www.theicct.org

BRIEFING

JULY 2017

How rapeseed and soy biodiesel drive oil palm expansion

This briefing paper reviews a recent study by Santeramo (2017) estimating the degree of substitution between various oils and fats and explains what its results mean for the greenhouse gas performance of biodiesel. Santeramo (2017) finds that an increase in the price of rapeseed oil in the European Union (EU) and of soybean oil in the United States (U.S.) both lead to increased palm oil imports to those regions. These results are important because they indicate that rapeseed biodiesel production in the EU and soybean oil production in the U.S. will contribute to high land use change emissions associated with oil palm expansion. This effect limits – or even reverses – the climate benefits of policies supporting food-based biodiesel.

BIOFUELS, LAND USE CHANGE, AND PALM OIL

The role of food-based biofuels in climate mitigation policies has long been controversial because of their impact on food prices and land use. Biofuels do not categorically deliver greenhouse gas (GHG) savings compared to petroleum; the biofuel crops must be grown somewhere, and that land use is associated – directly and indirectly – with GHG emissions. If a forest is cut down so the land can be used to grow biofuel crops, the GHG savings from avoided petroleum use will not offset the amount of carbon that is released from disturbed vegetation and soils within a reasonable timeframe. That is why direct land use change on forest land to produce biofuels is prohibited in biofuel policies in the EU and the U.S.

Direct land use change does not occur when crops harvested from existing agricultural land are used for biofuel, but there are indirect effects. For example, if the harvest

Prepared by: Stephanie Searle

from 1 hectare of a rapeseed farm is diverted to biofuel, the farm will deliver 1 hectare's worth less product to the market (note: rapeseed is known as canola in North America). Rapeseed supply at the market will then be reduced, increasing competition for the remaining resource and raising the price. Another rapeseed farmer at the market will notice the increase in price. The next year, she will till a meadow on the edge of her farm to produce more rapeseed, because this expansion is economically profitable at the higher price. Tilling up the meadow disturbs the biomass and soil, resulting in GHG emissions. So, although the rapeseed that is used for biofuel does not directly come from the plowed meadow, the plowed meadow is still a result of the biofuel production, and its indirect land use change (ILUC) emissions are attributable to it.

This expansion of rapeseed area may not be a full hectare's worth, because we would also expect other people at the market to buy a little less rapeseed because it is now more expensive. We might also expect a third farmer to invest in a new irrigation system because he can pay off the capital expense with the higher rapeseed prices, leading to increased rapeseed yields on his farm. After crushing the rapeseed and using the oil to make biodiesel, the biofuel producer will sell the leftover meal, a coproduct of the oil, to another farmer to use as livestock feed, and that farmer will grow slightly less corn and soybean the next year to feed her cows. The net effect of all these changes is that less than 1 hectare of meadow is converted to rapeseed production as a result of using 1 hectare's worth of rapeseed for biofuel. Researchers debate the relative size of these effects, but it is clear that, for all food-based biofuels, some amount of ILUC emissions occurs and reduces the GHG benefits of those biofuels (see Malins et al., 2014).

Land use change associated with biofuels production is especially worrisome when it involves palm oil. More than 80% of palm oil in the world is grown in Indonesia and Malaysia (FAOSTAT, 2017). When farmers expand their oil palm plantations, much of the new plantation area comes at the expense of tropical forests that are rich in biodiversity and carbon stocks. One third of all oil palm expansion is on peat soils; these low-oxygen waterlogged soils preserve organic matter that has built up over thousands of years (Miettinen et al., 2012). Palm trees do not grow well in waterlogged soils, and so farmers cut ditches to drain peatlands when expanding their palm plantations. Draining exposes the organic matter in the peat soils to oxygen, allowing millennia of peat to rot all at once and causing the release of massive amounts of carbon dioxide (CO_2) (Page et al., 2011). When ILUC emissions for palm oil are taken into account, palm biodiesel is actually worse for the climate than petroleum (Valin et al., 2015).

In the example above, the net result of using the hectare's worth of rapeseed for biofuel is that additional rapeseed area was cultivated—but this is not always the case. Perhaps a restauranteur usually buys rapeseed to use for frying chips. Palm oil is available at a lower price, but a small price premium may be worth the better taste of rapeseed oil. Now that the price of rapeseed oil has risen, however, the restauranteur reconsiders. It was worth paying a little more for rapeseed oil, but she cannot justify spending substantially more when palm oil only tastes a little worse—so she switches to buying palm oil. Now the demand for palm oil exceeds its supply, and the price of palm oil rises. In the end, an Indonesian farmer decides it is profitable to drain an area of peat swamp, cut down its trees, and plant oil palm. Less than 1 hectare of oil palm is planted, but because it is on drained peat, the land use change emissions are high. As a result, the rapeseed biofuel is not nearly as good for the climate as one would have thought considering direct emissions alone.

VEGETABLE OIL SUBSTITUTION

Whether rapeseed oil, soybean oil, and palm oil substitute for one another in a significant way is a key question for understanding global vegetable oil markets and the magnitude of ILUC emissions. There are reasons to believe both that they do and do not replace each other. On one hand, different vegetable oils have different properties, which may make certain oils better suited to some uses. Palm oil is higher in saturated fat than soybean, rapeseed, sunflower, and other oils and tends to be solid at room temperature, whereas the other vegetable oils tend to be liquid. For example, solid fats and oils are preferred for making baked goods with a flaky texture, such as pie crust and biscuits. On the other hand, liquid oils can be altered to produce a consistency similar to solid fat alternatives through hydrogenation. Partially hydrogenated soybean and rapeseed oils, or a mixture of fully hydrogenated and non-hydrogenated oils, can have a similar consistency to palm oil, and can also be substituted for lard or butter in baking applications.

All consumers are, to some extent, price sensitive. It is easy to envision a situation where a major food manufacturer switches between palm oil and hydrogenated rapeseed oil depending on which option is cheaper at any point in time. Simply examining the price histories of these oils suggests that these markets are linked. Figure 1 displays the global commodity price histories of palm, soybean, rapeseed, and sunflower oils over a 10-year period from 2007 to 2017 and shows that these oils have followed a similar price pattern over this period. An obvious feature in Figure 1 is the 2008 spike in the price of many food commodities, which does not necessarily indicate market linkages. As a counter example, we also show the commodity price history for rice; the rice price was similarly affected by the food price spike in 2008, but does not closely mirror the price pattern of the vegetable oils thereafter. For example, prices for each of the vegetable oils shown here dipped in 2009 and rose again in the beginning of 2011, remaining elevated until 2012 or 2013; the rice price remained

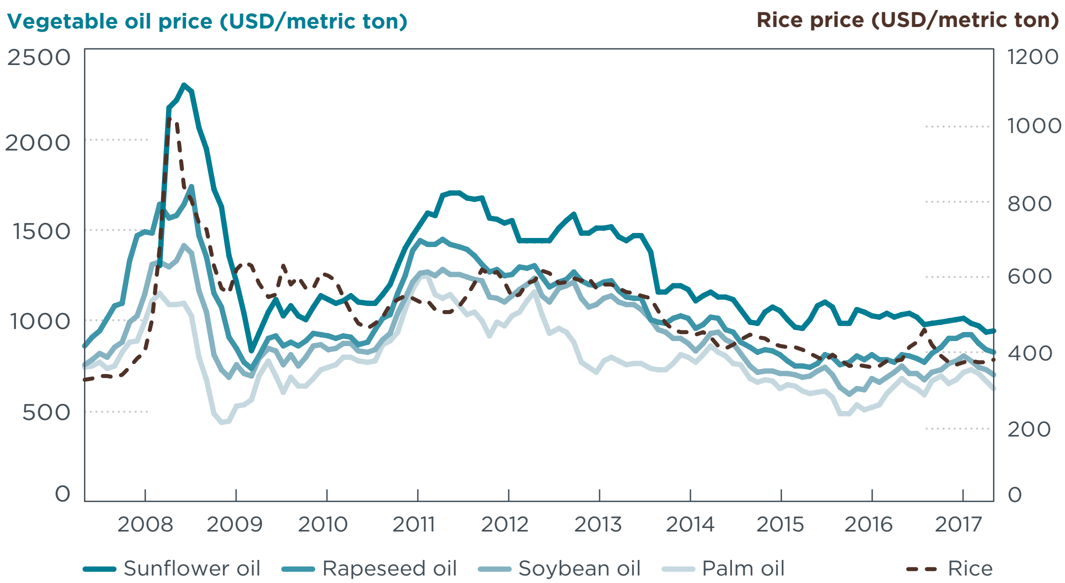

Figure 1: Global commodity prices for vegetable oils from 2007 to 2017.
Data source: Indexmundi (2017).

constant over this period. Furthermore, the commodity prices of these vegetable oils are well correlated: changes in the price of soybean oil explain 80% of the variation in the palm oil price and vice versa (i.e., the R^2 value for a simple linear regression for these two variables is 0.80 over this 10-year history), whereas for palm oil and rapeseed oil this value is 70%, and for soybean oil and rapeseed oil it is 90%. In contrast, only 17% of the variation in the price of palm oil can be explained by changes in the price of rice.

The price correlations of these vegetable oils suggest that price shifts in one commodity are transferred to others. As an illustrative example, a drought in Europe one year may reduce the supply of rapeseed oil and raise its price. The palm oil price rises too. However, the drought was not experienced in Southeast Asia, where the majority of palm oil is produced. Therefore, the most likely explanation is that increased palm oil was used to substitute for rapeseed oil, and that this increase in palm oil demand led to an increase in price.

In the U.S., there is further evidence to suggest that soy biodiesel is driving increased consumption of palm oil. Figure 2 shows the amount of soybean oil used in biodiesel and the amount of palm oil imports in the U.S. from 2000 to 2015. Palm oil was not historically a commonly used commodity in the U.S.; imports from 2000 to 2004 were low. Starting in 2005, a significant amount of soybean oil was used in biodiesel, and this amount continued to grow over time; palm oil imports have similarly risen.

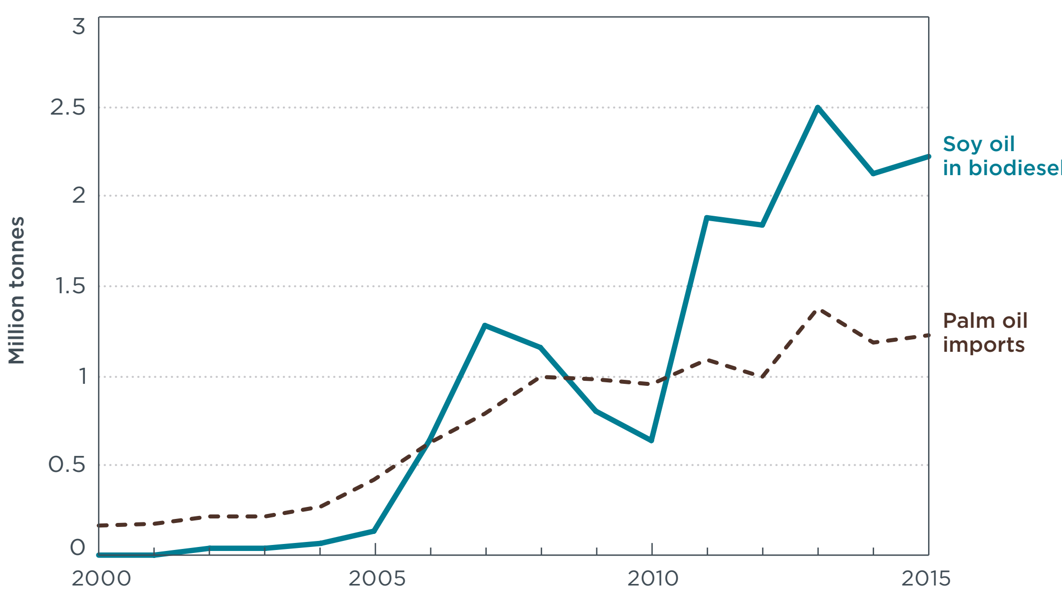

Figure 2: U.S. soy oil used in biodiesel and palm oil imports from 2000 to 2015. Data sources: USDA FAS (2017) and U.S. EIA (2017).

Similarly, palm oil imports to the EU have risen at the same time that total biodiesel production has increased (Figure 3). A fraction of the increase in palm oil imports is due to palm oil used directly for biodiesel, but this is unlikely to explain the full rise in palm oil imports. According to Valin et al. (2015), palm oil is expected to contribute to 16% of the total biodiesel used in the EU in 2020. Assuming the same is true in 2013, only 35% of the increase in palm oil imports over the period 2000–2013 would be accounted for by direct use in biodiesel; 65% of the increase in palm oil imports would thus be due to increased use in other sectors. This analysis does not consider imports of palm biodiesel (rather than palm oil) from Indonesia and Malaysia and so likely overestimates the amount of palm oil used in domestic EU biodiesel production and underestimates the proportion of the increase in palm oil imports going to non-biodiesel uses. These data suggest that palm oil imports to the EU are backfilling the demand for vegetable oils in non-biodiesel uses as rapeseed and other vegetable oils are increasingly diverted to biodiesel. But, as with the U.S. data shown in Figure 2, it is not possible to determine causality from such a casual examination of the data.

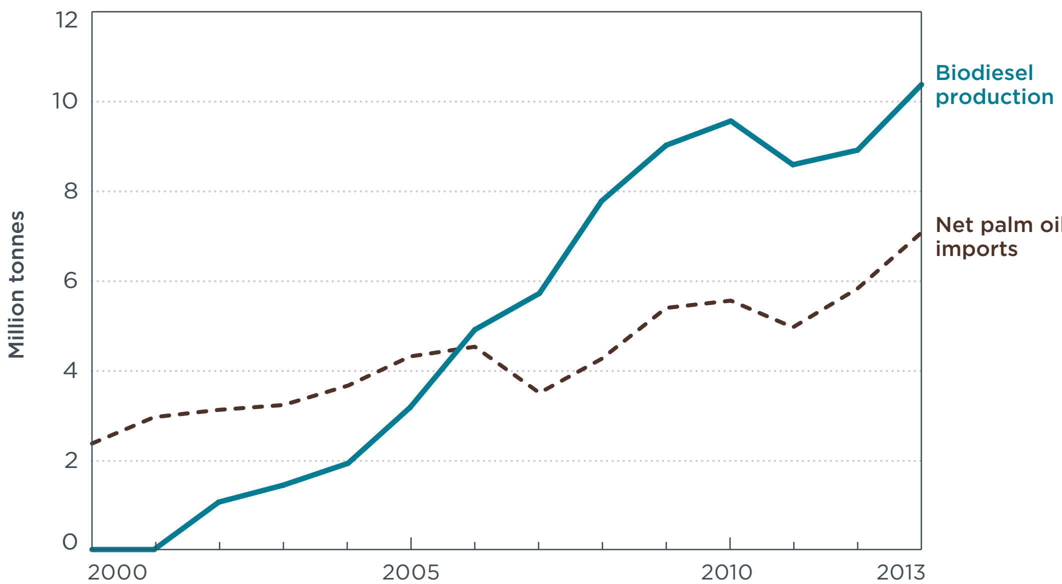

Figure 3: Total biodiesel production and net palm oil imports in the EU from 2000 to 2013. Data sources: FAOSTAT (2017) and European Biodiesel Board (2017).

NEW EVIDENCE OF VEGETABLE OIL SUBSTITUTION IN SANTERAMO (2017)

Although the data shown in Figure 2 suggest that soy biodiesel demand leads to increased palm oil imports, it is not possible to establish cause and effect by visually comparing the trends or looking at an R^2 value from a simple linear regression. For example, what if a bumper crop of rapeseed lowers the price of all vegetable oils, leading to greater use of both palm oil and soybean biodiesel? Or what if a new technology emerges that uses vegetable oils to produce some type of material, and this raises the demand for both soybean and palm oils? It is difficult to know that the increase in palm oil imports is due to changes in the soybean oil market and not the other way around, or that it is due to an external factor.

Santeramo (2017) aims to determine whether the prices of soybean and rapeseed oil and animal fats affect the supply of soybean, rapeseed, and palm oil in the U.S., and whether the prices of soybean, rapeseed, and sunflower oils and animal fats affect the supply of soybean, rapeseed, sunflower, and palm oil in the EU. The study uses instrumental variables, an econometric technique to determine causality in correlations. An instrumental variable is correlated with the explanatory variable (the variable that we believe is causing the change, so in this case, e.g., soybean oil price) but not with the dependent variable (the variable that we believe is reacting to the explanatory variable, so in this case, e.g., palm oil supply). In theory, if the instrumental variable is correlated with the dependent variable, it should only be through the effects of the explanatory variable. This would show that the explanatory variable is indeed affecting the dependent variable. The use of instrumental variables allows one to exclude potential confounding factors and spurious results and thus to correctly assess the relationships among prices.

Following an analysis by Roberts and Shlenker (2013) that estimates supply and demand elasticities of agricultural commodities, Santeramo (2017) uses past production shocks and commodity consumption as instrumental variables. To illustrate: domestic consumption of soybean oil in the previous year should affect soybean oil price (e.g., high consumption one year would decrease stocks and lead to higher prices in the next year) but should not directly affect palm oil imports. A statistically significant result showing a correlation between the previous year's soybean oil consumption and palm oil imports indicates that palm oil imports are reacting to changes in soybean oil price, whereas a result that is not statistically significant suggests that palm oil imports are acting independently of the soybean oil market.

Santeramo (2017) went through this process with each of the combinations of vegetable oil price and supply listed above for the U.S. and EU markets to determine which vegetable oil and animal fat prices were driving changes in the supply of other oils. For several combinations, the results show no scientifically evident relationships, indicating that the price of one commodity has no clear impact on the supply of another. A few combinations, however, did have scientifically evident relationships.

The study's results for the EU show that an increase in rapeseed oil price leads to an increase in the supply of rapeseed and palm oils. We would expect the rapeseed oil price to drive changes in the rapeseed oil supply. With a higher price, farmers in the EU would be incentivized to grow more rapeseed because it is more profitable, and traders would be likely to sell more rapeseed oil domestically and export less because of the increased profit in the EU market. But an increase in rapeseed oil price also drives increases in palm oil supply. The most plausible explanation for this is that palm oil is substituting rapeseed oil somewhere in the EU market. Earlier we gave an example of the restauranteur switching to cheaper palm oil when rapeseed oil becomes too expensive; this is exactly the type of action that would lead to an increase in palm oil imports as a result of higher rapeseed oil price.

Similarly, Santeramo's (2017) results for the U.S. show that an increase in soybean oil price leads to an increase in palm oil supply, as well as a weak increase in soybean oil supply. This indicates that palm oil is likely substituting for soybean oil in some uses in the U.S. The response of soybean oil supply to soybean oil price is low, showing that an increase in soybean oil price will only lead to a small increase in supply. This effect is much smaller than the increase in rapeseed oil supply that would result from an increase in rapeseed oil price in the EU. There is a key difference between these two commodities: rapeseed oil accounts for two thirds of the value of the whole rapeseed, whereas soybean oil accounts for only one third of the value of the whole soybean.[1] For the rapeseed market, the oil is the most valuable fraction and thus is likely to drive a larger share of rapeseed production decisions, whereas soybean production is more likely to be driven by changes in the value of soybean meal.

1 Calculated with prices from USDA (2017), rapeseed oil and meal yields from Heuzé, Tran, Sauvant, Lessire, & Lebas (2017), and soybean meal yield from Purcell, Salmeron, & Ashlock (2000).

It is worth noting that according to Santeramo (2017), rapeseed oil price does not affect palm oil supply in the U.S., and the prices of soybean and sunflower oil do not affect palm oil supply in the EU. Why is the rapeseed oil price more influential in the EU than in the U.S., and vice versa for soybean oil? Soybean oil is by far the most consumed oil in the U.S., and rapeseed oil is the dominant oil the EU, according to the supply data used in Santeramo (2017). A possible explanation is that other oils, for example rapeseed oil in the U.S. and sunflower oil in the EU, tend to be used in niche applications that would be slower to switch to a substitute. Applications that are less sensitive to differences in the properties of oils, for example livestock feed, would logically utilize the lowest cost options and would thus tend to be more price sensitive. Palm oil is the cheapest oil in both the U.S. and EU markets, but soybean oil is cheaper than rapeseed oil in the U.S. and vice versa for Europe (Santeramo, 2017). Because the cheapest and dominant oils are soybean in the U.S. and rapeseed in the EU, these are also the dominant biodiesel feedstocks in these regions, and thus the most relevant to consider in the context of vegetable oil substitution.

PALM OIL SUBSTITUTION IN LAND USE CHANGE MODELS

The theory behind ILUC is that the demand for biofuel raises the overall demand for its feedstocks, raising its price and leading to a global increase in supply. The findings in Santeramo (2017) support the idea that rapeseed biodiesel demand in the EU results not just in an increase in global rapeseed production, but also an increase in global palm oil production. Similarly, soybean biodiesel demand in the U.S. results in an increase in global palm oil supply. Furthermore, the results in Santeramo (2017) suggest that demand for U.S. soybean biodiesel will have a limited effect on global soybean production. These findings are important because they indicate that rapeseed biodiesel production in the EU and soybean oil production in the U.S. will lead to increased deforestation and peat drainage, and thus high land use change emissions, in Southeast Asia. This effect limits – or even reverses – the climate benefits of policies supporting food-based biodiesel.

Vegetable oil substitution has a significant impact on estimated ILUC emissions of biodiesel feedstocks. ILUC is typically estimated using equilibrium models that represent either the entire global economy or key sectors of it. These models compute the price impacts for a range of commodities in response to biofuel policies and predict where in the world land use change will occur. There are various research teams using a number of these economic models to estimate ILUC, and treatment of vegetable oil markets is one key factor leading to divergent results.

To illustrate the importance of palm oil substitution in ILUC modeling, we analyze the results of a recent study using the GLOBIOM model that was contracted by the European Commission to assess the impact of EU biofuel policy (Valin et al., 2015). In this study, ILUC emissions for all biodiesel pathways were estimated to be very high – so high that rapeseed or sunflower biodiesel produced at a typical biorefinery would not reduce GHG emissions at all compared to petroleum, and soybean and palm biodiesel would actually have a worse climate impact than fossil diesel (shown in the left three columns in Figure 4). Based on the detailed results presented in Valin et al. (2015), we estimate the approximate ILUC emissions that would be predicted using the modeling in that study if it is assumed that no substitution could occur between palm and other vegetable oils. We did this by estimating and subtracting the amount of emissions caused by peat drainage, deforestation, and other land use changes associated with palm expansion. We then added land use change emissions to compensate for other crops that would be grown instead of that amount of palm oil, assuming the average land use change emissions for all other types of agricultural expansion for that pathway. Our estimates for "no palm substitution" ILUC emissions are shown in the three columns on the right side of Figure 4. The direct emissions in this figure are for "typical facilities" in the European Commission (2016).

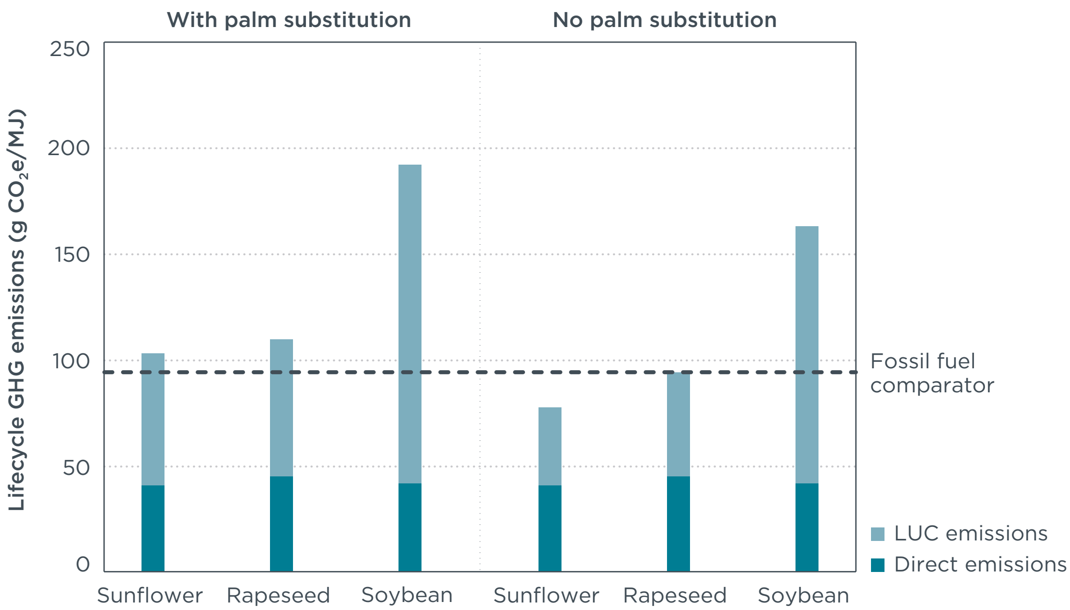

Figure 4: Lifecycle GHG emissions of EU biodiesel pathways with and without palm substitution. Estimated from results in Valin et al. (2015).

We estimate that if Valin et al. (2015) had not allowed palm oil substitution, the land use change emissions would be around 40% lower for sunflower biodiesel, 25% lower for rapeseed biodiesel, and 20% lower for soybean biodiesel. This amount is enough to change our understanding of the climate impacts of these biofuels. For example, if we believed that no palm oil substitution could occur, sunflower biodiesel would offer modest GHG savings compared to petroleum, but accounting for palm oil substitution leads to a result that is higher than fossil diesel for a typical biodiesel facility.

Valin et al. (2015) does not assume a particularly high degree of vegetable oil substitution compared to other ILUC modeling studies. An earlier study commissioned by the European Commission using the MIRAGE model assumed a much higher elasticity of substitution for all world regions outside the U.S. (Laborde, 2011). Both Laborde (2011) and Valin et al. (2015) assume an emission factor for peat drainage substantially lower than that recommended by a comprehensive review study (Page et al., 2011). If Valin et al. (2015) had assumed a similar elasticity of substitution as Laborde (2011) and the peat emission factor recommended by Page et al. (2011), the land use change emissions due to palm oil substitution would be much higher than what is shown in Figure 4.

Other ILUC modeling studies have assumed weaker substitution effects. In the U.S. Environmental Protection Agency's (EPA's) ILUC analysis for the Renewable Fuel Standard, soybean biodiesel demand results in fairly low expansion of oil palm. Only 3% of gross land expansion is new oil palm plantations in this scenario, while 9% is rapeseed expansion and 73% is soybean expansion (EPA, 2010). As a comparison, Valin et al. (2015) assumes that 12% of land expansion for soybean biodiesel demand is caused by oil palm plantations and 6% of land expansion for rapeseed biodiesel demand is for palm. EPA's assumption that an increase in soybean oil price will lead to a strong increase in soybean area is counter to the result in Santeramo (2017) that soybean oil price has only a weak effect on soybean oil supply, and is surprising given that soybean oil represents a minority of the total value of soybeans.

There is another lesson from examining the results in Figure 4: even if no palm oil substitution occurred, ILUC emissions for EU biodiesel feedstocks would still be very high. For typical biodiesel facilities, sunflower biodiesel would offer only around a 20% GHG savings compared to petroleum, while rapeseed biodiesel would have a similar climate impact to fossil diesel and soybean biodiesel would still be far worse. While there is compelling evidence of vegetable oil substitution, it is important to remember that regardless of this question, ILUC emissions substantially limit the climate benefits that can be expected from policies that support food-based biofuels.

REFERENCES

European Biodiesel Board. (2017). Statistics: The EU biodiesel industry. http://www.ebb-eu.org/stats.php

European Commission. (2016). Proposal for a Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources (recast). COM(2016) 767 final/2. https://ec.europa.eu/energy/sites/ener/files/documents/1_en_act_part1_v7_1.pdf

FAOSTAT. (2017). Food and Agricultural Organization of the United Nations. http://www.fao.org/faostat/en/#home

Heuzé V., Tran G., Sauvant D., Lessire M., & Lebas F. (2017). Rapeseed meal. Feedipedia, a programme by INRA, CIRAD, AFZ and FAO. http://www.feedipedia.org/node/52

Indexmundi. (2017). Monthly prices for commodities. http://www.indexmundi.com

Laborde, D. (2011). Assessing the land use change consequences of European biofuel policies. Report commissioned by the European Commission: Contract No SI2. 580403. http://trade.ec.europa.eu/doclib/docs/2011/october/tradoc_148289.pdf

Malins, C., Searle, S., & Baral, A. (2014). A guide for the perplexed to the indirect effects of biofuel production. Washington, DC: International Council on Clean Transportation. http://www.theicct.org/sites/default/files/publications/ICCT_A-Guide-for-the-Perplexed_Sept2014.pdf

Miettinen, J., Hooijer, A., Tollenaar, D., Page, S., Malins, C., Vernimmen, R., Shi, C., & Liew, S. C. (2012). Historical analysis and projection of oil palm plantation expansion on peatland in Southeast Asia. Washington, DC: International Council on Clean Transportation. http://www.theicct.org/sites/default/files/publications/ICCT_palm-expansion_Feb2012.pdf

Page, S. E., Morrison, R., Malins, C., Hooijer, A., Rieley, J. O., & Jauhainen, J. (2011). Review of peat surface greenhouse gas emissions from oil palm plantations in Southeast Asia. Washington, DC: International Council on Clean Transportation. http://www.theicct.org/review-peat-surface-greenhouse-gas-emissions-oil-palm-plantations-southeast-asia

Purcell, L. C., Salmeron, M., & Ashlock, L. (2000). Chapter 19: Soybean facts [PDF]. Arkansas Soybean Production Handbook – MP197. Little Rock, AR: University of Arkansas Cooperative Extension Service. p. 1.

Roberts, M., & Schlenker. W. (2013). Identifying supply and demand elasticities of agricultural commodities: Implications for the US ethanol mandate. *American Economic Review 103*(6), 2265–2695.

Santeramo, F. (2017). Cross-price elasticities for oils and fats in the US and the EU. Report commissioned by the International Council on Clean Transportation. Washington, DC: ICCT. http://www.theicct.org/sites/default/files/publications/Cross-price-elasticities-for-oils-fats-US-EU_ICCT_consultant-report_06032017.pdf

U.S. Department of Agriculture (USDA). (2017). Oil crops yearbook. https://www.ers.usda.gov/data-products/oil-crops-yearbook

U.S. Department of Agriculture Foreign Agricultural Service (USDA FAS). (2017). Oilseeds: World markets and trade. https://apps.fas.usda.gov/psdonline/circulars/oilseeds.pdf

U.S. Energy Information Administration (EIA). (2017). Monthly biodiesel production reports. https://www.eia.gov/biofuels/biodiesel/production

U.S. Environmental Protection Agency (EPA). (2010). Renewable Fuel Standard Program (RFS2) regulatory impact analysis. Washington, DC: U.S. EPA. https://www.epa.gov/sites/production/files/2015-08/documents/420r10006.pdf

Valin, H., Peters, D., van den Berg, M., Frank, S., Havlik, P., Forsell, N., & Hamelinck, C. (2015). The land use change impact of biofuels consumed in the EU: Quantification of area and greenhouse gas impacts. Report commissioned by the European Commission: Project number: BIENL13120. https://ec.europa.eu/energy/sites/ener/files/documents/Final%20Report_GLOBIOM_publication.pdf