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Challenges for climate-smart oil palm production

Production systems at a crossroad

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Summary

Palm oil is recognised as a major source of foreign reserves in tropical countries, as well as the main instrument of poverty alleviation and rural economic development. This perennial tropical crop is a champion in terms of productivity, but is it resilient enough to face the intrinsic risks caused by the large-scale monoculture of one single species over extended areas?

Even if the public debate is not as opinionated as it was in the past decade, the production of oil palm is still associated in the public arena with damage to the environment and an unbalanced diet due to the high proportion of saturated fatty acids in palm oil. The sector is also facing growing constraints linked to, among many other parameters, climate change, price volatility and labour scarcity.

In this context, there is an urgent need to rethink the oil palm production model and proposing a change of paradigm based on nature-based solutions. Implementing a successful agroecological transition in a US$ 70 billion sector, covering 25 million hectares worldwide, calls for drastic changes in mind-sets and practices. The key issue is no longer to simply increase productivity, but to foster innovations while providing a decent living for shrinking agricultural communities in the Global South.

Building on restored ecosystem functions, agroforestry-based solutions are slowly emerging and they are gaining ground. Agroforestry practices have a role to play in providing substantial climate change mitigation with an impact comparable to other climate-focused solutions, such as reforestation. The expected contribution of oil palm-based agroforestry relies on agro-environmental services, as basic agricultural functions such as soil preservation, pollination and pest control can be ensured by a diversity of living organisms, both inside and around the plantation. Innovative approaches are bolstering the restoration of degraded lands and expanding agroforestry. Building on regenerative agriculture, new plantation designs are emerging and deserve to be thoroughly assessed to establish evidence-based advocacy for change.

Introduction

Oil palm (Elaeis guineensis Jaq.) is still the archetypal intensive monoculture developed in tree crop plantations. Cultivated on 25 million hectares in the intertropical belt, its farming system has changed little over the last century [1]. Although the large-scale development of this perennial crop has slowed considerably over the last decade [2], it still raises a number of recurring questions for research on the sustainability of its production systems.

The controversy that has accompanied the development of oil palm for over thirty years also concerns the management of climate change in a sector that is highly globalised and in the throes of change. The colonial legacy has shaped a geopolitical status based on the exploitation of resources in the South (plantations) and processing in the North (refining, industrial processing and distribution). This global landscape is changing fast: industrialists from the South (Indonesia, Malaysia, Colombia, and Thailand) are gradually investing in downstream activities, including the production of biofuels.

The oil palm sector remains linked to intercontinental trade, with the Asian giants (China and India) playing a growing role, both in the consumption of crude palm oil (CPO) and in its processing. The increasing scarcity of rural labour (20 per cent of the labour force in plantations in the pre-COVID years is still unavailable) will constrain the development of the sector.

Palm oil is here to stay

Palm oil is the most widely consumed vegetable oil in the world, and demand has accelerated with the emergence of new outlets in the agrofuels sector, in addition to traditional food and oleochemical uses [3]. This strong growth has undeniably contributed to the economic

Page 2:
Recently harvested fresh fruit bunches (FFBs) in Indonesia
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Below:
A mature oil palm plantation in Indonesia
© Alain Rival, CIRAD

Average oil yield of major oil crops (tonnes per hectare)

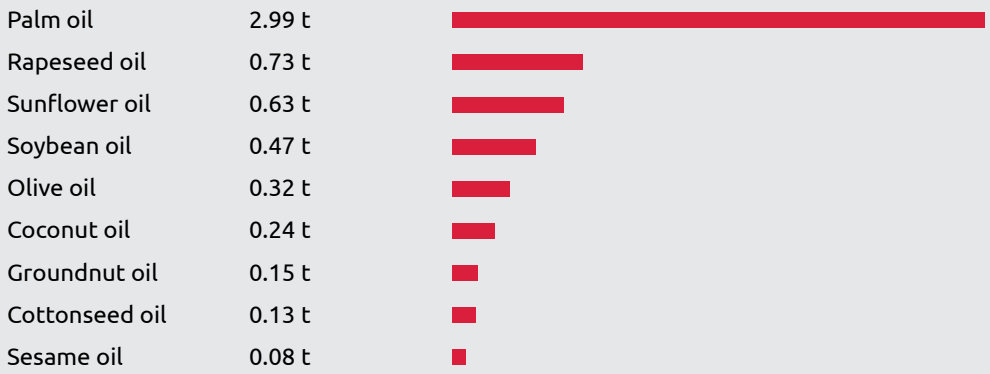

Figure 1 (Source: Food and Agriculture Organization of the United Nations (2023) "Production: Crops and livestock products" [original data]).

Top 10 palm oil producing countries

Market	Total Production (2023/2024, Metric Tonnes [t])	per cent of Global Production
Indonesia	47,000,000	59 %
Malaysia	19,250,000	24 %
Thailand	3,280,000	4 %
Colombia	1,900,000	2 %
Nigeria	1,500,000	2 %
Guatemala	920,000	1 %
Papua New Guinea	820,000	1 %
Côte d'Ivoire	600,000	0.75 %
Honduras	595,000	0.75 %
Brazil	585,000	0.74 %
Others	3,820,000	4.76 %
Total	**80,270,000**	**100 %**

Figure 2 Source: Food and Agriculture Organization of the United Nations (2023) "Production: Crops and livestock products" [original data].

development of the main producing countries, mainly Indonesia and Malaysia, which now satisfy 83 per cent of global demand [4]. The sector is a key source of foreign exchange reserves, as well as a major instrument for poverty reduction and rural economic development [5], [6].

On a global scale, palm oil supplies 40 per cent of the world's vegetable oil demand on just under 6 per cent of the land used to produce all vegetable oils. To obtain the same quantity of oil from other sources such as soya, rapeseed or sunflower, between four and ten times as much land

Major palm oil consuming countries.

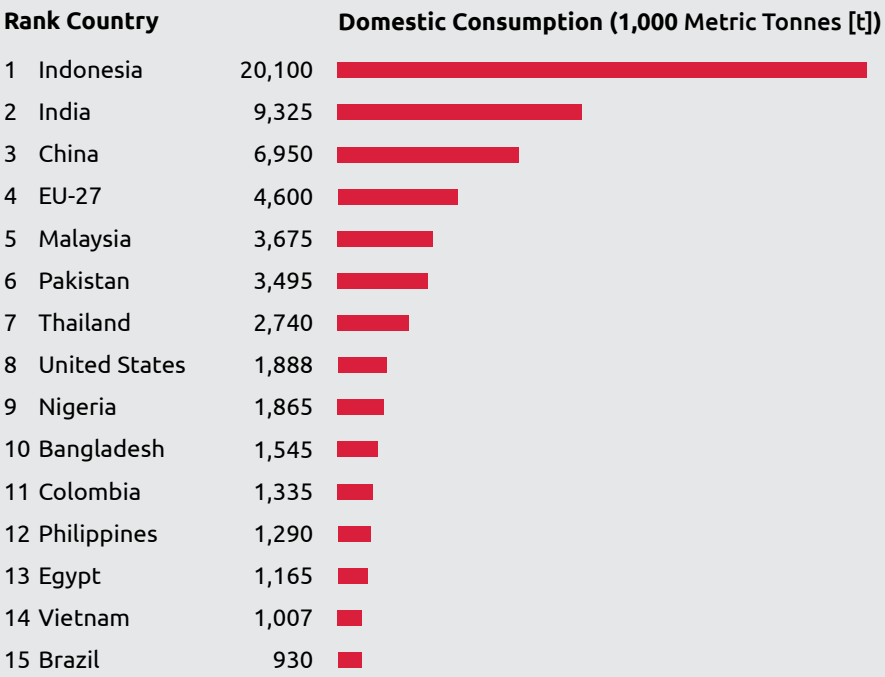

Figure 3 (Source: USDA FAS 2023)

would have to be cultivated. The comparative advantages of palm oil over competing vegetable oils are still based on low production costs, which are structurally due to the availability of arable land, the high natural productivity of the crop - easily exceeding 3 tonnes per hectare - and the low cost of labour [7].

The oil palm is an impressive oil factory, able to generate exceptional oil yields of 3.8 tonnes per hectare as a global average, nearly six tons/hectares in the best plantations in Southeast Asia and more than 12 tonnes/hectares in the highest yielding genetic (non-GMO) trials currently underway in research institutions. Such yields make the oil palm the leader among industrial oil crops (see Figure 1). The proportion of the oil palm in worldwide production of vegetable oils has continued to grow over recent decades to reach the number one spot, ahead of soybean. Today it accounts for over a third of the vegetable oil produced worldwide. Two countries – Indonesia and Malaysia – are responsible for the bulk of world palm oil production, and between them they account for 83 per cent of supplies (see Figure 2). The consumption of palm oil is governed by the countries from the Global South and it is driven by demographic growth and the rising standard of living in emerging countries with large populations such as India, Indonesia and China (see Figure 3). European consumption accounts for 12 per cent of the world total and the United States' share is 3 per cent.

Indonesia and Malaysia, the world's leading suppliers of palm oil, are projected to account for 83 per cent of global palm oil production and 34 per cent of global vegetable oil production by 2030. Further pro-

duction growth in these countries is projected to be limited although Indonesia plans to transition to 100 per cent biodiesel, requiring 100 million tonnes of palm oil per year by 2040, and a doubling of the current plantation area [7]. Indonesia's expected increase in domestic biodiesel production will lower its export growth of crude palm oil in the medium term. Indonesia and Malaysia will continue to dominate the vegetable oil trade, exporting over 70 per cent of their combined production and jointly accounting for nearly 60 per cent of global exports. India, the world's biggest importer of vegetable oil, is projected to maintain its high import growth due to growing domestic demand and limited domestic production.

A pygmy elephant freely wandering in an oil palm plantation in Sabah, Borneo. © Alain Rival, CIRAD

Which certification for which markets?

Sustainability certification schemes were introduced in the palm oil industry as a response to address the negative environmental and social impacts associated with the development of the industry. The first certification scheme for palm oil, the Roundtable on Sustainable Palm Oil (RSPO), was established in 2004, followed by other non-governmental initiatives to ensure the sustainable production of palm oil. Indonesia and Malaysia, the two largest palm oil producers in the world, established Indonesia Sustainable Palm Oil (ISPO) and Malaysia Sustainable Palm Oil (MSPO) in 2011 and 2015, respectively. Sustainability schemes aim to ensure that the development of the palm oil industry does not contribute to further deforestation and environmental degradation, but contributes to improving the social well-being of the workers and the communities involved. Producing countries, such as Malaysia and Indonesia, have taken a step further by developing their own sustainability schemes. Despite the varying results on certification effectiveness in delivering multiple sustainability objectives, certification has been the practical mechanism in managing and monitoring the production of certified sustainable palm oil to

RSPO: The Roundtable on Sustainable Palm Oil. When it was launched in 2004, RSPO was a business-to-business initiative bringing together about ten members, private actors in the industry and NGOs (such as WWF). It is an international, multi-stakeholder initiative, aimed at certifying and promoting sustainable palm oil. Starting with 200 members from 16 countries in 2004, RSPO now counts more than 5,700 members in over 100 countries and territories spanning the globe.

ISCC: International Sustainability and Carbon Certification. This scheme is a system for certifying sustainbable oil palm produce to achieve a reduction in greenhouse gas emissions, sustainable land use, protection of the natural biosphere and social sustainability. ISCC applies across the supply chain and in doing so it can verify traceability from a plantation right through to the consumer. It is strong in the derivatives sector.

ISPO: Indonesian Sustainable Palm Oil. ISPO was introduced by the government of Indonesia in March 2011. ISPO was designed from a legal framework based on Indonesian legislation involving the Ministry of Agriculture, the State Ministry for the Environment, the Ministry of Forestry and the National Land Agency. ISPO is mandatory: it is legally binding to all palm oil plantations within Indonesia and involves fines and sanctions.

MSPO: Malaysian Sustainable Palm Oil. MSPO is anational certification standard created by the Malaysian government and developed with input from various stakeholders in the palm oil industry. It was first launched in November 2013, and officially came into effect as of 1st January 2015. MSPO aligns the management of palm oil production with many existing national laws and regulations. The MSPO certification became mandatory as of 1st January 2020 and those companies that failed to obtain the MSPO certification by that date faced penalties.

date [8]. Through the implementation of sustainable certification, the palm oil industry can play a significant role in achieving the sustainable development goals (SDG).

RSPO insists that to gain certification new plantings since November 2005 must not have replaced primary forest or any area required to maintain or enhance one or more High Conservation Values (HCV). An HCV assessment, including stakeholder consultation, must be conducted prior to any conversions and dates of land preparation and commencement must also be recorded. The HCV assessment process requires appropriate training and expertise, and must include consultation with local communities, particularly so as to identify social HCVs, such as sacred grounds or traditional places of worship. Development should actively seek to utilize previously cleared and/or degraded land. Plantation development should not put indirect pressure on forests through the use of all available agricultural land in an area. In order to improve the participation of smallholders, local certification schemes, such as the Malaysian Sustainable Palm Oil (MSPO) and Indonesian Sustainable Palm Oil (ISPO) initiatives, have been set up, although internationally traded palm oils are almost exclusively certified by RSPO.

Through the implementation of sustainable certification, the palm oil industry can play a significant role in achieving the SDGs.

Profitability: size matters

Industry experts say the current price of palm oil is about two or three times the actual cost of production from growers. As a result, many growers are thought to be well above break-even levels. The largest and most efficient companies are

Biodiversity in shapes and colours in mature oil palm fruits.

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An oil palm smallholder in the province of Riau on Sumatra, Indonesia. Oil palm has helped to improve the livelihoods of millions of small-scale farmers in Indonesia and Malaysia. However, their business remains a challenge.

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therefore cash-rich and in a good economic position. For such companies, it would be logical, under the present circumstances, to invest in fire management as well as other aspects of sustainability such as emissions reduction, keeping long-term net zero commitments in mind. However, the situation may be different for smallholder farmers who are less efficient in their output and for some small to medium-sized companies that may also be struggling even amidst the current palm oil prices. While the price of palm oil is high, the price of inputs (and especially chemical fertilisers) and operating costs have also increased.

The standard definition, used by the FAO, describes smallholdings as those farms under two hectares. However, this definition can vary greatly across commodities, regions, and countries. The RSPO uses 50 hectares as the default size limit for palm oil smallholdings, with smaller or larger figures in some national interpretations. Smallholders are often described according to the nature of their farming systems. Typically, they rely mainly on family members for labour and operate informally, without corporate management structures. Many smallholders grow a mixture of crops for home consumption and for markets. Smallholders may be indigenous or local families, or they may be

recent settlers from elsewhere. A study on the palm oil value chain shows that while smallholders from countries such as Indonesia are struggling to make a profit, downstream actors like food manufacturers and consumer goods companies and retailers from industrialised nations generate 66 per cent of the gross profits on palm oil. Similarly, at the global level, palm oil had a value of US$ 282 billion in 2020, but smallholders only generated US$ 17 billion, or six per cent of the value in the entire chain because of low levels of processing [7].

Northeast India, known as a global biodiversity hotspot, is home to one third of India's rainforest: the region has been grappling with rapid deforestation.

A recent study shows the global distribution of smallholder and industrial plantations at high resolution [9]. Smallholders account for 30 to 40 per cent of global land palm oil cultivation [10]. In SE Asia there are more than three million smallholders, nearly all of whom cultivate individual family-owned and managed plots of less than 50 hectares and often as little as one to two hectares. In Indonesia, which is the largest oil palm producing country, smallholder plots account for 40 per cent of the total crop area, although they only produce 30 per cent of total national output [10]. However, although the larger commercial plantations tend to be more efficient in terms of oil yield and overall economics, smallholder units serve important social roles in providing a stable income and employment to rural populations [11], [10].

Key players are changing

The global oil palm sector is changing from North-South postcolonial geopolitics to multi-actor commodity chains, characterised by the emerging roles of China and India. India is a significant player in the production, consumption, and import of edible vegetable oils and is the second-largest consumer of palm oil after Indonesia. However, palm oil production in India remains relatively low, forcing the nation to rely on export markets to satisfy national demand. Recognising the vulnerability of dependence on external sources, India swiftly identified the pressing need to

Happy farmers in India? The country intends to transform Northeast India into a thriving "hub of oil palm", backed up by government investments worth US$ 1.4 billion.

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establish self-reliance in the field of edible oils. This prompted a strategic plan to transform the Northeast India region into a thriving "hub of oil palm" backed by a substantial government budget of US$ 1.4 billion. Despite its potential benefits, this move has ignited debate and controversy within the region. Northeast India, known as a global biodiversity hotspot, is home to one third of India's rainforest: the region has been grappling with rapid deforestation due to unsustainable agricultural practices and poorly regulated developmental projects [7].

Oil palm and deforestation: deciphering the link

In 2022, Indonesia's deforestation levels hit around 104,000 hectares, which is the lowest on record. The FAO "State of the World's Forests" report recently showed that an initial review of data for Indonesia for 2021–2022 indicated a notable 8.4 per cent decrease in deforestation compared with 2020–2021 [12]. This is the lowest recorded deforestation rate in

Indonesia since the Indonesian Ministry of Environment and Forestry began tracking annual rates in 1990; overall, the rate decreased by nearly 90 per cent over the period.

Data on plantation expansion from environmental consultancy TheTreeMap, which operates the Nusantara Atlas platform (https://thetreemap.com/) show that most plantation expansion has not been on forest areas, and therefore may not reflect any deforestation risk. The estimated expansion on forest areas is still significant in absolute terms. The oil palm plantation expansion on forestland in 2023 was about 30,000 hectares, or around 40 per cent the size of Singapore. Nevertheless, the amount of expansion on forest areas is far less than the levels seen in the early 2000s to the mid-2010s, particularly in the palm oil sector [13]. Estimates of plantation expansion may in fact be registering replanting of existing areas rather than new expansion. Oil palm stands have an approximately 25-year commercial lifespan, and palm trees planted during the palm oil industry's boom period of the late 1990s to early 2000s are now due or overdue for replacement. This situation creates an outstanding opportunity for the large scale adoption of selected planting material such as Ganoderma-tolerant seeds or cultural practices like the production of quality compost from organic waste.

Slash-and-burn practices to clear and transform land for agricultural or agroforestry purposes are considered inacceptable and widely banned in numerous voluntary sustainability standards (VSS) and other regulatory frameworks.

The EU Deforestation Regulation

A major development that may influence the future of global palm oil trade is the European Union's deforestation regulation (EUDR). The EUDR takes full effect on 30 December 2024, covering seven product categories including several key exports from the ASEAN region. Businesses importing goods into the EU will need to prove that the products are not connected to any recent deforestation that has occurred after 2020 [13]. The European Commission will play a primary role in the implementation of the EUDR and will classify producing countries, or parts of them, as low-risk, standard-risk or high-risk in order to facilitate the implementation of the mandatory due diligence, which operators and traders of regulated goods must conduct. The EUDR will provide for significant penalties for those who break the rules, which include a fine of up to four per cent of the company's total annual turnover for failing to comply with the requirements of the regulation [14].

In principle, the EUDR should be positive for the global sustainability of the oil palm sector by discouraging the expansion of plantations onto forest areas [13]. However, there may be unintended consequences of the regulation, like a short-term surge in demand from European buyers, with companies stocking up on products and inputs before the EUDR

takes full effect. The EUDR might inadvertently undermine existing voluntary sustainability certifications if producers feel that all they need to export to Europe is EUDR compliance rather than other product labels.

In Malaysia and Indonesia, a potential high-risk designation by EUDR could seriously hamper market access to the EU, thus tarnishing the global reputation of the sector. Furthermore, it is crucial to understand that this high-risk labelling is not solely based on the oil palm industry's compliance with deforestation standards. Other significant export commodities, such as rubber, timber and cocoa, also fall under the EUDR's purview. These commodities must also adhere to stringent sustainability and deforestation standards to ensure that the EU does not label any oil palm supplier as a high-risk country. This multi-commodity scope broadens the challenges and necessitates a holistic approach to sustainability and traceability across various sectors of the export industry in all producing countries [15].
EUDR might be a new law, but it refers to old questions, principally on the imbalance between growers and European policy makers: its acceptability is questioned not only by the oil palm industry, but also by several major NGOs. It is clear that major commodity companies will not have any issues complying with the EUDR: their supply chain is used to following the major

Drastic effects: the well intended EUDR may lead to a full squeeze-out of smallholders from EU- and EEA-focussed value chains.

As of September 2024: The EU Commission still faces severe delays in getting its own act together so as to implement a seamless EUDR that is highly functional and legally safeguarded from January 1, 2025 onwards.
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international regulatory schemes such as RSPO. However, there is a high risk that many cooperatives and smallholder farmers may be excluded from the European market; palm oil producing countries may therefore aim to increase sales to markets like China and India that currently have lower sustainability requirements, or to increase their domestic consumption, sometimes through agrofuel. In this context, it will be important to see how Indonesia, Malaysia, and other commodity exporters in ASEAN respond [13].

Asia Matters! The ASEAN economic area is increasingly freeing itself from the dependencies that Europeans established in colonial times and which continue to have an impact today.

A delay to EUDR implementation is a matter of debate among many palm oil supply chain participants, from Indonesian smallholders to European manufacturers. Producers, exporters and importers of multiple commodities have over the past months been raising their concerns about the mounting problems of the EU meeting its implementation timeline. Several EU officials are now calling for a delay in the implementation for a year, as several governments will not agree to the implementation of the regulation until the benchmarking is ready. The technical implementation of EUDR needs further fine-tuning: the IT technology that is supposed to implement the system is behind schedule, as the ability to upload due diligence statements is hampered by a small file size limit. Many importers will reach this limit in a single shipment. Indeed, the supply chains for simple commodities and products – from paper to animal feed – are actually very complex. The harvesting or production location is the easy part; tracing through the supply chain is more complicated. Also, the legal basis of the benchmarking process still needs to be clarified, and only then can the benchmarking indicators be adequately determined.

The climatic emergency

The agricultural sector has a direct impact on climate as it generates significant amounts of greenhouse gas emissions. Indeed, the recorded increase of GHG concentration in the atmosphere, coupled with a steady rise in temperatures together with disturbance of precipitation regimes, is currently influencing not only the volume, quality and stability of agricultural production, but also the natural environment surrounding agricultural activities.

Global palm oil production is approaching 80 million tonnes, for a total mapped area of 25 million hectares, 40 per cent of which is planted with industrial oil palms and 60 per cent farmed by smallholders. These two types of farmers have very different direct impacts on climate change. Small family farmers (less than 40 hectares) have different farming systems to those of the large agro-industrial estates, based on the intensive use of inputs (mainly chemical fertilisers). Small growers are still handicapped by the lack of access to suitable, selected planting material, even though the seed industry has made enormous progress in its ability to disseminate genetic progress. The capacity to adapt and mitigate, due to a lack of means and resources, will be much weaker in smallholders‘ plantations than in large-scale agroindustrial estates. Several plantation companies, both in Latin America and Southeast Asia, have developed

irrigation and fertigation systems to cope with recurrent and more intense droughts. In Africa, smallholders account for over 80 per cent of palm oil production in most producing countries (Côte d'Ivoire, Cameroon, Nigeria). These systems use very few – if any – chemical inputs and are based on the use of unselected planting material, leading to low yields and higher costs of production.

The low climatic resilience of current cropping systems is revealed when extreme droughts occur, with measurable consequences for productivity [16]. In Southeast Asia, the El Niño episodes of 2015 and 2019 have highlighted the low climatic resilience of current farming systems, both at village and industrial levels [17]. Intense drought has the direct consequence of blocking gas exchange and the photosynthetic capacity of palm trees. At the same time, the haze generated by forest fires and uncontrolled clearing of bushes greatly reduces the productivity of plantations. The oil palm also has the property of bifurcating towards male flowering (thus drastically reducing the yield of fresh fruits per hectare) when agro-climatic conditions become unfavourable, with a measurable impact on productivity over several years [18].

Climate change is progressing relentlessly: The shifting of rainy and dry seasons and the partial disappearance of pronounced tropical dry seasons, as well as greatly altered precipitation patterns with sometimes torrential rainfall, are putting entire stretches of land under water in parts of Asia. The oil palm can take a lot. But wet feet are hard on it. Irrespective of this, land cannot be cultivated when it is under water. This also potentially means a serious loss of fresh fruit yields.
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Left:
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In the climate change context, agricultural management strategies must innovate to improve biodiversity and ecosystem functions in oil palm-dominated landscapes [19]. Agricultural practices in tree crop plantations are changing in response to growing social [20] and environmental

Female technical staff at work in an oil palm plantation in Indonesia
© Alain Rival, CIRAD

[21] concerns. Plantation management now increasingly relies on agro-environmental services, meaning that basic agricultural functions, such as soil preservation, pollination and pest control can be ensured by living organisms (plants, insects, microbes).

When tree-crop plantations are replacing natural forest habitats, several functions show decreases with potentially irreversible global impacts (e.g. reductions in gas and climate regulation, habitat and nursery functions, genetic resources). Such impacts become more serious when the forest is cleared to establish new plantations and immediately afterwards, especially on peat soils. Several specific changes in plantation management can prevent or reduce losses of various ecosystem functions, and synergistic mitigation measures can improve multiple ecosystem functions simultaneously [22].

Challenges in labour

To the careful observer, many aspects of the rapid and large-scale development of oil palm cultivation bring to mind the image of a clay-footed colossus, as a sector showing very strong growth and commercial success, but which is nevertheless masking several worrying weaknesses [1]. Many issues are plaguing the sector: its dependence on foreign labour, especially in Malaysia [23], sluggish growth in productivity [16], and its overall sustainability [11]. Recently, El Pebrian and Mohiddin [24] estimated the average degree of mechanization in field operations in Malaysia's oil palm plantations at around 11 per cent, considering it to be a slow pace when compared to the 74.22 per cent of mechanization reported for Malaysia's rice cultivation. Monzon et al. [16] investigated how intensification in existing plantations could help Indonesia

Large-scale composting of organic waste from an agro industrial oil palm mill in Indonesia
© Alain Rival, CIRAD

meet palm oil demand while preserving fragile ecosystems. They found that the current average yield amounts to 62 per cent and 53 per cent of the attainable yield in large and smallholder plantations, respectively. Narrowing yield gaps through improved agronomic management, together with limited expansion that excludes fragile ecosystems, would save 2.6 million hectares of forests and peatlands and avoid 732 MtCO2e compared to following historical trends in yield and land use.

Malaysia's plantation industry and economy, as a whole, has benefitted from foreign labour and remains crucially dependent upon it. Yet, this dependence can prevent optimum productivity by disincentivizing mechanization and innovation. Education and social programs mandated at company and policy level can also help to improve plantation living conditions and thereby mitigate problems of productivity, worker retention, and recruitment. These changes must be made to improve retention rates among the current migrant workforce and encourage incoming migrants to see the plantation sector as a destination rather than a transit point towards other industries. Women in plantations will gain from equal opportunities offered by the increasing implementation of mechanisation and automation technologies in plantations. The role of labour-saving technologies in reducing women's work and time burden in agriculture has gained research attention in recent years. Various studies show that women are engaged in various household areas and in the agricultural sector and technology can be leveraged for reducing their work burdens [25].

Circular economy in plantations

One of the fundamental principles of a circular economy is that material waste is avoided by prioritizing the end-of-use capture of materials to create a positive value-driven closed loop. Circular Economy (CE) is a sustainable development paradigm that promotes resource efficiency, closed-loop systems, and waste reduction to minimize environmental impacts while fostering economic growth; its popularity is rising on a global scale since the negative effects of linear consumption patterns become more apparent. Enhancing agroecosystem properties through the development and implementation of agroecological practices can generate high palm oil yields while reducing external inputs such as mineral fertilisers and pesticides [21]. It is of paramount interest to reduce such external inputs as much as possible, given the large environmental burdens they may create, accounting for emissions and impacts both upstream in the supply chain and in the field. The recycling of oil palm and palm oil co-products at both the plantation and mill stages makes it possible to reduce the amounts of mineral fertilisers without depleting the soil nutrient resources or stressing the palms. The recycling of co-products reduces the polluting emissions and environmental impacts related to waste treatments. The co-composting of

> **The circular economy is the order of the day. The palm oil sector, more than almost any other, has long been geared towards using as much of the oil palm as possible.**

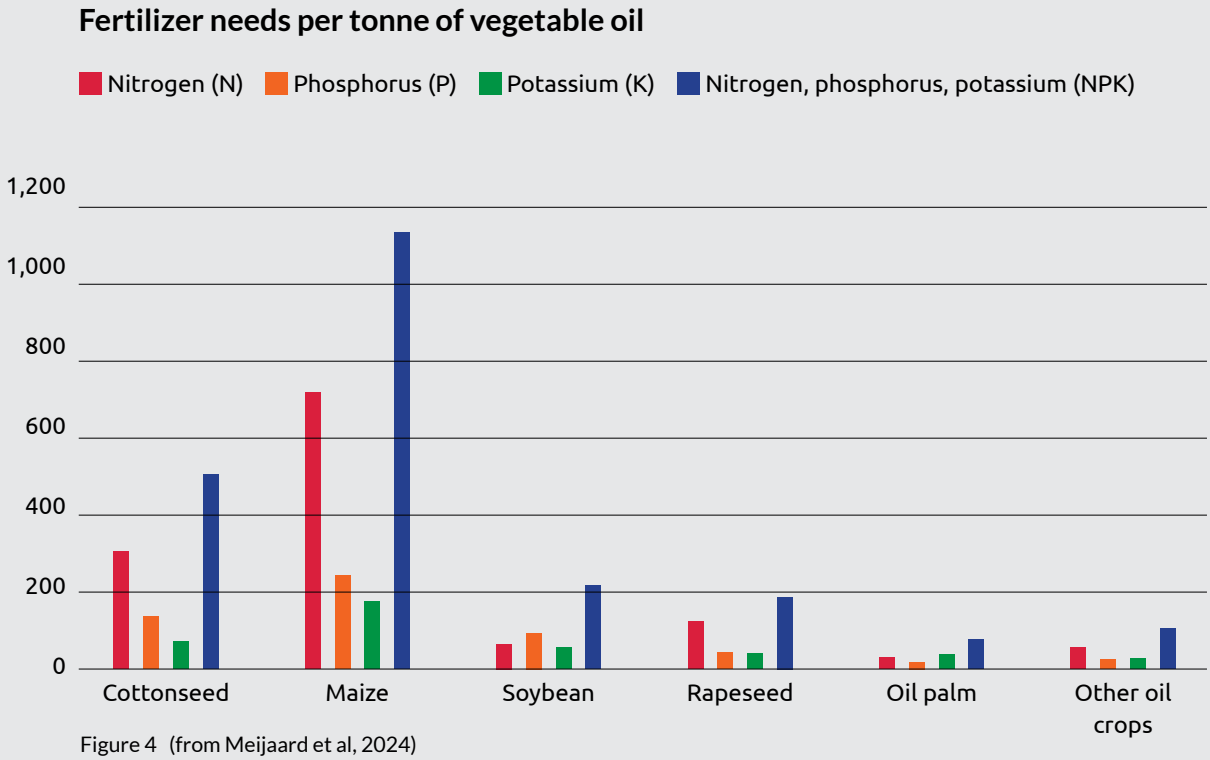

Figure 4 (from Meijaard et al, 2024)

empty bunches together with palm oil mill effluent drastically reduces methane emissions during the conventional anaerobic effluent digestion.

Among major oil crops, maize requires the highest fertiliser application, primarily in the form of nitrogen, followed by cottonseed, soybean, rapeseed, and oil palm [7]. Additional fertiliser application is common to ensure an adequate nutrient supply. On the other hand, oil palm requires the least amount of fertiliser to produce one tonne of oil [6]. This higher fertiliser efficiency provides a key comparative advantage for oil palm, in a context of increasing exploitation costs, principally due to the surge in the price of chemical fertilisers. The purchase and transportation of inorganic fertilisers can account for up to 60 per cent of management costs incurred at plantation level. Optimal palm oil waste management is usually carried out using composting, and considered as a sustainable technology because it is aimed at environmental conservation and providing economic value. From an environmental perspective, composting has several benefits [26]. The reduction in the amount of waste through biological activity means that less transportation is necessary for field application (60 per cent reduction) as against fresh EFB (Empty Fruit Bunches). Palm Oil Mill Effluent (POME) treated through the aerobic process of composting avoids the negative impacts of pond treatment, such as GHG emissions to the atmosphere. An efficient nutrient recycling through composting would significantly reduce the amount of imported inorganic fertilizers and all the negative impacts resulting from their use. Moreover, compost application improves soil quality and can store additional carbon in soils. For young palms replanted in Oryctes-infested areas (areas affected by the Rhinoceros beetle), compost can reduce the need to use insecticide as compared to EFB. The co-composting process helps to reduce the volume of POME, thereby reducing organic pollution and greenhouse gas emissions [27], [28].

The giant rhinoceros beetle causes a variety of damage to oil palms, including large holes in the lower stems of the palm fronds, which can lead to the death of the palms.

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Moreover, co-composting EFB and POME showed some effects during nursery and field trials, with improved vegetative growth observed in plants treated with compost. Furthermore, the addition of co-composted EFB and POME to podzols has been found to enhance overall soil physicochemical properties and the assimilation of N nutrients by oil palm seedlings.

Among organic fertilizers applied, composted EFB was found to perform better than fresh EFB. Such trials showed the added value of composting EFB, especially in improving the chemical properties of soil and the assimilation of N nutrients by oil palm seedlings and adult palms.

Planting for the future

The recent IPCC report [29] highlighted that Southeast Asian countries (where almost 90 per cent of the world's palm oil production is concentrated) are regularly identified as the most vulnerable to climate risks, with key sectors such as agriculture, cities, infrastructure and terrestrial ecosystems expected to be highly exposed to multiple hazards. Due to their rapid development and large populations, Asian countries are emitting more and more GHGs, even though both per capita and cumulative emissions are relatively lower than in developed economies.

The oil palm is a relatively recent plant to be domesticated and exploited on a large scale. Its rapid development, among both small-scale growers and agro-industrialists, has led (for palm as for all plant species) to a reduction in the useful genetic base, guided mainly by profitability per hectare. The development of varieties resistant to Fusarium and then Ganoderma pathogens has further narrowed this genetic base, by reducing exploitable agro-biodiversity in oil palm genetic resources. In the case of oil palm, varietal improvement is progressing at the pace imposed by a long-cycle perennial crop. It will take almost 50 years of research to create, propagate and evaluate a cultivar in various replicable and different agro-ecological conditions, thus R&D programmes will continue to focus on drought resistance for a long time to come.

In 2022, a total 130.1 million oil palm seeds were sold worldwide, the highest level of sales in nearly a decade [13]. How-

An oil palm nursery in Malaysia.
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ever, 123.8 million seeds were sold in 2023, down from the amount sold in 2022, suggesting that the peak of replanting may have already passed. Major plantation companies have already been practicing phased replanting to avoid having to replace trees en masse in the same year. The present need for replanting may also drive up palm oil prices over the coming years, due to diminished supply. Old plantation areas which are overdue for replanting will gradually become less productive, and freshly replanted areas will require two to three years before they start producing fruits again.

Conclusion and perspectives

The future of oil palm, as of most tropical sectors, is clouded by growing constraints linked to, among many other parameters, climate change, price volatility and labour scarcity. Perpetuating agricultural systems inherited from the colonial era (a time of abundant arable land, protected markets, and cheap and disciplined labour) will not be enough to prepare these sectors in facing immediate crucial challenges, unless substantial structural transformations are made.

Implementing a successful agroecological transition in a US$ 70 billion sector, covering 25 million hectares worldwide, calls for drastic changes in mind-sets and practices. The key issue is no longer simply to increase productivity, but to foster innovations designed to support endangered tropical biodiversity, while providing a decent living for shrinking agricultural communities in the Global South. There are no viable alternatives to oil palm in terms of its yield and delivery of a range of oil-derived products for human use. It is therefore important to implement transparent and effective certification schemes right across the industry to guarantee that oil palm products can be labelled as being derived from environmentally sustainable and socially responsible sources [11].

It remains an undisputed fact: no palm oil is not the solution. Substituting palm oil with other oil sources will lead to an expansive escalation of agricultural land.

Faced with the urgent need to respond to climate change, the palm oil production sector is now at a crossroads [1]. In a highly globalised sector facing multiple challenges, the status quo is no longer an option: urgent and concrete responses are needed to transform production systems in depth. Faced with the growing uncertainties of the sector, linked to its climatic vulnerability, the agroecological transition of production systems must be a priority for scientists, political decision-makers and the oil palm industry in all producing countries. To simply boycott palm oil will not solve any of the most urgent problems faced by the sector. First, this would promote the cultivation of alternative crops, which on the one hand provide less oil yield per hectare and on the other hand do not necessarily have a better ecological and social balance. Second, the demand for sustainably produced palm oil would collapse at global level, because only western markets actually demand certified sustainable palm oil. Indeed, a boycott of palm oil would promote the emergence of non-certified palm oil thus having the opposite effect to whatactually urgently needs to be achieved.

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Abstract

Challenges for climate-smart oil palm production

Production systems at a crossroad

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Palm oil is recognised as a major source of foreign reserves in tropical countries, as well as the main instrument of poverty alleviation and rural economic development. This perennial tropical crop is a champion in terms of productivity, but is it resilient enough to face the intrinsic risks caused by the large-scale monoculture of one single species over extended areas?

Even if the public debate is not as opinionated as it was in the past decade, the production of oil palm is still associated in the public arena with damage to the environment and an unbalanced diet due to the high proportion of saturated fatty acids in palm oil. The sector is also facing growing constraints linked to, among many other parameters, climate change, price volatility and labour scarcity. Palm oil is here to stay. On a global scale, palm oil supplies 40 per cent of the world's vegetable oil demand on just under 6 per cent of the land used to produce all vegetable oils. To obtain the same quantity of oil from other sources such as soya, rapeseed or sunflower, between four and ten times as much land would have to be cultivated. The comparative advantages of palm oil over competing vegetable oils are still based on low production costs, which are structurally linked to the high natural productivity of thecrop, which easily exceeds 3 tonnes per hectare, and the low cost of labour in most of the producing countries.

The role of sustainability schemes

Sustainability certification schemes were introduced in the palm oil industry as a response to address the negative environmental and social impacts associated with the development of the industry. The first certification scheme for palm oil, the Roundtable on Sustainable Palm Oil (RSPO), was established in 2004, followed by other non-governmental initiatives to ensure the sustainable production of palm oil. Indonesia and Malaysia, the two largest palm oil producers in the world, established Indonesian Sustainable Palm Oil (ISPO) and Malaysian Sustainable Palm Oil (MSPO) in 2011 and 2015, respec--tively. Producing countries, such as Malaysia and Indonesia, have taken a step further by developing their own sustainability schemes. Despite sustainability objectives, certification has been the practical mechanism in managing and monitoring the production of certified sustainable palm oil to date. Through the implementation of sustainable certification, the palm oil industry can play a significant role in achieving the SDGs.

Climatic emergency and the EUDR

Climate change is progressing relentlessly: Shifting precipitation patterns, with torrential rainfall and flash floods, are putting entire stretches of land under water throughout the tropical world. In other producing areas, severe drought epidodes can hamper the oil palm fruit's setting, with direct impacts on productivity. The plant is also very sensitive to changes in yearly rainfall distribution, potentially meaning a serious loss of fresh fruit yields in the most affected areas.

A major development that may influence the future of the global oil palm trade is the European Union's deforestation regulation (EUDR). In principle, the EUDR should be positive for the global sustainability of the oil palm sector, by discouraging the expansion of plantations onto forest areas. However, there may be unintended consequences of the regulation, like a short-term surge in demand from European buyers, with companies stocking up on products and inputs before the EUDR takes full effect. The EUDR might inadvertently undermine existing voluntary sustainability certifications if producers feel that all they need to export to Europe is EUDR compliance rather than other product labels. There is a high risk that many cooperatives and smallholder farmers may be excluded from the European market; palm oil producing countries may therefore aim to increase sales to markets like China and India that currently have lower sustainability requirements, or to increase their domestic consumption, sometimes through agrofuel.

A need for a paradigm shift

Building on restored ecosystem functions, agroforestry-based solutions are slowly emerging and they are gaining ground. Agroforestry practices have a role to play in providing substantial climate change mitigation with an impact comparable to other climate-focused solutions, such as reforestation. The expected contribution of oil palm-based agroforestry relies on agro-environmental services, as basic agricultural functions such as soil preservation, pollination, or pest control can be ensured by a diversity of living organisms, both inside and around the plantation. Innovative approaches are bolstering the restoration of degraded lands and expanding agroforestry. Building on regenerative agriculture, new plantation designs are emerging and deserve to be thoroughly assessed to establish evidence-based advocacy for change.

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