



SHORT COMMUNICATION

Navigating the Path to Sustainable Oil Palm Cultivation: Addressing Nexus Challenges and Solutions

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Abstract: Global palm oil demand for energy, food, and chemical uses has led to a rapid expansion of tree plantations in Southeast Asia, Central Africa, Latin America and the Caribbean. This oil tree is the world's most productive, highly profitable and traded vegetable oil crop, and the demand is expected to increase further in the near future. Nevertheless, oil palm expansion involves risks and nexus challenges. This work supports the idea that disruptive farming intensification, instead of land expansion, could scale up productivity, reducing the anthropogenic pressure on tropical forests and biodiversity losses. Findings from recent studies suggest that there is considerable scope for further yield improvements per hectare of palm oil with sustainable agronomic practices and farming intensification. Smallholder producers, agribusiness investors, civil society actors, NGOs, governments, researchers, and industry should make coordinated efforts with regulatory and support schemes and landscape design to increase yield and productivity with sustainable management practices and to achieve zero deforestation by protecting ecosystems.

Keywords: Land-use changes; Ecosystem services; Sustainable intensification; Deforestation; Tree plantations

1. Introduction

The global demand for biomass for food, energy, and chemical uses has led to a rapid expansion of oil palm tree (*Elaeis guineensis* Jacq.) plantations in Southeast Asia, Central Africa, Latin America and the Caribbean ^[1].

It was estimated that by 2050 the worldwide oil palm plantations are expected to increase from 14.6 million hectares in 2010 to 31.1 million hectares ^[2]. Moreover, oil palm cultivation has become a major source of income for many countries in the tropics and subtropics, contributing significantly to the provision of private and community

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goods in rural villages^[3].

The process of planting oil palm trees typically begins with the preparation of the land. This involves clearing the existing vegetation and trees, which often results in deforestation and soil degradation. The land is then drained and plowed, and young oil palm seedlings are planted in rows. The seedlings are carefully tended to until they mature, which takes about three years. Once the oil palm trees mature, they start to produce fresh fruit bunches (FFBs) which are harvested and then transported to a mill where they are processed to extract the crude palm oil (Figure 1).

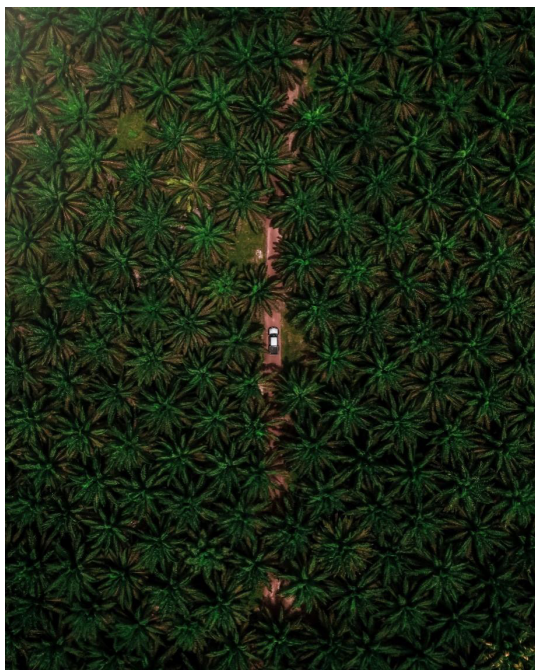


Figure 1. Oil palm plantation in Negeri Sembilan, Malaysia.

Source: Image courtesy of Nazarizal Mohammad. <https://unsplash.com>.

Oil palm is the most productive (average oil yield 5.5 tonnes per hectare)^[4], versatile, highly profitable and traded vegetable oil crop in the world^[5], and demand is expected to grow further in the near future. Today, palm oil is used in an impressive number of packaged products (e.g. soap, cosmetics, detergents, chocolate, margarine, and cookies), cooking oil, as well as for biofuel^[6]. Oil palm is not only a source of edible oil but also a source of bioenergy (Figure 2).

In the last decade, driven by government support^[7] tropical oils used as biodiesel-diesel blends were promoted as a renewable resource in many scenarios for achieving climate change commitments. However, the rapid expansion of oil palm plantations has also led to environmental, social, and economic challenges. Global palm oil demand acts as a driver of land-use changes with associ-

ated nexus challenges in the environmental, social and economic spheres, leading to concerns about deforestation, soil degradation and losses of ecosystem services^[8,9], and other telecoupled effects such as land-grabbing, food price volatility, income inequalities, and land conflicts associated with palm oil concessions, especially for independent smallholder plots. In this perspective essay, we claim that achieving sustainable oil palm cultivation requires a collaborative effort that involves all stakeholders, including governments, producers, retailers, and consumers. We argue that the adoption of sustainable and smart cultivation practices is essential to ensure that palm oil production supports economic development and poverty reduction in tropical regions, while minimizing the negative impacts on the environment and society. In summary, the path to sustainable oil palm cultivation involves balancing the economic benefits with environmental and social considerations.

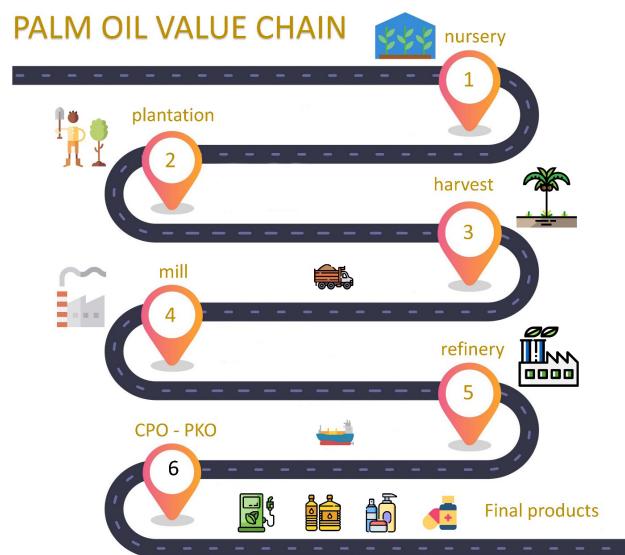


Figure 2. Palm oil value chain.

Source: This cover has been designed using resources from <https://freepik.com>.

2. Nexus Challenges

Addressing the challenges facing the palm oil industry requires a comprehensive approach that considers economic, social, and environmental issues. Several studies have identified many future challenges, including emerging threats from GHG emissions and climate change, land degradation, and pests and diseases^[10]. Nevertheless, previous studies have suffered from siloed approaches in addressing the range of challenges associated with oil palm cultivation. In this study, the authors attempt to solve nexus domains that coexist within the oil palm value

chain, highlighting the multifaceted challenges and possible solutions.

One of the main nexus challenges is deforestation. Large-scale oil palm cultivation has been a leading cause of deforestation in many tropical regions. This has resulted in the loss of valuable carbon sinks and biodiversity hotspots, leading to climate change and ecosystem destruction. Overall, tropical oil trees expansion has implications in the well-known trilemma^[11] posed to scientists, international organizations, economists and governmental institutions for balancing the domain of biofuel production, food security and environmental implications. For instance, land use changes and landscape fragmentation affected high-biodiversity wilderness areas, as recently suggested by de Almeida et al.^[12] in a long-term trajectory of oil palm expansion in the eastern Brazilian Amazon. In the same vein, Rulli et al.^[13] argue that bioenergy and food industry demands have driven forest losses, forest fragmentation and freshwater pollution in different areas across Indonesia.

However, the GHG emissions following land use/cover changes have been questioned by researchers in many cross-sectional studies, suggesting substantial challenges and trade offs concerning the accounting of greenhouse fluxes^[14,15]. Bioenergy production is another interconnected challenge associated with oil palm cultivation. As 46% of total palm oil imported by the European Union was used as biofuels, in 2018 the EU Parliament provisionally agreed to phase out the use of palm oil for transport fuel to reduce the risk of direct and indirect land-use changes^[16]. Nevertheless, avoiding palm by switching to alternative replacement oils is not the solution in the short term because other cultivated crops (e.g. jatropha, jojoba, soybean, rapeseed) are less productive and will require additional land resources^[17]. A recent assessment found that land-intensive bioenergy will play a significant role in the energy mix in the coming decades during the energy transition towards net-zero emissions targets^[18]. Future biofuel targets and mandates will require a further land area with substantial land-use changes and probably may lead to multiple interdependencies. In this sense, completely banning exports of bioenergy may not be the best solution for the planet.

Social impacts are also a major concern associated with oil palm cultivation. Strictly linked with the oil palm expansion are land grabbing, displacement of indigenous communities, poor working conditions for plantation workers, and human rights abuses. Agribusiness multinational corporations and big companies may drive continuous expansion impacting the rural villages, populations and territories^[19], putting at risk freshwater availability,

food sovereignty and drinkable water for livestock. Moreover, recent studies suggest a clear link between deforestation and outbreaks of vector-borne and zoonotic diseases^[20,21]. New plantations take up large tracts of land, exacerbating interdependent connections on land, water, food and human rights.

3. Solutions toward Sustainability

To address these challenges and controversies, a new paradigm for modernizing oil palm cultivation and the value chain is necessary. First, a viable solution is to support sustainable intensification with disruptive technologies, i.e., agriculture 4.0 (agriculture revolution which uses digital technologies)^[22] and precision agriculture, scaling-up productivity reducing pressure on tropical deforestation and biodiversity losses.

In this sense, findings from recent field-scale studies and reviews suggest that there is considerable scope for further yield improvements with improved high-yielding varieties (i.e. breeding, genetic improvement) and integrated farming systems for optimal inputs management of nutrients, irrigation, pests and diseases. For example, scientists are developing oil palm varieties that are more resistant to drought and heat, which will become increasingly important as the climate changes^[4,23]. Although technology transformation and industry 4.0 are relatively new concepts in the palm industry^[24], the application of disruptive innovations can effectively improve the sustainability of the value chain. Under a high-yield growth scenario of doubling global average palm oil yields up to 9 metric tons per hectare^[2], future expansion of oil palm plantations can be counterbalanced, and the harvested area will slow at 2010 levels assuming no change in global demand.

Regarding the issues on biodiversity and ecosystems, new agroforestry systems planting buffer zones of native vegetation around oil palm plantations and integrating trees with crops can create more diverse and resilient landscapes. For example, shade-tolerant crops like coffee, cocoa, and black pepper can be grown beneath oil palm trees, which provide habitat for wildlife and helps to reduce the impact of monoculture cropping. This could diversify and stabilize the price and supply of the food basket and income of smallholders, reinforcing the resilience and livelihoods of local communities.

4. Conclusions and Future Perspectives

To develop appropriate and sustainable oil palm cultivation practices, nexus challenges and viable solutions in the production pathway need to be better understood.

As stated above, the palm oil processing industry, large agricultural companies, researchers, governments, and small-scale producers should raise their ambition toward technology innovations and new processing technologies to modernize their practices of production and to reduce competition and conflicts among different land uses.

If growth in palm oil demand continues to rise in the next years, a key priority for policymakers should therefore be to plan for effective supply-chain interventions. Important vehicles for nexus solutions include regulatory support and economic support schemes^[25]. Regulatory support instruments can include company pledges, codes of conduct, sector-wide sanctions^[26] and rigorous accounting rules protecting tropical and subtropical rainforests and biodiversity-rich ecosystems against unnecessary and detrimental land conversions. In this sense, commitments such as “No Deforestation, No Peat, No Exploitation (NDPE)” can help raise awareness and prevent new damage^[6]. Companies that adopt NDPE policies commit to sourcing palm oil from suppliers who do not engage in deforestation, conversion of peatlands, or exploitation of workers. Economic support instruments include realistic measures to regulate production and implementing policy instruments such as mandatory quotas, tax incentives or credits, capital subsidies, grants and rebates, and voluntary market initiatives. Furthermore, sustainability indicators such as those established by the Roundtable on Sustainable Palm Oil principles and criteria (see The RSPO, 2020)^[27], and certified international standards checked against performance measures (e.g. practical to implement, sensitive, measurable and traceable) can further increase sector sustainability, encouraging companies to adopt sustainable practices and provide assurance to consumers that palm oil is produced sustainably.

In conclusion, the path to sustainable oil palm cultivation involves a comprehensive approach that balances economic, social, and environmental considerations. Addressing the challenges requires the cooperation of governments, industry, and civil society. Adopting sustainable practices can benefit not only the environment and local communities but also the long-term profitability and reputation of the palm oil industry.

Data Availability

The data presented in this study are available on request from the corresponding author.

Conflict of Interest

The author declares that there have no known competing financial interests or personal relationships that could

have appeared to influence the work reported in this paper.

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