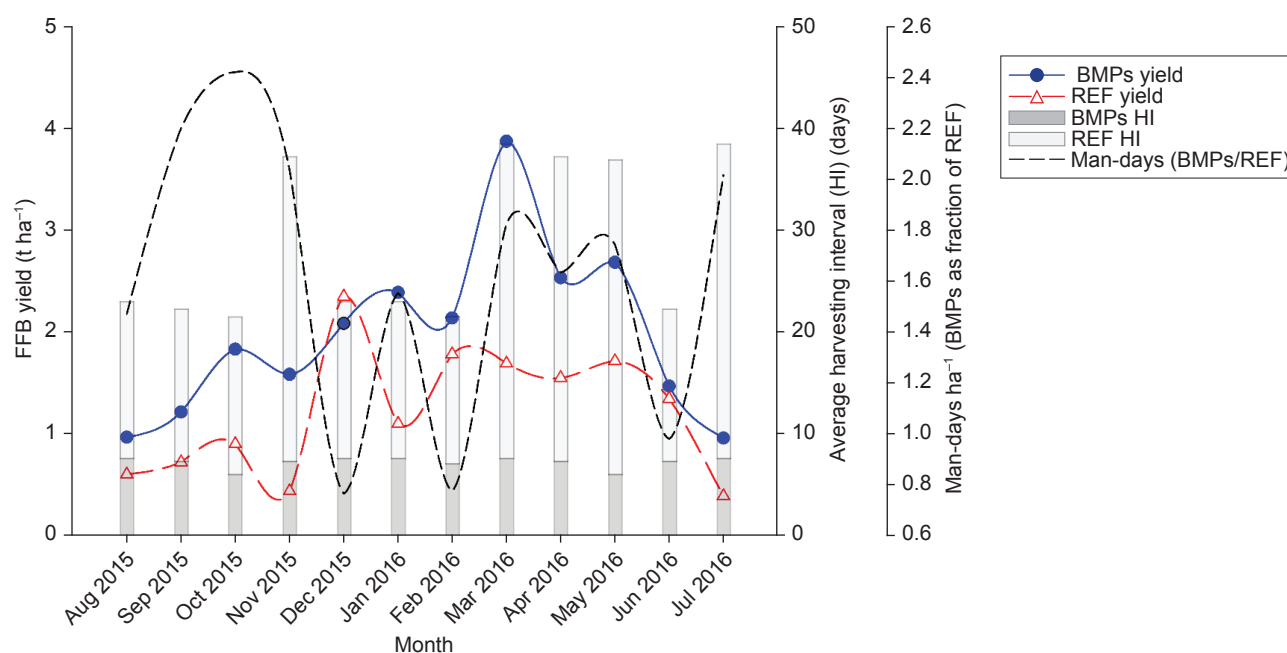


Figure 8. Monthly yield (t ha^{-1}) distribution, average monthly harvesting intervals (HI day^{-1}) and man-days (BMPs expressed as a fraction of REF) for reference (REF) plantings, representing current standard practices and plantings under best management practices (BMPs), which employed improved yield intensification strategies. Data from a yield intensification study at Norpalm Ghana Ltd. (year 3) show that during peak production months (February–May 2016), adequate labour for harvesting and maintaining harvest intervals of 7–10 days is critical to minimising crop losses. BMPs plots achieved a FFB yield of 23.9 t ha^{-1} compared to 14.8 t ha^{-1} for REF plots, where consistent harvest teams were employed in BMPs plots, while REF plots faced labour shortages during peak periods.

Despite its benefits, mechanisation has not been widely adopted in many regions. In Malaysia, only a few of the innovations—primarily for crop evacuation have been adopted, mainly by large plantation groups. Even then, their use is often restricted to areas suitable for machine access and operations (Donough, personal communication, 2024).

In Ghana and other African countries, mechanisation is even less prevalent. Smallholders face prohibitive costs in acquiring tools and equipment, while plantations face additional challenges such as limited access to spare parts and a lack of skilled personnel for machinery maintenance. These factors discourage investment in mechanisation. Moreover, some plantations remain reluctant to mechanise, citing the availability of manual labour as sufficient. Low daily wages and labour rates compared to mechanisation costs further diminish its perceived necessity (Panyin, personal communication, 2024; Tarigan, personal communication, 2024). Similar barriers exist in Malaysia, where a skills deficit among machine operators and support staff persists (Donough, personal communication, 2024).

While mechanisation in the oil palm sector has progressed, there remains significant potential for improvement (Abd Rahim *et al.*, 2010). FFB harvesting, in particular, presents challenges such as assessing fruit ripeness and cutting heavy FFB from heights of 10–20 m (Murphy, 2014). Alternative strategies, such as breeding shorter, high-yielding

palms, could facilitate harvesting (Arolu *et al.*, 2016; Murphy, 2009). These palms could also improve land-use efficiency through increased planting density, higher per-hectare yields and extended crop cycles, thereby reducing replanting costs (Zulkifli *et al.*, 2017).

Although mechanisation could bring significant benefits to Ghana's oil palm industry, it must be approached with caution. The sector plays a crucial role in providing economic and social benefits through rural employment, and mechanisation might be viewed as a threat to job opportunities. However, the goal of mechanisation is to enhance productivity within the existing workforce (Abd Rahim *et al.*, 2010; Anon, 2004). Addressing social and labour sensitivities requires effective consultation, education and the development of tailored mechanisation strategies. A well-planned and coordinated implementation program is essential for long-term success (Anon, 2004).

Socioeconomic Constraints and Opportunities at the Industry Scale

Expansion of the area under oil palm in Ghana is likely to occur mostly through an increase in the number and size of smallholdings rather than an expansion of large corporate plantations (Rhebergen *et al.*, 2014). This is because the establishment of large new plantations is limited by the availability of contiguous tracts of land due to complex land tenure systems (Ruml *et al.*, 2022). Expansion of

the smallholder sector will have socioeconomic and environmental benefits (Sayer *et al.*, 2012). The corporate sector also benefits, as the profitability of processing mills associated with large plantations increases with throughput, even if the FFB comes from smallholders.

Thus, the main opportunities for increased palm oil production are from increased FFB supply from smallholders and yield improvement strategies. These strategies include improving crop recovery through unimpeded field access and maintaining regular harvesting intervals (HI) of 7-10 days and ensuring balanced palm nutrition. Combined, these measures have demonstrated an average yield increase of 61% reaching 17.9 t ha⁻¹ in plantations, and 232%, reaching 17.6 t ha⁻¹ in smallholder farms (Rhebergen *et al.*, 2020), highlighting their significant potential.

Increasing yield from current levels to 21.0 t ha⁻¹ would increase national FFB production by 4.8 million tonnes across the smallholder and plantation sectors or enable the same production from an area almost 800,000 ha smaller (Table 1). Achieving that yield increase would result in a total annual CPO production of approximately 1.4 million tonnes (assuming an OER of 21%), which is more than adequate to meet Ghana's current demand of 140,000 t yr⁻¹ (FAO, 2023) without additional land. Smallholder farmers in Ghana generally express a desire to intensify production (Acheampong *et al.*, 2021, 2022).

There is thus considerable scope for improving overall production through better integration of the corporate and smallholder sectors. While contractual arrangements between smallholders and plantation companies may, in some cases, be unfavourable to the smallholders, they could also offer benefits and opportunities that are essential for the development of commercially viable smallholder production systems (Sayer *et al.*, 2012). Improved connections between smallholder farmers and the corporate sector could offer an effective way to address key constraints to increasing yields, such as limited knowledge of good management practices, inadequate infrastructure and restricted access to high-quality seedlings, agronomic inputs, credit and technical support (Rhebergen, 2019).

Poor road infrastructure is a major constraint to agricultural development in Africa (Acheampong *et al.*, 2018). In Ghana, many oil palm cultivation areas lack access roads, and during peak harvest seasons, which coincide with heavy rains, unsurfaced or neglected roads become impassable. This leads to FFB spoilage and income losses for farmers (MASDAR, 2011). The inefficiency of road networks affects the entire value chain, from transporting FFB to mills to distributing palm oil and other by-products (Asante, 2023). Inadequate roads also raise transport costs and reduce logistics efficiency, impacting profitability by increasing travel time and causing breakdowns (MASDAR, 2011). Furthermore, rural populations, particularly women, face significant challenges in marketing their products due to the lack of all-weather roads, and relying on labour-intensive methods like head-loading, which exacerbate post-harvest losses (MASDAR, 2011). The poor state of roads also limits smallholder farmers' ability to engage in contract farming, hindering income stability and excluding them from the technology adoption, training and innovation needed to increase productivity (Acheampong *et al.*, 2018; Wongnaa *et al.*, 2024). Study conducted in the oil palm belt of Ghana has shown that improving road infrastructure and providing agronomic inputs result in better market integration, higher yields and reduced pressure to expand into forests (Acheampong *et al.*, 2018, 2021).

Milling-plantation companies, which rely on securing a sufficient crop supply, could support smallholder oil palm growers by providing inputs and advice. These companies could offer inputs such as fertilisers, agrochemicals, tools and quality seedlings on credit, with repayment tied to future crop deliveries, following practices observed in other regions (Figure 9) (Rhebergen, 2019). Additionally, milling-plantation companies could play a crucial role in enhancing regional transportation networks, such as through the construction and maintenance of roads, as demonstrated by Ghana Oil Palm Development Company Ltd. (GOPDC) (Huddleston & Tonts, 2007). This improvement would not only benefit the oil palm industry, but also stimulate other industries in the region.

TABLE 1. IMPACT OF OIL PALM YIELD INTENSIFICATION ON PRODUCTION OR LAND AREA IN GHANA

Sector	Current situation			Production situations with yield improvement strategies					
	Area (ha)	Yield (t ha ⁻¹)	Production (t)	Target yield = 18.0 t ha ⁻¹			Target yield = 21.0 t ha ⁻¹		
				Production (t)	Production increase (t)	Land saved (ha)	Production (t)	Production increase (t)	Land saved (ha)
Smallholder	311,000	6.0	1,866,000	5,598,000	3,732,000	622,000	6,531,000	4,665,000	777,500
Plantation	16,600	11.0	182,600	298,800	116,200	10,564	348,600	166,000	15,091
Total	327,600		2,048,600	5,896,800	3,848,200	632,564	6,879,600	4,831,000	792,591

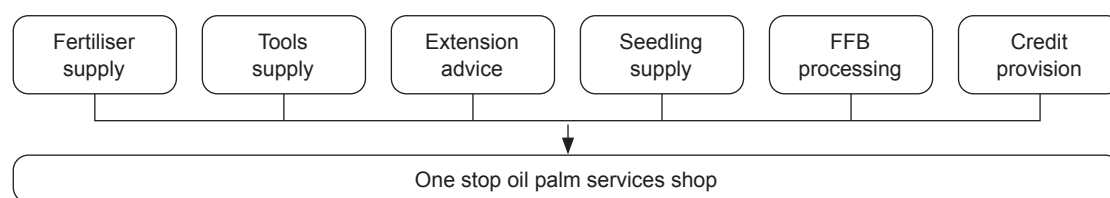


Figure 9. Large corporate mills can serve as one-stop shops to provide services and inputs for smallholders in Ghana.

To monitor smallholder production effectively and to identify yield gaps on a larger scale, it is essential to collect farm data and then collate and analyse it using a database such as Agrisoft Systems' Oil Palm Management Program (OMP) (Agrisoft Systems, 2018; Rhebergen, 2019). This approach can also help milling companies offer targeted advice to growers for yield improvement and mitigate the risks associated with providing loans. Improvements to infrastructure (particularly feeder roads to the farm) may also be provided by milling-plantation companies due to mutual benefits. Currently, more commercialised smallholder households are better off in some but not all aspects of welfare (Dzanku & Hodey, 2022), but voluntary implementation of the changes suggested here will enhance the benefits of intensification among smallholder producers. Optimal integration of the smallholder and corporate sectors will require careful collaborative design, taking into account the Ghanaian context and the needs of smallholders with little political power (Khatun *et al.*, 2020; Naess & Chinsinga, 2022; Ruml *et al.*, 2022).

In addition to integrating smallholders with mills, coordination through farmers' groups or smallholder schemes has considerable potential to increase production and optimise expansion. Enabling institutional arrangements may advantage smallholder participation in supply chains and substantially increase their productivity (Dzanku & Hodey, 2022; Jelsma *et al.*, 2017). Coordinating smallholder farmers into consolidated cooperatives, similar to the smallholder schemes used in Malaysia and Indonesia, could help transition from the current mosaic landscape to conserving large, contiguous areas of native vegetation. This approach, shifting from 'land sharing' to 'land sparing' (Green *et al.*, 2005), has been demonstrated to enhance biodiversity conservation in multiple-use regions (Edwards *et al.*, 2010; Fitzherbert *et al.*, 2008; Phalan, 2018; Phalan *et al.*, 2009, 2011). However, such a shift would require effective supporting policies and a significant reform of land tenure.

Evidence suggests that the increased commercialisation of smallholder farming in Ghana facilitated by improved road access has contributed to a decline in deforestation (Acheampong *et al.*,

2018). This is because better market integration and higher input use have led to increased yields on existing farmland, reducing the pressure to expand cultivation into forested areas (Acheampong *et al.*, 2018). In contrast, Abman and Lundberg (2024) suggest that improved market access facilitated through production contracts, in which smallholders receive credit to establish production, a guaranteed price and quantity for the contract duration, and output pickup at the village may increase deforestation. It is therefore essential to recognise that intensification alone does not guarantee land sparing and conservation. In fact, intensification may increase financial incentives for forest clearing and oil palm expansion if higher yields and profitability increase the opportunity costs of conserving land (Laurance *et al.*, 2014; Phelps *et al.*, 2013).

Furthermore, if the demand for palm oil is elastic, higher yields could lead to increased production targets, thereby encouraging further expansion into agricultural land (Green *et al.*, 2005). For instance, even if the palm oil supply increases, it may not reduce prices, thereby maintaining the incentive to cultivate more land. Conversely, a decrease in prices might also drive land expansion to sustain income levels (Baudron & Giller, 2014). Therefore, efforts to ecologically intensify production should be accompanied by the implementation of policies and practices to strategically optimise the allocation of land for conservation and agriculture (Asubonteng *et al.*, 2018; Laurance *et al.*, 2014; Sayer *et al.*, 2012). Successful examples of such integration exist in Ghana (Acheampong *et al.*, 2020).

In summary, promoting specific practices for yield intensification, particularly among smallholders, is recommended, along with fostering better integration between smallholder and corporate sectors through arrangements that ensure fairness to smallholders. These recommendations correspond closely with those given by Sayer *et al.* (2012) to improve the sustainability of palm oil production globally, including the attainment of the best possible outcomes for the carbon cycle and biodiversity conservation. There has been much recent discussion about the benefits of sustainability certification for oil palm farmers, especially the Roundtable on Sustainable Palm Oil (RSPO). The inclusion of smallholders in certification

schemes subscribed by plantation companies may help improve smallholder productivity and welfare, but there are many challenges to effective implementation, including high transaction costs (Brako *et al.*, 2021; Djama, 2018; Nelson, 2023). The approaches discussed here may be facilitated by sustainability certification but will have a positive impact on smallholder productivity and well-being with or without certification (Ogahara *et al.*, 2022).

CONCLUSION

The Ghanaian oil palm industry faces numerous challenges, primarily related to low productivity and disorganised expansion. Productivity is limited by dry climate and poor soil fertility, low inputs, shortage of labour and poor infrastructure (especially transport) and services. Additionally, the expansion of large-scale plantations is constrained by limited available land and complex land tenure systems. To address these challenges, production increases must be pursued through intensification and yield increases on smallholder farms. However, this presents a significant challenge, as smallholders are poorly organised and not yet effectively integrated into the palm oil supply system. Policies, organisational models and implementation pathways suitable for increasing overall productivity in Ghana's complex oil palm sector should be explored. Future study should, therefore, focus on investigating options to foster institutional arrangements that benefit both smallholder and plantation agriculture in Ghana. This will necessitate coordinated efforts from both industry stakeholders (plantations and smallholders) and government bodies.

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FROM LOCAL TO GLOBAL: EXAMINING THE IMPACT OF PRE- AND POST-INTERNATIONALISATION STRATEGY BY BURSA MALAYSIA OF GLOBAL OIL MARKETS TO THE FUTURES CRUDE PALM OIL

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ABSTRACT

This study investigates the level of cointegration between futures crude palm oil (FCPO) and competitor oils during the pre- and post-internationalisation strategy implemented by Bursa Malaysia Derivatives Berhad (BMDDB). The Autoregressive Distributed Lags (ARDL) model is employed to analyse cointegration and causality among these variables using weekly data from January 1980 to December 2022. The empirical results show a reduction in the level of cointegration by 0.017% with soybean futures, 0.179% with exchange rates and no cointegration with Brent crude oil futures after implementing BMDDB's international strategy. The results from this study contribute to more robust financial models for the FCPO market and provide empirical input to authorities on how policy or strategy shapes the relationship between FCPO and competitor oils so that BMDDB can maintain FCPO status as a global index reference.

Keywords: ARDL, BMDDB, FCPO, global commodities, internationalisation.

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INTRODUCTION

Malaysia's two markets manage palm oil businesses: Physical crude palm oil (CPO) and futures crude palm oil (FCPO). The first market is used by registered producers and refiners. The prices are compiled and released by the Malaysian Palm Oil Board (MPOB). The latter deals with market participants of retailers and institutions under the authorisation of Bursa Malaysia Derivatives Berhad (BMDDB). Like other commodities, CPO is also exposed to price fluctuations. Thus, in October 1980, BMDDB

decided to launch FCPO with several economic objectives. This involves introducing Malaysia's top commodity to the international market, offering an effective price discovery system and providing a hedging mechanism against the risk of price fluctuations for the industry and market participants (Go & Lau, 2020). Since then, FCPO has been used as a standard index reference by market participants and policymakers.

Dedicated to upholding and enhancing the status of FCPO as a global index reference (GIR), Malaysia, through BMDDB in 2009, established a strategic partnership and sold 25% of its stake to the Chicago Mercantile Exchange (CME) as part of its internationalisation strategy (IS). This strategy enables including all existing and upcoming BMDDB products, particularly FCPO, into the CME Globex System. This electronic trading platform system is widely distributed, with multiple access points through various telecommunication centres and vast global distribution (Chow *et al.*, 1996; Rentzler *et al.*, 2006). Hence, this will enable foreign

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retailers and institutions to gain direct access and participate in the FCPO market through the CME Globex System.

BMDB and CME formalised their partnership on 28th September 2010. *Figure 1* illustrates the discrepancies between FCPO and other futures contracts offered by BMDB in terms of traded volume and market demography before and after the internationalisation of FCPO. The total traded volume and the number of foreign institutions has been continuously increasing, indicating the positive outcomes of this IS (Bursa Malaysia, 2011). Since then, FCPO has emerged as one of BMDB's most successful products (Ahmad, 2010) and one of the most active futures markets globally (Go & Lau, 2015). Furthermore, FCPO has become a cornerstone of BMDB (Bacha & Sarojati, 2023) mentioning that FCPO generates nearly 80% of BMDB's income. BMDB will sustain this strategy until 2028 to ensure the ongoing global accessibility of FCPO and attract new market participants (Bursa Malaysia, 2023).

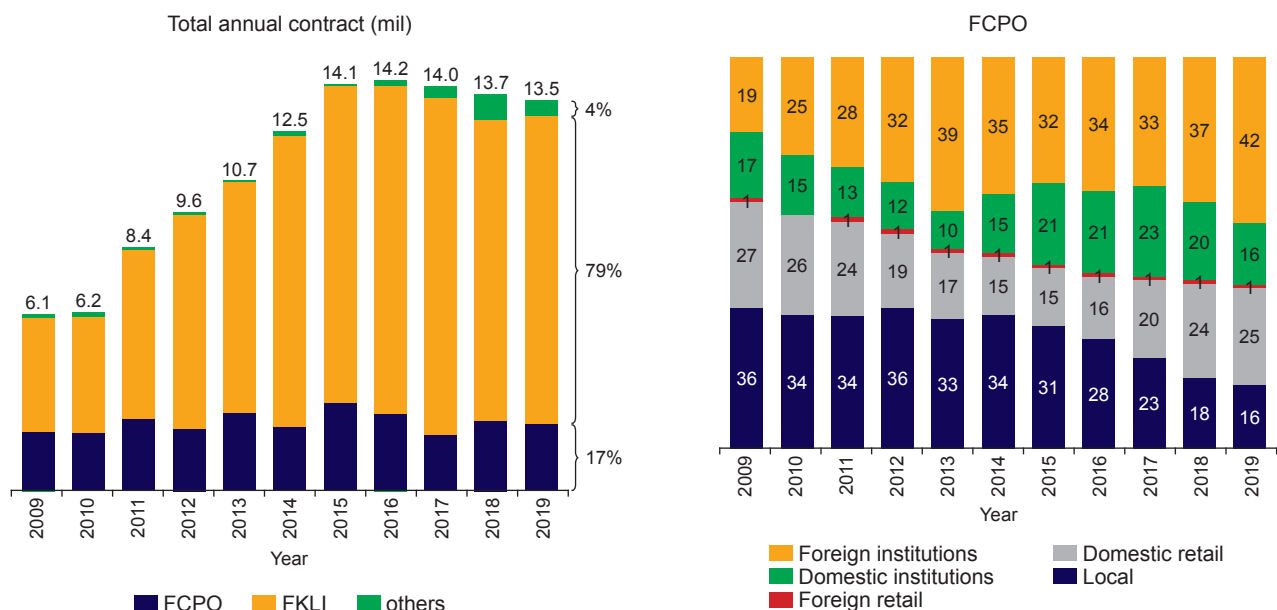
However, rather than focusing on traded volume or revenue, this study aims to explore the level of cointegration between FCPO and its rival oils, pre- and post-BMDB's strategy for internationalisation by listing FCPO on the CME Globex System. Positioning FCPO in global markets will lead to price fluctuations and increased exposure to international market prices due to a surge in market participants with varying trading objectives (Buyuksahin & Robe, 2014; Fattouh *et al.*, 2013). Therefore, this study investigates the impact of BMDB's IS on the cointegration level between FCPO and rival oils by comparing empirical findings

from periods before and after the implementation of the strategy. Addressing this issue will enrich both the existing knowledge and BMDB's expertise.

Several studies Azam *et al.* (2020), Rifin and Naully (2021), Sarmidi *et al.* (2022) and Declerck *et al.* (2023) have examined the relationship between FCPO and rival oils, but there is a gap where previous study did not consider the impact of the IS by BMDB. Furthermore, the crucial question is whether this IS has significantly altered the relationship between FCPO and its competitors' oils. This study aims to explore this question by evaluating the influence of IS and segmenting the data into pre- and post-series. This study aims to broaden our comprehension of how policies or strategies influence the relationship between FCPO and rival oils.

From a policy standpoint, the empirical outcomes of this study could aid BMDB in future planning by determining whether to prolong its IS post-2028 or explore new partnerships with other exchanges to access different segments of new market participants globally. Both contributions will offer novel insights into the transmission mechanisms of these relationships, enhance the robustness of financial models for the palm oil market and provide empirical insights to policymakers to further improve and uphold FCPO's standing as a GIR.

The study comprises five sections. Section 1 presents the background and motivation of the study, while Section 2 delves into a brief literature review. Section 3 details data selection and the methods for analysing the impact of BMDB's IS on the relationship between FCPO and rival



Source: Bursa Malaysia (2020).

Figure 1. Total volume traded and market demography.

oils. Section 4 summarises the discussion of the empirical findings, while Section 5 outlines the results, conclusions and recommendations.

Classical economic theory asserts that the price of goods is determined by market supply and demand. However, adhering to this theory's assumptions may be difficult in situations where substitution is easy and competition is intense. For example, one type of edible oil could influence the prices of others (Azam *et al.*, 2020). Palm oil and soybean oil are two of the most crucial and popular edible oils globally, attracting the interest of many researchers aiming to understand the dynamic interplay between these markets.

Researchers such as Alias and Othman (1998), Talib and Darawi (2002), Khalid *et al.* (2018), and Lee *et al.* (2022) have delved into the relationship between CPO and soybean oil. Meanwhile, Azam *et al.* (2020), Rifin and Naully (2021), and Declerck *et al.* (2023) focused on the connection between CPO and rapeseed oil. These studies have identified evidence of cointegration among FCPO and rival oils. Yet, none have considered the impact of BMDB's IS, particularly related to the level of cointegration between FCPO and its competitors.

Compared to agricultural commodities like soybean and rapeseed, the correlation between CPO and crude oil has yielded mixed results. Although crude oil is classified as an energy commodity, the emergence of biodiesel produced from palm oil as a competitor to crude oil has elevated the relationship between palm oil and crude oil. Studies by Yu *et al.* (2006) and Campiche *et al.* (2007) found no cointegration between CPO and crude oil from 1999-2007. In contrast, Nazlioglu and Soytaş (2012), Arshad and Hameed (2012), Jeong *et al.* (2023) and Supriya and Mamilla (2024) identified a significant relationship between CPO and crude oil, suggesting that market participants need to monitor crude oil markets to anticipate price changes in the palm oil market. Due to conflicting findings in prior studies, this research sought to explore whether BMDB's IS influences this relationship, positioning Malaysia's top traded commodity in global markets and enabling access to the FCPO market for participants in edible oil markets.

Literature review revealed an interesting trend on investigations related to market system changes. Barrett and Scott (2000) analysed the impact of electronic trading on the operations of major international financial futures exchanges, indicating opportunities for market access beyond traditional futures exchanges. Subsequent studies by Rentzler *et al.* (2006) and Tse *et al.* (2006) highlighted the efficiency gains in currency futures markets due to electronic trading platforms. Martinez and Tse (2008) focused on the impact of

volatility changes in electronic markets and the role of informed traders in liquidity provision. Ahmed (2010) studied the effects of transitioning from open outcry to computerised trading systems in Malaysia, revealing slightly higher volatility persistence under automated trading for FCPO. It could be argued that based on empirical evidence, existing studies primarily examined the pros and cons of market system changes.

To extend the body of knowledge on IS, this study further explores the level of relationship between FCPO and rival oils before and after its listing on the CME Globex system. Assessing the cointegration level between these markets is essential for grasping their dynamics and the implications of BMDB's IS.

METHODOLOGY

This study utilised weekly data from 7th April 1995 to 28th June 2024 and divided it into two subsamples: Pre- and post-internationalisation of FCPO, as shown in *Table 1*. In this study, FCPO is the dependent variable quoted in Malaysian Ringgit (MYR). Meanwhile, competing oils, namely soybean oil futures (SOY), rapeseed oil futures (RAP) and Brent crude oil futures (BRENT), serve as regressors, all quoted in US Dollars (USD). The exchange rate (EXR) of USD against MYR is included as a controlled variable following the International Capital Asset Pricing Model, where the exchange rate plays a vital role in positioning any instrument in the international market (Solnik, 1974). This study will solely concentrate on the futures market, and all data were extracted from the Bloomberg trading terminal.

TABLE 1. DATA PERIOD

Internationalisation period	Date
Pre	7 April 1995-25 September 2009
Post	28 September 2009-28 June 2024

The basic model of this study is similar to previous studies (Alias & Othman, 1998; Azam *et al.*, 2020; Khalid *et al.*, 2018; Lee *et al.*, 2022; Talib & Darawi, 2002). The basic function of this study can be written as follows:

$$\text{FCPO} = f(\text{SOY}, \text{RAP}, \text{BRENT}, \text{EXR}) \quad (1)$$

Equation (1) depicts the futures crude palm oil (FCPO) as a function of soybean oil (SOY), rapeseed oil (RAP), Brent crude oil (BRENT) and exchange

rate (EXR). To approximate a normal distribution, this study re-specifies Equation (1) in econometric form and converts all variables into logarithms (L). The econometric model can be written as follows in Equation (2):

$$LFCPO_t = \alpha + \beta_1 LSOY_t + \beta_2 LRAP_t + \beta_3 LBRENT_t + \beta_4 LEXR_t + \varepsilon_t \quad (2)$$

where, α is a constant, ε_t is a random error term, and $\beta_1, \beta_2, \beta_3$ and β_4 denote the unknown parameters to be estimated. The preliminary analysis starts with a descriptive analysis of general data, followed by a unit root test. Augmented Dickey Fuller (ADF) by Dickey and Fuller (1979) and Phillips-Perron (PP) by Phillips and Perron (1988) were employed in this study to determine the level of stationarity.

This study utilised the Autoregressive Distributed Lags (ARDL) model, as it efficiently addressed endogeneity and residual correlation issues (Manasseh *et al.*, 2017; Ullah & Lin, 2024). Although ARDL allows variables to be stationary at different levels, its maximum order is at I(1). The long-run relationship was tested using the ARDL F-statistic bound test by Pesaran *et al.* (2001) within the ARDL framework to examine cointegration among the variables. The F-statistic bound test uses two asymptotic bounds with critical values based on the I(d) regressors ($0 \leq d \leq 1$), and the value of F-statistic that exceeds the upper bound [I(1)] critical value implies cointegration (Pesaran *et al.*, 2001). Conversely, this study accepts the null hypothesis if the F-statistic value falls below I(1), showing that no cointegration is found in the model. Hence, the specific null hypothesis is $H_0 : \varphi_i = 0$ shows no cointegration in the model, while alternative hypothesis $H_a : \varphi_i \neq 0$ implies the evidence of cointegration. The specific ARDL model can be expressed [Equation (3)]:

$$\begin{aligned} \Delta LFCPO_t = & a_0 + \sum_{i=1}^p \beta_{1i} \Delta LFCPO_{t-i} + \sum_{i=0}^q \beta_{2i} \Delta LSOY_{t-i} + \sum_{i=0}^q \beta_{3i} \Delta LRAP_{t-i} + \sum_{i=0}^q \beta_{4i} \Delta LBRENT_{t-i} + \sum_{i=0}^q \beta_{5i} \Delta EXR_{t-i} \\ & + \varphi_1 \Delta LFCPO_{t-1} + \varphi_2 \Delta LSOY_{t-1} + \varphi_3 \Delta LRAP_{t-1} + \varphi_4 \Delta LBRENT_{t-1} + \varphi_5 \Delta LEXR_{t-1} + \varepsilon_t \end{aligned} \quad (3)$$

where, β_i is the short-run dynamic and φ_i represents the corresponding cointegration multiplier of the underlying ARDL. In addition to examining cointegration, this study also aims to analyse the short-term impact of the IS by BMDB on FCPO. The causal relationship between these variables was tested by employing the error correction

model based on ARDL (ECM-ARDL), provided that $LFCPO_t$ in Equation (3) is cointegrated with the competitor oils in the previous cointegration test. The specific ECM-ARDL model is as follows in Equation (4):

$$\begin{aligned} \Delta LFCPO_t = & a_0 + \sum_{i=1}^p \beta_{1i} \Delta LFCPO_{t-i} + \sum_{i=0}^q \beta_{2i} \Delta LSOY_{t-i} + \sum_{i=0}^q \beta_{3i} \Delta LRAP_{t-i} + \sum_{i=0}^q \beta_{4i} \Delta LBRENT_{t-i} + \sum_{i=0}^q \beta_{5i} \Delta EXR_{t-i} \\ & + \theta ECT_{t-1} + \varepsilon_t \end{aligned} \quad (4)$$

where, ECT_{t-1} in Equation (4) signifies the performance of the dependent variable about the lagged deviation from the long-run equilibrium, while θ represents the coefficient of the speed of adjustment of the error correction term. ECT_{t-1} is statistically significant, provided the coefficient value is less than 1.

In the case of no cointegration, this study employed the short-run model-based ARDL framework in the first difference form without ECT_t in determining the causality relationship between FCPO and the competitor oils. Short-run causal impact was tested using the Wald test. The null hypothesis is $H_0 : \beta_i = 0$ and the alternative hypothesis is $H_a : \beta_i \neq 0$. Failing to reject the null hypothesis indicates no short-run causal impact from the competitor oils on FCPO.

Finally, this study conducted diagnostic tests, specifically autocorrelation and heteroskedasticity, to evaluate the adequacy and robustness of the selected ARDL models. Stability tests were also conducted by utilising Ramsey's regression equation specification error test (RESET) to identify potential misspecifications in the model, followed by cumulative sum (CUSUM) and the cumulative sum of squares (CUSUMSQ) tests to identify systematic changes in the regression coefficients and to detect sudden changes from the constancy of the regression coefficient, respectively.

RESULTS AND DISCUSSION

This study begins with a general overview of the data series. Table 2 provides a summary of the descriptive statistics for 754 and 770 data points, which represent observations made pre- and post-internationalisation of FCPO. The first moment (mean) for LFCPO indicates a positive mean value and a slight increase from 7.338 (Pre) to 7.972 (Post). Compared to other variables, LFCPO exhibits the highest mean value for both periods. The second moment shows a decrease in the volatility of LFCPO, from 0.351 (Pre) to 0.279 (Post). The LBRENT experienced the highest volatility during the pre-internationalisation period. Furthermore,

the LFCPO variable exhibited a positive skewness value (third moment), indicating a longer tail on the right side. All other variables, with the exception of LEXR and LBRENT (post), also experienced a positive skewness value, indicating a lack of symmetric distribution. The fourth moment (kurtosis) shows that LFCPO experienced negative excess kurtosis, where the kurtosis value is less than 3 during pre-internationalisation and turned into a leptokurtic distribution (value greater than 3) in post-internationalisation.

Table 3 provides a summary of the unit root test results for the stationarity of the variable series. All variables are stationary at the first difference [I(1)], and none of the variables are stationary at I(2) or higher. Therefore, the ARDL model is the most effective, suitable and appropriate model for cointegration analysis between LFCPO and the regressors.

Table 4 presents the results of the ARDL F-bound test together with the optimal ARDL lags for both periods based on the lowest value of the Akaike information criterion. The bounds test results for cointegration in Table 4 show evidence of

cointegration relationships between LFCPO, LSOY, LRAP, LBRENT and LEXR for both time periods. This result indicates the potential co-movement and impact of LFCPO from the regressors on LFCPO towards long-run equilibrium.

Meanwhile, Table 5 presents the estimated long-run regression coefficients, indicating a significant influence of LSOY on LFCPO during both pre- and post-internationalisation periods. The coefficient of LSOY during post-internationalisation is slightly lower compared to pre-internationalisation, from 1.220%-1.203%. A 1% increase in soybean oil leads to 1.220% (Pre) and 1.203% (Post) increases in the price of FCPO, implying a positive relationship between the two oils. Therefore, the implementation of the IS by BMDB has a minimal impact, resulting in a reduction of 0.017%. The overall result of a positive relationship between FCPO and soybean oil is in line with previous studies conducted by Alias and Othman (1998), Talib and Darawi (2002), Khalid *et al.* (2018) and Lee *et al.* (2022).

Concerning LRAP, the results show no cointegration between these oils, indicating that the price movement of rapeseed oil has no

TABLE 2. DESCRIPTIVE STATISTICS

Variable	Period	Mean	SD	Skew	Kurtosis
LFCPO	Pre	7.338	0.351	0.364	2.908
	Post	7.972	0.279	0.877	3.426
LSOY	Pre	3.205	0.323	0.858	3.883
	Post	3.722	0.278	0.227	1.760
LRAP	Pre	5.881	0.219	0.208	3.066
	Post	6.325	0.255	1.023	3.389
LBRENT	Pre	3.472	0.609	0.383	2.209
	Post	4.309	0.337	-0.539	2.754
LEXR	Pre	1.244	0.152	-1.419	3.538
	Post	1.338	0.148	-0.350	1.591

Note: Data observation for Pre and Post is 754 and 770 respectively. SD - standard deviation; Skew - skewness. All variables are expressed in logarithm form. L - logarithms; FCPO - futures crude palm oil; SOY - soybean oil futures; RAP - rapeseed oil futures; BRENT - brent crude oil futures; EXR - exchange rate between US Dollar (USD) against Malaysian Ringgit (MYR).

TABLE 3. UNIT ROOT TEST

Variable	Period	ADF		PP	
		I(0)	I(1)	I(0)	I(1)
LFCPO	Pre	-2.074	-12.189***	-1.945	-24.968***
	Post	-1.907	-12.428***	-1.961	-29.136***
LSOY	Pre	-1.435	-17.359***	-1.304	-27.108***
	Post	-1.529	-27.889***	-1.500	-27.889***
LRAP	Pre	-1.984	-16.957***	-1.915	-27.684***
	Post	-1.976	-27.592***	-1.949	-27.598***
LBRENT	Pre	-1.082	-14.378***	-1.052	-28.745***
	Post	-1.896	-8.877***	-2.163	-26.419***
LEXR	Pre	-2.465	-7.757***	-2.179	-33.472***
	Post	-0.561	-13.377***	-0.518	-26.674***

Note: ADF - Augmented Dickey-Fuller and PP - Philip Perron. I(0) and I(1) represent the stationarity level. *** - 1% level of significance respectively. All variables are expressed in logarithm form. L - logarithms; FCPO - futures crude palm oil; SOY - soybean oil futures; RAP - rapeseed oil futures; BRENT - brent crude oil futures; EXR - exchange rate between US Dollar (USD) against Malaysian Ringgit (MYR).

impact on FCPO during both pre- and post-internationalisation periods. The result of this study contradicts the previous study conducted by Azam *et al.* (2020), who found that palm oil led the price of rapeseed oil from 2006 until 2014. This suggests that the relationship between these oil prices in the physical and futures markets varies, likely due to the diverse types of market participants and their varying trading objectives. The empirical outcome of LBRENT is quite surprising. The results indicate that LBRENT had a significant 1% influence on LFCPO during the pre-internationalisation phase, but this influence became insignificant once BMDA implemented its IS. During pre-internationalisation, the coefficient of LBRENT, which stands at -0.213, suggests that a 1% increase in Brent crude oil corresponds to a -0.213% decrease in the price of FCPO, indicating a negative relationship between these oils. The result of this study is in line with Yu *et al.* (2006) and Campiche *et al.* (2007) but contradicts Nazlioglu and Soytaş (2012), Arshad and Hameed (2012), Jeong *et al.* (2023) and Supriya and Mamilla (2024).

The exchange rate, as denoted by LEXR, demonstrates a significant result at the 1.000% level for both the pre- and post-internationalisation of FCPO. This result is in line with the ICAPM, where the exchange rate works as an explanatory variable for CPO, especially after positioning this commodity in the global market. However, the result shows that the coefficient of LEXR decreased from 1.120% (pre) to 0.941% (post). This is due to changes in the exchange rate regime, where Malaysia pegged the MYR against the USD

starting in September 1998 and de-pegged it after seven years in July 2005. Therefore, a stronger or weaker MYR increases the attractiveness of FCPO for foreign market participants who hold foreign currencies.

Further analysis of the causality relationship, as depicted in Table 6, between the regressors and FCPO provides substantial statistical evidence of short-term impacts. Strong evidence existed for causal impacts from LSOY and LEXR to LFCPO, both pre- and post-internationalisation. Thus, soybean futures and exchange rates play a significant role in predicting FCPO's behaviour and movements in the short term.

The results of LRAP and LBRENT differ from other regressors. Rapeseed oil did not have a significant causal impact during the pre-internationalisation phase but had a strong causal impact after BMDA listed FCPO on the CME Globex system. One possible explanation is that foreign market participants involved in the rapeseed oil business may enter FCPO, either to hedge or arbitrage during specific economic events. The causal impact analysis from LBRENT to FCPO reveals a similar relationship pattern to the cointegration test. Brent crude oil had a significant causal impact before the internationalisation of FCPO and became insignificant during post-internationalisation. A plausible explanation is that the price of crude oil dropped from USD140-USD35 per barrel in 2008 as a result of the Global Financial Crisis. Consequently, the lower crude oil prices make biofuel less appealing, as crude oil traders are not compelled to engage in FCPO to hedge against higher crude oil prices.

TABLE 4. ARDL F-BOUND TEST

LFCPO = f(LSOY, LRAP, LBRENT, LEXR)				
Period	Model	Critical value		F-Stat
		I(1)		
		10%	5%	
Pre	(4, 4, 1, 2, 1)	3.09	3.49	3.440*
Post	(4, 3, 1, 0, 1)	3.09	3.49	3.365*

Note: Model is optimal lag model selection criteria based on the lowest Akaike Information Criterion (AIC) where the maximum number of lags is set to four. F-Stat for F-Statistic. * - 10% level of significance respectively. All variables are expressed in logarithm form.

TABLE 5. ARDL LONG RUN COEFFICIENTS

LFCPO = f(LSOY, LRAP, LBRENT, LEXR)				
Period	LSOY	LRAP	LBRENT	LEXR
Pre	1.220***	0.090	-0.213***	1.120***
Post	1.203***	-0.364	-0.205	0.941***

Note: *** - 1% level of significance respectively. All variables express in logarithm form. L - logarithms; FCPO - futures crude palm oil; SOY - soybean oil futures; RAP - rapeseed oil futures; BRENT - Brent crude oil futures; EXR - exchange rate between US Dollar (USD) against Malaysian Ringgit (MYR).

Meanwhile, the result for the cointegrated model's ECT for both periods are statistically significant at the 1.0% level, as the coefficient value (θ) is less than 1 with a negative sign. The associated ECT coefficient values are -0.047 and -0.038 respectively. These values indicate that during pre-internationalisation, a 4.7% deviation from the long-run equilibrium was corrected each week for about 21.3 weeks ($1/\theta$). During post-internationalisation, a 3.8% deviation from the long-run equilibrium was corrected each week for about 26.3 weeks. The adjustment speed of correction rate towards long-run equilibrium is longer during post-internationalisation compared to the pre-internationalisation.

This study examines the goodness of fit of the ARDL model, with results presented in Table 7 and Figure 2 and 3. According to the Jarque-Bera test statistic, normality testing rejects the null hypothesis of a normal distribution for both pre- and post-internationalisation periods, indicating a non-normal distribution of the residual series. Nevertheless, with 754 observations for the pre-internationalisation phase and 770 for the post-internationalisation phase, the series are considered normally distributed based on the central limit theorem due to the substantial observations ($N > 30$).

Furthermore, the results indicate that the models are devoid of autocorrelation. However, both models failed the heteroskedasticity test, suggesting residual errors in the model. Subsequently, this study re-estimated ARDL models, employing the heteroskedasticity and autocorrelation consistent (HAC) estimator. The RESET test affirmed the correct specification of the ARDL regression models. Additionally, the CUSUM test portrays

stable regression coefficients within the 5% critical bounds. Nevertheless, CUSUMSQ reveals variance inconsistencies as displayed in Figure 2 and 3.

The presence of non-normality and variance inconsistency in the series suggests potential autoregressive conditional heteroskedasticity (ARCH) effects. This warrants the application of models such as ARCH or Generalised ARCH to better capture the dynamics of time-varying volatility. Hence, these findings highlight the need for further investigation. Consequently, future studies should delve into the level of volatility spillover and transmission before and after positioning FCPO in the global market using this international strategy. This approach will enhance our comprehension of the relationship between FCPO and rival oils by scrutinising the associated risks.

CONCLUSION

Positioning FCPO in global markets can expose it to significant global market price fluctuations due to an increase in market participants with diverse trading objectives. This study presents the outcomes of the IS implemented by BMDB using the ARDL model to evaluate the level of cointegration between FCPO and competing oils in both pre- and post-samples. The empirical findings indicate that soybean oil futures, the primary competitor of CPO, are cointegrated with FCPO both before and after internationalisation. The degree of cointegration, based on the ARDL long-run coefficient, slightly decreased from 1.220%-1.203% post-internationalisation compared

TABLE 6. SHORT RUN CAUSALITY TEST

LFCPO = $f(\text{LSOY}, \text{LRAP}, \text{LBRENT}, \text{LEXR})$					
Period	LSOY	LRAP	LBRENT	LEXR	ECT
Pre	37.410***	1.122	3.173**	69.977***	-0.047***
Post	61.988***	6.662***	1.589	8.833***	-0.038***

Note: *** and ** - 1% and 5%, level of significance respectively. ECT - an error correction term and only applicable to the models in the presence of cointegration. All variables express in logarithm form. L - logarithms; FCPO - futures crude palm oil; SOY - soybean oil futures; RAP - rapeseed oil futures; BRENT - brent crude oil futures; EXR - exchange rate between US Dollar (USD) against Malaysian Ringgit (MYR).

TABLE 7. DIAGNOSTIC TEST

LFCPO = $f(\text{LSOY}, \text{LRAP}, \text{LBRENT}, \text{LEXR})$				
Period	JB	SC	HET	RESET
Pre	143.764***	3.963	59.680***	2.576
Post	77.521***	2.275	71.329***	1.523

Note: JB - Jarque Bera test; SC - autocorrelation test based on the Breush-Godfrey Serial Correlation Lagrange multiplier test; HET - heteroscedasticity based on the White test; RESET - Ramsey Regression Equation Specification Error Test. *** - 1% level of significance respectively.

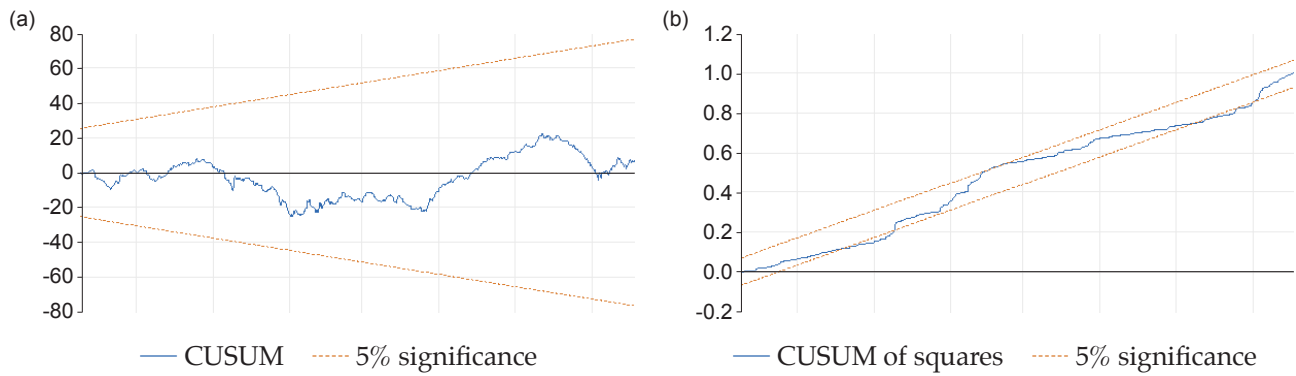


Figure 2. (a) CUSUM and (b) CUSUMSQ for the period of pre-internationalisation.

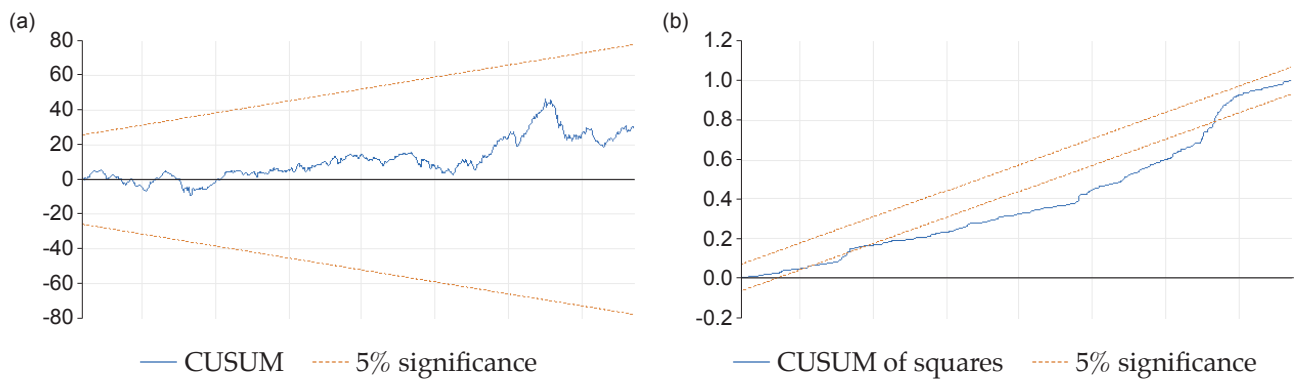


Figure 3. (a) CUSUM and (b) CUSUMSQ for the period of post-internationalisation.

to pre-internationalisation. BMDB's IS has resulted in a minimal impact, with a reduction of 0.017%. This implies that FCPO and soybean oil will move together regardless of variations in trading systems involving diverse market participants.

Conversely, another competitor, rapeseed oil, did not show cointegration with FCPO before or after internationalisation. Nevertheless, causal analysis reveals that rapeseed oil significantly influenced FCPO after being listed by BMDB in the CME Globex system. Foreign market participants involved in the rapeseed oil sector may enter FCPO's market during specific economic events for hedging or arbitrage opportunities.

In contrast, Brent crude oil yielded contrary and unexpected results. The study shows that Brent crude oil significantly affected FCPO before internationalisation, but this influence diminished post-internationalisation following BMDB's strategy. The causal impact analysis mirrors this relationship. Prior to FCPO's internationalisation, Brent crude oil had a significant causal impact, which lost significance post-internationalisation. A possible explanation is the drop in crude oil prices from USD140-USD35 per barrel in 2008 before the international strategy, reducing the attractiveness of

biofuels and the need for hedging due to low crude oil prices, thereby lowering incentives for crude oil traders to engage in the FCPO market.

Although this study focuses on the relationship between FCPO and competing oils, the influence of exchange rates on FCPO remains crucial. Exchange rates significantly affect the price of FCPO both pre- and post-internationalisation. However, the exchange rate coefficient decreased from 1.120% pre-internationalisation to 0.941% post-internationalisation. This is attributed to changes in the exchange rate regime before BMDB positioned FCPO in the global market via its listing in the CME Globex system. Malaysia pegged the MYR to the USD from September 1998-July 2005, attracting foreign market participants holding foreign currencies to participate in the FCPO market during fluctuations in the MYR.

The ARDL model results indicate that BMDB's IS, listing FCPO in the CME Globex system, has mitigated the impact of price fluctuations from competing oils and exchange rates on FCPO. As a result, FCPO's positioning in global markets has not exposed it to additional risks, effectively preserving palm oil's status as a primary edible oil and FCPO as a GIR. BMDB should continue this international strategy beyond September 2028

with CME and explore partnerships with other exchanges, especially The Dalian Commodity Exchange in China and the National Commodity and Derivatives Exchange in India, the two largest palm oil exporters, to broaden the participation of market players from these regions.

As one of the most crucial and controversial edible oils, CPO has faced export restrictions from the European market. Malaysia, through MPOB and BMDB, has implemented numerous strategies, policies, and initiatives to tackle this issue. Apart from positioning FCPO in global markets, BMDB ensures that local and foreign market participants opting for physical delivery receive CPO from mills complying with Malaysian Sustainable Palm Oil (MSPO) certification criteria. This ensures that the physical delivery of FCPO drives the palm oil industry towards sustainability, aligning with the United Nations' Sustainable Development Goals Agenda 2030. In conclusion, MPOB and BMDB play essential roles by meticulously executing policies and strategies to safeguard one of Malaysia's most valuable assets.

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UNITED STATES TARIFF SHOCKWAVES: MALAYSIA'S PALM OIL IN THE CROSSHAIRS

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ABSTRACT

This article presents an analysis on the implications of the 2025 United States (U.S.) tariffs policy introduced under President Donald Trump administration on Malaysian palm oil industry (when this article was written). It examines the multifaceted impact of the early slapped of 24% tariff by the U.S. before it was escalated to 25%, then reduced to 19% on August 2025 (after went through delicate trade negotiations and bargaining) necessitates discussion on the Malaysian exports through economic, political, and strategic lenses. The analysis reflects on the broader context of global trade tensions and protectionist trends, while also evaluating Malaysia's policy responses and adaptive strategies. Drawing on current developments and historical parallels, the article offers a forward-looking perspective on the long-term viability and resilience of Malaysia's palm oil industry in an increasingly uncertain trade environment.

Keywords: export, Malaysia, palm oil, tariff, Trump.

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INTRODUCTION

Palm oil remains a cornerstone of Malaysia's economy, generating over RM80 billion annually and sustaining the livelihoods of more than 450,000 smallholders (Malaysian Palm Oil Council [MPOC], 2025). While the United States (U.S.) is not among the top importers by volume, it represents a high-value destination for refined palm oil, particularly in sectors such as food processing, cosmetics and biofuels (Malaysia External Trade Development Corporation [MATRADE], 2024).

In recent years, the U.S. has emerged as an increasingly strategic market for Malaysian palm oil, driven by Malaysia's diversification efforts and shifting global consumer preferences. Traditionally dependent on major buyers like India and China, Malaysia is actively broadening its export base to reduce market concentration and enhance trade resilience (Salehuddin, 2025). The U.S. market is especially attractive due to its rising demand for sustainably sourced and certified palm oil – Aligning with North America's growing environmental consciousness and stringent regulatory standards (Salehuddin, 2025).

In response to evolving global market demands, Malaysia has significantly strengthened its sustainability agenda through the Malaysian Sustainable Palm Oil (MSPO) certification scheme. The upgraded MSPO 2.0 now integrates advanced environmental safeguards, including high conservation value (HCV) assessments and greenhouse gas (GHG) emissions tracking, reflecting Malaysia's commitment to responsible palm oil production (Salehuddin, 2025; Yap *et al.*, 2021). In other words, unlike the original MSPO (MSPO 1.0) which focused primarily on promoting sustainable practices, MSPO 2.0 introduces mandatory compliance, stricter audits and

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enhanced traceability across all industry players. The upgraded scheme ensures that Malaysian palm oil is not only sustainably produced but also ethically sourced, verifiable and meeting the expectations of international markets and consumers. Hence, it should position Malaysian palm oil as a responsible and competitive choice in the global supply chain.

As of December 2024, a total of 4.89 million hectares of oil palm plantations had been certified under the MSPO framework, reinforcing Malaysia's credibility as a sustainable producer on the global stage (BERNAMA, 2025a). The scheme's inclusion in the International Trade Centre's Sustainability Map further elevates its visibility among international buyers and trade bodies (YYC Advisors, 2025).

By aligning its production standards with global sustainability benchmarks, Malaysia is positioning itself as a trusted and ethical supplier – Particularly in discerning markets like the U.S. However, this progress faces new challenges. The re-election of Donald Trump in 2024 and the subsequent imposition of tariffs on Malaysian palm oil in April 2025 have disrupted bilateral trade flows, prompting an urgent reassessment of Malaysia's export strategies and market diversification efforts. This situation has been foresighted by Clausen and Obstfeld (2024) on the adverse effects from Trump's tariff.

The 2025 Tariff Policy: Context and Rationale

On April 2, 2025, the president proclaimed "Liberation Day," unveiling a sweeping trade policy that included a 10% baseline tariff on all imports and a punitive 25% then reduced to 19% through negotiation and bargaining of trades which equates to "reciprocal tariff" targeting countries like Malaysia, which he accused of imposing unfair trade barriers (Flach & Baur, 2025). The justification was based on a contested claim that Malaysia levies a 47% tariff on U.S. goods – An assertion strongly

refuted by Malaysian officials, who cited an average tariff rate of just 5.6% (Ahn, 2025; Ikram & Hazim, 2025).

Although a 90-day suspension of the higher tariff was granted starting April 9, 2025, the uncertainty surrounding its final implementation has already disrupted trade flows and shaken business confidence. Malaysian exporters continue to operate under the 10% baseline tariff, but the looming threat of hike has created a volatile and risk-averse environment.

Tariff: Good or Bad

There are always two sides to a coin, and tariffs are no exception. Tariffs present a dual spectrum that must be thoroughly understood, and striking a balance between their advantages and disadvantages is essential. *Figure 1* illustrates both the positive and negative aspects of tariffs.

On the positive side, tariffs are often viewed as a form of economic nationalism (Sheldon *et al.*, 2018). They serve to protect domestic industries, aligning with initiatives like those of President Trump, who aimed to repatriate companies with manufacturing plants or warehouses located abroad. Additionally, tariffs generate revenue for the government and can function as a strategic trade policy. This is evident when other nations seek negotiations with the U.S. (Zhao & Wang, 2025), indicating that the policy is achieving its intended impact.

However, excessive protectionism can lead to significant drawbacks, particularly in terms of economic efficiency. One of the primary reasons companies established operations overseas was to benefit from lower operating costs (Biglaiser *et al.*, 2025). These cost savings translated into higher profits. Forcing companies to relocate back to the U.S. can introduce inefficiencies into the production process.

Moreover, trade wars and retaliatory measures have already emerged, with countries such as Canada, China and Mexico responding

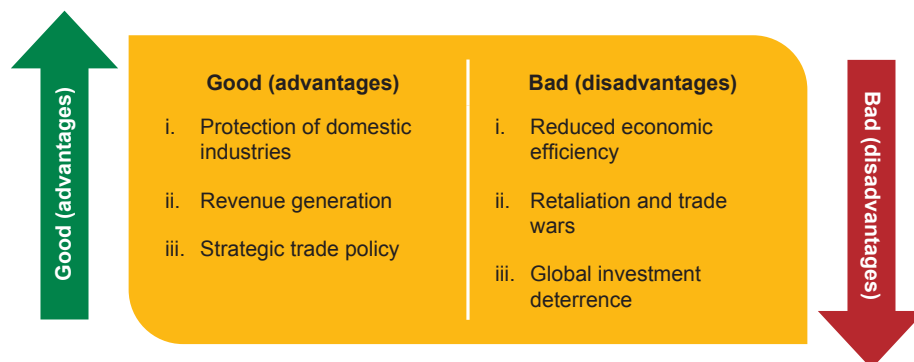


Figure 1. Tariff effects: Good vs. bad.

with varying tariff rates depending on the product category (Alessandria *et al.*, 2025). These developments can deter global investment, as increased costs, bureaucratic hurdles, trade conflicts and geopolitical tensions create a less attractive business environment.

Malaysia's Minister of Investment, Trade and Industry (MITI) described the situation as "fluid and uncertain," emphasising that the temporary pause is a window for negotiation – Not a resolution (Kausikan, 2025; Ng, 2025). The unpredictability of U.S. trade policy has led many exporters to delay shipments or reassess their supply chain strategies. The Malaysian Industrial Chamber of Commerce and Industry (MICCI) has warned that reinstating the 25% tariff could result in up to 50,000 job losses, particularly in industrial hubs like Penang and Johor (Kausikan, 2025; YYC Advisors, 2025).

Beyond trade, the uncertainty has also affected investor sentiment and currency stability, with the ringgit weakening amid fears of a broader economic slowdown. This depreciation has increased the cost of imported raw materials, further straining small

and medium-sized enterprises (SMEs). Despite the temporary reprieve, the broader impact on trade confidence, employment and long-term economic planning remains significant – Underscoring the urgent need for diplomatic engagement and strategic market diversification (BERNAMA, 2025b).

MALAYSIAN PALM OIL: EXPOSURE AND VULNERABILITY

Export Profile

Malaysia exported approximately 1.2 million tonnes of palm oil and palm-based products to the U.S. in 2024, valued at over RM3.5 billion (MPOC, 2025). *Figure 2* shows the year-over-year growth in Malaysia's palm oil export volume to the U.S. from 2020-2024. The export volume increased steadily from 0.8 million tonnes in 2020 to 1.2 million tonnes in 2024, and at the same time the value of export also steadily increased over the duration, as depicted in *Figure 3*.

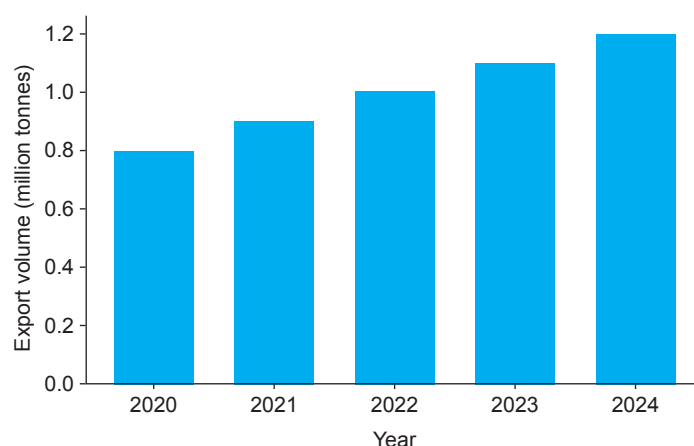


Figure 2. Malaysia palm oil export volume to the U.S. (2020-2024).

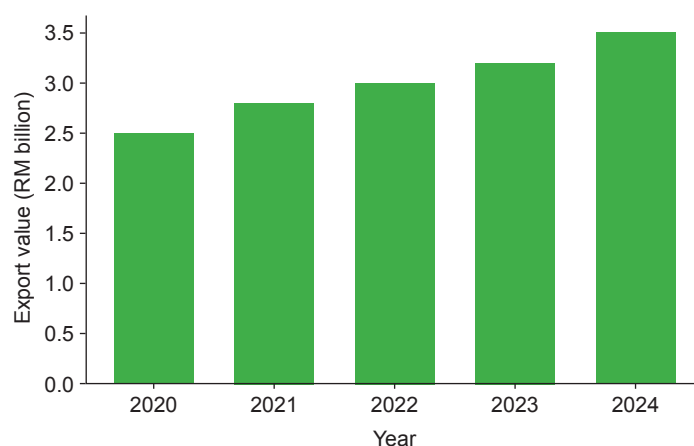


Figure 3. Malaysia palm oil export value to the U.S. (2020-2024).

Figure 3 depicts that the export value rose from RM2.5 billion in 2020 to RM3.5 billion in 2024, reflecting both increased volume and higher market prices for the U.S. market. These exports include:

Refined, bleached and deodorised (RBD) palm olein. This is one of the primary processed palm oil products exported by Malaysia. In 2024, RBD palm olein remained a key export item, with Free on Board (FOB) prices averaging RM4,417/t (Parveez, 2024).

Palm kernel oil (PKO). While not always highlighted separately in trade summaries, PKO is a significant derivative of the oil palm fruit and is commonly included in Malaysia's export portfolio, especially for industrial and food applications (Parveez, 2024).

Palm-based oleochemical. These are widely used in personal care, cosmetics, detergents and industrial applications. Malaysia is a global leader in oleochemical production, and exports to the U.S. include fatty acids, glycerine and other derivatives used in both consumer and industrial sectors (Parveez, 2024).

These product categories are part of Malaysia's broader palm oil export strategy, which in 2024 saw total exports rise to 16.9 million tonnes globally, with the U.S. receiving approximately 1.2 million tonnes of palm oil and palm-based products (Parveez, 2024).

Tariff Impact

The imposition of a starting 2% tariff before increased to 25% and reduced back tremendously to 19% (through a lot of negotiations and bargaining of trades) has significantly undermined the competitiveness of Malaysian palm oil in the U.S. market, making it less attractive compared to alternatives such as Colombian and Guatemalan palm oil, as well as domestically produced U.S. soybean oil (Boucher & Thies, 2019; Salim, 2025). This policy shift has triggered a cascade of disruptions across the palm oil export value chain:

Contract renegotiations or cancellations. The uncertainty surrounding the permanence of the tariff has led many U.S. buyers to renegotiate or cancel long-term contracts with Malaysian exporters. Industry sources report a shift toward short-term spot contracts or a pivot to Latin American suppliers as a hedge against rising costs (Salim, 2025). This has disrupted forward planning and reduced the predictability of export volumes.

Increased warehousing costs due to shipment delays. With many shipments delayed pending tariff clarification, exporters have faced rising

warehousing and demurrage costs. Containers are being held at ports or redirected to third-party logistics hubs, increasing operational expenses and straining storage capacity (Salim, 2025). This has particularly affected exporters in Johor and Selangor, where port congestion has intensified.

Price volatility in futures markets. The tariff announcement has also triggered volatility in palm oil futures markets, both in Malaysia and globally. On Bursa Malaysia, crude palm oil (CPO) futures dropped over 12% from their February 2025 peak of RM4,463/t to RM3,911/t by mid-May (Nair, 2025). This decline reflects investor uncertainty and speculative repositioning in response to shifting trade dynamics and geopolitical risks.

The MPOC estimates that the tariff could reduce palm oil exports to the U.S. by up to 40% if fully implemented (Malay Mail, 2025). This would translate to a revenue loss of RM1.4 billion annually and could affect up to 15,000 jobs in the downstream processing sector (BERNAMA, 2025c). This projection is based on 2024 export figures, where Malaysia shipped approximately 1.2 million tonnes of palm oil and palm-based products to the U.S., valued at over RM3.5 billion (Malay Mail, 2025).

Impact on Employment

The downstream processing sector, which includes refining, packaging, and value-added palm-based manufacturing, is particularly vulnerable. The MPOC warns that up to 15,000 jobs could be at risk if the tariff is fully enforced (BERNAMA, 2025c; Malay Mail, 2025). These jobs are concentrated in industrial zones in Johor, Selangor and Sabah, where palm oil processing clusters are located.

Vulnerability of Small and Medium Enterprises (SMEs)

The SMEs in the palm oil value chain particularly those involved in refining and downstream processing are among the most vulnerable to the tariff shock. Operating on tight margins and often lacking the financial resilience of larger corporations, many SMEs are ill-equipped to absorb sudden cost increases or pivot swiftly to alternative export markets.

The impact is especially severe for SMEs engaged in the production of oleochemicals, specialty fats, and personal care ingredients, as these products are frequently customised to meet U.S. regulatory and consumer standards. This specialisation makes market diversification more complex and time-consuming (Malay Mail, 2025).

Without immediate support or strategic intervention, these businesses face a heightened risk of cash flow disruptions, reduced production capacity, workforce downsizing, or even closure. The ripple effects could extend beyond the palm oil industry, affecting employment, supply chains and regional economies that depend heavily on SME activity.

MALAYSIA'S STRATEGIC RESPONSE

Diplomatic Engagement

In response to the early imposition of a 25% tariff on Malaysian exports including the palm oil, the MITI has launched high-level diplomatic efforts to mitigate the fallout. On April 24, 2025, a Malaysian delegation led by the Minister of MITI traveled to Washington, D.C., for direct consultations with the U.S. Trade Representative to reflect the seriousness of Malaysia's intention.

The mission's primary objective was to advocate for sector-specific exemptions or adjustments, particularly for industries such as palm oil, semiconductors, electrical and electronics, which are deeply embedded in U.S. supply chains. Minister of MITI underscored Malaysia's role as a neutral, constructive and reliable trade partner, emphasising its contributions to global supply chain resilience and its adherence to multilateral trade norms.

MITI clarified that while the visit did not constitute formal negotiations, it was a strategic diplomatic engagement aimed at fostering goodwill and laying the foundation for structured dialogue (Singh & Cheng, 2025). As the 2025 Association of Southeast Asian Nations (ASEAN) Chair, Malaysia also used the platform to present the regional bloc's collective position, advocating for a rules-based international trading system and urging the U.S. to reconsider unilateral measures that risk undermining long-standing economic partnerships.

Market Diversification

In response to escalating trade uncertainties with the U.S., Malaysia is accelerating efforts to strengthen and diversify its palm oil export markets. This initiative forms part of a broader national trade strategy aimed at enhancing the industry's resilience and ensuring long-term, sustainable growth.

China. China continues to be a key growth market for Malaysian palm oil, underpinned by robust bilateral agreements and the Belt and Road Initiative (BRI). Within the framework of

the Malaysia-China Five-Year Economic and Trade Cooperation Programme, palm oil has been designated a priority commodity. In 2024 and early 2025, Malaysia expanded exports of refined palm oil and oleochemicals to China, particularly for use in food processing and industrial applications (MATRADE, 2025). Infrastructure and logistics enhancements under the BRI have also improved access to inland Chinese markets, further boosting trade efficiency.

India. Despite historical diplomatic frictions, India remains a cornerstone market for Malaysian palm oil exports. In 2024, India imported over 2.5 million tonnes of Malaysian palm oil, driven by robust demand from its food processing and hospitality sectors (MATRADE, 2025). This enduring trade relationship has been reinforced by the India-Malaysia Comprehensive Economic Cooperation Agreement (CECA), which has played a pivotal role in stabilising trade flows and fostering bilateral economic ties.

Recent high-level dialogues have focused on broadening cooperation in value-added palm-based products, particularly in segments such as specialty fats, bakery ingredients and industrial applications. These efforts reflect a shared interest in moving beyond commodity trade toward higher-value, innovation-driven partnerships that benefit both economies.

Middle East and Africa. Malaysia is also targeting Muslim-majority markets in the Middle East and Africa with halal-certified palm oil products. These include cooking oils, margarine and personal care items that comply with both halal and international quality standards. In 2024, exports to countries like Saudi Arabia, Egypt and Nigeria saw double-digit growth, supported by promotional campaigns led by the MPOC and Halal Development Corporation (HDC). These markets are particularly receptive to Malaysia's branding of palm oil as both sustainable and Shariah-compliant.

As part of its market diversification strategy, Malaysia is pursuing dual objectives: Expanding into new high-potential markets while simultaneously navigating emerging regulatory challenges. This balanced approach is essential to sustaining palm oil export growth amid shifting global trade dynamics.

However, Malaysia now faces increasing scrutiny from the European Union (EU) environmental trade policies, particularly the Carbon Border Adjustment Mechanism (CBAM). This initiative aims to prevent carbon leakage by imposing a carbon cost on imports from countries with less stringent climate regulations. In parallel, the EU Deforestation-Free Regulation (EUDR) targets agricultural commodities including palm

oil, soy, wood and coffee requiring exporters to prove that their products are not linked to deforestation or forest degradation.

These evolving regulatory frameworks present both a compliance challenge and a strategic inflection point for Malaysia, underscoring the need to align its sustainability practices with international expectations while continuing to diversify its export base.

Downstreaming and Environmental, Social and Governance (ESG) Compliance

To reduce reliance on raw exports, Malaysia may invest in refining. This will stimulate growth in biodiesel refining capacity, creating downstream jobs and tech transfer.

Oleochemical production for pharmaceuticals and cosmetics. Malaysia is significantly expanding its oleochemical sector, which produces fatty acids, glycerine and esters used in pharmaceuticals, cosmetics and personal care products. This move is part of a broader strategy to increase the value-added component of palm oil exports. According to the Malaysian Investment Development Authority (MIDA), Malaysia is one of the world's top producers of oleochemicals and new investments in biorefineries and specialty chemical plants are being prioritised in Johor and Selangor. These facilities are designed to meet stringent international standards, including those required by the U.S. Food and Drug Administration (FDA) and EU Registration, Evaluation, Authorisation, and Restriction of Chemicals (REACH) regulations.

Sustainable palm oil certification (MSPO and RSPO) to meet EU and global ESG standards. To meet global ESG standards, Malaysia is accelerating the adoption of MSPO and Roundtable on Sustainable Palm Oil (RSPO) certifications. The MSPO standard, which is mandatory for all Malaysian palm oil producers, is being upgraded to align with the EUDR and other international benchmarks. These certifications enhance traceability, reduce deforestation risks and improve labour practices are key requirements for maintaining access to premium markets in the EU, Japan and North America.

Biofuel innovation, including palm-based aviation fuel. Malaysia is also investing in biofuel innovation, particularly in the development of palm-based sustainable aviation fuel (SAF). This aligns with global decarbonisation goals and the International Civil Aviation Organization's (ICAO) push for greener aviation. The Malaysian Palm Oil Board (MPOB) is collaborating with local universities and international partners to

scale up pilot projects and commercialise palm-based SAF by 2027 (MATRADE, 2025). These efforts are supported by national policies under the National Energy Transition Roadmap (NETR), which includes palm oil as a key feedstock for next-generation biofuels.

Besides, Malaysia already implemented the biodiesel blending mandates (such as B10) in shaping domestic demands and pricing. This mandate is important in cushioning against the global price volatility. The Malaysian Biodiesel Association (MBA) anticipates an increase in the nation's biodiesel production to 2.5 million tonnes upon the full implementation of the government's B20 mandate (Kondalamahanty *et al.*, 2024).

GLOBAL TRADE AND ENVIRONMENTAL CONSIDERATIONS

Trade Realignment

The imposition of the latest tariff on Malaysian palm oil by the U.S. in 2025 is not an isolated policy move, but it is emblematic of a broader global trend toward deglobalisation and trade fragmentation. This shift is driven by a growing preference among major economies for economic nationalism, supply chain reshoring and strategic autonomy, particularly in sectors deemed critical to national security, such as agriculture and energy (Wengerek *et al.*, 2025).

For Malaysia, this trend poses significant challenges. With a trade-to-GDP ratio of 130%, the country is among the most trade-dependent economies in the world, since Malaysia's economic structure makes it highly sensitive to global trade disruptions, especially in key export sectors like palm oil (ASEAN, 2025). The palm oil industry, which contributes billions to Malaysia's export earnings and supports hundreds of thousands of jobs, is now at the forefront of this global realignment.

Environmental Impact

The imposition of the latest trade tariff on Malaysian palm oil by the U.S. in 2025 has not only economic but also environmental consequences. With reduced export pressure, Malaysia may find new opportunities to reassess land use strategies and focus on reforestation and biodiversity conservation. Malaysia has made significant strides in improving the sustainability of its palm oil industry.

Likewise, between 2014 and 2023, the country reduced primary forest loss by 65% and overall tree cover loss by 52%, according to data from Global Forest Watch and the World Resources Institute (Sron, 2025). These achievements are supported

by the MSPO certification, which enforces strict environmental and traceability standards across the supply chain.

The EUDR, set to take effect in 2025, has further incentivised Malaysia to maintain low deforestation rates. The country is actively seeking a “low-risk” classification under the EUDR, which would ease compliance burdens for exporters and enhance Malaysia’s reputation as a sustainable palm oil producer (Sron, 2025).

However, there is a countervailing risk. If access to regulated markets like the U.S. and EU becomes more difficult, some producers especially the smaller and less capitalised ones may pivot to less regulated markets in Africa, South Asia, or parts of the Middle East. These markets often lack stringent environmental or labour standards, potentially undermining Malaysia’s sustainability gains.

This risk is particularly acute for non-certified producers or those operating on the margins of the formal economy. Without strong enforcement and incentives, these actors may prioritise short-term survival over long-term environmental stewardship. Therefore, international cooperation among the main palm oil producers is necessary to ensure that palm oil is a global brand that reflects on the commitment towards sustainability and quality. This is no longer a task for one country alone, but it requires a unified, global effort.

CONCLUSIONS

Trump’s 2025 tariffs have posed a multifaceted challenge to Malaysia’s palm oil industry. While the immediate economic repercussions are considerable, this article argues based on prior analysis, that the crisis also unveils a strategic opportunity for long-term structural reform and industry resilience. The 2025 tariff crisis has underscored the need for Malaysia to future-proof its palm oil industry. By investing in innovation, sustainability, and strategic partnerships, Malaysia is laying the groundwork for a more resilient, diversified and globally competitive industry. This transformation is not only essential for economic survival but also for long-term leadership in the global palm oil market.

Malaysia is accelerating its transition from a raw commodity exporter to a value-added producer. Investments are being channelled into oleochemicals, specialty fats and bio-based materials (products used in pharmaceuticals, cosmetics and industrial applications). These segments offer higher margins and are less exposed to commodity price volatility. The MPOB has prioritised downstream innovation in its 2025 research and development agenda.

All the forces are reshaping Malaysia’s palm oil sector. Together, it offers both threats and transformative opportunities, especially if the industry can respond through sustainable rebranding (*i.e.* rich in antioxidants and beta-carotene), Islamic green finance (*i.e.* *sukuk* for biodiesel infrastructure) and regional policy coordination among the ASEAN block (*i.e.* ASEAN Biodiesel Sustainable Framework).

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