

Oil Palm Industry Economic Journal

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PALM OIL PRICE REVIEW AND OUTLOOK 2024

SATHIA VARQA^{1*}

ABSTRACT

This article reviews the palm price movement in the first four months of this year and presents a price outlook for the rest of the year. This article identifies and explores the underlying price drivers of crude palm oil (CPO) futures and cash prices by exploring related palm fundamentals and relevant external variables. CPO futures on Bursa Malaysia have been on a rising trajectory since the start of this year rallying from RM3,661 (USD774)/t in January, accelerating to a peak of RM4,407 (USD932)/t at the beginning of April, or up RM746 (USD158) or 20% in the three months. Prices took a turn after testing the high of RM4,407 (USD932)/t, decelerating rapidly to RM3,818 (USD808)/t towards the end of April or down by RM492 (USD104) or 11% in the space of four weeks. Overall year-to-date ending 30 April active month CPO futures averaged RM3,989 (USD844)/t or just RM76 (USD16) or 2% higher than the same period last year reflecting a steady to marginal increase in prices compared to last year. This article will address the main factors in understanding the dynamics of CPO futures pricing behaviour by discussing the main fundamental price drivers for the rest of the remaining part of this year.

Keywords: palm oil price; price forecast.

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INTRODUCTION

This article mainly delves into discussing the palm oil price scenario using Malaysian data although Malaysia is the second largest producer of crude palm oil (CPO) accounting for 25% of global production while Indonesia makes up nearly two-thirds. This is because Malaysian palm oil data is largely viewed as a global reference in understanding the dynamics of benchmark CPO futures contract pricing movement which is listed on Bursa Malaysia. Therefore, Malaysian palm oil supply and demand situation is a far more significant predictor than Indonesia's. Malaysia's supply and demand data are released in a timely, consistent and accurate manner by the government regulator, the Malaysian Palm Oil Board (MPOB) whereas Indonesia's supply and demand data are released somewhat accurately and always

late by the voluntary body, Indonesian Palm Oil Association (IPOA) or known locally as Gabungan Pengusaha Kelapa Sawit Indonesia (GAPKI).

Palm prices started off the year significantly below the same period of last year by a gap of RM592 (USD125) but witnessed a rapid rise subsequently underpinned by a tight supply outlook from seasonal low output and exacerbated by adverse weather conditions resulting in sub-optimal output amid prospects of strong seasonal demand, particularly from China to meet the Lunar New Year consumption demand. The beginning of the year also saw CPO futures receiving support from externals of higher crude oil prices strengthened by geopolitical risk following supply risk assessments from the intensifying maritime tension in the Red Sea, a crucial trade route between Asia and Europe through the Suez Canal.

Although exports in the four months from November 2023 to February 2024 were trending lower month-on-month, largely weighed by the loss in palm oil competitiveness to soft oils, the pace of exports picked up strongly in March rising by 28.61% aiding to depress end-month stocks for

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the four successive months to land at the lowest in 10 months as of the end of March at 1.71 million tonnes (MPOB, 2024).

Further bolstering prices in the first three months of the year were positive sentiments both within the palm sector and, at the macro level. Palm price outlook received a huge dose of positive sentiment from the largest palm oil industry gathering Price Outlook Conference (POC) in March 2024 in Kuala Lumpur, Malaysia as leading industry analysts converged to the view of a 'tight supply outlook' scenario for the first quarter. Meanwhile, at the macro level signs of slowing inflationary pressure in the US raised hopes of a pivot to a lower interest rate path from the Federal Reserve opening the opportunity for steady aggregate demand growth while easing the strength of the dollar and increasing the value of the sharply depreciating emerging currency values. The sectoral and external factors supported CPO futures to notch a year-high price of RM4,407 (USD932)/t on 3 April. Prices have since declined to RM3,818 (USD808)/t as of the end of April or down RM589 (USD126) or 13% lower (Bursa Malaysia Derivatives, 2024).

MAIN PRICE DRIVERS: JANUARY TO APRIL 2024

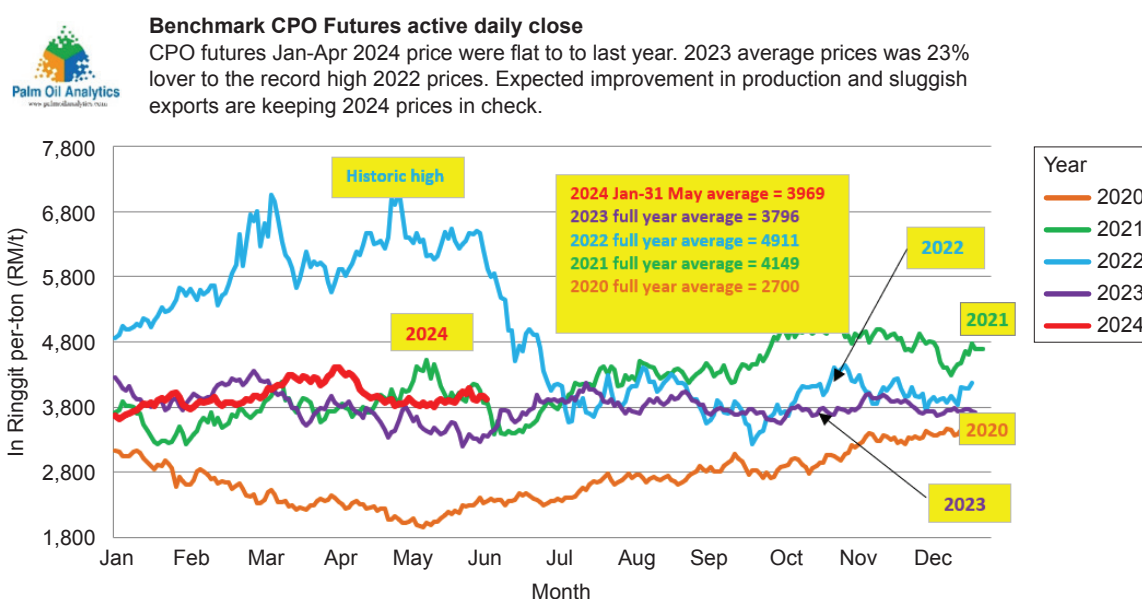
Beneficial Weather and Steady Production

CPO futures averaged RM3,969 (USD840)/t in the first five months of this year, or 2% higher than the same period last year and returned to the long-

term pricing band after prices broke out of trend to hit a historical record high in 2022 (Figure 1). CPO futures and cash derivatives products were at record on a culmination of factors. They are Indonesia's short-term export ban, droughts in Argentina decimating soybeans production, labour shortage in Malaysia due to COVID-induced border closure to foreign workers who work in the harvesting sector, and the break out of Ukraine-Russia war blocking out crucial agriculture product exports from the Black Sea, sapping supply.

The main price driver of CPO futures and palm cash prices in the first four months of this year and for the rest of the year is likely to be the 'weather' variable. Related to weather are production and supply. The weather has been a pivotal factor in determining the extent of palm production performance and the subsequent supply situation and price outlook.

Although last year began with a high expectation of an *El Niño* weather phenomenon to occur in the second half of 2023 and into the first half of 2024, the impact of the weather phenomenon was largely limited to production in Malaysia and Indonesia. Malaysia's annual 2023 CPO production materialised at 18.55 million tonnes or just 0.53% higher than the prior year (MPOB, 2024) while Indonesian CPO production was 48.50 million tonnes or 500,000 t lower than in 2022 (GAPKI, 2024; Palm Oil Analytics, 2024). The Australian Bureau of Meteorology and other weather agencies such as the US National Weather Service, correctly predicted the emergence of *El Niño* weather conditions by activating an alert in July of 2023



Source: Bursa Malaysia Derivatives (2024).

Figure 1. Malaysia's CPO futures benchmark month daily close price.

and officially declaring the occurrence of *El Niño* in September 2023. However, the *El Niño* weather phenomenon was mild compared to the one in 2015-2016. The last major *El Niño* in 2015-2016 witnessed Malaysia's palm oil output shrinking by 13.2% year-on-year in 2016 to end the year at 17.32 million tonnes, as lingering effects of the climate pattern affected oil yields.

Meanwhile, Indonesia's Meteorology, Climatology, and Geophysical (BMKG) said in June 2023 that the country was expected to experience a severe dry season in the coming months caused by *El Niño*, with the dryness worsening until September and affecting almost the whole of Indonesia. The main islands of the country were also expected to see 0%-30% of the usual rainfall (BMKG, 2023).

An *El Niño* weather phenomenon is typically characterised by lesser rainfall and prolonged dry conditions in Southeast Asia, raising the risks of forest fires and causing damage to crops in the southern hemisphere. On the other, the arrival of *El Niño* would bring wetter conditions and a better crop outlook in the northern hemisphere. This has largely been the case in Argentina where the third largest soybean producer is set to see a strong recovery in 2023-2024 to 50 million tonnes as yields rebound from the dismal performance of 25 million tonnes in the prior marketing year. In contrast, neighbouring Brazil is seeing excessive rains resulting in major crop losses leading to the

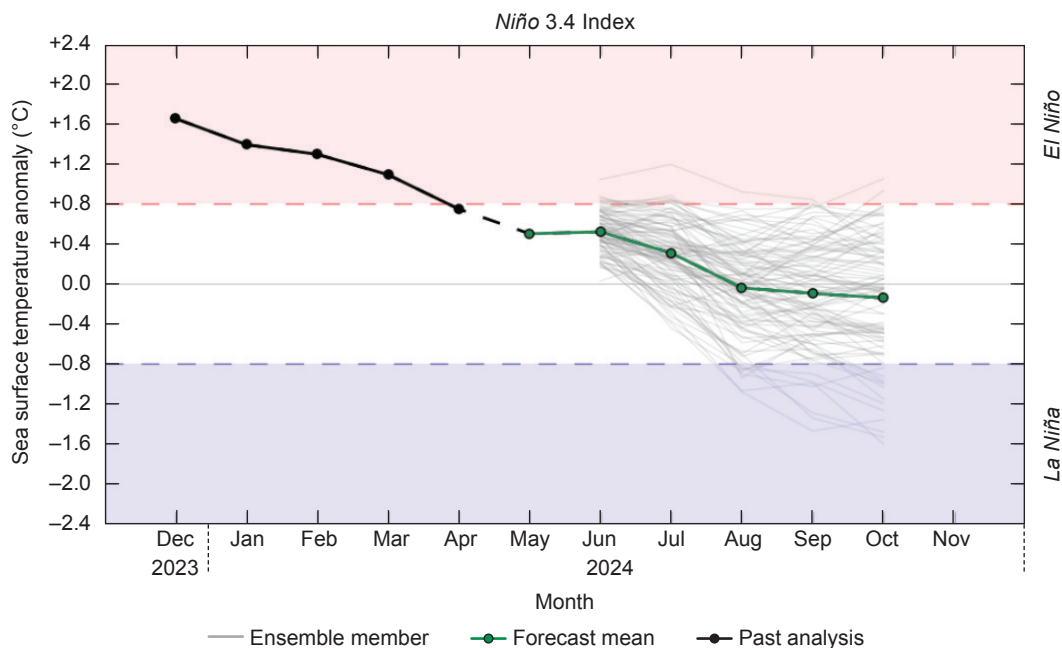
United States Department of Agriculture (USDA) to slash the 2023-2024 soybean production to 154 million tonnes versus 162 million tonnes in the previous marketing year (USDA, 2024).

Malaysia's CPO production year-to-date (January to April 2024) is trending 8.58% or 439,254 t higher than the same period last year at 5.556 million tonnes with the peninsular of Malaysia accounting for 94.00% of the rise. Sabah, the largest CPO producer in the country recorded a 4.60% or 62 622 t, fall but was offset by the largest oil palm planted area, Sarawak also located in East Malaysia posting a rise of 8.26% or 89,573 t during the same period (MPOB, 2024).

Overall, the negative impact of *El Niño* weather has been limited on palm production particularly in Malaysia while the impact on Indonesian production is a little unclear. However, the impact on soybean production in the northern hemisphere has largely been positive to damaging due to excessive turn in the *El Niño* weather phenomenon (Figure 2).

Sluggish Exports

With 70.00% of Malaysia's crude and processed palm supply accounting for the export market, overseas demand is a significant component of demand that subsequently determines the end-month stock position and the consequent impact on CPO futures and cash price behaviour.



Source: Australia Bureau of Meteorology (2024).

Figure 2. Ensemble and best-fit line projecting Nino 3.4 index. The impact of climate change on weather and temperature is likely to dwarf the influence of *El Niño* and *La Niña* weather conditions.

Malaysia's first four months of exports have been trending 1.95% higher at 4.934 million tonnes to the same period last year reflecting steady export performance year-on-year (MPOB, 2024).

However, the monthly performance has been sluggish when viewed on a month-on-month basis with only March recording a sharp pace of increase of 23.00% helping to offset the losses in the four consecutive months from November 2023. After posting a strong rise in March, overseas demand reverted to a decline of 6.97% in April as major buyers took time to work through the bloated stocks (MPOB, 2024).

Meanwhile, palm exports from the world's number one producer Indonesia plunged sharply in February. Total palm oil exports in February fell by 22.92% month on month to 2.17 million tonnes according to GAPKI (2024), the Indonesian Palm Oil Association data. While cargo surveyor, Intertek Testing Services (ITS) reported Indonesia's palm oil exports in the first three months at 5.45 million tonnes or 10.00% lower on the year while exports to India and the subcontinent rose by 243,283 t, 18.00% to 1.59 million tonnes (ITS Indonesia, 2024).

Malaysia's export performance has been sluggish since November of last year due to expectation of a further drop in prices prompting buyers to delay purchasing plans and, on a sharp and quick drop in soft oil prices particularly crude degummed soybean oil (CDSBO) to below refined, bleached deodorised (RBD) palm olein, the most traded palm product since the middle of January eroding palm competitiveness to the soft oil in the edible oil segment (Palm Oil Analytics, 2024).

Abundant supplies of soft oils particularly soybean oil from Brazil and the U.S. amid weakening exports specifically to China dampened demand and weighed on global bean oil prices. CDSBO on free on board (FOB) Brazil offer prices have been on a persistent negative trend falling since November of last year when offers were at RM4,962 (USD1047.50)/t thereafter declining to RM4,028-RM4,454 (USD850.00-USD940.00)/t by April of this year or down RM936 (USD197.50). Meanwhile, RBD palm olein on FOB Malaysia was at RM4,076 (USD860.00)/t in November commanding a healthy RM568-RM710 (USD120.00-USD150.00) discount to bean oil but offers subsequently accelerated to RM4,265-RM4,739 (USD900.00-USD1,000.00)/t in March and April eroding palm competitiveness to bean oil and dampening exports (Palm Oil Analytics, 2024).

Palm discount to soft oils is expected to witness a recovery in May as palm prices continue to face a steep sell-off. CPO futures active month ended lower for the fifth week in the week ending 10 May, erasing RM600 (USD127) from the year high of RM4,407 (USD932) notched on 3 April (Palm Oil Analytics, 2024). In summary,

palm product prices have largely outpriced its rival oils from January - April, limiting demand growth.

Declining Stocks

End-month stock is the most sensitive variable to CPO futures and consequently palm cash price movement. End-month stocks are generally inversely related to price behaviour, *i.e.*, a higher end-month stock results in lower prices and *vice versa*. Malaysian palm oil stocks have been on a declining trend after reaching a peak of 2.40 million tonnes in November 2023. Since then, stocks fell 734,319 t to the end of March 2024 (MPOB, 2024).

During the period, CPO futures were mostly at RM3,700-RM3,900 (USD783-USD825)/t levels from September 2023 to February 2024, with the most noticeable increase from March surpassing the psychological level of RM4,000 (USD846)/t as the underlying fundamentals of stocks decreased (Palm Oil Analytics, 2024). April stocks snapped to rise by 1.85% to 1.744 million tonnes following higher production and soaring imports (MPOB, 2024).

Expectations are for stocks to recover and possibly surpass the 2 million tonnes mark once again by the end of this year. The last time stocks were above 2 million tonnes was in January 2024.

Stellar production in the first four months of this year was driven by productivity improvements following an increased intake of labour particularly harvesters compared to last year and, a favourable weather front is expected to boost output in the second and third quarters, rising at a faster pace than export growth thus fuelling higher stocks.

Over in Indonesia, palm oil end-month stock as of the end of February was printed at 3.26 million tonnes or up 7.49% from a low base in January following a larger decline in demand from reduced exports compared to the fall in supply (GAPKI, 2024). Despite the low volumes, stocks are creeping into a year-on-year surplus after staying in the deficit for over 12 months. February stocks are up 494,000 t compared to the same period last year, according to GAPKI data (GAPKI, 2024). Indonesian base stocks are estimated at around 3.00-3.50 million tonnes, while Malaysia's is at 1.80-2.00 million tonnes (MPOB, 2024).

In summary, fundamentals of tight supply expectation to reality, sluggish but a spike in export growth in March and, rapidly shrinking stocks drove palm prices higher steadily from January to April. CPO futures and cash prices have since been swiftly heading lower at the back of a rising palm production outlook and bountiful related soft oils supply assessment.

The next section explores some of the main palm price drivers for the remaining year and draws to a conclusion by offering an average price outlook.

MAIN PRICE DRIVERS: MAY TO DECEMBER 2024

Weather and consequently production, China's palm oil export demand, palm oil competitiveness to soft oils and, geopolitics are the main five factors that are likely to have significant weight in determining CPO futures and subsequently the cash prices.

Weather and Production

Malaysia's CPO production is forecast to rise by about 1.60% to 18.95 million tonnes in the calendar year 2024 compared to 18.55 million tonnes in 2023 (MPOB, 2024). If the 2024 production is realised, it will be the highest production volume in four years and near the five-year historical average of 18.82 million tonnes. Production in the first four months of this year is trending 436,940 t or 8.54% higher at 5.56 million tonnes compared to the same period last year and the highest in five years reflecting a strong prospect of surpassing the previous year's production volume (MPOB, 2024).

Improved rain patterns this year after the presence of mild *El Niño* conditions last year from May to December (Australia Bureau of Meteorology, 2024) aided the development of oil palm crops this year, although it is worth noting crop conditions vary widely between oil palm plantations. Production is also likely to perform better this year supported by higher labour productivity versus last year as more harvesters are hired and trained with the results of increased harvesting cycles and resulting higher fresh fruit bunches harvested.

With oil palm planted area decreasing for four successive years to 2023 wiping off 247,588 ha of land (MPOB, 2024). National average yields are unlikely to improve significantly in 2024. Therefore, CPO production will crucially depend on weather in the short and long term.

As of now, weather forecast models predict the likelihood of the start of *La Niña* weather conditions from August and increasing in October (Australia Bureau of Meteorology, 2024). *La Niña* weather brings wetter conditions in the southern hemisphere where over 80% of global palm production is located, but the influence varies, particularly in conjunction with other climate influences (Australia Bureau of Meteorology, 2024). The Australian weather agency cited some early signs that a *La Niña* might form in the Pacific Ocean in 2024. As a result, the Bureau's ENSO Outlook has shifted to *La Niña* Watch' on 14 May 2024.

Historically *La Niña* following an *El Niño* is positive for oil palm yields, assisting in recovery except for multi-year *La Niña* (Gan Ling, 2023). Conversely, the northern hemisphere like the U.S. and Canada will experience warmer than

usual temperatures during the *La Niña* weather phenomenon negatively impacting crops including soft oils like soybeans and canola.

Given oil palm cropping systems are rain-fed, water availability depends on rainfall and soil characteristics for yield growth. On average, a minimum annual rainfall of 1,800 mm is considered optimal, ranging up to 2,500 mm without harm. According to Verheye (2010), it is found that 2,000 mm of rain per annum produces the best yields in Malaysia.

Meanwhile, excessive rains of above 2,500 mm are considered unfavourable as this can also pose severe problems to production. Studies observed in Malaysia showed excessive rain can reduce the pollinating weevil population, increase the absence of sufficient male flowers and promote infection with parasites (Woittiez *et al.*, 2017).

Overall, the positive weather outlook for the rest of this year in the form of beneficial rains is conducive to higher oil palm yields. Apart from weather other factors such as soil texture, and soil depth, application of fertiliser such as nitrogen or potassium, ground vegetation, pests, and diseases are some of the other variables that can impact production.

China's Palm Oil Export Demand

With 70% of Malaysian palm oil supply exported rather than consumed domestically, the export market is a significant component of demand. India, China and the E.U. make up the three largest export markets for Malaysian palm oil accounting for 50% of the total volume. According to cargo surveyor ITS data, Malaysia's exports to the three countries in 2023 were 2.93, 1.48 and 2.43 million tonnes, respectively (ITS Malaysia, 2023).

Despite palm oil's loss of competitiveness to soft oils in the first half of this year and even as the E.U. is set to enforce the European Union Deforestation Regulation (EUDR) on palm product imports into the block, the importance of these three export markets to Malaysian palm oil will remain unchanged this year and in the medium term.

Malaysia and Indonesia collectively exported 6.93 million tonnes of palm products to China in 2023, with Indonesia accounting for 78% of the volume and Malaysia 22%. Indonesia has traditionally been a dominant exporter to China commanding 60% to 80% of the market share (ITS Indonesia, 2023; ITS Malaysia, 2023).

Malaysia's year-to-date export (January to April 2024) is presently trending at 1.95% higher than the same period last year at 4.93 million tonnes or the highest volume for the first four months in five years but considerably lower than the peak of 6.28 million tonnes witnessed in 2019 (MPOB, 2024).

After dismal export performance in 2023 ending the year with a fall of 3.86% to 15.13 million tonnes to a year ago (ITS Malaysia, 2023), exports are expected to reach 16.00 million tonnes or a sharp 5%-6% increase in 2024 year-on-year basis.

Demand from importing countries is expected to rebound in 2024 driven mainly by increases to the African continent and China. Malaysia's exports to China tumbled by a sharp 25.93% or a staggering 522,470 t in 2023 from a year ago (ITS Malaysia, 2023). While exports to the Middle East and the E.U. contracted by 25.04% and 9.72% or 373,540 t and 327,123 t respectively (ITS Malaysia, 2023).

Malaysia's palm oil export performance in 2024 will mainly depend on the pace of shipment to China. China is the world's largest oils and fats consumer. As such the pace of consumption spending will likely be influenced by the state of aggregate demand in the economy. After recording an average of over 9% Gross Domestic Product (GDP) growth since 1980, China's post-pandemic growth has moderated to around 5%. In 2024, growth is projected at 4.50% contracting from 5.20% in 2023 (World Bank, 2024) reflecting the prolonged property crisis, persistent weak consumption pattern and, reeling from the impact of disruption to supply chains from the escalating geopolitical tensions.

China mainly buys refined, bleached and deodorised (RBD) palm olein from Indonesia and Malaysia for use in the edible oil segment and faces intense competition from other oils, like soybean, rapeseed, sunflower and peanut.

While Indonesia's RBD palm olein export to China reached 3.04 million tonnes in 2023 or up a staggering 58% or 1.11 million tonnes, Malaysia's shipment fell by 19% or 177,110 tonnes during the same period (ITS Indonesia, 2023). *Figure 3* shows the shipment of RBD palm olein from Malaysia and Indonesia origin to China.

This year we forecast Malaysia's and Indonesia's palm oil exports to China to rise by a mere 1% to a pre-pandemic level of 7.00 million tonnes from 6.93 million tonnes recorded in 2023. In 2022, export volume was 5.73 million tonnes. The increase of 1% or around 68,000 t is expected to come mainly from Indonesia driven by lower prices than Malaysia's.

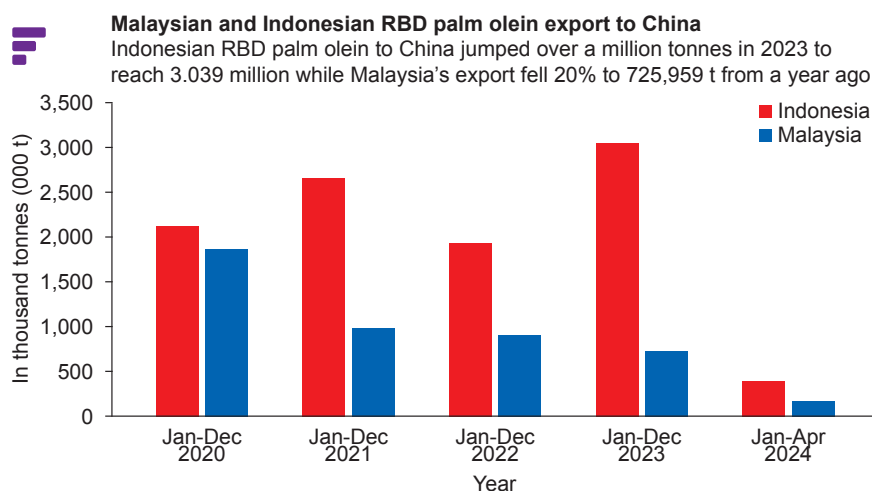
Palm Oil Competitiveness to Soft Oils

This year started with palm olein losing its competitiveness to its nearest competitor soybean oil. Palm olein which typically trades as the cheapest edible oil flipped into a premium by RM142-RM284 (USD30-USD60) to CDSBO in the middle of January after CPO futures accelerated fuelling palm olein cash prices to surpass CDSBO, consequently eroding palm competitiveness in the export market.

CPO futures and palm product prices accelerated from January to April underpinned by a persistent tight supply outlook in Malaysia and Indonesia in the first quarter of this year as Malaysia's end-month stocks dwindled from just above 2.00 million tonnes at the end of January down to 1.71 million tonnes in March or down 15% or 307,472 t (MPOB, 2024).

In contrast, palm's closest substitute in the edible oil market, soybean oil cash prices fell following projections of bountiful soybeans crop from Brazil, Argentina and the U.S. amidst poor export demand, particularly to China.

The loss of competitiveness in palm resulted in lower exports in February. Malaysia and Indonesia's palm exports tumbled 24% or 324,997 t in February month-on-month while Indonesia's shrunk by 27% or 556,739 t (ITS Indonesia, 2024; ITS Malaysia, 2024) during the same period. Malaysia's export recovered in March rising by 29.49% sparked by active re-stocking after major importers slowed



Source: ITS Indonesia (2023; 2024); ITS Malaysia (2023; 2024).

Figure 3. Malaysian and Indonesian RBD palm olein export to China.

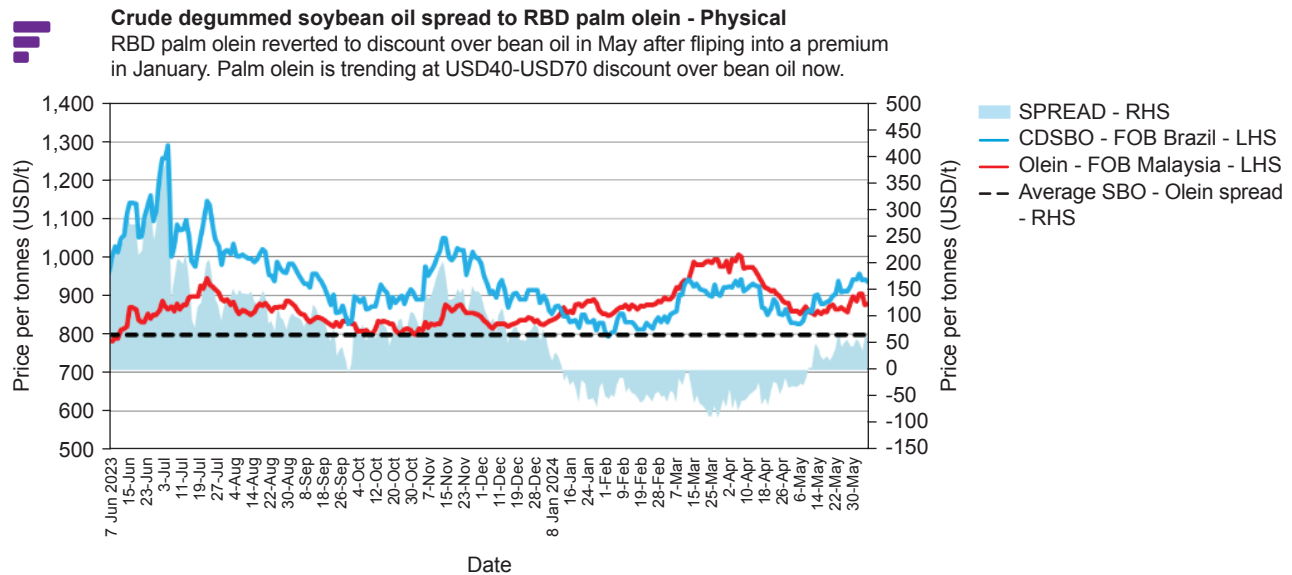
buying for four successive months from November 2023 - February 2024 (MPOB, 2024). Malaysia and Indonesia account for over 80% of the global palm export volume.

Palm olein returned to a discount in May after CPO futures and cash prices dwindled from a peak of RM4,407 (USD932)/t in April down to RM3,900 levels (USD825) or down 12% (Palm Oil Analytics, 2024). Palm discount looks likely to be sustained as palm futures and cash prices remain under pressure from higher production outlook from seasonal rise.

Malaysia's exports recovered sharply and suddenly in May rising by 11.66% to 1.38 million tonnes from a month ago and reaching the highest volume in six months. The sharp rise coincided with palm regaining its price competitiveness with

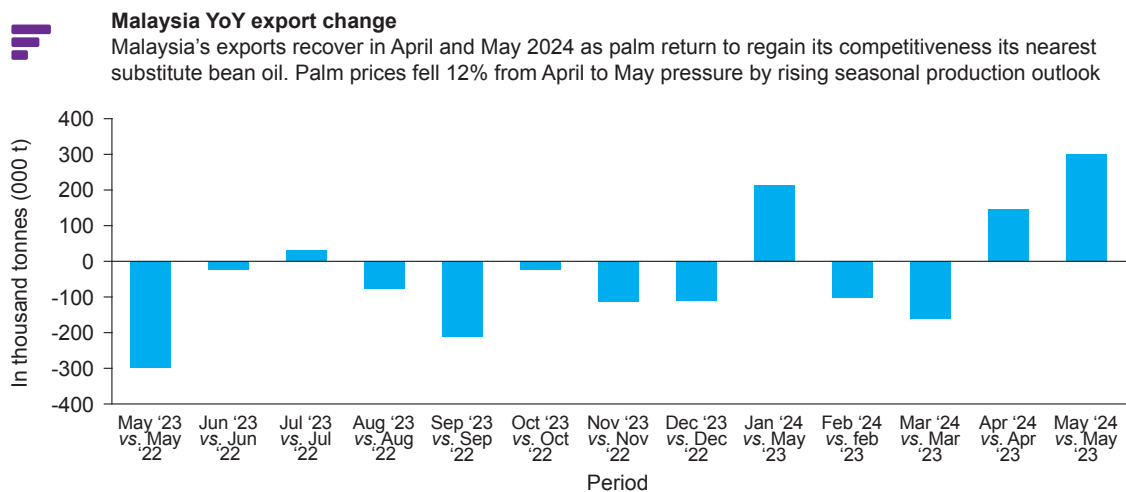
bean oil (Figure 4). Palm olein has been trading RM95-RM284 (USD20-USD60) below bean oil in May compared to being overpriced by an average of USD40 from January to April. Palm olein pricing is likely to remain at a discount to soft oils for the rest of the year raising the prospect of increased edible oil export market share (Figure 4).

For the full year, we forecast Malaysia's exports to reach 16.00 million tonnes in 2024 or up 5.76% from 2023. Malaysia's January to May exports is trending 6.66% higher than the same period last year at 6.31 million tonnes reaching the highest in five years for the first five months. Figure 5 shows Malaysia's year-on-year change reflecting the sharp improvement in export performance coinciding with recovery in palm pricing to its nearest competitor bean oil.



Source: Palm Oil Analytics (2024).

Figure 4. Crude degummed soybean oil (CDSBO) price spread to RBD palm olein.



Source: MPOB (2024).

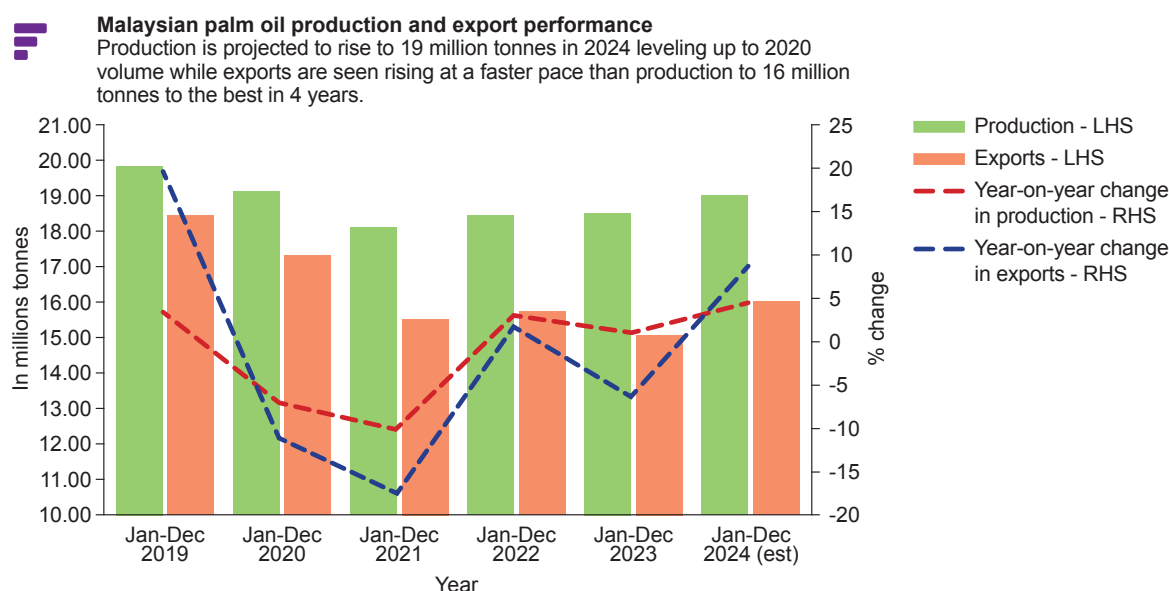
Figure 5. Malaysia's year-on-year change in exports.

CONCLUSION

In conclusion, the supply side driven by production is a critical determinant for CPO futures pricing for the rest of 2024. Malaysia palm production has been in a high output cycle since March and is likely to pick up the pace of production from July to September based on historical trends (MPOB, 2024). This is likely to add downward pressure on prices. In the event of a strong *La Niña*, we can be optimistic about production, projected to exceed 19 million tonnes in 2024 and into 2025 or up 2.43% from 2023 (Figure 6). Favourable weather conditions and relatively higher labour availability this year compared to last year are likely to boost Malaysia's CPO production. This means CPO

futures and cash prices of palm derivatives products are likely to stay rangebound for the rest of the year.

CPO futures active month contract is expected to remain rangebound between RM3,700-RM3,900 (USD783-USD825)/t for the rest of this year as production becomes the main price determinant for the rest of 2024. Exports are likely to pick up pace in June and July propelled by palm price competitiveness and increased stocking up from major importers. Malaysia's export rise to 16 million tonnes in 2024 or up 5.76% from 2023 will be driven mainly by increases in shipment to the African continent. Figure 7 shows the supply and demand projections for 2024.



Source: MPOB (2024); Palm Oil Analytics (2024).

Figure 6. Malaysia supply and demand time series with projection for 2024.

Estimate			
Malaysia	2023	2024	% change
Carry forward	2.20	2.29	4.27
Production	18.55	19.00	2.43
Imports	0.89	1.00	12.74
Total supply	21.63	22.29	3.04
Exports	15.13	16.00	5.76
Domestic consumption	4.22	4.20	-0.45
Stock	2.29	2.09	-8.76
Total demand	21.64	22.29	3.01

Note: In million tonnes.

Source: Palm Oil Analytics (2024).

Figure 7. Malaysia supply and demand projection summary for 2024.

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COMPARISON OF 2023 PRODUCTION COSTS BETWEEN HYBRID OxG AND *Elaeis guineensis* CROPS IN COLOMBIA

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ABSTRACT

The area planted with *Elaeis oleifera* x *Elaeis guineensis* hybrids (OxG hybrids) crops in Colombia is on the rise and nowadays more than 90,000 ha (10% of the cultivated area in Colombia) are currently planted with them. Today, after 15 years of commercial operations of OxG hybrids, there is a set of management practices that includes artificial pollination, harvesting of fresh fruit bunches (FFB) by implementing appropriate ripeness criteria for each type of OxG cultivar, adjustments to OxG nutrition programs and adjustments to the oil extraction process from OxG FFB. This set of OxG crop management practices is the result of years of research by CENIPALMA and, technological adoption by Colombian companies that have pioneered the planting of OxG hybrid cultivars. The adoption of OxG crop management practices has led to the production of an average of 30 t FFB/ha in mature crops, which is higher than FFB production obtained in *E. guineensis* crops. The results of this analysis allow us to conclude that the OxG hybrid business is currently viable with a unit cost of production of USD102.22/t of FFB [and USD507.90/t of crude palm oil (CPO)], very close to that obtained in *E. guineensis* cultivars of USD107.65/t of FFB (and USD510.03/t of CPO). Our analyses also yield that cropping OxG hybrid oil palms is a better economic alternative than cropping *E. guineensis* oil palms. Presenting results on the estimation of unit costs for OxG crops is relevant because the palm oil agri-business from OxG hybrids is a relatively recent development.

Keywords: artificial pollination, cost estimation, optimal harvest time.

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INTRODUCTION

In 2022, more than 24 million hectares of oil palm were cultivated worldwide, resulting in a production of 79.157 million tonnes of oil. In 2022, Colombia contributed 2.2% of the oil produced in the world (1,932,000 t grown on 576,799 ha) (FEDEPALMA, 2023). Oil palm (*Elaeis guineensis*) stands out for its high productivity. In 2022, yields/ha ranged from 3.25-4.19 t of crude palm oil (CPO). These results exceed most other oilseeds

in the world. It is estimated that to meet the global oil demand, 78 million hectares would be needed under palm cultivation, while other oilseeds would require between 75% and 90% more land (Ritchie & Roser, 2021).

In Colombia, palm oil production has been restricted by the presence of the disease known as bud rot (BR), caused by the pathogen *Phytophthora palmivora* and which has particularly affected the cultivars of *E. guineensis* (Martínez *et al.*, 2014). The spread of this disease has been observed mainly in regions with high rainfall and relative humidity for prolonged periods (Torres *et al.*, 2016).

Over time, there have been BR outbreaks in all oil palm planting regions from Colombia. The first of them destroyed 2,400 ha in the North Zone

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(Urabá Region). Subsequently, between 2006 and 2012, BR affected more than 75,000 ha in the Central Zone (Puerto Wilches, Santander) and Southwestern Zone (Tumaco, Nariño) palm areas (Mosquera-Montoya *et al.*, 2023). By 2022, BR had forced the elimination of more than 14,000 ha cultivated in the Northern Zone (Magdalena) (Mosquera-Montoya *et al.*, 2023b; Romero, 2022).

One of the strategies that oil palm producers in Colombia have adopted to confront BR has been the establishment of OxG hybrid cultivars. The decision to plant OxG cultivars was due to the partial resistance to BR shown by some OxG crosses (Avila-Diazgranados *et al.*, 2016; Ayala-Díaz *et al.*, 2023). Since 2007, the planting of OxG cultivars has experienced a sustained increase in Colombia, going from having less than 1% of the cultivated area in 2006 to approximately 14% of the cultivated area in Colombia in 2022 (90,000 ha out of a total of 590,000 ha) (FEDEPALMA, 2023).

There are differences between OxG hybrid cultivars and *E. guineensis* cultivars. In OxG hybrids there is great genetic variability which conditions their physiology, productive behaviour, oil quality (fatty acid content), resistance to BR, and ripening period of the fresh fruit bunches (FFB), among others (Romero *et al.*, 2021). The most frequently planted crosses in Colombia are Coari x La Mé, Brasil x Djongo, Cereté x Deli, Manaos x Compacta (Ayala-Díaz *et al.*, 2023).

Hybrids are characterised by having a low rate of stipe growth, which could prolong their economic life. Given the robustness of these cultivars, the commercial planting densities of these crops vary between 116 and 128 palms/ha. In addition, they exhibit high yields, with productions varying between 30 and 45 t FFB/ha/yr depending on the geographical region (Romero *et al.*, 2021). The oil of OxG hybrids contains more than 55% oleic acid and 33% saturated acids (Romero *et al.*, 2021).

A feature of OxG hybrids is their limited natural pollination, which is the result of the sexual incompatibility between the two crossed species. This is reflected in the low viability and germinability of pollen. In addition, female inflorescences have peduncular bracts that prevent access by anemophilous insects (Romero *et al.*, 2021). This implies that in OxG hybrid crops, it is necessary to pollinate female inflorescences to induce fruit formation. One of the alternatives is assisted pollination, which consists of applying *E. guineensis* pollen to female inflorescences during anthesis (Ruiz-Alvarez *et al.*, 2021a). Another alternative is artificial pollination, which consists of three applications of naphthaleneacetic acid (NAA) to female inflorescences to encourage the growth of parthenocarpic fruits. Commonly, the

first application takes place at anthesis, the second seven days after anthesis and the third 14 days after anthesis (Daza *et al.*, 2021a; Mosquera-Montoya *et al.*, 2023).

The set of practices required for the proper management of OxG cultivars includes the cutting of bunches in an optimal state of ripeness, that is, at the optimal time of harvest (OTH). The difficulty is that the FFBs of each OxG hybrid crossing have different ripeness characteristics (Mosquera-Montoya *et al.*, 2023).

The results of the research carried out for the management of nutrition in OxG hybrid cultivars suggest that they are very efficient in the intake of nutrients such as nitrogen (N) and phosphorus (P). Foliar analyses of nutritional content for hybrid OxG cultivars usually yield foliar levels of nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg) and boron (B), lower than those yielded by foliar analyses of *E. guineensis* cultivars (Arias *et al.*, 2023).

The fruit from FFB of OxG hybrid cultivars contain less palm kernel than *E. guineensis* cultivars, and even if artificial pollination is implemented there may not be palm kernel at all. This difference has forced the Colombian palm oil agroindustry to rethink the oil extraction process for OxG FFBs, mainly in the pressing process, which in turn affects the demand for energy (electrical and thermal) and water for the process (García-Nuñez, 2023).

The above paragraphs showed the potential investor in OxG hybrid crops that it is a different business from *E. guineensis*. Consequently, this article presents the unit production costs of companies that grow OxG hybrids in the four palm areas of Colombia. It should be noted that the unit cost is an indicator that allows one to evaluate the economic efficiency of a productive activity by considering the expenditure on resources needed to obtain a unit of the product. These resources range from those required to operate (such as labour, agricultural inputs and fuel, among others), investment in infrastructure and machinery, and costs associated with running a business. Presenting results on the estimation of unit costs for OxG crops is relevant because the business of obtaining palm oil from OxG hybrids is a relatively recent development for the global oil palm agroindustry.

MATERIALS AND METHODS

Selection of Participants

Production costs were estimated under an economic engineering approach, ranging from establishment, cropping and palm oil extraction. The production processes were evaluated for hybrid

cultivars OxG and *E. guineensis* in the mature stage (more than seven years) in plantations with high levels of technology adoption Mosquera-Montoya *et al.* (2022a). Plantations located in the four palm areas of Colombia were analysed: Eastern, Northern, Central and Southwestern Zones (Figure 1). For OxG hybrids, we gathered data from 11 plantations representing 9,258 ha cultivated (approximately 10% of the total area with hybrids in the country). In the case of *E. guineensis* cultivars, costs were estimated in 22 plantations covering 26,049 ha (corresponding to 5% of the cultivated area in Colombia).

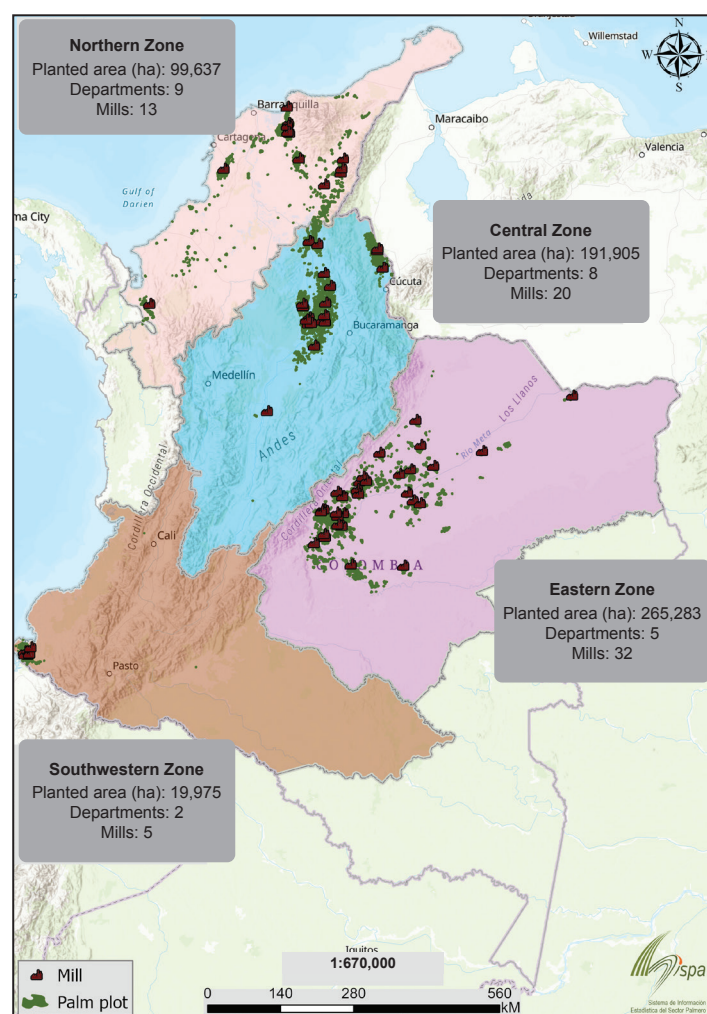
Regarding oil extraction, data were gathered from 59 oil palm mills from four Colombian oil palm growing zones, which corresponds to 89% of the total installed capacity at the national level. A total of 52% of the FFB processed corresponds to *E. guineensis* cultivars, 42% of the FFB processed corresponds to mixtures of *E. guineensis* and OxG hybrids and, 6% of the FFB processed is OxG hybrids.

Main Characteristics of Cropping Systems in Colombia

The companies in which the costs were estimated are characterised by the adoption of good agronomic practices in the different production processes and are mentioned in detail in Table 1.

Production Cost Estimation

The methodology proposed by Mosquera-Montoya *et al.* (2022a) was implemented. Consequently, production costs according to crop age were estimated for three different moments of palm development (unproductive oil palms, immature oil palms and adult oil palms). The method consisted of three stages. The first stage consisted of average yield estimation. To this end, surveys were carried out inquiring about the average productivity of each participating company for each year after planting. The values were then weighted according to the company's area.



Source: FEDEPALMA (2023).

Figure 1. Palm areas of Colombia.

The second stage consisted of asking for prices and amounts required of labour, inputs, tools and machinery for each oil palm productive process. To this end, surveys and interviews were conducted with the agronomic directors of the participating plantations, in which they inquired about doses and prices of inputs, frequencies of execution of tasks, labour yields, wage rates, costs associated with machinery and equipment, land rent values, payments for supervision, management and technical assistance of the crop.

The third stage was the estimation of unit cost/ha and cost/t of FFB and cost/t of CPO. The cost/ha for each company was estimated as the sum of the costs of each task carried out in that unit of area along the whole economic lifecycle of

the crop. The total costs were estimated for labour, supplies, tools and machinery, fuel and utilities. The unit cost/t was obtained from the ratio between the sum of the cost/ha over the sum of yields over 25 years. To obtain the national values, a weighting of the costs of the companies was made according to the area.

Cultivation costs. Oil palm is a long-term crop, so the time window of analysis is wide given that costs and yields are not the same at different times of plant growth. In the context of this study, the unproductive stage goes from the first to the third year; the developmental stage goes from the fourth to the sixth year and the adult stage covers from the seventh year onwards when production stabilises (Table 2).

TABLE 1. CHARACTERISTICS OF CROPPING SYSTEMS IN COLOMBIA

Task	Most used method
Fertilisation	It is carried out manually together with wheeled containers pulled by working animals. Machinery is used to bring fertilisers to the border of the lots. Fertilisation rates vary in accordance with fertilisation prescription but, on average, OxG hybrid cultivars received 11.69 kg/palm/yr, while <i>E. guineensis</i> cultivars received 8.99 kg/palm/yr (Mosquera-Montoya <i>et al.</i> , 2023).
Harvest	FFB cutting is performed manually with the help of sickles at FFB phenological stages 807 and 809 (Romero, 2022). For picking up FFBs one may use either labour/grabber and FFBs are placed in wheeled containers pulled by working animals/tractors.
Weed control	It is carried out manually with the support of scythes/machete. Manual control alternates with the application of herbicides. Less frequently, it is observed the use of tractors with weed cutters.
Pruning	It is done manually with the help of a sickle.
Phytosanitary control	Phytosanitary control consists of two processes: 1) Monitoring: The work is manual and is carried out by trained personnel. 2) Control and disposal: The work is manual with the help of a scythe for the removal of oil palm trees and pesticide sprayers. Since OxG cultivars are partially resistant to diseases such as lethal wilt and bud rot less frequent monitoring with respect to <i>E. guineensis</i> crops is required (CENIPALMA, 2023).
Pollination	This task is performed only on OxG hybrid crops. It is carried out manually with the assistance of tools for the removal of bracts and for the spraying of pollen or NAA. Each inflorescence is applied three times, first at anthesis, the second application seven days after anthesis and the third application fourteen days after anthesis (Camperos <i>et al.</i> , 2021; Ruiz-Alvarez <i>et al.</i> , 2021b).
Irrigation	Irrigation is not very common in oil palm in Colombia but in some areas highly exposed to water deficit (more than four months a year). Surface irrigation is the most used irrigation system.

TABLE 2. COST INDICATOR

Indicator	Descriptions
Establishment (USD/ha) (Year 0)	It corresponds to the summation of costs related to investments that must be made before planting oil palm in the field (plantation design, soil correction, land preparation, nursery and sowing, among others).
Unproductive stage (USD/ha) (Year 1-3)	It is defined as the sum of costs incurred along the period between planting and its third year when palms have low to no yield.
Immature stage (USD/ha) (Year 4-6)	It is the sum of the costs incurred for the maintenance of the plantation, the harvest, and FFB transportation to the oil palm mill, which occur from the moment in which the palms begin to produce bunches but have not yet reached productive maturity.
Adult stage (USD/ha) (Year 7 onwards)	It corresponds to the annual costs incurred to manage an oil palm plantation, once it has reached productive maturity. For this study, it is considered that this moment arrives from year 7.

The unit cost in terms of USD/t FFB is obtained from the ratio between the sum of costs/ha for each year at all stages of the crop with respect to the sum of production/ha over the entire life cycle of the crop, as expressed in the following Equation (1).

Cost/t of CPO. The estimate of the cost/t of CPO results from three components: 1) Costs of processing 1 t of FFB, 2) the cost of raw material and 3) palm kernel credit which results from selling the kernel to PKO producers. These values depend on the installed capacity of the plant (determines the fixed costs), the OER (determines the amount of raw material required to obtain 1 t of oil), the kernel content/t FFB (establishes the amount of kernel obtained after processing the bunches), the prices/t of palm kernel and prices/t of FFB.

The cost of processing includes plant depreciation and variable costs (maintenance, labour, and industrial services). Labour costs include operational, administrative, support, and maintenance personnel. Maintenance costs refer to the costs of spare parts and outsourced equipment maintenance services. Industrial service costs refer to energy and water. Finally, the cost of the raw material, this is for the purchase of FFB, was obtained considering the estimated costs for the cultivation stage by zones and at the national level. The cost of production of 1 t of oil (USD/t of CPO) is expressed as Equation (2).

The production cost of palm oil was calculated by estimating the amount of tonne of FFB required to obtain a tonne of CPO, plus fixed and variable costs of processing FFB at the oil palm mill (Guerrero-Sanchez *et al.*, 2020). The cost of raw material (*i.e.*, FFB) was defined as the cost of production/t at cropping. In addition, the cost of raw material (FFB) was estimated based on the price/t of FFB and the amount of FFB needed to extract 1 t of palm oil. Note that the oil extraction rate (OER) is the key parameter. This study considered data from oil palm mills that process in separate lines for each type of cultivar (either *E. guineensis* or OxG hybrids). Fixed costs include investment in palm oil mill equipment and palm oil mill infrastructure. Variable costs include labour (direct and indirect), maintenance (spare parts, supplies for repairs and outsourcing of maintenance services) and industrial services (energy and water). In the case of *E. guineensis* cultivars, at the palm oil mill, one separates the palm kernel and

sells it to companies producing palm kernel oil (PKO) and palm kernel cake. The selling price of palm kernel is calculated as 35% of PKO price due to PKO's extraction rate. This study used the 2023 PKO average price of USD976.77/t.

Economic Indicators to Comparing OxG Hybrid Crops with Respect to *E. guineensis* Crops

Financial indicators that allow one to compare an economic standpoint the two different types of cultivars were estimated. We estimated the net present value, yearly expected income/ha, payback period and internal rate of return. To estimate these indicators, it was considered the cash flow for each type of cultivar (*i.e.*, *E. guineensis* and OxG hybrids) regarding a 25 year crop life cycle. For estimating these indicators, it was used the 2023 average price/t of FFB (USD151.45). As a discount rate, we used an annual value of 8.75% corresponding to credit lines for investing in oil palm cropping, offered by the Colombian Agriculture Ministry through Banco Agrario. This interest rate reflects the opportunity costs of the money borrowed for investing in oil palm crops. In Colombia, these indicators are relevant because most oil palm growers are FFB suppliers. This is a company owning a palm oil mill that does not necessarily own most of the crops where the FFB is produced for its business.

RESULTS AND DISCUSSION

2023 Crop Yield

OxG hybrid cultivars and *E. guineensis* cultivars start producing FFB from the second year of planting and show an upward behaviour of crop yield until maturity is reached. In 2023, for the adult stage, the yield of OxG hybrid cultivars reached an average of 30.4 t of FFB/ha/yr, while *E. guineensis* cultivars reached 26.3 t of FFB/ha/yr (Figure 2). These results indicate the higher productive potential of OxG hybrid cultivars. This has been true after the previously referenced set of management practices for the OxG hybrid cultivars were implemented (Ayala-Díaz *et al.*, 2023). Specifically, reference is made to nutrition, sanitary management, artificial pollination and optimal harvest moment (Ayala-Díaz *et al.*, 2023; Daza *et al.*, 2021; Mosquera-Montoya *et al.*, 2023; Ruiz-Alvarez *et al.*, 2021b).

$$\frac{\text{USD}}{\text{t FFB}} = \frac{\text{Establishment (USD/ha)}_0 + \sum_{i=1}^3 \text{Unproductive (USD/ha)}_i + \sum_{i=4}^6 \text{Immature (USD/ha)}_i + \sum_{i=7}^{25} \text{Adult (USD/ha)}_i}{\sum_{i=1}^{30} \text{Annual yield (t FFB/ha)}_i} \quad (1)$$

$$\frac{\text{USD}}{\text{t CPO}} = \text{Processing} \left(\frac{\text{USD}}{\text{t CPO}} \right) + \text{Raw material} \left(\frac{\text{USD}}{\text{t CPO}} \right) - \text{Palm kernel credit} \left(\frac{\text{USD}}{\text{t CPO}} \right) \quad (2)$$

Establishment Costs

In 2023, the cost of establishing 1 ha of OxG hybrid cultivars was 20% lower than establishing 1 ha of *E. guineensis* cultivars (Figure 3). The difference is explained by the planting density, given that in a ha of OxG, oil palm is planted between 116-128 palms/ha, while for *E. guineensis*, oil palm is planted 143 palms/ha.

Costs per Cropping Stage

In both types of cultivars as the palms reach productive maturity, the cropping costs/ha increase. This is because the demand for nutrients increases, as well as there is a greater demand for labour to pollinate female inflorescences and FFB harvesting (Figure 4).

The unproductive stage covers the first three years after planting. It is characterised by the low participation of harvesting and pollination (in the case of the OxG hybrid) in the total costs, due to the low production of bunches (Figure 5). Fertilisation and weed control are the direct costs that dominate the cost structure at this stage.

The developing stage runs from the fourth to the sixth year after planting. As palms come into production, items such as harvesting, transportation, and pollination begin to weigh more heavily on the cost structure. The cost of the hybrid is 21.9% higher compared to *E. guineensis* not only because of the pollination requirement but also because the yields achieved are higher and this increases the cost of harvesting and transport (Figure 5).

The adult stage runs from the seventh year onwards and at this stage, FFB yields tend to

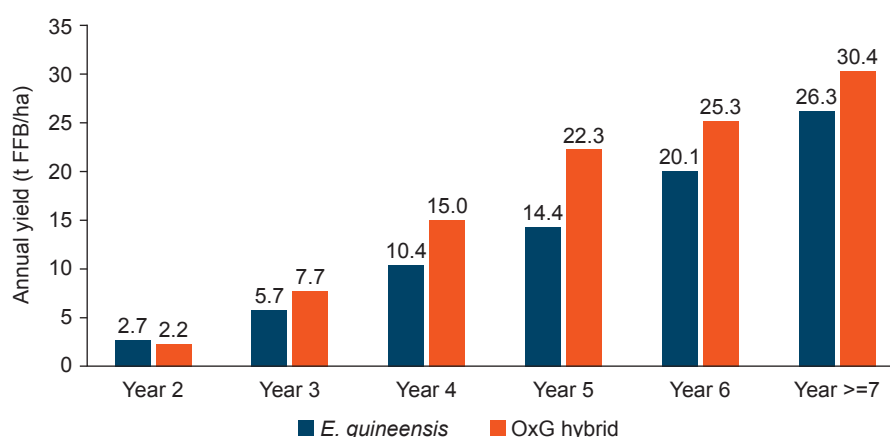


Figure 2. Yield according to age and cultivar.

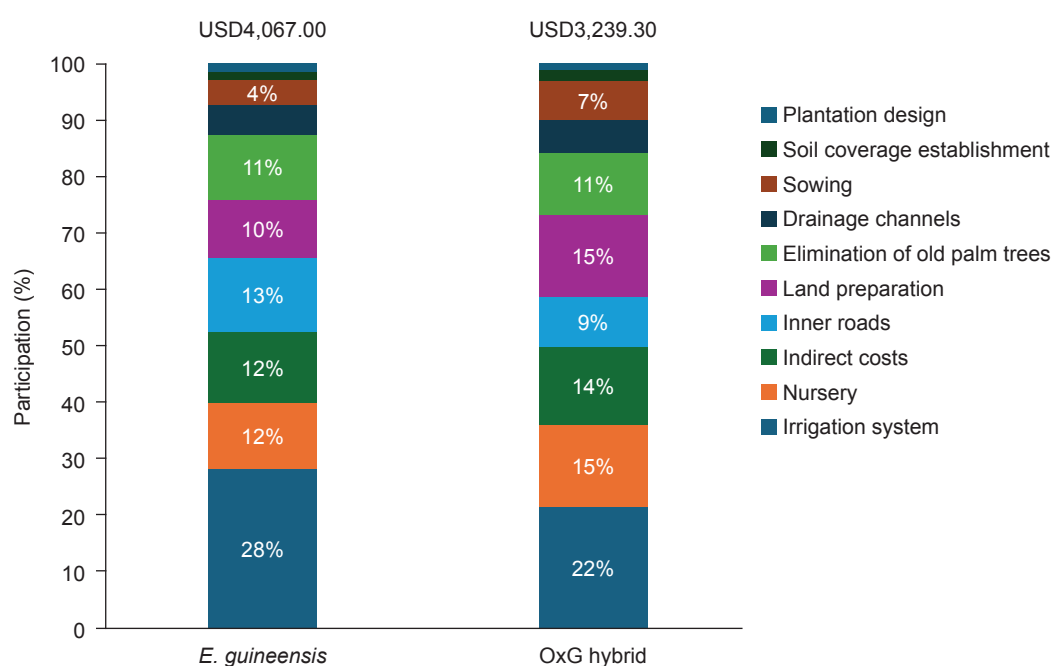


Figure 3. Crop establishment costs structure according to the type of cultivar.

stabilise. The increase in yield implies a greater requirement for nutrients so fertilisation costs increase, compared to the developing stage for both cultivars. FFB harvesting, FFB transportation and pollination (in OxG hybrids) also increase compared to the developing stage.

Cultivation costs/ha of OxG hybrid palm are 14% higher compared to cultivars of *E. guineensis*. Since these are different cultivars, input and labour requirements also vary. The main difference is the need for assisted pollination in hybrid OxG cultivars.

In artificial pollination (Figure 4), labour represents about 70% of the cost of the task (Ruíz-Álvarez *et al.*, 2022). The estimated cost is USD433/ha/yr and labour productivity ranges from 3-5 ha/man/day (Daza *et al.*, 2021; Mosquera-Montoya *et al.*, 2023).

Pollination for the management of OxG cultivars increases the demand for daily wages/ha, which has an impact on the indicator of the area served for each worker. In 2023, OxG hybrid crops value was 6.9 ha/worker/yr (to performing

all cropping tasks), while in *E. guineensis* it was 11.6 ha/worker/yr (to performing all cropping tasks) (Ruíz-Álvarez *et al.*, 2022). This indicates that it is needed to continue research on strategies to increase pollination's labour productivity. On the other hand, in 2023, harvesting costs and FFB transportation costs were 23% higher in hybrid crops compared to *E. guineensis* crops, due to the higher yield of hybrid OxG crops (Figure 6).

An important difference between the two types of cultivars studied corresponds to the cost of pests and disease control, which includes phytosanitary control. The reduction in pest controlling costs is 59% in OxG hybrid cultivars compared to that of *E. guineensis* cultivars. This is due to the partial resistance to BR of some OxG hybrid cultivars (Coari x La Me and Coari x Pobe crosses). These cultivars have evidenced a lower degree of severity and a lower number of removed palms/ha, compared to *E. guineensis* cultivars when attacked by BR (Avila-Diazgranados *et al.*, 2016; Ayala-Díaz *et al.*, 2023).



Figure 4. Artificial pollination.

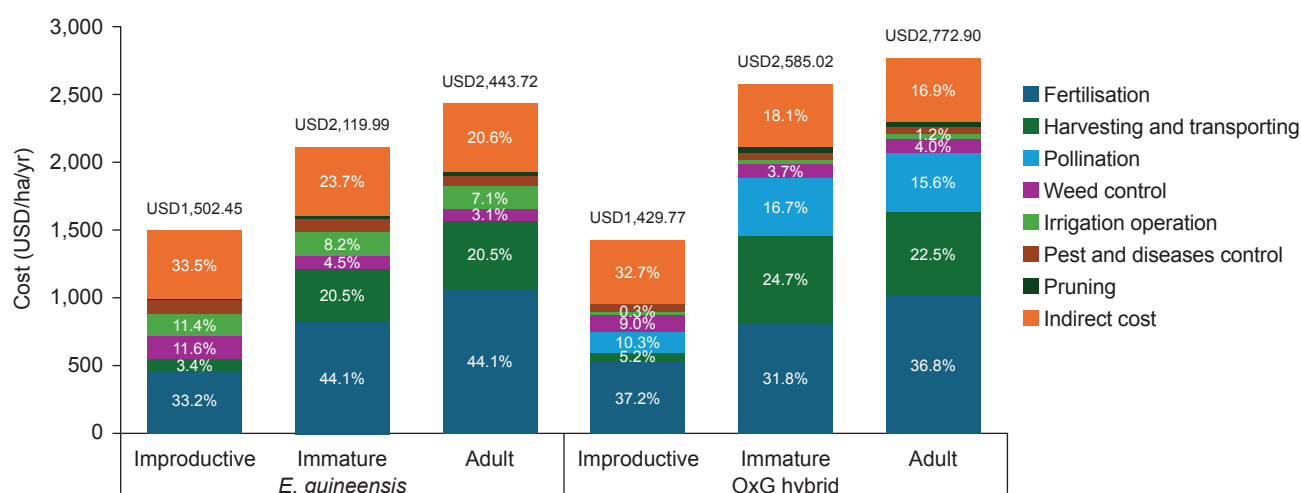


Figure 5. Costs for each hectare by age and cultivar.



Figure 6. Mature bunches of OxG hybrid cultivars.

Cost Structure According to Cultivar

Figure 7 and 8 show the tasks with the highest cost participation along the oil palm crop life cycle for each type of cultivar. Fertilisation and harvesting, in both cases, are the tasks requiring the most resource investment. Note that OxG hybrids, require pollination as well and it participates with about 15% of the hybrid OxG crops' cost structure.

Unit Costs

Cost/t of FFB. The unit cost includes all expenses from the establishment of the crops to maintenance during the 25 years useful life of the productive project. In addition, it includes the yields of FFB (t) that occur in that period on a cultivated ha. The costs/t of FFB are similar in the two cultivars, close to USD100.00 (with a 5% difference in favour of the *E. guineensis* cultivars). If the opportunity cost of land was not considered, the total cost is estimated at USD94.31/t. If only the costs of the adult stage were considered, then hybrid OxG crops had a unit cost of 2% lower than those of *E. guineensis* crops (Table 3).

TABLE 3. FFB UNIT COST OF PRODUCTION

Item	Total cost (USD/t FFB)	Cost without land cost (USD/t FFB)	Adult stage cost (USD/t FFB)
<i>E. guineensis</i>	107.65	98.10	93.01
Hybrid OxG	102.22	94.31	91.19

Mainly, the lower planting density and the higher productivity of a hectare of land cultivated with OxG hybrids make it possible to compensate for the cost overruns associated with the inclusion of artificial pollination in these cultivars. It is important to note that the current competitiveness of OxG hybrid cultivars in Colombia is due to

the experience and adaptation of appropriate technological alternatives for these crops, and this trend has been consistent over the last five years (Mosquera Montoya *et al.*, 2022a).

Cost/t of CPO. Once FFBs are taken to the palm oil mill for oil extraction, the cost of raw material is defined by the oil content. In the case of the OxG hybrid cultivars, a higher OER was found, compared to that of *E. guineensis* cultivars. This result is consistent with the higher accumulated oil content in parthenocarpic fruits resulting from NAA application (Romero *et al.*, 2021). However, palm kernel content is higher in *E. guineensis* cultivars (4.22%) compared to OxG hybrid cultivars (0.55%), which is consistent with a greater formation of normal fruits in *E. guineensis* cultivars (Cortés *et al.*, 2024; Daza *et al.*, 2021). Thus, although the extraction rate is higher in the raw material from OxG hybrids when considering the palm kernel credit, it yields a higher cost of OxG hybrid raw material (Table 4).

TABLE 4. CPO UNIT COSTS

Item	<i>E. guineensis</i>	Hybrid OxG
OER (%)	21.99%	23.49%
Kernel content per t of FFB (%)	4.22%	0.55%
Price of FFB needed to obtain 1 t of CPO (USD/t CPO)	490	435
Milling costs (USD/t CPO)	87	92
Palm kernel credit (USD/t CPO)	-66	-8
CPO unit costs (USD/t CPO)	510	508

In terms of processing costs for the two types of FFB, processing 1 t of hybrid OxG FFB is 13% more expensive compared to *E. guineensis*. This is due to palm oil mills processing FFB from hybrid OxG crops using the same technology for *E. guineensis* with minor adjustments (García-

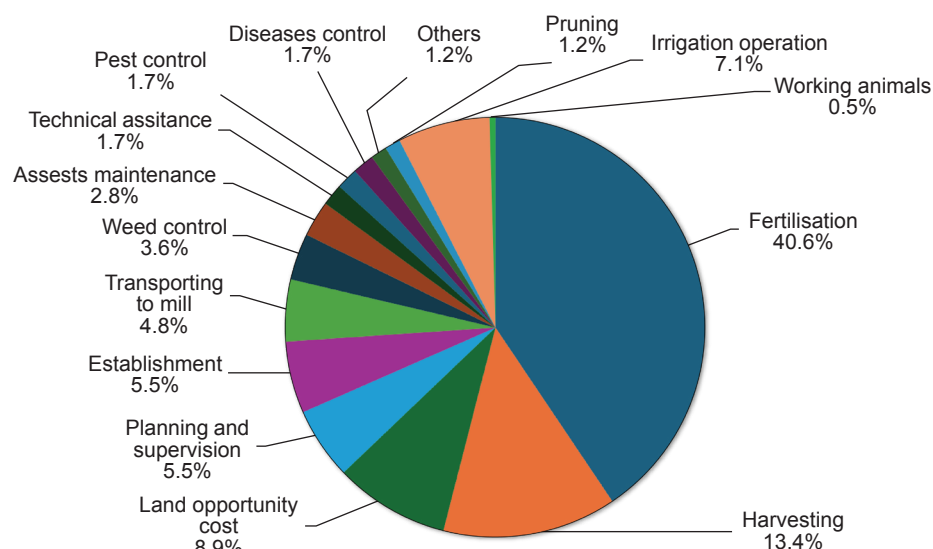
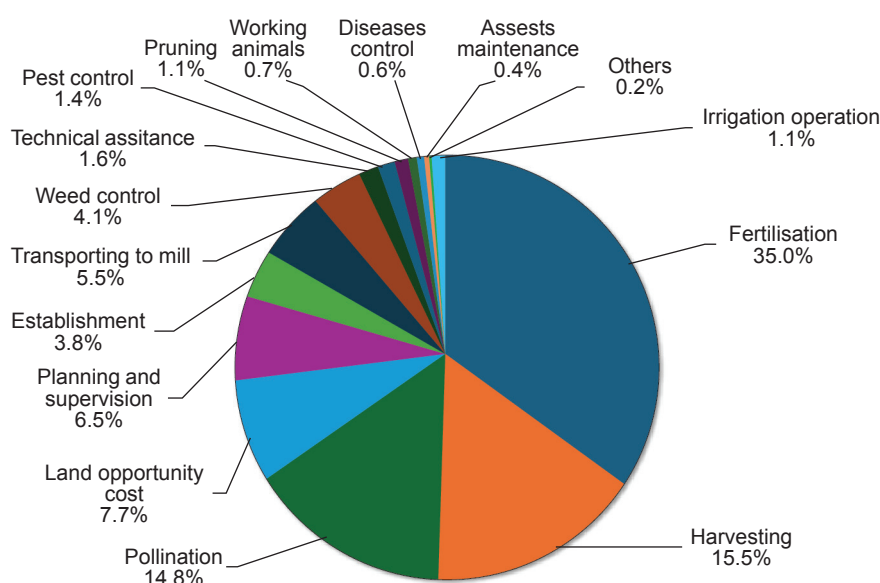
Figure 7. Cost structure for *E. guineensis* in 2023.

Figure 8. The cost structure for OxG hybrid in 2023.

Núñez *et al.*, 2023). Given that OxG hybrids FFB have higher fibre content and a lower content of nuts there is a loss in pressing capacity ranging from 15%-20% (Ruiz-Alvarez *et al.*, 2021b; Ruíz *et al.*, 2024).

Taking into account the above considerations production of 1 t of CPO from FFB of OxG hybrids was 0.41% less expensive than using raw material from *E. guineensis* cultivars.

Economic Indicators for OxG Hybrid Crops and *E. guineensis* Crops

Table 4 synthesises the results of economic indicators comparing the two types of crops under

consideration. Note for both crops NPV yields positive values (greater than zero) indicating that both crops are to be considered good investment alternatives (Table 5), however, the NPV for OxG crops is almost two times greater than the one estimated from *E. guineensis* crops. The internal rate of return (IRR) is five percentual points higher for OxG hybrid crops (with a value of 18%) with respect to the IRR estimated for *E. guineensis* crops with a value of 13% (Table 5). Regarding the annual expected income per hectare OxG crops yield a value 36% greater than the one estimated for *E. guineensis* crops. The payback period for *E. guineensis* would be the 17th year, while the payback period for OxG hybrid crops would be the

10th year. All in all, these economic indicators allow one to state that OxG crops are a better alternative to investing financial resources than *E. guineensis* crops

TABLE 5. ECONOMIC INDICATORS FOR *E. guineensis* CROPS AND OXG CROPS

Indicator	<i>E. guineensis</i>	OxG hybrids
Net present value (NPV)	3,394	7,071
Annual expected net income per ha	861	1,172
Payback period (yr)	17	10
Internal rate of return (IRR)	13%	18%

Departing from these figures, one could state that in 2023 the Colombian oil palm agroindustry had the potential of generating USD536.00 million of net revenue/yr from cropping oil palms. This is considering that in the year 2023, about 500,000 ha was planted with *E. guineensis* cultivars and 90,000 with OxG hybrid cultivars. If the whole area planted with oil palms in Colombia in 2023, had been planted with OxG cultivars the Colombian oil palm agroindustry would have got a net revenue of USD691 million where the difference between these net revenue scenarios is 29%.

CONCLUSION

The production of palm oil from the planting of OxG hybrid cultivars during the last 15 years in a commercial way, has allowed us to conclude that the business of these cultivars is different from that traditionally implemented with *E. guineensis* cultivars, with a different technological package that involves adjusting the cultivation and oil extraction processes. However, the potential is great, considering that in some plantations across the country yields as high as 45 t/ha or 11 t CPO/ha have been achieved.

OxG hybrid cultivars have become a real alternative for investors in the oil palm industry. Over the past 15 years, technological adjustments have been made including a methodology for parthenocarpy induction, ripeness criteria for bunches of different types of hybrid cultivars, and modifications to the hybrid pressing process. These changes have helped make hybrids an attractive business for those interested in oil production, especially in areas affected by BR outbreaks. In 2023, with the set of OxG cropping and milling practices available, producing 1 t of FFB from hybrid cultivars has been 5% less expensive than from *E. guineensis* cultivars, while producing 1 t of CPO has been 0.42% lower in hybrids compared to *E. guineensis* cultivars.

Although hybrids have been a strategy to deal with BR, it is necessary to continue implementing strategies for monitoring and timely control of this disease. Although it is not evident in this document, there are already records of significant BR incidence in regions with high precipitation regimes in Colombia.

The FFB from OxG hybrids imply important changes in the palm oil extraction process that increase energy consumption (thermal and electrical). However, it is crucial to make progress on processing FFB from hybrids OxG, as this could lead to optimising palm oil extraction costs. Finally, it should be noted that the characteristics of OxG hybrid palm oil are different from those of *E. guineensis* oil, so they have different markets where to be sold.

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MALAYSIAN PALM OIL PRICE PREDICTION USING ARIMA – ARCH MODEL

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ABSTRACT

Palm oil is one of Malaysia's primary industries. In 2022, Malaysia was responsible for 25.14% of global palm oil production, totalling 18.55 million tonnes, and 31.65% of worldwide palm oil exports, amounting to 15.71 million tonnes (MPOB, 2024; Trend Economy, 2024). This article presents a study for Malaysian palm oil price forecasting using the traditional time series model, with three objectives, to identify the behaviour of palm oil prices in Malaysia, to determine the best model for predicting palm oil prices using the ARIMA model, and to perform a short-term forecast of the future palm oil price in Malaysia. The analysis was conducted using monthly Malaysian palm oil prices for a period of 10 years, 2013–2023. EViews software was used to run the data analysis. It is found that ARIMA (1,1,4) – ARCH (1) model is the most parsimonious model for forecasting the crude palm oil prices in Malaysia. Overall, predicting the monthly price of Malaysian palm oil provides valuable insights that support decision-making across the entire palm oil value chain, from producers and traders to policymakers and investors.

Keywords: ARIMA-ARCH model, forecasting, Malaysian palm oil, price volatility.

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INTRODUCTION

Commodity prices, such as those for oil, metal, agricultural products and energy, are critical to the global economy, impacting inflation, trade balances and overall economic growth. Within this broader context, the Malaysian palm oil industry is a cornerstone of the agricultural commodities market, playing a pivotal role in global economies, food security and environmental sustainability. In 2022, Malaysia produced 25.14% of world's palm oil production (18.55 million tonnes). It accounted for 31.65% of the world's palm oil exports (15.71 million tonnes), with major buyers including India, China, the European Union, Türkiye and Kenya (MPOB, 2024; Trend Economy, 2024). The agriculture sector, particularly oil palm, provides 10% of total employment in Malaysia in 2023, engaging over

3 million individuals, including nearly 500,000 smallholders (MPOC, 2024). However, the industry's market dynamics are affected by global demand, geopolitical events and environmental regulations, making accurate forecast palm oil prices essential for stakeholders – producers, traders, policymakers and consumers – who rely on such insights for informed decision-making regarding production levels, inventory management and resource allocation. Price volatility introduces financial risks, underscoring the importance of reliable forecasts for risk management and investment assessments, while also enabling policymakers to understand market trends and design supportive interventions to stabilise the sector.

Forecasting models, particularly the Autoregressive Integrated Moving Average (ARIMA) model, is a widely adopted methodology in time series forecasting, particularly suited for capturing the complex dynamics of financial and economic data. By analysing historical price trends, ARIMA models can identify underlying patterns,

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trends, and seasonal variations that affect Malaysian palm oil prices. This approach not only facilitates short-term predictions but also supports strategic planning and risk management in the palm oil industry.

The Malaysian palm oil industry has experienced significant price volatility in recent years, driven by diverse economic, environmental and geopolitical factors. Despite the extensive research into price forecasting techniques, there remains a need to develop and validate robust ARIMA models specifically tailored to predict Malaysian palm oil prices accurately. This study seeks to address this gap by investigating the effectiveness of ARIMA models in forecasting palm oil prices, identifying key time series components (such as trends, seasonality and cyclical patterns), and assessing forecasting performance over different time horizons. The objective is to develop a more robust and optimal ARIMA-ARCH model for Malaysian palm oil prices and conduct a short-term forecast to compare observed and fitted values.

Research on palm oil price forecasting has utilised a range of methodologies. In time series modelling, researchers typically use historical price data to identify trends, seasonality and cyclical patterns. A comparative study by Khin *et al.* (2013) found that the Multivariate ARMA model is the best predictive model than ARIMA and Vector Error Correction model (VECM) for forecasting the spot palm oil price. Ahmad *et al.* (2014) combined ARIMA with GARCH to model price volatility, finding a hybrid ARIMA-GARCH model most effective for the Malaysian CPO price from January 1999 to May 2014. Hamid and Shabri (2017) preferred the Autoregressive Distributed Lag (ARDL) model over ARIMA, while Khalid *et al.* (2018) identified ARIMA with exogenous variables (ARIMAX) as superior to ARDL and ARIMA. Zaidi *et al.* (2021) employed Support Vector Autoregression (SVAR) technique to assess the impact of substitute goods on palm oil prices.

Econometric models incorporate economic variables such as crude oil prices, exchange rates, and global demand into the forecasting process. These models often use regression techniques to establish relationships between palm oil prices and relevant economic indicators (Ahmad *et al.*, 2014). Vector Autoregression (VAR) models are also employed to capture the dynamic interactions among multiple time series variables affecting palm oil prices.

Machine learning techniques have recently gained popularity for modelling and forecasting palm oil prices (Kanchymalay *et al.*, 2017). Algorithms such as Support Vector Machines (SVM), Artificial Neural Networks (ANN) (Karia *et al.*, 2013), and Random Forests (Li *et al.*, 2016) were applied due to their ability to handle complex non-linear relationships and large datasets. These models often

outperform traditional statistical approaches when sufficiently large data is available for training and validation. Rahim *et al.* (2018) found that the Fuzzy Time Series-based forecasting model was a simpler method to forecast CPO price than the ARIMA-ANN method. Moreover, Yee and Samsudin (2021) found that ANN outperformed ARIMA in forecasting palm oil price movement between January 2008 and December 2018.

In conclusion, modelling and forecasting Malaysian palm oil prices requires a multidisciplinary approach that integrates economic theory, statistical methods and advanced computational techniques. While machine learning algorithms is useful for modelling a complex, and non-linear patterns, the ARIMA model remains to be a competitive, robust, and practical tool, particularly in scenarios where the underlying data has a more linear or well-known patterns. To advance research in this field, it is essential to address data challenges and sustainability considerations.

MATERIAL AND METHOD

The Box-Jenkins model (1976) was named after the statisticians who developed systematic procedures for identifying and estimating ARIMA models. This model is favoured for its ability to capture complex patterns, trends, seasonality and random noises in time series data. It includes both the autoregressive (AR) component, which models the relationship between an observation and several of its lagged values (previous observation), and the moving average (MA) component, which represents the relationship between an observation and the residual errors from a moving average process applied to the lagged observations. The methodology encompasses statistical tests for residual diagnostic and short-term forecasting.

The stationarity of data series is a fundamental requirement for applying the ARMA (p, q) model. A stationary time series does not exhibit trends, seasonal effects, or any structure that evolves over time. However, most economic variables are non-stationary and have trends. If the variable is non-stationary, it needs to be differenced to remove the trend. ARIMA (p, d, q) model, in contrast to the ARMA (p, q) model, includes the 'I' for integration, where d is the number of differencing operations required to achieve stationarity. The equation of ARIMA (1,1,1) is given by (Lazim, 2005):

$$w_t = \mu + \phi_1 w_{t-1} + \theta_1 \epsilon_{t-1} + \epsilon_t \quad (1)$$

where, $w_t = y_t - y_{t-1}$ represents the first difference of the series.

Traditional econometrics models assume that residuals (errors) are homoscedastic, meaning they have constant variance over time. However, many economic time series face periods of volatility higher than usual, which violates the homoskedasticity assumption. This can result in biased parameter estimates and standard errors, impacting the model's reliability and reducing forecast accuracy. To address heteroscedasticity, models such as, Autoregressive Conditional Heteroscedasticity (ARCH) are used. The ARCH model, introduced by Engle (1982) in his article "Autoregressive Conditional Heteroscedasticity with estimates of the variance of United Kingdom Inflation" earned him the 2003 Nobel Memorial Prize in Economic Sciences. The model was later extended in 1986 by Bollerslev with the introduction of Generalised Autoregressive Conditional Heteroscedasticity (GARCH) models. Thus, ARCH/GARCH models capture conditional heteroscedasticity, allowing for the modelling of financial time series with time-varying volatility and volatility clustering. While GARCH is generally preferred for its flexibility, efficiency and forecasting accuracy, ARCH models can be suitable for simpler problems or datasets with limited volatility structure, where the added complexity of GARCH might not provide substantial benefits; therefore, for short time series or limited data, ARCH may still be a reasonable choice.

The error terms in an ARCH (1) model are normally distributed with a mean of 0 and the conditional variance of the error terms is represented by Equation (2):

$$Var(\epsilon_t) = \sigma_t^2 = \alpha_0 + \alpha_1 \sigma_{t-1}^2 \quad (2)$$

The above model is known as ARCH (1), since the conditional variance depends on only one lagged squared error.

Data Description

The historical monthly price data of Malaysian palm oil was retrieved from MPOB (2024), for a period of 10 years, ranging from February 2013 to February 2023. There is a total of 121 observations. All the data is used for model fitting. To forecast Malaysian palm oil prices using an ARIMA model, there are four major stages, namely model identification, parameter estimation, diagnostic checking as well as forecasting. EViews software, 10th edition was used to run data analysis.

Initial Data Investigation and Model Identification

In the very first step, the data will be examined for the presence of any trend, seasonality or non-

stationarity. This is done by plotting the raw data using a simple line chart, analysing the patterns of Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) plots and conducting a unit root test. If the data is stationary at the level, an ARMA model will be estimated. If the data is non-stationary, differencing will be applied to remove the trend. Usually, a first difference ($d=1$) is sufficient, but if the data remains non-stationary, a second differencing may be required. Once the data becomes stationary, an ARIMA (p, d, q) model will be used. The next step involves examining the correlogram to identify the appropriate values for p and q in the ARIMA model. The number of significant spikes of the ACF and PACF plots will guide the selection of potential models. The PACF will be used to determine the AR component while the ACF will assist in identifying the MA component.

Model Estimation

In this step, the parameters of the ARIMA model will be estimated based on the identified characteristics of the data by using the least squares estimator. Then the significance of the coefficients will be evaluated and the Akaike-Information-Criterion (AIC) and Bayesian or Schwartz-Criterion (BIC) scores obtained will be compared. The optimal model will be chosen based on the significance of coefficients, lowest volatility, lowest AIC and BIC values, and highest adjusted R-squared. The model with the least volatility will increase the power of prediction.

Model Diagnostic

Once a potential model is identified, diagnostic checks will be performed to ensure that it meets the requirement for a stable univariate process. It is important to verify that the model's residuals are white noise, meaning they have independent observations with constant mean and variance and exhibit no autocorrelation between consecutive residuals in the data series. This is assessed using the Ljung-Box Q-statistic test for autocorrelation in ARIMA models. A test for the ARCH effect will also be conducted. If the ARCH effect is detected, ARCH/GARCH models should be used to model the conditional variance explicitly. If all conditions are met, we can proceed with forecasting using the estimated model. Otherwise, we need to re-estimate and explore another potential model.

Forecasting

Once the most parsimonious model is identified, it will be used for generating future forecasts. In this context, the dynamic forecast option in EViews will be employed. Dynamic forecasting assumes that the

forecasts will be made without using any data from beyond the sample period (out-sample data) even if relevant data is available.

Evaluation metrics such as Root Mean Squared Error (RMSE) and Mean Absolute Percentage Error (MAPE) are commonly used to assess the accuracy of ARIMA forecasts (Kanchymalay *et al.*, 2017; Khalid *et al.*, 2018; Yee & Samsudin, 2021; Zhou *et al.*, 2018). RMSE measures the average magnitude of forecast errors, with larger errors receiving more weight due to the squaring of differences. A lower RMSE indicates better predictive accuracy. RMSE for one-step-ahead forecast is written as:

$$\text{RMSE} = \sqrt{\frac{\sum_{j=1}^n (y_j - \hat{y}_j)^2}{n}} \quad (3)$$

Unlike RMSE, MAPE focuses on the relative size of errors as a percentage of the actual values, with lower percentages indicating closer predictions to actual values. A MAPE value below 10% is considered as good. MAPE is written as:

$$\text{MAPE} = \frac{1}{n} \sum_{j=1}^n \left| \frac{y_j - \hat{y}_j}{y_j} \times 100 \right| \quad (4)$$

Cross-validation techniques may be employed to validate the robustness of the ARIMA models and identify potential overfitting issues.

RESULTS AND DISCUSSION

At the initial stage, a preliminary data analysis was performed to identify the basic pattern of the series and to detect any unusual observations or

characteristics. *Figure 1* shows Malaysian palm oil prices fluctuations over the 10 years. A cursory observation of *Figure 1* illustrates that the series is not stationary. Although the series does not show any seasonal effects, there are notably large values in mid-2022, which could be interpreted as irregularities. The palm oil price surge in mid-2022 was caused by a combination of supply disruptions caused by the Russia–Ukraine war which started in February 2022, Indonesia’s temporary export ban from April to May 2022, labour shortages and production constraints in Malaysia and strong global demand for palm oil as a substitute for other edible oils (Voora *et al.*, 2023).

Stationarity Test

The ACF and PACF were plotted to determine the stationarity of the series. Based on *Figure 2*, the ACF plot tailing off extremely slowly in a linear fashion. The autocorrelations remain high over many lags and decline at a steady rate, suggesting that the series exhibits a trend and is non-stationary.

The Augmented Dickey-Fuller (ADF) test is also employed to assess whether the series is non-stationary. According to the results presented in *Table 1*, the p -value = 0.262 exceeds the 5% significance level, leading to a failure to reject the null hypothesis. This indicates that the series unsurprisingly possesses a unit root, meaning the data is non-stationary at level.

To address the high autocorrelation and achieve stationary, we applied the first difference to the data. Upon reapplying the ADF test to the differenced series, we obtained a p -value of 0.000, which is below the 5% significance level. Therefore, we conclude that the data now is stationary in the mean, allowing us to proceed with estimating the model.

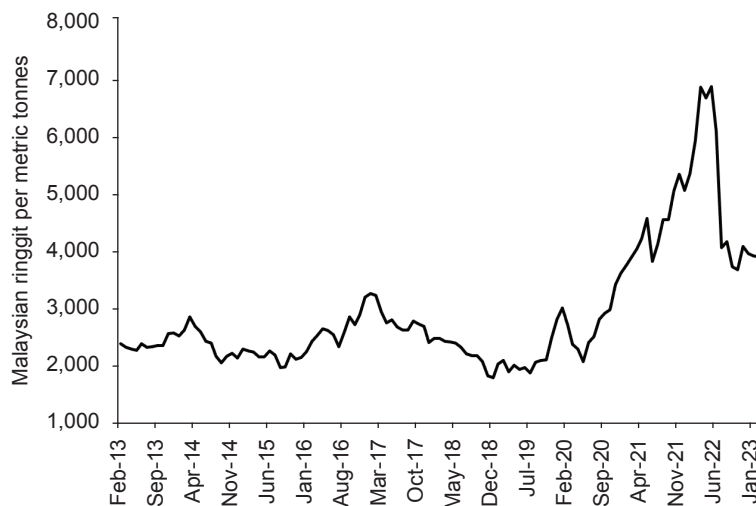


Figure 1. Malaysian palm oil price.

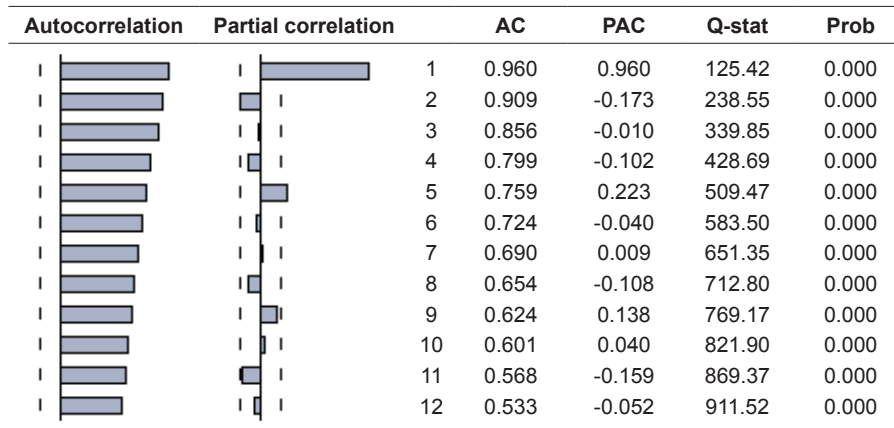


Figure 2. The correlogram of Malaysian palm oil price at level.

TABLE 1. THE RESULTS OF AUGMENTED DICKEY-FULLER TEST

Model	Test for unit root at	Test statistic	p-value
Trend and intercept	Level	-2.644	0.262
	First difference	-8.543	0.000

Figure 3 graphically shows the fluctuations of the series around the zero line, indicating that stationarity in mean has been achieved after the first differencing. However, it is evident that there remains non-stationarity in variance of the series.

Model Identification and Estimation

The process of identifying the potential models for the data series involved analysing the ACF and PACF of the stationary series. As shown in Figure 4, both the PACF and ACF plots cut off at lag 1 and 4 respectively. This suggests that potential models to test could include ARIMA (1,1,1), ARIMA (1,1,4), ARIMA (4,1,1) and ARIMA (4,1,4).

As shown in Table 2, the ARIMA (1,1,4) was chosen as the preferred model because it fulfilled all the selection criteria.

Model Validation and Diagnostic Checking

In a well-fitted model, the residuals should ideally exhibit white noise characteristics. To verify this, diagnostic checks were performed by plotting the correlogram of the residuals. Figure 5 demonstrates that all values in the ACF and PACF plots lie within the 95% confidence interval, indicating that the absence of significant autocorrelation in the residuals of the selected models. The null hypothesis that the residuals are white noise could not be rejected, suggesting that the ARIMA (1,1,4) model is adequate.

The ARCH-LM test is performed to determine the presence of heteroscedasticity in variance of the residuals. The null hypothesis states that there are no ARCH effects up to the specified lag order. If p -values are less than the significance level,

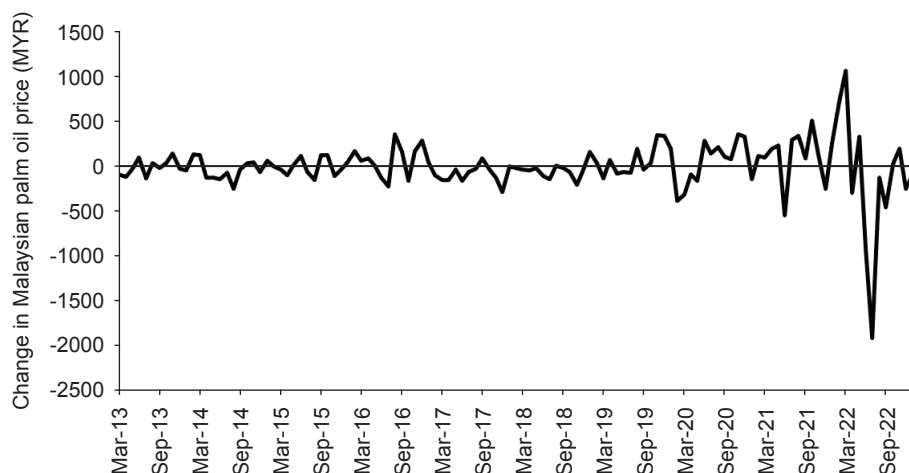


Figure 3. Malaysian palm oil price after first differencing.

the null hypothesis will be rejected. As shown in Table 3, before fitting ARCH (1) model into the ARIMA (1,1,4) model, the p-values are 0.0142, which is less than $\alpha = 0.05$. Therefore, the null hypothesis is rejected, indicating the presence of heteroscedasticity in the residuals. Although the inclusion of additional lags was considered, the

ARCH (1) model was found to adequately address the heteroscedasticity in the model. The ARCH test was re-conducted to verify the absence of ARCH effects after fitting the ARCH (1) model. As shown in Table 3, the p-values are greater than 0.05, confirming that heteroscedasticity is no longer present in the model.

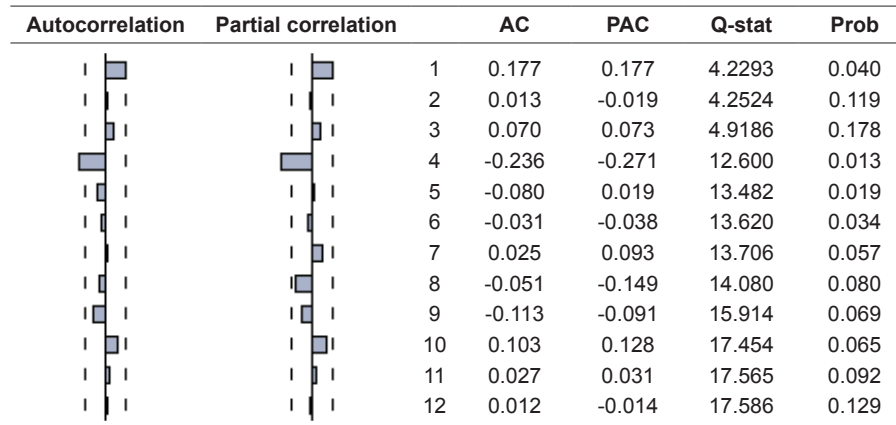


Figure 4. The correlogram of Malaysia palm oil price at first difference.

TABLE 2. TEST RESULTS OF ARIMA ($p,1,q$)

Model	Coefficient	Sigma2 (volatility)	Adj. R ²	AIC	BIC
ARIMA (1,1,1)	Significant	77617.37	0.0720	14.17352	14.26644
ARIMA (1,1,4)	Significant	74554.68	0.1086	14.12804	14.22096
ARIMA (4,1,1)	Significant	75503.02	0.0973	14.13988	14.23279
ARIMA (4,1,4)	Not significant	78300.60	0.0638	14.17625	14.26917

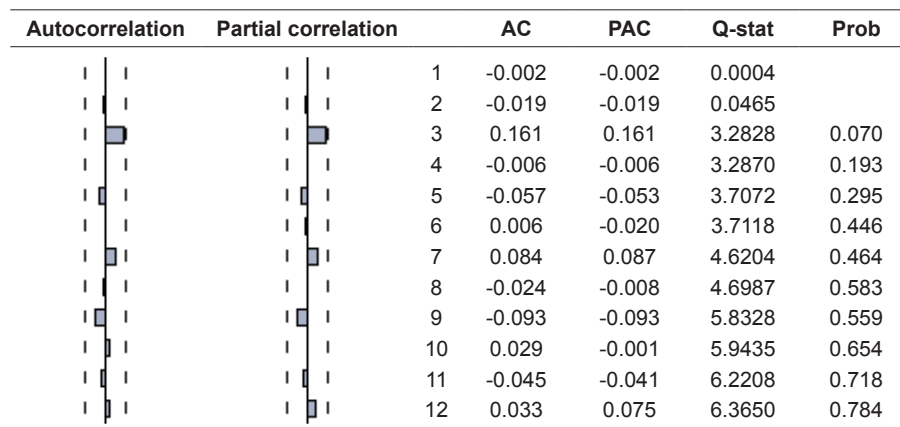


Figure 5. The Ljung-Box Test for ARIMA (1, 1, 4).

TABLE 3. HETEROSCEDASTICITY TEST

Heteroscedasticity test: ARCH	Before fitting ARCH (1)		After fitting ARCH (1)	
ARIMA (1,1,4)	Prob. F (1,117)	0.0142	Prob. F(1,116)	0.9487
	Prob. Chi-Square(1)	0.0144	Prob. Chi-Square(1)	0.9482

In general, the equation for ARIMA (1,1,4) model can be written as:

$$w_t = \mu + \phi_1 w_{t-1} + \theta_1 \epsilon_{t-1} + \theta_2 \epsilon_{t-2} + \theta_3 \epsilon_{t-3} + \theta_4 \epsilon_{t-4} + \epsilon_t \quad (5)$$

where, $w_t = y_t - y_{t-1}$ is the first difference of the series, μ is the constant term, ϕ_1 is the coefficient for the AR (1) term, ϵ_t is the error term at time t , and $\theta_1, \theta_2, \theta_3, \theta_4$ are the coefficients for the MA (4) term,

However, in this study, for the MA component, only one composite moving average term, θ is estimated, and this coefficient will affect all the lags of the error term simultaneously, not with separate coefficients for each lag.

$$w_t = \mu + \phi_1 w_{t-1} + \theta (\epsilon_{t-4} + \epsilon_{t-3} + \epsilon_{t-2} + \epsilon_{t-1} + \epsilon_t) \quad (6)$$

where, θ is a single parameter that reflects the cumulative effect of all four lags of the error term. This simplified model may be more stable and parsimonious, leading to more robust parameter estimates and significant coefficients.

The following is the estimation results of ARIMA (1, 1, 4) – ARCH (1) model.

This estimation result corresponds to the following specification,

$$w_t = 0.0553 + 0.2682 w_{t-1} - 0.1971 (\epsilon_{t-4} + \epsilon_{t-3} + \epsilon_{t-2} + \epsilon_{t-1} + \epsilon_t) \quad (7)$$

where the variance equation is,

$$\sigma_t^2 = 21242.68 + 0.7313 \sigma_{t-1}^2 \quad (8)$$

As we can see the α_1 value = 0.7313 which is close to 1 indicates that the persistence of the volatility is quite high. *Figure 8* demonstrates how the variance

has increased significantly in the period of the first quarter of 2022.

Forecasting

The ARIMA (1, 1, 4) – ARCH (1) model for Malaysia palm oil price was estimated using the whole 121 observations (or monthly observations from February 2013 until February 2023). Since the model fulfilled all the conditions, the next step is to generate forecast and assess its accuracy. A forecast for the palm oil price will be made for the next 12 observations, extending through 2024. This process begins by adding 12 out-of-sample observations to the dataset.

The 95% confidence interval for the mean is a range of values that we are 95% confident contains the population mean. It is typically calculated as the sample mean plus or minus the margin of error. In this case, the forecasted values are computed by adding and subtracting two times the standard error from the sample mean. This accounts for approximately 95% of the area under the normal distribution curve. *Table 4* presents the forecast evaluations for the ARIMA (1,1,4) and ARIMA (1,1,4)–ARCH (1) models. The model with the lower RMSE and MAPE are generally preferred, as it indicates better predictive performance on the test data.

For the hybrid ARIMA (1,1,4) – ARCH (1) model, the RMSE of 237.64 is lower than that of the ARIMA (1,1,4) model, indicating superior forecast accuracy. The MAPE of 5.53% means the average difference between the forecasted and actual values is 5.53%, which is also an improvement over the ARIMA (1,1,4) model of 10.55%.

Figure 9 visually displays the actual and forecasted prices, along with the two confidence bands.

Variable	Coefficient	Std. error	z-statistic	Prob.
C	0.055319	19.52330	0.002834	0.9977
AR(1)	0.268136	0.088874	3.017016	0.0026
MA(4)	-0.197132	0.061340	-3.213772	0.0013
Variance equation				
C	21242.68	4472.070	4.750078	0.0000
RESID(-1)^2	0.731298	0.173463	4.215873	0.0000
R-squared	0.108504	Mean dependent var		13.24370
Adjusted R-squared	0.093134	S.D. dependent var		295.31340
S.E. of regression	281.2256	Akaike info criterion		13.59191
Sum squared resid	9174189.	Schwarz criterion		13.70868
Log likelihood	-803.7189	Hannan-Quinn criter.		13.63933
Durbin-Watson stat	2.123342			
Inverted AR Roots	.27			
Inverted MA Roots	.67	-.00+.67i	-.00-.67i	-.67

Figure 7. The ARIMA (1, 1, 4) – ARCH (1) Model for Malaysian palm oil price.

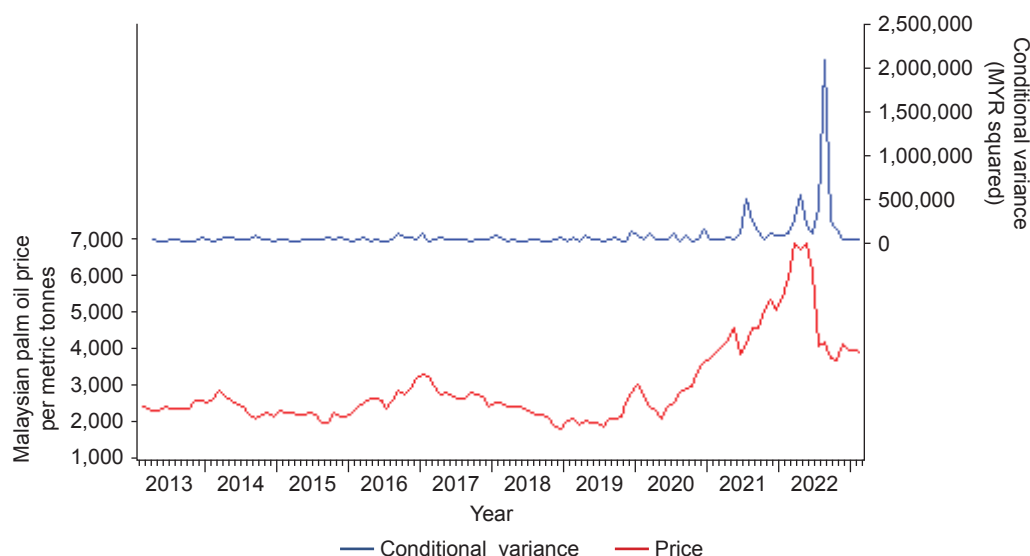


Figure 8. Conditional variance and Malaysian palm oil price.

TABLE 4. FORECAST EVALUATION FOR ARIMA (1,1,4) AND ARIMA (1,1,4)-ARCH (1) MODEL

Forecast: PRICEF ARIMA(1,1,4)		Forecast: PRICEF ARIMA(1,1,4)-ARCH(1)	
Actual: PRICE		Actual: PRICE	
Forecast sample: 2023M03 2024M02		Forecast sample: 2023M03 2024M02	
Included observations: 12		Included observations: 12	
Root mean squared error	419.3994	Root mean squared error	237.6398
Mean absolute error	395.7992	Mean absolute error	209.1486
Mean abs. percent error	10.55121	Mean abs. percent error	5.530055
Theil inequality coefficient	0.052587	Theil inequality coefficient	0.030631
Bias proportion	0.606486	Bias proportion	0.215054
Variance proportion	0.067194	Variance proportion	0.577258
Covariance proportion	0.326320	Covariance proportion	0.207688
Theil U2 coefficient	2.159479	Theil U2 coefficient	1.147275
Symmetric MAPE	9.991144	Symmetric MAPE	5.419211

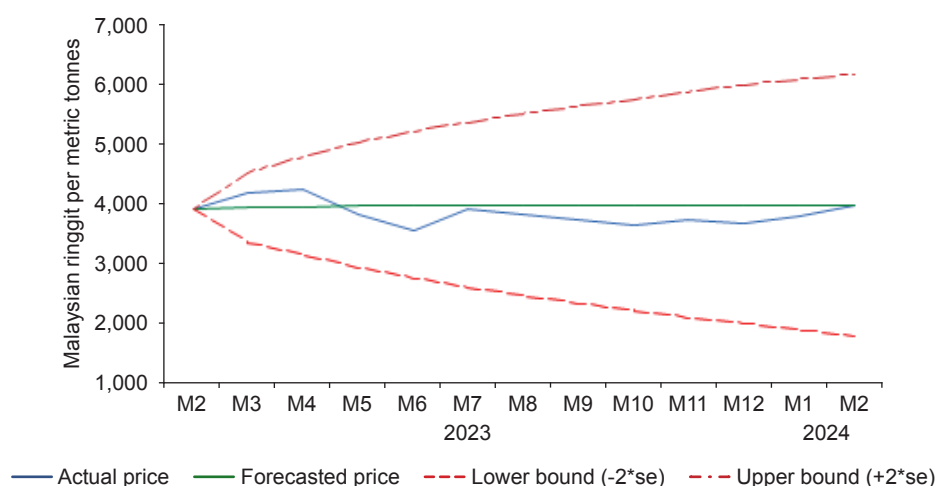


Figure 9. Malaysian palm oil price (Actual - Forecast).

CONCLUSION

This study elaborates the development of a statistical model for forecasting Malaysian palm oil prices using the Box-Jenkins methodology,

specifically the ARIMA model. The best-fitting model identified is ARIMA (1,1,4)- ARCH (1). Utilising this model, forecasts for palm oil price over the next 12 months were generated. Given the volatility in global commodity markets and

the recent fluctuations in Malaysian palm oil prices due to factors such as changing demand, geopolitical tensions and environmental policies, the ARIMA models have demonstrated their effectiveness in predicting Malaysian palm oil prices. These forecasts provide valuable insights that can help industry stakeholders, such as producers, exporters and policymakers, navigate the uncertainty in pricing trends and better align their strategies with market conditions. As the palm oil market faces continued challenges - such as price instability, fluctuating global demand and regulatory changes - further research and innovation in time series forecasting methodologies will be critical. Advances in these methods will enhance the accuracy and reliability of predictions, thereby supporting informed decision-making, effective risk management and the development of sustainable strategies for the Malaysian palm oil industry.

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