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The Intersection of Crude Palm Oil and Deforestation: A Sustainability Analysis

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ABSTRACT

In recent years, palm oil has gained international attention as an efficient, versatile, and inexpensive oil, and is now an ingredient in 50% of items in the grocery store. As a result, there has been an increase in complaints regarding the environmental impact stemming from the production of palm oil, including those of deforestation and harmful emissions. In response to these complaints, the Roundtable on Sustainable Palm Oil (RSPO) was created to certify palm oil that meets certain criteria, (including being produced without an element of deforestation) as sustainable. Now, the RSPO certifies over 3.09 million hectares of palm oil production area. However, the RSPO is getting backlash over their standards, with reports that their standards are not strong enough to be considered sustainable. This research aims to address these complaints by determining the environmental sustainability of palm oil produced with and without an element of deforestation in Malaysia. A Life Cycle Analysis (LCA) was used in this research, and the results of this LCA have indicated neither crude palm oil (CPO) associated to deforestation nor CPO not linked to deforestation is environmentally sustainable. Therefore, these results indicate the RSPO's certified sustainable palm oil may not actually be sustainable, given the large environmental impact of both variations of palm oil.

INTRODUCTION

Palm oil is an edible fat obtained from the flesh of the fruit of several palms (Merriam-Webster), and according to The U.S. Department of Agriculture, palm oil is the most consumed oil in the world (Lee, 2019). Palm oil is a low-cost, edible commodity, making it a desirable ingredient for food, cleaning, and makeup products. Palm oil is inexpensive due to how productive of a crop it is, compared to the production of other oil crops. For reference, palm oil makes up 35% of the world's vegetable oil consumption but only uses 10% of the total land used in vegetable oil production (8 things to know about palm oil, 2020). To show the productivity another way, palm oil produces up to 10 times more oil per hectare than other vegetable oils such as soya, rapeseed, and sunflower oils (Ecotricity, 2018).

Due to palm oil's versatility and inexpensive nature, it is an ingredient in *half* of items found on grocery store shelves, according to expert estimations (Lee, 2019), yet many Americans who use these products every day have never heard of palm oil, let alone the implications that result from it. Palm oil is also rising in popularity, as according to the Roundtable on Sustainable Palm Oil, there has been a 43% increase in the amount of land being used to produce palm oil over the past twenty years (Klein and Manasantivongs, 2011). Palm oil production is also expected to quadruple from current levels by 2050 (Tullis, 2019). There is a lack of awareness surrounding palm oil, as only 10% of items that contain palm oil list any variation of "palm" on the packaging (Tullis, 2019). This is because many of the personal care products that palm oil is used in, do not require disclosure of ingredients on the packaging. Due to this rise in popularity, experts currently estimate that globally, humans consume an average of eight kilograms, or 17.6 pounds of palm oil per year (Tullis, 2019).

This incredible consumption of palm oil comes at an expense because of the negative impact palm oil production has on the environment. The production of palm oil is known to destroy tropical forests, as they are often cleared to create palm oil plantations. In addition to the deforestation that results, the animals living in these forests (often time endangered species) are adversely affected, as their habitats are destroyed. Even in the production of deforestation-free palm oil, many greenhouse gas emissions are released into the air, water, and soil as a result.

As a result of the increasing awareness of the negative environmental impacts of palm oil, the Roundtable on Sustainable Palm Oil (RSPO) was created. The RSPO is a non-profit that develops and enforces standards for sustainable palm oil while uniting stakeholders throughout the industry (RSPO). The RSPO's criteria must be followed by all certified stakeholders as they produce palm oil that is then certified as 'sustainable'. One of the newest additions to RSPO criteria that was set in 2018, is a total ban on deforestation. Therefore, if palm oil is produced and can be associated with deforestation in any way, it cannot be certified by the RSPO as sustainable. Eighty-five percent of palm oil originates from either Indonesia or Malaysia (Tullis, 2019). This research will determine if, even with this new criterion by RSPO, deforestation-free palm oil originating from Malaysia, can be environmentally sustainable.

LITERATURE REVIEW

The following literature identifies various aspects of the environmental impacts, various uses, and the impact on plantation surroundings that result from palm oil production. Additionally, different studies identified the plusses and minuses of the RSPO, and how it impacts palm oil production. The RSPO regards itself as a compromise between sustainability and economic interests, but the practicability of this is analyzed throughout this review. While some authors may have focused on the positive impacts, while others on the negative, it is important to understand all aspects and points of view relating to palm oil production.

Deforestation-Free Palm Oil

The vast majority of palm oil being sold is bound by a no-deforestation commitment, as estimates range from a conservative 60% to 96% of global palm oil production (The Chain, 2016). These commitments come from a range of sources, such as from the RSPO, Non-Governmental Organizations (NGO's), or palm oil suppliers. More and more companies themselves are also committing to sourcing deforestation-free palm oil as well, in an effort to minimize their environmental impact. This 60-96% is a huge improvement, as less than 5% were bound by these same commitments as of 2013 (The Chain, 2016). However, this reveals an issue because the demand for palm oil is expected to continue to steadily increase, and most potential plantation areas are currently covered in forests. (Fitzherbert, et. al, 2008). This is an area of concern, as deforestation from palm oil production is not an issue that will be going away anytime soon. Soon, either deforestation and palm oil production will come hand in hand, or advancements will need to be made regarding how palm oil is produced. Commitments for deforestation-free palm oil are increasing in popularity due to an increase in awareness of the negative impacts of palm oil production, such as deforestation. This can be shown through a study by Pin Koh & Wilcove (2008) who found "during the period 1990–2005, between 55% and 59% of oil palm expansion in Malaysia can be attributed to conversion of forests". Additionally, over this same time period Fitzherbert et. al, (2008) estimated that at least one million hectares of forest were replaced by palm oil crops just in Malaysia alone. While palm oil production has other concerning elements (such as poor labor practices), it is hard to ignore the pace that tropical forests are being converted to palm oil plantations. While organizations such as RSPO aim to address multiple concerns of palm oil production, deforestation-linked palm oil is a major concern that companies are committing to avoid.

The Downfalls of Roundtable on Sustainable Palm Oil (RSPO)

Much of the previous literature was quite critical of the RSPO, with Kiezebrink (2017) believing the RSPO certifies palm oil from the companies that are committing the exact environmental and social violations that the RSPO was created to mitigate. Therefore, Kiezebrink believes RSPO certification does not inherently guarantee sustainable palm oil production, so companies and consumers should not solely rely on RSPO certification, even though it should ensure the palm oil is sustainable. Adding on to this, Silva-Castaneda (2012) claimed RSPO's certification procedures are not able to tackle the social challenges that they intended to address. Some of these challenges include conflicts over land rights, working conditions, or discrimination against workers. Additionally, Silva-Castaneda (2012) says, "third-party certification reinforces existing power relations between local communities and companies, … and RSPO fails to recognize the existence of significant conflicts between certified companies and local communities" (368). This insinuates that the RSPO exerts its power over smallholders (farmers who grow oil palm on an area less than 50 hectares) and local communities, all while ignoring many of the social challenges these smallholders face (Oxford Dictionary, 2020).

Greenpeace (2013) was even more critical as they believe the solution for the RSPO is twofold. First, standards must be strengthened to include banning further development and rainforest clearance; and second, to assure these standards are being strictly followed (Greenpeace, 2013). Greenpeace agreed directly with Kiezebrink, (2017) on the point to 'go beyond the RSPO', and even emphasized further importance on policies that ensure forests are being protected and which show the palm oil industry can actually be responsible. Kiezebrink (2017) conducted research by analyzing two RSPO member palm oil companies that operate in Riau, Sumatra, Indonesia, as well as field research in two Indonesian palm oil plantations. To supplement this, focus group discussions and key informant interviews were conducted. Silva-Castaneda (2012) took a different approach by conducting fieldwork between 2008 and 2010 in Indonesia. For secondary research, a total of 52 interviews with local villagers, non-governmental organizations (NGO's), and representatives from RSPO were conducted. Greenpeace (2013) added a third type of data collection by analyzing the Ministry of Forestry of Maps. This determined Indonesia lost at least 1,240,000 hectares of forest between 2009 and 2011.

<u>The Benefits of RSPO</u>

While there are many critical voices of the RSPO, even if RSPO's standards need to and can be improved, no other organization has been able to successfully unite the stakeholders in the palm oil supply chain under one body while requiring them to meet certain standards (Reinecke, et. al, 2011). As mentioned above, RSPO regards itself as a compromise between sustainability and economic interests, but it is questioned whether this compromise is realistic due to the deforestation and social conflicts that have been and continue to occur within the palm oil industry (Reinecke, et. al, 2011). These claims were built upon by Macdonald and Balaton-Chrimes (2016), who found that many of RSPO's guidelines are only voluntary and these guidelines are most practical when they collaborate with and support governments, NGOs, communities, and companies. Even though the RSPO has a code of conduct, production standards, and principles & criteria, these standards are not being followed as closely as they could, even when a complaint is made against RSPO (Macdonald and Balaton-Chrimes, 2016).

The RSPO Board of Governors (2014) outlined the minimum requirements for certification, showing the benefits of certification and the RSPO in general. Through that, the board (2014) said, “the production of sustainable oil palm products is comprised of legal, economically viable, environmentally appropriate, and socially beneficial management and operations” (12). This gives stakeholders an idea of what sustainable palm oil means to the RSPO and the different components that must make up certified sustainable palm oil.

These three authors used a variety of methods to conduct their research. Reinecke, et. al, (2011) analyzed volume and sales data of RSPO-certified palm oil, data of oil cultivated from production area by country, and type of oil to conclude their findings. Macdonald and Balaton-Chrimes (2016) took a similar approach by analyzing publicly available information. However, they also used field research and interviews with various informants that totaled 587 interviews with over 1,100 individuals. The RSPO Board of Governors (2014), did not use traditional research methods, as their aim was to provide certification documentation that complies with their Supply Chain Certification Standard.

Doubling of Palm Oil Production

Greenhouse gas (GHG) emissions in Kalimantan, Indonesia can be mitigated while doubling palm oil production (Austin et. al, 2015). Specifically, emissions can be reduced anywhere from 9%-60%, depending on the limitations posed by the type of land (such as peatland, forestland, or land with low carbon stocks) where this expansion would take place (Austin et. al, 2015). Agreeing with this, The Chemical Engineer (2016), found that land used for palm oil production could be doubled without further damage to sensitive environments like tropical forests. Specifically, this is 19.3 million hectares of land that is suitable for growing palm oil, and is not already in use, not protected by law, not high in biodiversity, and does not show high carbon stock potential (The Chemical Engineer, 2016).

A third study by Lee et. al., (2020) explained how deforestation is impacted by RSPO certification, finding in the Indonesian islands of Kalimantan and Sumatra, RSPO certification decreased deforestation on small slopes but had the opposite effect on slopes greater than 3 degrees. RSPO certification also resulted in saving more primary forests and reduced the incidence of water pollution in Sumatran villages on slopes less than 3 degrees. In

Kalimantan, it reduced the incidence of land pollution on slopes less than 2 degrees (Lee et. al., 2020).

For their research, Austin et. al, (2015) used a logistic regression model (to predict probabilities) that used data on the recent expansion of oil palm plantations and a set of explanatory variables describing biophysical suitability and infrastructure proximity to support their findings. The Chemical Engineer (2016) took a different approach by mapping suitable land for palm oil production on a global scale to determine the amount of land space available for palm oil production. In addition to creating their own map, the authors also used a map previously compiled by NASA and the IFPRI, data from other institutions, and information from local volunteers to further support their results. Lastly, Lee et. al., (2020) used observations from 11,000 villages over 11 years and applied quasi-experimental methods.

<u>Palm Oil and the Use of Biofuels</u>

Biofuels are fuels composed of or produced from biological raw materials (Merriam-Webster), which includes palm oil, and therefore has an impact on the industry. According to Harris (2013), the demand for palm oil can be partially attributed to the growth in demand for food. Environmental concerns will also grow with the increase in popularity of palm oil, especially if biofuels are vetted more carefully as an alternative energy source. Additionally, participation in certification schemes is important as this industry grows. As for RSPO specifically, politics amongst RSPO members has led to transparency and review measures (Harris, 2013). Mukherjee and Sovacool (2014), agreed saying the "successful implementation of national and international standards for oil palm plantations that are enforceable is a key priority" (10). Additionally, encouraging the development of new biofuel technologies is imperative to future sustainability. That being said, even though certification schemes are important, RSPO standards do not meet their own criteria for successful implementation and enforcement of standards for palm oil stakeholders. (Mukherjee and Sovacool, 2014). RSPO certification standards are voluntary, and thus they are not enforceable.

Oseghale, et. al, (2017) continued by discussing the impact of plantation growth on waste disposal. As the generation of wastes continues to grow, there is more of a need to treat waste in a sustainable manner. Certainly, palm oil plantation growth raises environmental sustainability concerns. However, a number of studies have found there is progress in the growth of sustainability in the Malaysia palm oil industry. Oseghale, et. al, (2017) took statistical data from the Malaysian Palm Oil Board as their primary source for research, but secondary data from literature was also used. Mukherjee and Sovacool (2014) took a similar approach as their research came from peer-reviewed academic articles published between 2000 and 2010, policy literature, and data from national ministries, major international research institutes, and multilateral development banks. Lastly, Harris (2013) conducted research using two case studies of palm oil companies. Three schemes were included in these case studies, one of which is RSPO. The two case studies looked at Wilmar and Dinant.

The Impact of Palm Oil Plantations on the Surrounding Environment

The price of palm oil has a positive effect on the expansion of rubber, cocoa, and coffee plantations; however, “the effect of palm oil prices is inferior to the influence of plantation labor wages in cocoa and coffee models” (p. 7) (Harianto, 2019). The industries of both cocoa and coffee use labor intensively, so an increase in labor wages will have an adverse impact on these industries (Harianto, 2019). Harianto (2019), focused on the impact palm oil plantations have on the plantations of other competing crops, while Teuscher, et. al, (2016) focused on another aspect of the environment: biodiversity of vegetation, birds, and invertebrates. They found initial positive responses from the presence of palm oil, which suggests that tree islands can be an acceptable way to increase biodiversity in degraded landscapes (Teuscher, et. al, 2016). This may be relevant for palm oil smallholders seeking to diversify their production to reduce their dependence on palm oil, in addition to other risks.

Land use is the third aspect of the environment that was researched by Varkkey, et. al, (2018). They found there could be a potential impact resulting from commercial buyers vying to use only no deforestation, no peat, no exploitation (NDPE) palm oil. Another interesting finding is that middle-class Indonesians, Malaysians, and many others have not yet hit the point where an increase in incomes and shifts in their purchasing preferences begin to reduce environmental impacts (Varkkey, et. al, 2018). Therefore, we are stuck in a cycle of economic growth that requires further exploitation of plantations, and land in general (Varkkey, et. al, 2018). All three of these studies took the smallholders of Indonesia and Malaysia into consideration, whether considering labor wages, diversification, or looking at consumer preferences.

Harianto (2019) used time-series data from 1991 to 2015 that was built into an econometric model for their research. The three commodities that were input include rubber, coffee, and cacao. The world price of crude palm oil (CPO) and the world price of palm kernel oil (PKO) was also used in this research. Harianto (2019), also used the multiple regression method to "estimate the influence of predictor variables on variable area and variable production of each commodity". Teuscher, et. al, (2016) used surveys and conducted a baseline survey of the environment, vegetation, birds, and invertebrates in 2013 and again in 2014. Soil composite samples were also taken at the oil palm plantations. Lastly, Varkkey, et. al, (2018) conducted research using mapping as well as a sample of recently published studies on the political economy of palm oil and land use policy based on general database searches.

<u>Barriers to Deforestation-Free Palm Oil</u>

Many companies have signed commitments for deforestation-free palm oil without realizing all that it entails and the potential barriers to reaching such commitments. For example, in 2014, Mars® first committed to source deforestation-free palm oil by year-end 2015 (Lierly, 2020). They missed this ambitious goal, as Mars® sourced palm oil from 1,500 mills at the time. Mars® then began a process to simplify their supply chain- one that will reduce their supplier mills to 100 by 2021. This seemed to have worked eventually for Mars®, as they announced in October of 2020 that their palm oil supply chain was deforestation-free (Southey, 2020). Mars® is not the only company that has pushed back the end date on its palm oil sustainability goals. In fact, Lyons-White & Knight, (2018) conducted interviews with 23 organizations regarding the barriers to implementing deforestation-free palm oil commitments. One of the major barriers they found was the complexity of the supply chain hindering the implementation. Specifically, complex supply chains were a major barrier to successful no-deforestation commitments, as they make traceable supply chains and communication with customers and suppliers much more difficult (Lyons-White & Knight, 2018). If companies do not have the traceability to see exactly where their palm oil is being sourced from, it is very difficult to ensure deforestation is not linked to the palm oil.

Another barrier found was the lack of a definition of ‘deforestation-free’ palm oil throughout the supply chain. Some growers found this concept inconceivable and therefore overlooked these commitments. On the other hand, different members of the supply chain took this concept quite literally (Lyons-White & Knight, 2018). Committing to a practice without a general acceptance of what it entails with every entity a company is doing business with makes these commitments very difficult to implement. Some other barriers Lyons-White & Knight, (2018) found include a variety of barriers within the company themselves, market forces, and even the cost barrier. Some of these examples may include battling the way a company has always done something or losing their customers because they are unwilling to pay the increase in price that may come with deforestation-free palm oil. What might seem initially as a great commitment to decrease a company’s environmental footprint has proven to be much more complex for many different businesses.

While these articles gave a solid foundation to this research, there are limitations that exist. First, there was a common theme of studies examining either RSPO or the environmental impacts of palm oil cultivation. No studies were found that directly compared the environmental impacts that result from deforestation-free and deforestation-linked crude palm oil. The objective of this new study aims to add to the current literature by researching the intersection of deforestation and the environmental impacts of crude palm oil by performing a life cycle analysis (a method not seen in this literature). Analyzing palm oil production while taking levels of deforestation into consideration will allow for conclusions to be drawn on whether deforestation-free palm oil is environmentally sustainable in the Malaysian palm oil industry.

GOAL & SCOPE

The goal of this project is to compare the environmental impact that arises from the production of palm oil that is associated to deforestation, to palm oil produced without an element of deforestation. To aid in this comparison, palm oil produced with an average element of deforestation will also be evaluated. This project is significant because of the massive volume of palm oil that humans currently consume, combined with the predictions that palm oil usage will only grow in the coming years. This project is also relevant because organizations such as the RSPO have been established to try and offer environmentally conscious companies the option to purchase sustainable palm oil. This project will determine if by removing deforestation, (a main element to RSPO 'sustainable' palm oil), from the production of palm oil, if sustainable palm oil is feasible.

In this study, the element of deforestation includes the clearing of any primary or secondary forest. A primary forest is a forest that has not ever been damaged or cleared by humans. A secondary forest is one that has been damaged or cleared by humans, but it has been long enough that the impacts are no longer evident (Mongabay, 2012). Therefore, a plantation will create CPO not linked to deforestation if it was produced on land that was not (or had ever been) forest-covered when the plantation was made. On the other hand, CPO associated to deforestation comes from plantations where either a primary or secondary forest was cleared in order to make the plantation. Once a primary or secondary forest is cleared, a palm oil plantation can never occupy that same land while producing palm oil considered 'not linked to deforestation'.

To hone the scope of the project, certain limitations have been made. First, Malaysia will be the only origin of palm oil evaluated in this project. Malaysia, along with Indonesia, makes up the vast majority of global palm oil production, which is the reason behind this location selection. This comparison will also only be evaluating palm oil from cradle-to-gate. Cradle-to-gate will evaluate the environmental impact stemming from the origin (resource extraction) to the gate, which in this case is the destination port before being transported to the consumer. To further limit the scope of the project, the most significant factors will be discussed the most. For this project, the indicators with the most significant results are carcinogenic substances into air, main air pollutants and PM, non-radioactive waste to deposit, and water pollutants. While the total environmental impact takes every indicator into consideration and will be discussed as well, these four will be the primary focus.

The application of this project's findings can be applicable to any companies or individuals sourcing or consuming palm oil. Companies worried about their environmental footprint may opt to source a more environmentally friendly ingredient, while consumers may choose not to purchase any products containing palm oil, or any palm derivatives. In addition, stakeholders may be more inclined to hold organizations such as RSPO accountable for their claims or demand more transparency behind the environmental impact of their certified sustainable palm oil.

METHODOLOGY

Much of the research previously conducted related to palm oil and RSPO sustainability standards took the approach of field research (including many interviews), in addition to using secondary data. However, this research utilized a Life Cycle Analysis (LCA) on palm oil. LCA is an established process that is best fit to analyze the environmental impact raw materials, products, or other objects have on the world (Liebsch, 2020). The LCA quantifies these environmental impacts and therefore is a more concrete form of research. This method took a cradle-to-gate approach, meaning analyzing environmental impact from the production of palm oil through the factory gate. Specifically, for this research, it includes the production process, transportation from the plantation to the mill, transportation from the mill to the Malaysian port, and transportation from the Malaysian port to a French port. Any environmental impacts beyond this point are not included in this study due to a lack of available data. The LCA method evaluates each included stage of the palm oil's "life" from the perspective that each stage is independent of the others. This enables the approximation of the cumulative environmental impact palm oil has on the world by combining each of the stages (Liebsch, 2020).

There are four phases in an LCA. First, the goal and scope definition phase, second is the inventory analysis phase, third is the impact assessment phase, and finally, the interpretation phase (Liebsch, 2020). The goal and scope of this research can be found above on page 10. The second stage is the data collection stage which analyzes the inputs and outputs of palm oil at each stage of its life. This stage is quantitative, as it is necessary to quantify these inputs and outputs in order to identify the environmental impact. These inputs and outputs could be anything from emissions to air or land, water, energy, etc. (ISO, 2006).

To collect data, I used the third version of the Agribalyse database, within the OpenLCA software. This software was chosen as it is free and works with many compatible databases.

Agribalyse is a database that focuses on the agricultural and food sector. Given palm oil falls within this realm, Agribalyse was the chosen database. Within Agribalyse, the relevant product systems were chosen to be evaluated and compared. The first product system is Crude Palm Oil (CPO) Malaysia, not linked to deforestation. The second product system selected is Crude Palm Oil Malaysia, associated to deforestation. To see the average of the two graphically, I added a third product system, Crude Palm Oil Malaysia, average. Each of these three has the same functional unit (kg of crude palm oil), and each includes the same cradle-to-gate components, and therefore, can be compared with one another.

The third stage is the impact assessment phase where a Life Cycle Impact Assessment (LCIA) method is chosen to compare the product systems. To compare these three product systems with one another, the Ecological Scarcity (2013) LCIA method was chosen. This method was selected for the valuable indicators it evaluates, as these indicators include the emissions into the air, water, and soil. It is also one of the newer methods, as it was updated in 2013. Lastly, the interpretation stage draws conclusions based on the results generated by the chosen LCIA method. The results of this study can be found below, under Results.

RESULTS

The chart below (Figure 1) displays the results of this LCA run under the ecological scarcity (2013) method. For each indicator, the maximum value is equal to 100% on the y-axis. Each subsequent result is displayed in relation to the maximum result. Additionally, each product system has been renamed for simplicity, shown at the bottom of Figure 1. Crude Palm Oil (CPO) Malaysia, not linked to deforestation is shown as “No Def.”, Crude Palm Oil Malaysia, associated to deforestation is shown as “Assc. to Def.”, and Crude Palm Oil Malaysia, average is shown as “Average”. Of the thirteen indicators, there are significant differences between the three product systems in four indicators, in addition to the total. A significant difference in this instance is greater than or equal to a 33% difference between two of the variables, and those are the indicators that will be focused on.

While Figure 1 shows the summary of the indicators in terms of percent of the maximum value, the output of the individual indicators in Figures 2-11 is quantified in the unit UBP. The unit of UBP stands for the German word umweltbelastungspunkte, which translates to pollution points, or eco-points. Rather than quantifying the environmental impact as kilograms of waste, for instance, the ecological scarcity (2013) method assigns country-specific eco-points for each indicator. The more eco-points a product system has, the larger the environmental impact it has.

Similarly, Figure 2 shows the summary of the indicators, but rather than the maximum indicator equaling 100%, we now see the indicators and their environmental impact quantified in UBP. While Figure 1 is helpful to see which indicators have the biggest differences between the product systems, Figure 2 is helpful to see which indicators are contributing the most to the total environmental impact.

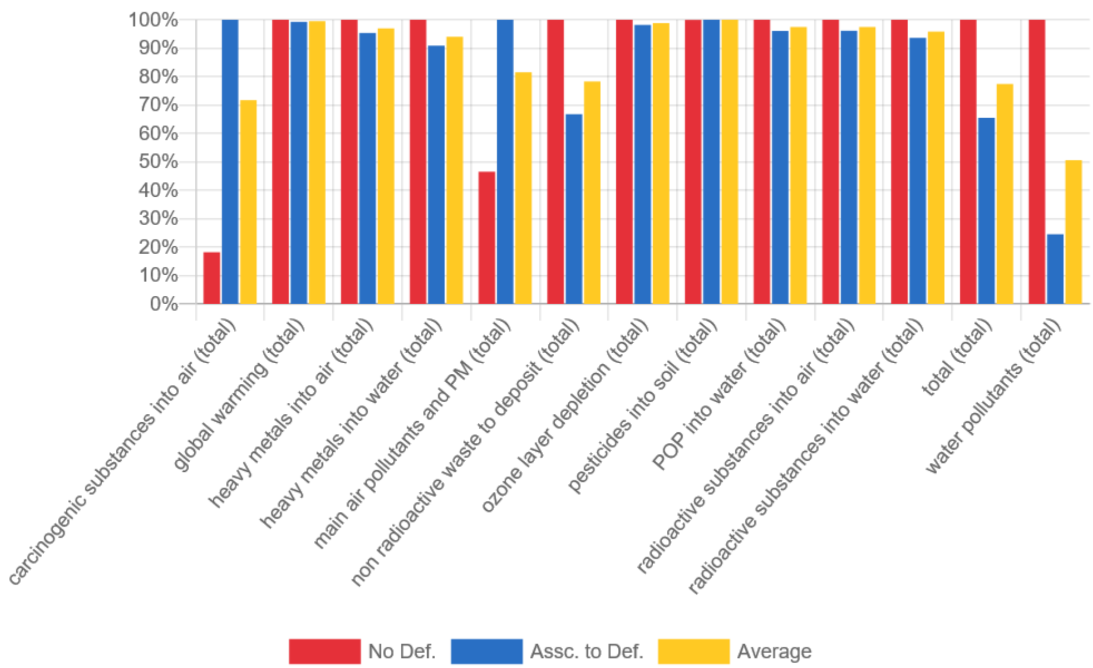


Figure 1: Total LCA Indicator Results- Percentage

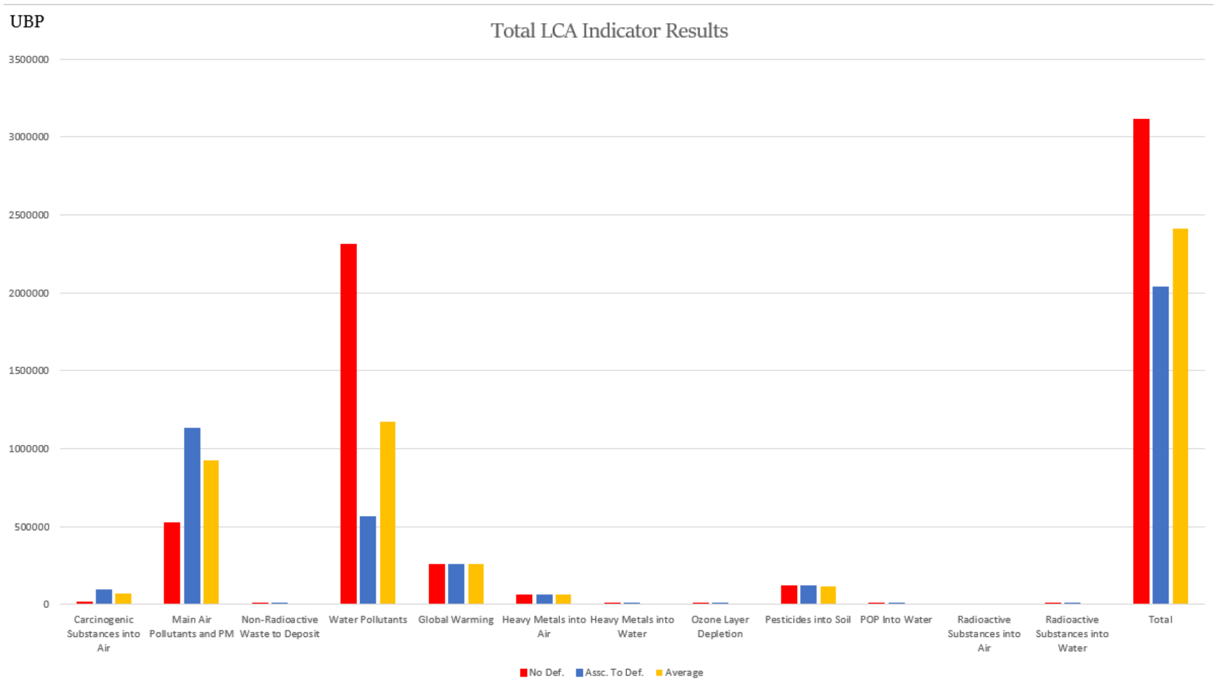


Figure 2: Total LCA Indicator Results- UBP

Carcinogenic Substances into Air

The first of the significant indicators is carcinogenic substances into air, shown below in Figure 3. These are defined as cancer-causing substances that include, but are not limited to, arsenic, benzidine, cadmium, etc. (Cancer.gov, 2018). CPO not linked to deforestation releases only 18% of carcinogenic substances into the air as CPO associated to deforestation. This indicator represents the biggest difference between the two factors, as CPO not linked to deforestation has a score of 1.76*10^4 UBP compared to CPO associated to deforestation's 9.67*10^4 UBP. This result indicates a benefit to producing palm oil not linked to deforestation, as fewer carcinogenic substances are released into the air compared to CPO, associated to deforestation.

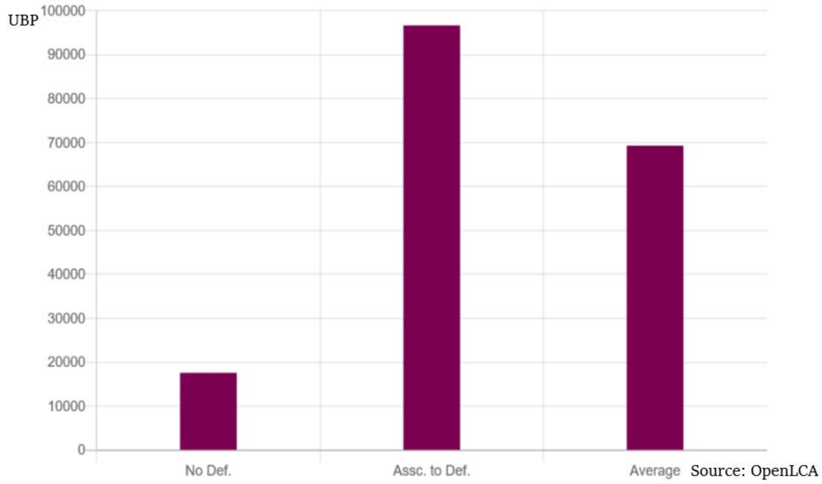


Figure 3: Carcinogenic Substances into Air

Main Air Pollutants and PM

The next indicator with a significant result is main air pollutants and PM (Particulate Matter), shown in Figure 4. Air pollutants and PM are pollutants released into the atmosphere that result from chemical reactions. Some common air pollutants include sulfur dioxide and nitrogen oxides (U.S. EPA, 2020). CPO not linked to deforestation releases 47% of main air pollutants and particulate matter (5.27*10^5 UBP) than CPO associated to deforestation (1.13*10^6 UBP). This indicator shows CPO not linked to deforestation releases less environmental air pollutants and PM than CPO associated to deforestation.

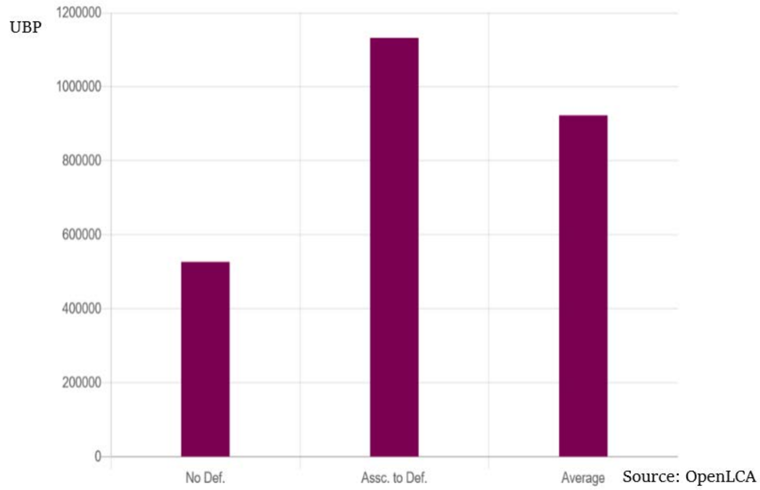


Figure 4: Main Air Pollutants and PM

<u>Non-Radioactive Waste to Deposit</u>

The third indicator with a significant result is non-radioactive waste to deposit, shown in Figure 5. This includes any type of waste that results from the production of CPO that is not radioactive (or that containing nuclear fuel) (Rinkesh, 2020). This indicator includes both liquid and solid waste and consists of empty fruit bunches and shells, palm oil mill effluent (POME), amongst others. Contrary to the first two significant indicators, the maximum value for this indicator comes from CPO not linked to deforestation with 4.81*10^3 UBP. CPO associated to deforestation creates only 67% of non-radioactive waste (3.21*10^3 UBP) compared to CPO not linked to deforestation. This is the first indication that CPO not linked to deforestation does not necessarily have a lower environmental impact than CPO associated to deforestation.

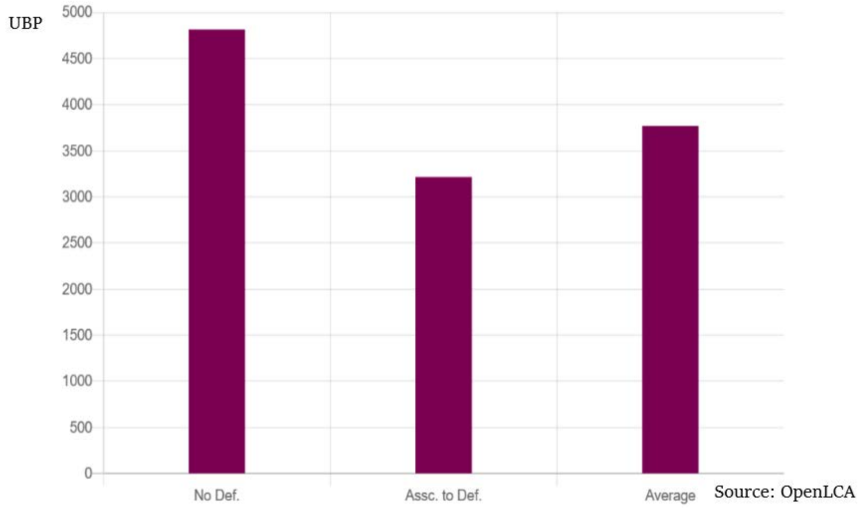


Figure 5: Non-Radioactive Waste to Deposit

Water Pollutants

The last significant individual indicator is water pollutants. There are many different categories of water pollutants, but they include metals such as arsenic and zinc (Denchak, 2020). This is another indicator where the maximum result comes from CPO not linked to deforestation with 2.31*10^6 UBP. In comparison, CPO associated to deforestation creates only 24% of those water pollutants with an impact of 5.66*10^5 UBP. This indicator shows a major difference between the production of CPO not linked to deforestation, and CPO associated to deforestation. Of the four significant indicators discussed, both product systems had the maximum value for two of them.

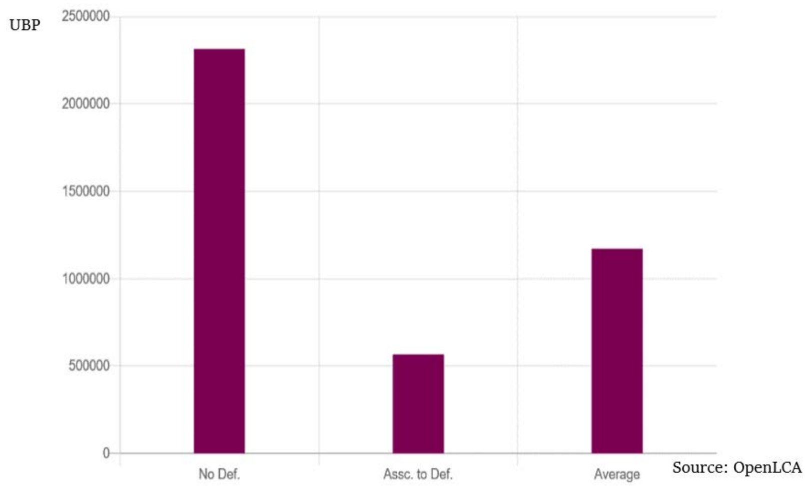


Figure 6: Water Pollutants

Indicator Total

Figure 7 below shows the total of all twelve indicators of the ecological scarcity (2013) method. Even though the significant results showed the indicators with the largest gap between the two product systems, they do not tell the whole story. Once each indicator was compiled, CPO associated to deforestation has only 65% of the total environmental impact as CPO not linked to deforestation. Of the eight other indicators (shown in Figure 1) that had a much smaller difference between the two product systems, CPO not linked to deforestation had the maximum value for each indicator. Therefore, the cumulation of all twelve indicators has CPO not linked to deforestation receiving a total score of 3.1*10^6 UBP, compared to 2.04*10^6 UBP for CPO associated to deforestation.

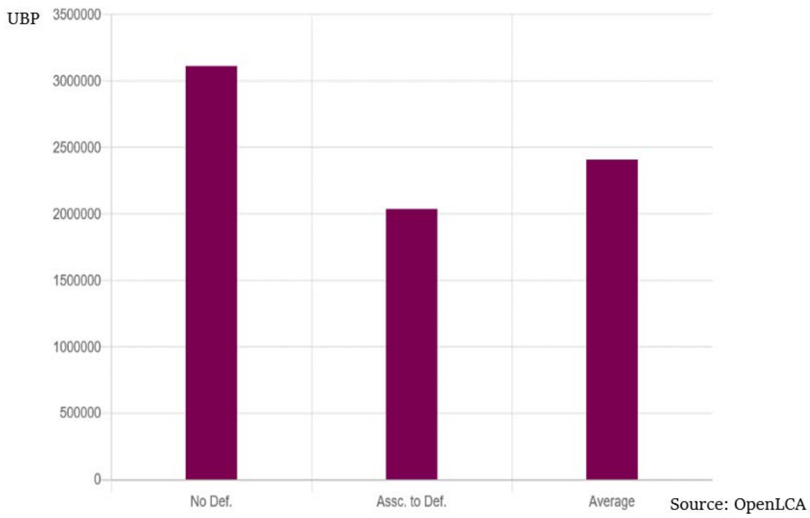
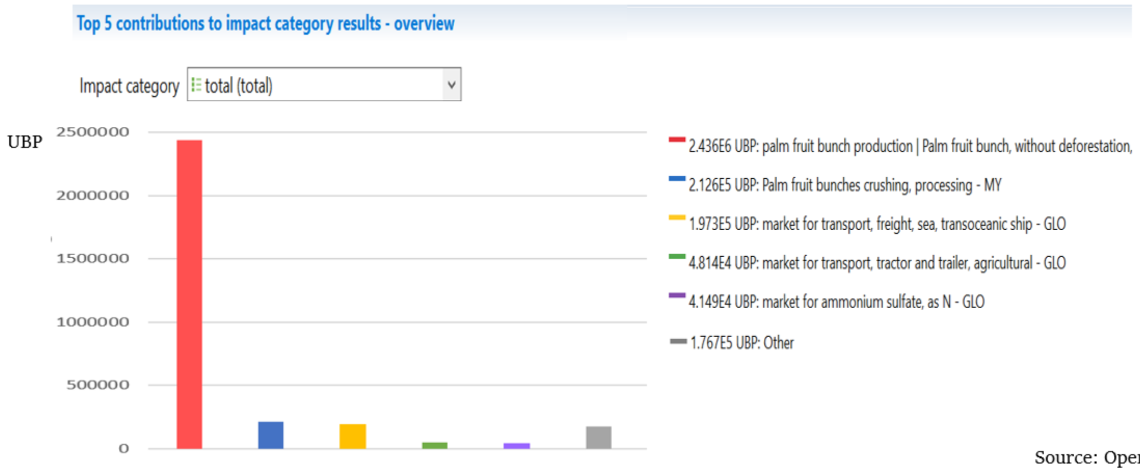


Figure 7: Indicator Totals

Contributions to Total Environmental Impact

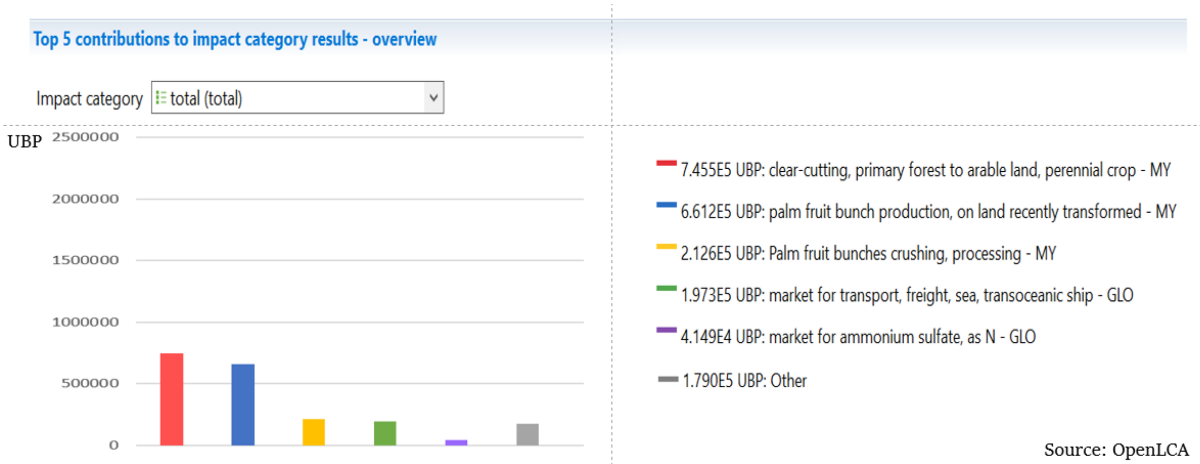
Once a difference in the environmental impact between the two product systems was identified, a closer look was taken to see what components of the processes of the two product systems were contributing the most to these results. As CPO not linked to deforestation has the larger environmental impact, that was assessed first, shown below in Figure 8. Even though this palm oil was produced without deforestation, the most significant contributor to the total environmental impact comes from the production of palm fruit bunches (the crop that palm oil is produced from). The second-largest contributor is the crushing of the bunches- another stage in the production of palm oil. The first transportation category was only the third-largest contributor. This signifies that even when palm oil is produced without deforestation, the process of producing the palm oil has a negative impact on the environment.



Source: OpenLCA

Figure 8: CPO Not Linked to Deforestation- Contributions to Environmental Impact

To compare these results, Figure 9 below shows the largest contributors for CPO associated to deforestation. Unlike the first product system, the largest contributor to the environmental impact from CPO associated to deforestation is actually clear-cutting the land to create a plantation. It is important to note that the environmental impact of this process consists *only* of the impact associated to the production of 1kg of CPO. The forest was only cleared once (not each time 1 kg of CPO is produced), so the total environmental impact of that singular process is divided by the life of the plantation in kilograms of CPO. This allows us to compare the clear-cutting process to every other process. The palm fruit bunch production that was the largest contributor for CPO not linked to deforestation, comes in as the second-largest contributor here. The third-largest contributor is the crushing of the palm fruit bunches. In the production of this palm oil, transportation factors do not appear in the top three contributors.



Source: OpenLCA

Figure 9: CPO Associated to Deforestation- Contributions to Environmental Impact

<u>Palm Fruit Bunch Production Contributors</u>

After this analysis, it became clear the process with the biggest difference between them was palm fruit bunch production without deforestation and palm fruit bunch production on land recently transformed. In order to determine the cause behind this difference, the flows that contribute to these processes were evaluated. First, Figure 10 shows the flows that make up palm fruit bunch production without deforestation. Figure 11 shows the same for palm fruit bunch production on land recently transformed. While there are many flows that make up the entire environmental impact of each process, there are only two flows that have a different UBP value between the two processes. Those flows are Nitrate and Ammonia. Nitrate equates to 625 UBP for palm fruit bunch production without deforestation compared to just 151 UBP for palm fruit bunch production on land recently transformed. Ammonia's values were 41 and 34, respectively.

total (total)			661.74345 UBP
Nitrate	Emission to water/ground water	0.02316 kg	625.44461 UBP
Ammonia	Emission to air/low population density	0.00061 kg	41.04815 UBP
Dinitrogen monoxide	Emission to air/low population density	0.00018 kg	25.63204 UBP
Cypermethrin	Emission to soil/agricultural	2.88000E-6 kg	20.44800 UBP
Glyphosate	Emission to soil/agricultural	4.05000E-5 kg	6.07500 UBP
Carbofuran	Emission to soil/agricultural	2.04000E-5 kg	3.06000 UBP
2,4-D	Emission to soil/agricultural	5.84000E-6 kg	2.27760 UBP
Nitrogen oxides	Emission to air/low population density	3.84000E-5 kg	1.49760 UBP
Lead	Emission to soil/agricultural	7.48000E-8 kg	1.27160 UBP
Cadmium	Emission to soil/agricultural	1.45000E-9 kg	0.39150 UBP
Benomyl	Emission to soil/agricultural	3.72000E-8 kg	0.01748 UBP
Thiram	Emission to soil/agricultural	6.61000E-8 kg	0.01586 UBP
Zinc	Emission to soil/agricultural	-4.22000E-6 kg	-11.81600 UBP
Copper	Emission to soil/agricultural	-3.83000E-6 kg	-53.62000 UBP

Figure 10: Flows Contributing to Palm Fruit Bunch Production Without Deforestation

total (total)			179.63555 UBP
Nitrate	Emission to water/ground water	0.00558 kg	150.62490 UBP
Ammonia	Emission to air/low population density	0.00050 kg	33.75996 UBP
Dinitrogen monoxide	Emission to air/low population density	0.00018 kg	25.63204 UBP
Cypermethrin	Emission to soil/agricultural	2.88000E-6 kg	20.44800 UBP
Glyphosate	Emission to soil/agricultural	4.05000E-5 kg	6.07500 UBP
Carbofuran	Emission to soil/agricultural	2.04000E-5 kg	3.06000 UBP
2,4-D	Emission to soil/agricultural	5.84000E-6 kg	2.27760 UBP
Nitrogen oxides	Emission to air/unspecified	3.84000E-5 kg	1.49760 UBP
Lead	Emission to soil/agricultural	7.48000E-8 kg	1.27160 UBP
Cadmium	Emission to soil/agricultural	1.45000E-9 kg	0.39150 UBP
Benomyl	Emission to soil/agricultural	3.72000E-8 kg	0.01748 UBP
Thiram	Emission to soil/agricultural	6.61000E-8 kg	0.01586 UBP
Zinc	Emission to soil/agricultural	-4.22000E-6 kg	-11.81600 UBP
Copper	Emission to soil/agricultural	-3.83000E-6 kg	-53.62000 UBP

Figure 11: Flows Contributing to Palm Fruit Bunch Production on Land Recently Transformed

These differences indicated that the difference was coming from fertilizer usage, as both nitrate and ammonia are major ingredients in fertilizers. However, land that has been recently cleared has less fertile soil, so plantations on land recently transformed actually have a higher need for fertilizer (Bernhard, 2010). So, in a case where the same amount of fertilizer is applied to two plantations, (one on land recently transformed, the other without an element of deforestation) the plantation on land recently transformed will absorb more of the fertilizer. Since the land without deforestation already has more nutrients, less fertilizer will be absorbed into the soil, and the remainder will escape in the form of nitrate and ammonia emissions. This introduces the issue of fertilizer runoff because when it rains, the unabsorbed fertilizer will runoff into nearby water sources polluting them. This gives us further confirmation, as water pollutants is the variable with the highest environmental impact.

CONCLUSION & SUMMARY

The results of this research have identified both variations of palm oil (and therefore the average as well), have a large environmental impact. Therefore, this suggests that each product system has a significant environmental impact that would most likely make it difficult to become sustainable. These results put into question the practicability of certified sustainable palm oil from the RSPO, as these results do not indicate sustainable palm oil is achievable through a 'no-deforestation' commitment. While the RSPO's certified sustainable palm oil does have other characteristics besides being made with no deforestation, the 'no deforestation' requirement is a considerable component of the requirements that are set with the goal of minimizing environmental impact. It is also important to note that this research solely evaluated the environmental impact of these product systems, rather than the entire ecosystem impact.

Therefore, it cannot be assumed that CPO associated to deforestation is simply ‘better’, as other factors unrelated to environmental impact (such as habitat loss) are not taken into consideration in this research. Rather, the large environmental impact of both variations of palm oil highlights the likelihood that palm oil is inherently not sustainable. Although each product system evaluated is not currently environmentally sustainable, does not mean it cannot become sustainable in the future. Technology has allowed humans to innovate in many different ways, including how to make some processes more environmentally friendly. With enough emphasis and awareness of the issue of crude palm oil, a path towards sustainable palm oil is indeed possible.

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