057750/EU XXVI.GP
Eingelangt am 13/03/19

EUROPEAN
COMMISSION

Brussels, 13.3.2019
COM(2019) 142 final

REPORT FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS

on the status of production expansion of relevant food and feed crops worldwide

Contents

I. INTRODUCTION

The new Renewable Energy Directive[1] ("REDII" or the "Directive") entered into force on 24 December 2018[2]. This Directive promotes the development of renewable energy in the next decade through an EU-wide renewable energy binding target of at least 32% by 2030, to be achieved collectively by Member States. In order to do so, the Directive includes a number of sectoral measures promoting further deployment of renewables in the electricity, heating and cooling and transport sectors, with the overall aim of contributing to reducing greenhouse gas (GHG) emissions, improving energy security, reinforcing Europe's technological and industrial leadership in renewable energy and creating jobs and growth.

The Directive also reinforces the EU sustainability framework for bioenergy, in order to ensure robust GHG emission savings and minimize unintended environmental impacts. In particular, it introduces a new approach to address emissions from indirect land-use change ("ILUC") associated with the production of biofuels, bioliquids and biomass fuels. To this end, the Directive sets national limits, which will gradually decrease to zero by 2030 at the latest, for high ILUC-risk biofuels, bioliquids and biomass fuels ("high ILUC-risk fuels") produced from food or feed crops for which a significant expansion of the production area into land with high carbon stock is observed. These limits will affect the amount of these fuels that can be taken into account when calculating the overall national share of renewables and the share of renewables in transport. However, the Directive introduces an exemption from these limits for biofuels, bioliquids and biomass fuels that are certified as low ILUC-risk.

In this context, the Directive requires the Commission to adopt a delegated act setting out criteria both for (i) determining the high ILUC-risk feedstock for which a significant expansion of the production area into land with high carbon stock is observed and (ii) certifying low ILUC-risk biofuels, bioliquids and biomass fuels ("low ILUC-risk fuels"). The delegated act is due to accompany the present report (the "report") on the status of production expansion of relevant food and feed crops worldwide. This report provides information linked to the criteria set out in the above-mentioned delegated act in order to identify high ILUC-risk fuels from food or feed crops with a significant expansion into land with high carbon stock and low ILUC-risk fuels. Section 2 of this report describes the EU policy developments to address the ILUC impacts. Section 3 reviews the latest data on the status of production expansion of relevant food and feed crops worldwide. Sections 4 and 5 describe the approach for determining high ILUC-risk fuels from food or feed crops with a significant expansion into land with high carbon stock and for certifying low-ILUC fuels, respectively.

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[1] Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources.

[2] Member States need to transpose its provisions into national law by 30 June 2021.

II. EU LEGAL FRAMEWORK ON BIOFUELS, BIOLIQUIDS AND BIOMASS FUELS

The transport sector is particularly challenging from an energy and climate perspective: it consumes around one third of EU's total energy demand, is almost entirely dependent on fossil fuels and its GHG emissions are increasing. To address these challenges, in the early 2000s, EU legislation[3] at that time already required Member States to set indicative national targets for biofuels and other renewable fuels in transport, since, because of technological advances, the engines of most vehicles in circulation in the Union at that time were already adapted to run on fuels containing a low biofuel blend. Biofuels were the only available renewable energy source to start decarbonising the transport sector, in which CO_2 emissions were expected to rise by 50% between 1990 and 2010.

The 2009 Renewable Energy Directive[4] ("RED") has further promoted the decarbonisation of the transport sector by setting a specific 10% binding target for renewable energy in transport by 2020. According to reported data and estimates, renewable energy made up around 7 % of all final energy consumption in transport in 2017. With renewable electricity, biogas and advanced feedstock currently playing only a small role in transport, the bulk of renewable energy use in this sector comes from conventional biofuels[5].

Furthermore, RED sets out binding greenhouse gas saving and sustainability criteria with which biofuels[6] and bioliquids, as defined in this Directive, need to comply in order to be counted towards the national and EU renewables targets and to qualify for public support schemes. These criteria define no-go areas (principally land with high carbon stock or high biodiversity) that cannot be the source of the raw material used for producing biofuels and bioliquids, and set out minimum GHG emission saving requirements to be achieved by biofuels and bioliquids compared to fossil fuels. These criteria have contributed towards limiting the risk of direct land use impacts associated with the production of conventional biofuels and bioliquids, but they do not address indirect impacts.

ILUC associated with conventional biofuels

Indirect impacts can occur when pasture or agricultural land previously destined for food and feed markets is diverted to the production of fuels from biomass. The food and feed demand will still need to be satisfied either through intensification of current production or by bringing non-agricultural land into production elsewhere. In the latter case, ILUC (conversion of non-agricultural land into agricultural land to produce food or feed) can lead to GHG emissions[7], especially when it affects land with high carbon stock such as forests, wetlands and peat land. These GHG emissions, which are not captured under the

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[3] Directive 2003/30/EC of the European Parliament and of the Council of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport

[4] Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC

[5] Biofuels produced from food or feed crops.

[6] The definition of 'biofuels' in RED includes both gaseous and liquid biomass fuels used in transport. This is no longer the case in REDII, where 'biofuels' is defined as including only liquid biomass fuels used in transport.

[7] The CO_2 stored in trees and soil is released when forests are cut down and peatlands are drained

GHG saving criteria set out in RED, can be significant, and could negate some or all of the GHG emission savings of individual biofuels[8]. This is because almost the entire biofuel production in 2020 is expected to come from crops grown on land that could be used to satisfy food and feed markets.

However, ILUC cannot be observed or measured. Modelling is required to estimate the potential impacts. Such modelling has a number of limitations, but nevertheless, it is robust enough to show the risk of ILUC associated with conventional biofuels. Against this background, the 2015 ILUC Directive[9] adopted a precautionary approach to minimise the overall ILUC impact by setting a limit to the share of conventional biofuels[10] and bioliquids that can be counted towards the national renewable energy targets and the 10% renewable transport target. This measure is accompanied by an obligation for each Member State to set an indicative target for advanced renewable fuels with a reference value of 0.5% for 2020, in order to incentivise the transition towards such fuels, which are considered to have lower or no ILUC impacts.

In addition, the ILUC Directive includes ILUC factors for different categories of food and feed based feedstock. These factors indicate the emissions from ILUC associated with the production of conventional biofuels and bioliquids and are to be used by fuel suppliers for reporting purposes, but not to calculate GHG emissions savings from biofuel production.

Addressing ILUC through REDII

REDII takes a more targeted approach to reduce ILUC impacts associated with conventional biofuels, bioliquids and biomass fuels[11]. Since ILUC emissions cannot be measured with the level of precision required to be included in the EU GHG emission calculation methodology, it keeps the approach of having a limit on the amount of conventional biofuels, bioliquids, and biomass fuels[12] consumed in transport that can be taken into account when calculating the national overall share of renewable energy and the sectoral share in transport. However, this limit is expressed in the form of national caps that correspond to the existing levels of these fuels in each Member State in 2020.

Some flexibility is allowed as these national limits may be further increased by one percentage point, but an overall maximum is kept so that they cannot exceed 7% of the 2020 final consumption of energy in road and rail transport. Furthermore, Member States may set a lower limit for biofuels, bioliquids and biomass fuels which are associated with a high risk of ILUC, such as fuels produced from oil crops.

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[8] SWD(2012) 343 final

[9] Directive (EU) 2015/1513 of the European Parliament and of the Council of 9 September 2015 amending Directive 98/70/EC relating to the quality of petrol and diesel fuels and amending Directive 2009/28/EC on the promotion of the use of energy from renewable sources

[10] "Biofuels" as defined in RED.

[11] "Biomass fuels" is a new term introduced in REDII, which defines these fuels as gaseous and solid fuels produced from biomass.

[12] Since the limitation only affects conventional biomass fuels consumed in transport, that is, in practice, gaseous fuels for transport (part of the definiton of biofuels in RED), there is no substantive change on the fuels covered by this limitation.

In parallel, the promotion of advanced biofuels and biogas is reinforced via a specific binding target of a minimum 3.5% share for 2030, with two intermediary milestones (0.2% in 2022 and 1% in 2025).

In addition, even if Member States can count conventional biofuels and biomass fuels to achieve the renewable target of 14% of energy consumption in the transport sector, they may also reduce the level of this target if they decide to account less of these fuels towards the target. If for instance a Member State decides not to count conventional biofuels and biomass fuels at all, the target could be reduced by the full maximum amount of 7%.

Furthermore, the Directive introduces an additional limit for biofuels, bioliquids and biomass fuels produced from food or feed crops for which a significant expansion of the production area into land with high carbon stock is observed as for biofuels, bioliquids and biomass fuels produced from those feedstock a high risk of ILUC is evident[13]. Given that the observed expansion into land with high carbon stock is the result of increased demand for crops, a further increase of the demand of such feedstock for the purpose of producing biofuels, bioliquids and biomass fuels can only be expected to aggravate the situation unless measures preventing displacement effects such as low ILUC certification are applied. Consequently, the contribution of such fuels towards the renewable transport target (and also for the calculation of the national overall share of renewable energy) will be limited as of 2021 to the level of consumption of these fuels in 2019. As of 31 December 2023, their contribution will have to be gradually reduced down to 0% by 2030 at the latest.

The Directive however makes it possible to exclude biofuels, bioliquids and biomass fuels produced from that feedstock from that limit, provided that they are certified as low ILUC-risk. This certification is possible for feedstock for biofuels, bioliquids and biomass fuels that are produced under circumstances that avoid ILUC effects, by virtue of having been cultivated on unused land or emanating from crops which benefited from improved agricultural practices as further specified in this report.

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[13] It is important to note that the observed expansion of the production area into land with high carbon stock does not constitute direct land use change in the meaning of the Renewable Energy Directive. The expansion is rather the consequence of increased demand for crops from all sectors. Direct land use change of land with high carbon stock for producing biofuels, bioliquids and biomass fuels is prohibited by of the EU sustainability criteria.

III. IDENTIFYING BIOFUEL, BIOLIQUIDS AND BIOMASS FUELS FEEDSTOCK WITH HIGH ILUC-RISK

Setting the criteria for determining high ILUC-risk feedstock for which a significant expansion of the production area into land with high carbon stock is observed includes two tasks:

1. identifying the expansion of feedstock used for producing biofuels, bioliquids and biomass fuels into land with high-carbon stock; and
2. defining what a 'significant' feedstock expansion is.

For this purpose, the Commission has carried out extensive research and public consultation, including:

- a review of the relevant scientific literature;
- an global assessment based on GIS (Geographic Information System) data; and
- a wide consultation through a number of meetings with experts and stakeholders who provided the Commission with valuable input that was taken into account in the preparation of this Report and the related Delegated Act.

III.1 Global expansion in agriculture commodities

Over the past decades, growing world population and higher standards of living have led to increasing demand for food, feed, energy and fibre from the earth's ecosystems. This expanded demand has led to an increased need for agricultural commodities globally, a trend that is expected to continue in the future[14]. The increased use of biofuels in the EU has contributed to this existing demand for agricultural commodities.

This report aims to capture the global trends in expansion of biofuel relevant feedstocks observed since 2008. This date was chosen to ensure policy coherence with the cut-off dates for the protection of highly biodiverse land and land with high carbon stock set out in Article 29 of the Directive.

As shown in Table 1, over the period 2008-2016, the production of all major agricultural commodities that are used for the production of conventional biofuels increased, with the exception of barley and rye. Growth of production was particularly pronounced for palm oil, soybean and maize, which is also reflected in the data on the harvested areas. Increase in production of wheat, sunflower, rapeseed and sugar beet were mostly achieved by increasing productivity.

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[14] JRC report 2017: "Report Challenges of Global Agriculture in a Climate Change Context by 2050".

	Total production 2008 ktonnes	Annual net increase of production 2008 to 2016 (%)	Harvested area 2008 kha	Annual net increase of harvested area 2008 to 2016 (kha)	Annual net increase of harvested area 2008 to 2016 (%)
Cereals					
Wheat	680.954	1,2%	222.360	-263	-0,1%
Maize	829.240	3,6%	163.143	4028	2,3%
Barely	153.808	-0,7%	55.105	-931	-1,8%
Rye	18.083	-3,7%	6.745	-283	-5,0%
Sugar crops					
Sugar cane	1.721.252	1,0%	24.139	300	1,2%
Sugar beet	221.199	2,8%	4.262	39	0,9%
Oil crops					
Rapeseed	56.873	2,3%	30.093	302	1,0%
Palm oil	41.447	5,1%	15.369	703	4,0%
Soybean	231.148	4,8%	96.380	3184	3,0%
Sunflower	36.296	3,4%	25.324	127	0,5%

Table 1: Global production expansion of main biofuel feedstock (2008-2016); source: own calculation based on data from FAOstat and USDA-FAS

Typically agriculture demand increases can be met through yield increases and expansion of agricultural land. In a situation where both suitable agricultural land availability and potential yield increases are limited, increased demand for agricultural crops becomes the basic driver for deforestation. Some other key factors, such as achieving maximum profit from the production and complying with related legislation in place, are also likely to play a role in determining how the increased demand is to be met and to which extent it causes deforestation.

III.2 Estimating feedstock expansion into high carbon stock land

Due to growing global demand for agricultural commodities, part of the demand for biofuels has been met through an expansion of land devoted to agriculture worldwide. When this expansion takes place in land with high-carbon stock, it can result in significant GHG emissions and severe loss of biodiversity. In order to estimate the expansion of the relevant feedstock into carbon-rich land (as defined in RED II), the Joint Research Centre (JRC) of the European Commission has carried out a review of the relevant scientific literature (see Annex I), complemented by a global GIS-based assessment (see Annex II).

Review of the scientific literature

The review of the scientific literature on the expansion of production areas of agricultural commodities into high carbon-stock land has found that no single study provides results for all feedstocks that are used for the production of biofuels, bioliquids and biomass fuels. Instead, studies typically focus on specific regions and specific crops, overwhelmingly on soy and palm oil, while data is very sparse for other crops. Furthermore, different studies not only report on different periods for crop expansion, but also have a different approach on the time delay occurring between deforestation and crop expansion. Therefore, studies that consider the land-cover only during one or two years before crop planting will attribute less deforestation to a crop than those that consider the land-cover since an earlier period. This can lead to an underestimation of the deforestation impact of a crop because, even if deforested areas are not immediately used for crop production, the final aim to use the land for crop production may be one of the most important drivers for deforestation. Whenever possible, the results of these regional studies were combined to derive a global estimate of expansion for each individual crop, as summarized below.

Soybean

Given the lack of studies providing recent data on a global scale, data were combined from studies and databases from Brazil, other South American countries and the rest of the world. For Brazil, data on soy expansion since 2008 was taken from the Brazilian IBGE-SIDRA database and combined with data on expansion into forest areas in the Cerrado [Gibbs et al. 2015], averaging for the period 2009-13 in the Amazon [Richards et al. 2017] and the rest of Brazil [Agroicone 2018]. [Graesser et al. 2015] provides data for crop expansion onto forest in other Latin American countries. For the rest of the world, in the countries showing the greatest soy expansions since 2008, i.e. India, Ukraine, Russia and Canada, few concerns for soy cultivation causing direct deforestation could be found in the literature. Therefore, a share of 2% expansion onto forests was assumed for the rest of the world. As a result, the world average fraction of soy expansion onto high-carbon land was estimated at 8%.

Palm oil

Using sampling of palm oil plantations in satellite data, [Vijay et al. 2016] estimated the fraction of palm oil expansion onto forest from 1989 to 2013, and reported results by country. Setting those national averages in relation to the increases in national harvested area of palm oil in 2008 to 2016, globally 45% of palm oil expansion was onto land that was forest in 1989. Adding confidence to this result is the observation that its results for Indonesia and Malaysia are within the range of the findings of other studies that concentrated on these regions. The supplementary data of [Henders et al. 2015] allocated for the 2008-11 period an average of 0.43 Mha/y of observed deforestation to palm oil expansion. This also represents 45% of the estimated increase in world planted area of palm oil in that period[15]. Several studies have also analysied the fraction of palm oil expansion onto peatland. Placing the most weight on the results of [Miettinen et al. 2012, 2016], which can be considered the most advanced study in this area, and assuming zero peatland drainage for palm in the rest of the world, gives an interpolated weighted average estimate of 23% expansion of palm oil onto peat for the whole world between 2008 and 2011.

Sugar cane

More than 80% of global sugar cane expansion took place in Brazil from 2008 to 2015. [Adami et al. 2012] reported that only 0.6% of sugar cane expansion in the Centre-South of Brazil went onto forest between 2000 and 2009. Although the region accounted for about 90% of world sugar cane expansion in that time period, there was some expansion

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[15] Harvested area data is available for all countries. However, it is smaller than planted area because immature palm trees do not bear fruit. However, the ratio of increase in planted area to harvested area also depends on the area-fraction of immature palms from replanting. Planted area increases were found in national statistics of Indonesia and Malaysia, and combined with adjusted harvested area increases for the rest of the world.

in other regions of Brazil not covered by this study. [Sparovek et al. 2008] agreed that in 1996-2006 sugar cane expansion in the Brazilian Centre-South was almost entirely onto pasture or other crops; however, another 27% of expansion occurred in "peripheral" areas around and inside the Amazon biome, in the Northeast and in the Atlantic Forest biome. In those peripheral regions, there was a correlation between forest loss per municipality and sugar cane expansion. However, no figures on the share of expansion onto forest is given in the paper. As a result no adequate quantification of deforestation by sugar cane could be derived from the literature

Maize

Cereals like maize are not usually thought of as causing deforestation, because most production occurs in temperate zones where deforestation is generally modest. At the same time, maize is also a tropical crop, often grown by smallholders, and also often rotated with soybeans on large farms. The expansion in China was concentrated onto marginal land in the North-East of the country [Hansen 2017], which one supposes to be mostly steppe grasslands rather than forest. The expansion in Brazil and Argentina could be assigned the same % deforestation as soy in Brazil. [Lark et al. 2015] found that, of US maize expansion between 2008 and 2012, 3% was at the expense of forest, 8% shrubland and 2% wetlands. However, no global estimates of land conversion were found in the literature.

Other crops

There is very little data for other crops, especially on a global scale. The only data sets for the expansion of crops that cover the whole world only gives results by country [FAO 2018][USDA 2018]. A possible approach is therefore to correlate crop expansion at a national level with deforestation at a national level [Cuypers et al. 2013], [Malins 2018], but this cannot be considered as sufficient evidence to link a crop to deforestation as the crop in question might not be grown in the part of the country where the deforestation takes place.

As a result of the critical review of the scientific literature, it can be concluded that the best-estimates for the fraction of recent expansion onto high-carbon forested land include 8% for soy and 45% for oil-palm. There was not enough data in the literature to provide robust estimates for other crops.

GIS-based assessment of feedstock expansion into carbon-rich areas

With the view to address all biofuel relevant crops consistently, the literature review was complemented by a global GIS-based assessment of biofuel relevant feedstock expansion into carbon-rich areas, based on data from the World Resource Institute (WRI) and the Sustainability Consortium at Arkansas University (see Box 1).

Box 1: Methodology of the global GIS assessment

To observe the deforestation associated with the expansion of all biofuel-relevant crops since 2008, the methodology applied uses a geospatial modelling approach that combines a deforestation map from Global Forest Watch (GFW) with crop and pasture maps from MapSPAM and EarthStat. This approach covers the expansion of all relevant food and feed crops since 2008 into areas with a tree canopy cover higher than 10 percent. The pixel size was approximately 100 hectares at the equator. Peatland extent was defined using the same maps as [Miettinen et al. 2016]. For Sumatra and Kalimantan, [Miettinen et al. 2016] included peat from the Wetlands International 1:700,000 peatland atlases [Wahyunto et al. 2003, Wahyunto et al. 2004].

The analysis only considered pixels where commodity crops were the dominant cause of deforestation according to the recent map developed by [Curtis et al. 2018]. This map was overlaid on those showing the production areas of the biofuel-relevant crops of interest. Total deforestation and emissions within a given 1-kilometer100-ha pixel were allocated to different biofuel crops in proportion to the area of the crop of interest compared to the total area of agricultural land in the pixel, defined as the sum of cropland and pasture land. In this way, each biofuel crop's relative contribution to the pixel's total agricultural footprint served as the basis for allocating the deforestation inside the same pixel. For more information on the methodology followed see Annex 2.

Table 2 below summarizes the results of the GIS-based assessment, indicating a large difference between biofuel-relevant feedstocks with regard to the extent in which their expansion is associated with deforestation. Between 2008-2015, data shows that the production areas of sunflower, sugar beet and rapeseed have been expanding only slowly, and only an insignificant share of the expansion has taken place in land with high-carbon stock. In cases of maize, wheat, sugar cane and soybean, the total expansion has been more pronounced, but the shares of extension into forest fall short of 5% for each feedstock. In contrast, for palm oil the analysis showed both the highest speed of overall land expansion and the highest share of expansion into forestland (70%). Palm oil is also the only crop where a large share of expansion takes place on peatland (18%).

The results of the GIS-based assessment appear to be in line with the general trends observed in the scientific literature reviewed for this report. In the case of palm oil, the estimated share of expansion into forest is at the higher end of the findings reported in scientific literature, which indicates a high share of expansion into forest, typically in the range of 40-50%. One possible explanation for the difference is the time lag between the removal of the forest and the cultivation of palm trees[16].

Under REDII all areas that were forest in January 2008 count as deforested areas if they are used for the production of biofuel feedstock, independently of the date the actual cultivation of the feedstock starts. This provision was taken into account in the GIS-

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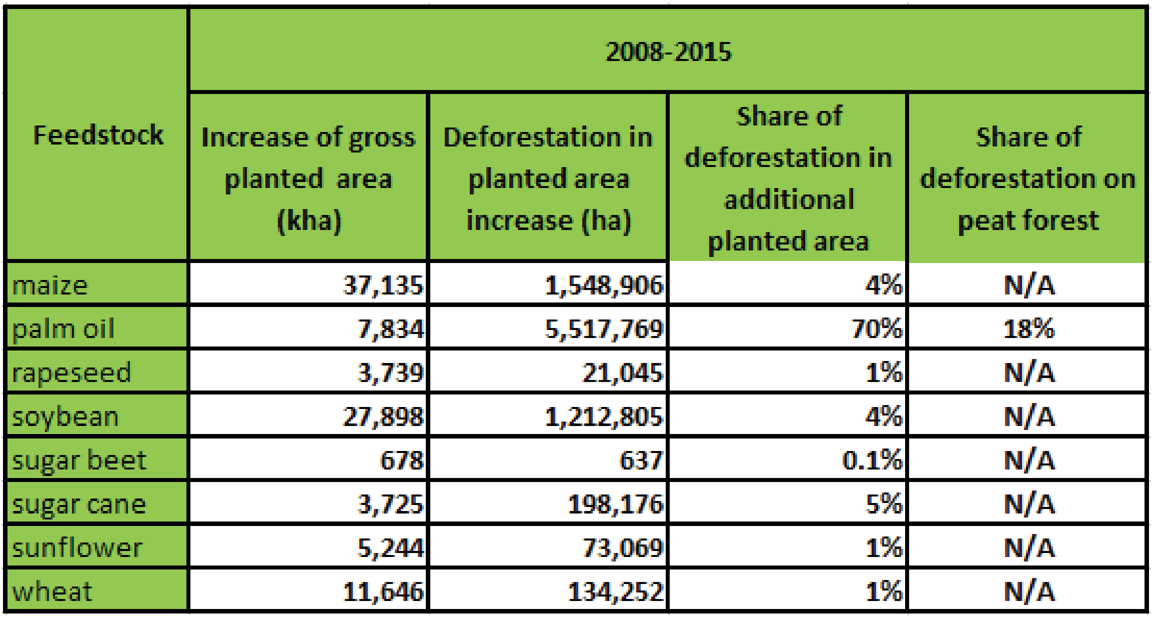
[16] Compared to the data from the literature, the GIS assessment ascribes less deforestation to crops that immediately follow forest clearance, but more to crops that may also be local drivers of deforestation, but are often planted several years after forest clearance which is in line with the approach taken by the REDII sustainability criteria..

based assessment, while most regional studies consider a shorter time delay between deforestation and planting of palm trees. On the other hand, the share of expansion into peatland derived from the analysis is broadly in line with the estimates found in the scientific literature. Therefore, the more conservative estimates of 45% as the world-average share of palm oil expansion into forestland and of 23% share of expansion of production area on peatland can be considered best available scientific evidence.

The GIS-based estimated land conversion figure of 4% for soy is lower than the combined estimates based on regional literature, which amount to 8%. This variation can be explained by the fact that the regional literature uses local data, complemented by expert judgement, on which crop directly follows deforestation in a particular pixel, which is impractical to apply at the global scale of the GIS-based assessment. For this reason, the estimate of 8% share of soy expansion on forestland derived from the regional literature can be considered reflecting the best available scientific data.



Feedstock	2008-2015			
	Increase of gross planted area (kha)	Deforestation in planted area increase (ha)	Share of deforestation in additional planted area	Share of deforestation on peat forest
maize	37,135	1,548,906	4%	N/A
palm oil	7,834	5,517,769	70%	18%
rapeseed	3,739	21,045	1%	N/A
soybean	27,898	1,212,805	4%	N/A
sugar beet	678	637	0.1%	N/A
sugar cane	3,725	198,176	5%	N/A
sunflower	5,244	73,069	1%	N/A
wheat	11,646	134,252	1%	N/A

Table 2: Observed expansion of the planted areas[17] of food and feed crops (from FAO and USDA statistics), and associated to deforestation based on the GIS-assessment.

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[17] The gross increase in planted area is the sum of expansion in all countires where the area did not shrink. For annual crops the cropped areas are approximated to harvest area; for multiannual crops allowance was made for the area of immature crops.

ILUC risks associated to food and feed-based biofuels

The findings of GIS-based research presented above are in line with the results of ILUC modelling, which has consistently identified oil crops used for biofuel production such as palm oil, rapeseed, soy and sunflower to be associated to a higher risk of ILUC, compared to other conventional fuels feedstock such as sugar or starch-rich crops. This trend has been further confirmed by a recent review of global ILUC science[18].

Furthermore, Annex VIII of REDII includes a list of provisional estimated ILUC emissions factors, where oil crops have approximately four times higher ILUC factor than other types of crops. Consequently, Article 26 (1) of RED II allows Member States to set a lower limit for the share of biofuels, bioliquids and biomass fuels produced from food and feed crops, with a specific reference to oil crops. Still, given the uncertainty about ILUC modelling, it is at this stage more appropriate to abstain from distinguishing between different categories of crops such starch-rich crops, sugar crops and oil crops when setting the criteria for determining the ILUC-risk fuels produced from food or feed crops for which a significant expansion of the production area into land with high carbon stock is observed.

III.3 Determining 'significant' expansion into high carbon stock land

According to the mandate of REDII, the Commission is required to determine what constitutes a 'significant' expansion of a relevant feedstock into high carbon stock land with the aim to ensure that all biofuels that count towards the 2030 renewable energy target achieve net GHG emission savings (in comparison with fossil fuels). For this purpose, three factors play a crucial role in determining the 'significance' of the land expansion: the absolute and relevant magnitude of the land expansion since a specific year, compared to the total production area of the relevant crop; the share of this expansion into land with high carbon stock; and, the type of relevant crops and of the areas with high-carbon stock.

The first factor verifies whether a given feedstock is actually expanding into new areas. For this purpose, it is necessary to consider both the average annual absolute increase in the production area (i.e. 100,000 ha reflecting a sizable expansion), and the relative increase (i.e. 1% to reflect an average annual productivity increase), compared to the total production area of that feedstock. This double threshold allows to exclude feedstock for which no, or only very limited, expansion of the total production area is observed (mainly because production increases are generated by improving yields rather than area expansion). Such feedstock would not cause significant deforestation and, therefore, high GHG emissions from ILUC. This is the case, for instance, of sunflower oil, since in the period 2008-2016 its production area expanded by less than 100,000 ha and by 0.5% per year, while its total production increased by 3.4% anually over the same period.

For crops exceeding these land expansion thresholds, the second decisive element is the share of the production expansion into land with high-carbon stock. Such a share determines whether, and to which degree, biofuels can achieve GHG emission savings. In a situation where the GHG emissions from the expansion of this feedstock into land with

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[18] Woltjer, et al 2017: Analysis of the latest available scientific research and evidence on ILUC greenhouse gas emissions associated with production of biofuels and bioliquids

high-carbon stock are higher than the direct GHG emission savings of biofuels from a certain type of feedstock, the production of such biofuels will not lead to GHG emissions savings compared to fossil fuels.

Under REDII, biofuels are required to reduce GHG emissions by at least 50% compared to fossil fuels[19], based on a life cycle analysis that covers all direct emissions, but not indirect emissions. As discussed in Box 2, biofuels produced from crops exceeding a general threshold of 14% of production expansion into high-carbon stock land would not achieve emission savings. Following the precautionary principle, it appears appropriate to apply a discount factor of about 30% to the identified level. Therefore a more conservative threshold of 10% is required to guarantee both that biofuels achieve net sizable GHG emission savings and that biodiversity loss associated to ILUC is minimized.

Third, in determining what constitutes ‘significant’ expansion, it is important to take into account the considerable differences in the type of high-carbon stock areas and in the type of feedstock considered.

For instance, peatlands need to be drained to establish and maintain a palm oil plantation. The decomposition of peat leads to significant CO_2 emissions, the release of which continues as long as the plantation is in production and the peatland is not re-wetted. Over the first 20 years after drainage, these CO_2 emissions cumulate to about three times the emissions assumed above for the deforestation of the same area. Accordingly, this important impact should be considered when calculating the significance of emissions from high-carbon stock land, e.g. through a multiplier of 2.6 for expansion into peatland[20]. Furthermore, permanent crops (palm and sugar cane), as well as maize and sugar beet have significantly higher yield, in terms of energy-content-of-traded-products[21], than assumed above for calculation of the 14% threshold[22]. These are considered via the the "productivity factor" in Box 3.

In conclusion, Box 3 provides the choosen formula to calculate wheather a biofuel relevant feedstock is above or below the identified 10% threshold of significant expansion. This formula takes into account the share of the feedstock expansion into high carbon stock areas as defined under REDII, and the productivity factor of different feedstock.

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[19] Stricter greenhouse gas emission savings criteria apply for biofuels produced in installations that started operation after 5 October 2015 and also biofuels produced in old installations often achieve higher savings.

[20] The C loss from peat drainage over 20 years is estimated to be about 2.6 times the estimated net carbon loss from converting forest to oil-palm on mineral soil (107 tonnes per hectare).

[21] In analogy to the approach applied by RED II for cultivation emissions, emissions from land use change have been allocated to all traded products from the crop (for example vegetable oil and oilseed-meal, but not crop residues) in proportion to their energy content

[22] Considering the average yields for 2008-15 in the top ten exporting countries (weighted by exports), the yields of this set of crops are higher than the “reference” 55 GJ/ha/y by a factor 1.7 for maize, 2.5 for palm oil, 3.2 for sugar beet, and factor 2.2 for sugar cane.

Box 2: The impact of indirect land use change on biofuel GHG emission savings

If land with high stocks of carbon in its soil or vegetation is converted for the cultivation of raw materials for biofuels, some of the stored carbon will generally be released into the atmosphere, leading to the formation of carbon dioxide (CO_2). The resulting negative greenhouse gas impact can offset the positive greenhouse gas impact of the biofuels or bioliquids, in some cases by a wide margin.

The full carbon effects of such conversion should therefore be taken into consideration for the purpose of indentifying the level of significant feedstock expansion into land with high carbon stock resulting from biofuel demand. This is necessary to ensure that biofuels lead to greenhouse gas emission saving. Using the results of the GIS assessment, the average net loss of carbon stock when biofuel feedstock replaces land with high carbon stock[23] can be estimated in about 107 tonnes of carbon (C) per hectare[24]. Spread over 20 years[25],' that amount is equivalent to a yearly emission of 19.6 tons of CO_2 per hectare.

It should be noted that the GHG emissions savings also depend on the energy content of the feedstock produced on the land each year. For annual crops, except maize and sugar beet, the energy-yield can be estimated at about 55 GJ/ha/y[26]. By combining both figures one can estimate the land use change emissions associated to biofuels production on deforested land at around 360 gCO_2/MJ. By comparison, the emissions savings resulting from replacing fossil fuel with biofuels produced from these crops can be quantified in about 52 gCO_2/MJ[27].

Given these assumptions, it can be estimated that the land use change emissions will negate the direct GHG savings resulting from fossil fuel replacement when biofuel crop expansion into land with high-carbon stock reaches a share of 14% (52 gCO_2/MJ / 360 gCO_2/MJ=0.14).

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[23] Wetlands (including peatlands), continuously forested areas and forested areas with 10-30% canopy cover. The land is categorised based on its status in 2008. Areas with 10-30% canopy cover are not protected if biofuels produced from feedstock cultivated on the land after its conversion can still comply with the greenhouse gas emission savings criteria, which can expected to be the case for perennial crops.

[24] The emissions from rainforest, which is usually selectively logged by the time it is converted to oil-palm, is considerably higher on average, but this is partly compensated by the higher standing carbon stock of the plantation itself. The net changes also take into account carbon stored in below-ground biomass and the soil.

[25] 20 years is already established as the amortization time for calculating emissions from declared direct land use changes in RED.

[26] The energy yield comprises the energy (LHV) in both the biofuel and the by-products considered in calculating default values for energy savings in annex V of the Directive. The yield considered is the average for 2008-15 in the top ten exporting countries (weighted by exports).

[27] Biofuels typically save more than the required minimum emissions savings of 50%. For the purpose of this calculationan average of 55% savings is assumed.

Box 3: Formula for calculating the share of expansion into land with high-carbon stock

$$x_{hcs} = \frac{x_f + 2{,}6x_p}{PF}$$

where

x_{hcs} = share of expansion into land with high-carbon stock;

x_f = share of expansion into land referred to in Article 29(4)(b) and (c) of RED II[28];

x_p = share of expansion into land referred to in Article 29(4)(a) of RED II[29];

PF = productivity factor.

PF shall be 1.7 for maize, 2.5 for palm oil, 3,2 for sugar beet, 2.2 for sugar cane and 1 for all other crops.[30].

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[28] Continuously forested areas.

[29] Wetlands, including peatland.

[30] The values of PF are crop specific and were calculated based on the yields achieved in the top ten exporting countries (weighted by their export share). Palm oil, sugar cane, sugar beet and maize have a considerably higher value than the other crops considered, and are therefore granted dedicated "productivity factors" of 2.5, 2.2 3.2 and 1.7 respectively, whereas the other crops can be roughly assumed to have a standard productivity factor of 1.

IV. CERTIFYING LOW ILUC-RISK BIOFUELS, BIOLIQUIDS AND BIOMASS FUELS

Under certain circumstances, the ILUC impacts of biofuels, bioliquids and biomass fuels generally considered as high ILUC-risk can be avoided and the cultivation of the related feedstock can even prove to be beneficial for the relevant production areas. As described in the section 2, the root cause of ILUC is the additional demand for feedstock resulting from increased consumption of conventional biofuels. This displacement effect can be avoided by certified low-ILUC risk biofuels.

Preventing land displacement through additionality measures

Low ILUC-risk biofuels are fuels produced from additional feedstock that has been grown on unused land or that is the result of a productivity increase. Producing biofuels from such additional feedstock will not cause ILUC because that feedstock is not in competition with food and feed production and displacement effects are avoided. As required by the Directive, such additional feedstock should qualify as low-ILUC risk fuel only if it is produced in a sustainable manner.

To fulfil the objective of low ILUC–risk concept, strict criteria are needed that effectively encourage best practice and avoid windfall gains. At the same time, measures need to be implementable in practice and avoid excessive administrative burden. The revised Directive identifies two sources for additional feedstock that can be used for production of low ILUC risk-fuels. These are feedstock resulting from applying measures increasing agriculture productivity on the already used land and feedstock resulting from cultivating crops on areas which were previously not used for cultivation of crops.

Ensuring additionality beyond business as usual

Average increases in productivity are still not sufficient to avoid all risks of displacement effects, though, because agricultural productivity is constantly improving while the concept of additionality, which is at the heart of the low ILUC certification, requires taking measures going beyond business as usual. Against this background, REDII stipulates that only productivity increases that go beyond the expected level of increase should be eligible.

For this purpose, it is necessary to both analyse whether the measure is going beyond common practice at the time it is implemented as well as to limit the eligibility of measures to a reasonable period that allows economic operators to recuperate investments costs and ensures the continued effectiveness of the framework. A time limit for the eligibility of 10 years is appropriate for this purpose[31]. Furthermore, realised productivity increases should be compared with a dynamic baseline taking into account global trends in crop yields. This refects that some yield improvements are achieved over time due to technological development anyway (e.g. more productive seeds) without the active intervention of the farmer.

However, in order to be implementable and verifiable in practice the approach applied to determine the dynamic baseline must be robust and simple. For this reason, the dynamic baseline should be based on the combination between the average yields achieved by the

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[31] Ecofys (2016) Methodologies identification and certification of low ILUC risk biofuels.

farmer over the 3-year period preceding the year of the application of the additionality measure and the long-time trend in yields observed for the feedstock concerned.

Eligibility of additional feedstock resulting from measures increasing productivity or cultivating feedstock on unused land should be limited to cases which are really additional compared to business as usual. The most accepted framework to assess the ‘additionality’ of projects is the Clean Development Mechanism (CDM) developed under the Kyoto protocol (see Box 4). It should be noted that the CDM focuses on industrial projects, therefore its approach cannot be replicated in its entirety, but its requirements regarding investment and barrier analsysis are relevant for certifying low ILUC-risk biofuels. The application of such requirements to the low ILUC certification would mean that measures for increasing productivity or for cultivating feedstock on previously unused land would not be financially attractive or would face other barriers preventing their implementation (e.g. skills/technology etc.) without the market premium associated to the EU biofuel demand[32].

Box 4: Additionality under the the Clean Development Mechanism

The CDM allows emission-reduction projects in developing countries to earn certified emission reduction (CER) credits, each equivalent to one tonne of CO_2. These CERs can be traded and sold, and used by industrialized countries to a meet a part of their emission reduction targets under the Kyoto Protocol.

Under the CDM a comprehensive set of methodologies was developed including rules to ensure additionality of a project[33] . The additionality check includes four steps.

Step 1 Identification of alternatives to the project activity;

Step 2 Investment analysis;

Step 3 Barriers analysis;

Step 4 Common practice analysis.

For the purposes of certifying low ILUC-risk biofuels verifying compliance with Step 2 and 3 are sufficient given that the scope of measures that are eligible for production of feedstock for low ILUC-risk biofuels is clearly described in RED II and that the repetition of the same kind of productivity increasing measures is intended by the legislation.

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[32] Under REDII, biofuels produced from high ILUC-risk feedstock will be gradually phased out by 2030 unless certified as low-ILUC risk. Low-ILUC risk biofuel, bioliquids or biomass fuel will therefore likely be able to obtain a higher market value.

[33] https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-01-v5.2.pdf/history_view.

Guaranteeing robust compliance verification and auditing

Demonstrating compliance with this criterion requires an in-depth assessment that might not be warranted under certain circumstances and could represent a barrier for the successful implementation of the approach. Smallholders[34], particularly in developing countries, for instance, will often lack the administrative capacity and knowledge to conduct such assessments while evidently facing barriers that hinder the implementation of productivity-increasing measures. Similarly, additionality can be assumed for projects using abandoned or severely degraded land as this situation of the land already reflects the existence of barriers that are preventing its cultivation.

It can be expected that voluntary schemes, which have gathered an extensive experience in the implementation of the sustainability criteria for biofuels across the globe, will play a key role in the implementation of the low ILUC certification methodology. The Commission has already recognised 13 voluntary schemes for demonstrating compliance with the sustainability and GHG emission savings criteria. Its empowerment to recognise the schemes has been extended under REDII to cover also low ILUC-risk fuels.

To ensure robust and harmonised implementation, the Commission will set out further technical rules regarding concrete verification and auditing approaches in an Implementing Act in line with Article 30(8) of the REDII. The Commission will adopt this implementing act by 30 June 2021 at the latest. Voluntary schemes can certify low-ILUC risk fuels, developing their own standards individually, as they do for the purpose of certifying compliance with the sustainability criteria and the Commission can recognise such schemes in line with the provisions set out in REDII.

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[34] An estimated 84% of the world’s farms are managed by small holders cultivating less than 2 ha of land. Lowder, S.K., Skoet, J., Raney, T., 2016. The number, size, and distribution of farms, smallholder farms, and family farms worldwide. World Dev. 87, 16–29.

V. CONCLUSIONS

Growing global demand for food and feed crops is requiring the agricultural sector to constantly increase production. This is achieved by both increasing yields and by an expansion of the agricultural area. If the latter takes place into land with high-carbon stock or highly biodiverse habitats, this process can result in negative ILUC impacts.

Against this background, REDII limits the contribution of conventional biofuels, bioliquids and biomass fuels consumed in transport towards the Union 2030 renewable energy target. In addition, the contribution of high ILUC-risk biofuels, bioliquids and biomass fuels will be limited at 2019 levels starting from 2020, and then gradually reduced to zero between 2023 and 2030 at the latest.

According to the best available scientific evidence on agriculture expansion since 2008, presented in this report, palm oil is currently the only feedstock where the expansion of production area into land with high carbon stock is so pronounced that the resulting GHG emissions from land use change eliminate all GHG emission savings of fuels produced from this feedstock in comparison to the use of fossil fuels. Palm oil, hence, qualifies as high ILUC-risk feedstock for which a significant expansion into land with high-carbon stock is observed.

It is important to note, however, that not all palm oil feedstock used for bioenergy production has detrimental ILUC impacts in the meaning set out in Article 26 of REDII. Some production could, therefore, be considered as low ILUC risk. In order to identify such production, two types of measures are available, *i.e.* increasing productivity on existing land and cultivation of feedstock on unused land, such as abandoned land, or severely degraded land. These measures are key to prevent that biofuel, bioliquids and biomass fuels production enters into competition with the need of meeting the increasing food and feed demand. The Directive excludes all certified low-ILUC risk fuels from the gradual phase-out. Criteria for certifying low ILUC-risk fuels could effectively mitigate displacement effects associated to the demand of these fuels if only the additional feedstock used for the production of biofuels, bioliquids and biomass fuels is taken into account.

The Commission will continue to assess the developments in the agricultural sector, including the status of expansion of agricultural areas, based on new scientific evidence, and gather experience in the certification of low ILUC-risk fuels when preparing the review of this report, that will be carried out by 30 June 2021. Thereafter, the Commission will review the data included in the report in light of evolving circumstances and latest available scientific evidence. It is important to recall that this report only reflects the current situation based on recent trends and future assessments may come to different conclusions on which feedstocks are classified as high ILUC-risk depending on the future development of the global agricultural sector.

EUROPEAN
COMMISSION

Brussels, 13.3.2019
COM(2019) 142 final

ANNEXES 1 to 2

ANNEXES

to the

REPORT FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS

on the status of production expansion of relevant food and feed crops worldwide

ANNEX 1

REVIEW OF THE LITERATURE ON EXPANSION OF CROPS ONTO HIGH CARBON LAND

Scope

This review undertaken by the Commission's Joint Research Centre gives an overview and summarizes the most relevant results of the scientific literature on the expansion of production areas of agricultural commodities into high carbon-stock land, as defined in RED II.

Soybean

There is only one peer-reviewed study that estimates deforestation caused by soybean on a global scale covering a time-frame that includes deforestation after 2008. [Henders et al. 2015] started with GIS-based measurements of year-by-year deforestation in all tropical regions, and allocated it to different drivers, including soy and palm oil expansion, according to a comprehensive review of the regional literature (the review is detailed in their Supplementary Information). However, their data only cover the period 2000-2011.

JRC estimate of percentage deforestation in Brazilian soy expansion

	Amazon	Cerrado	rest of Brazil
% of Brazilian soy expansion 2008-17	11%	46%	44%
% of expansion on forest	5%	14%	3%
BRAZIL WEIGHTED AVERAGE of expansion on forest	8.2%		

Given the lack of studies providing recent data on a global scale, data were combined from Brazil, other South American countries and the rest of the world. For Brazil, data on soy expansion since 2008 was taken from the Brazilian IBGE-SIDRA database and combined with data on expansion into forest areas in the Cerrado [Gibbs et al. 2015], averaging for the period 2009-13 in the Amazon [Richards et al][1] and the rest of Brazil [Agroicone 2018]. It resulted in a weighted average of expansion into forests of 10.4%: This was combined with the numbers from Argentina, Paraguay, Uruguay and Bolivia and the rest of the world, as follows:

JRC estimate of Latin America average percentage of soy expansion onto forest					
2008-2017	Brazil	Argentina	Paraguay	Uruguay	Bolivia
% of Latin American soy expansion	67%	19%	7%	5%	2%
% onto forest	8.2%	9%	57%	1%	60%
Latin America Average % onto forest	**14%**				
ESTIMATE OF WORLD AVERAGE % OF SOY EXPANSION ONTO FOREST					
Fraction of world soy expansion in Latin America	53%				
Assumed % expansion onto forest in rest of the world	2%				
World average fraction of soy expansion onto forest	**8%**				

For other Latin American countries, the only quantitative data found is [Graesser et al. 2015], who measured the expansion of all arable crops onto forest. For the rest of the world, where the greatest soy expansions since 2008 have been observed, i.e. India, Ukraine, Russia and Canada, little evidence for soy cultivation causing direct deforestation could be found. Therefore, a low share of 2% expansion onto forests was assumed for the rest of the world. As a result, the world average fraction of soy expansion was estimated at 8%.

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[1] According to [Gibbs et al. 2015, fig.1] the average percentage of soy expansion on forest in the Amazon from 2009-2013 was ~2.2%. 2008 data are not included as the Brazilain Government's Plan for Preventing and Controlling Deforestation in the Amazon (PPCDAa) Brazil forest law, which was followed by a dramatic reduction in Amazon deforestation, was not yet enforced. The estimate of [Gibbs et al. 2015] used the official PRODES deforestation database, which was also used to monitor the compliance with the PPCDAa law. However, [Richards et al.2017] observed that since 2008, the PRODES database has diverged increasingly from other indicators of forest loss. This is the result of it being used to enforce the law: deforesters have learnt to deforest small patches or in areas that are not monitored by the PRODES system. Using data from the alternative GFC forest monitoring database, [Richards et al.2017] show (in their Supplementary information) that since 2008 PRODES underestimates deforestation by an average factor of 2.3 compared to the GFC database. Data from forest fires confirms the GFC year-on-year variations in deforestation area, and not those seen by PRODES.

Comparison with other recent reviews

Most of the data on deforestation by soy pre-dates the Brazilian soy moratorium of 2008, and are therefore not relevant to the present estimate.

A review commissioned by Transport and Environment [Malins 2018] contains a careful review of regional data on soy expansion and deforestation concluding that *at least* 7% of global soy expansion since 2008 was on forest. However, different years were used for the soy expansion fractions and data and results from [Agricone 2018] and [Richards et al 2017] were not used.

A review commissioned by Sofiproteol [LCAworks 2018] also includes a review of the regional literature on deforestation by soy in the world from 2006-2016. It concludes that 19% of global soy expansion has been onto forest. However, the source of their assumption concering the expansion onto forest in “rest of Brazil” is unclear, and they have sometimes elided “natural land” with forest. Furthermore, when calculating averages, they weight the regional soy data by the total regional production of soy rather than the area of its expansion. Therefore, the number of 19% cannot be considered to be very robust.

Agroicone prepared a document for the Commission which cites unpublished 2018 work by Agrosatelite showing a huge reduction in the fraction of forest in soy expansion in the Cerrado (especially in the Matipoba part) in 2014-17, from 23% in 2007-14 to 8% in 2014-17.

Palm oil

Using sampling of palm oil plantations in satellite data, [Vijay et al. 2016] estimated the fraction of palm oil expansion onto forest from 1989 to 2013, and reported results by country. When setting those national averages in relation to the increases in national harvested area of palm oil in 2008 to 2016, the study derived that, globally, **45%** of palm oil expansion was onto land that was forest in 1989.

The supplementary data of [Henders et al. 2015] allocated for the 2008-11 period an average of 0.43 Mha/y of observed deforestation to palm oil expansion. This represents **45%** of the estimated increase in world planted area of palm oil in that period[2].

In a global study for the European Commission, [Cuypers et al. 2013] attributed measured deforestation to different drivers, such as logging, grazing, and various crops, at a national level. Their results imply that 59% of oil-palm expansion was linked to deforestation between 1990 and 2008.

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[2] Harvested area data is available for all countries. However, it is smaller than planted area because immature palm trees do not bear fruit. However, the ratio of *increase* in planted area to harvested area also depends on the area-fraction of immature palms from replanting. Planted area increases were found in national statistics of Indonesia and Malaysia, and combined with adjusted harvested area increases for the rest of the world.

Comparison of regional studies for Indonesia and Malaysia

Estimated percentage of expansion onto forest

	years	Malaysia		Indonesia		ROW
% of world palm expansion 2008-15	2008-15	15%		67%		17%
		Peninsula Malaysia	Malaysian Borneo	Indonesian Borneo	Rest of Indonesia	
% of **national** expansion 2008-15	2008-15	19%	81%	77%	23%	
Gaveau et al. 2016	2010-15		75%	42%		
Abood et al 2015	2000-10			>36%		
SARvision 2011	2005-10		52%			
Carlson et al. 2013	2000-10			70%		
Gunarso et al. 2013	2005-10	>6%				
Gunarso et al. 2013	2005-10	47%		37-75%		
Austin et al. 2017	2005-15			>20%		
Vijay et al. 2016	2013	40%		54%		13%
Vijay et al. 2016	2013	45%				

[Abood et al. 2015] found that 1.6 million hectares of deforestation in Indonesia between 2000 and 2010 took place inside concessions granted to industrial palm oil producers. That is 36% of the total expansion of planted palm oil area in that period, according to Indonesian Government figures.

For the same period, [Carlson et al. 2013] estimated a greater % of deforestation: 1.7 Mha of forest loss in palm oil concessions in Indonesian Borneo; about 70% of the harvested area expansion in that region [Malins 2018]. In a later paper, [Carlson et al. 2018] report 1.84 Mha forest loss in palm oil concessions in Indonesian Borneo and 0.55 Mha in Sumatra, for the period 2000-2015.

[SARvision 2011] found that from 2005 to 2010, 865 thousand hectares of forest were cleared inside the boundaries of known palm oil concessions in Sarawak, the Malaysian province in Borneo where most palm oil expansion takes place. This corresponds to about half of the increase in palm oil harvested area in that time[3].

[Gaveau et al. 2016] mapped the overlap of deforestation with expansion of industrial (i.e. not smallholder) palm oil plantations in Borneo, over 5-year intervals from 1990 to 2015. They point out that the great majority of palm oil plantations in Borneo were forest in 1973; lower fractions of deforestation come about when one restricts the delay time between clearance and planting of palm oil. Their results show that for industrial palm oil plantations in Indonesian Borneo, ~42% of the expansion from 2010 to 2015 was onto land that was forest only five years earlier; for Malaysian Borneo the figure was ~75%. The assessment applied a more restricted definition of forest than RED2 considering only forest with >90% canopy cover, and excluding secondary forest (i.e. re-grown forest and shrub after historical clearance or fire).

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[3] *Planted*-area data for that region and time period could not be found.

In a later paper, [Gaveau et al. 2018] show for the period 2008-17, that in Indonesian Borneo, 36% of the expansion of industrial plantations (88% of which were palm oil) was onto old-growth forest cleared the same year, whilst in Malaysian Borneo the average was 69%. In Indonesian Borneo, the rate of deforestation by plantations in different years correlated very strongly with the price of crude palm oil in the previous season, whereas in Malaysian Borneo the correlation was weaker, suggesting longer-term centralized planning of deforestation. The results showed that the rate of palm oil expansion has declined since its peak in 2009-12 while the fraction of it that occurs on forest remained stable.

[Gunarso et al 2013] analysed land cover change linked to oil-palm expansion in Indonesia and Malaysia for the Roundtable on Sustainable Palm Oil (RSPO). The most recent changes they report refer to areas of palm oil that were planted between 2005 and 2010. They show the % of this area that was under various land use categories in 2005. Adding the categories that would *unequivocally* meet the definition of forest in the Directive, a minimum of 37% was obtained for the expansion onto forest for all Indonesia. However, other land use categories reported includes scrubland (which is principally degraded forest, according to the paper), and this would generally also meet the Directive's definition of forest. This is a large category in Indonesia, as forest near plantations is often degraded by wildfires years before the plantation expands onto that land. Counting these prior land-use types as forest (as they may have been in year 2000), raises the total % deforestation for Indonesia 2005-10 to about 75%, confirming approximately the findings of [Carlson 2013].

For Malaysia, [Gunarso et al 2013] report that from 2006-10, 34% of palm oil expansion was directly onto forest. However, they also reported considerable expansion onto "bare soil" in 2006, and supposed that some of that was bare because it was being converted from forest. From their supplementary information, it can be seen that over a third of the bare soil in 2006 was forest six years earlier, indicating that it is likely to have been areas of forest cleared ready for planting. Including these forest areas would push the fraction of deforestation-linked palm oil expansion up to 47% in Malaysia.

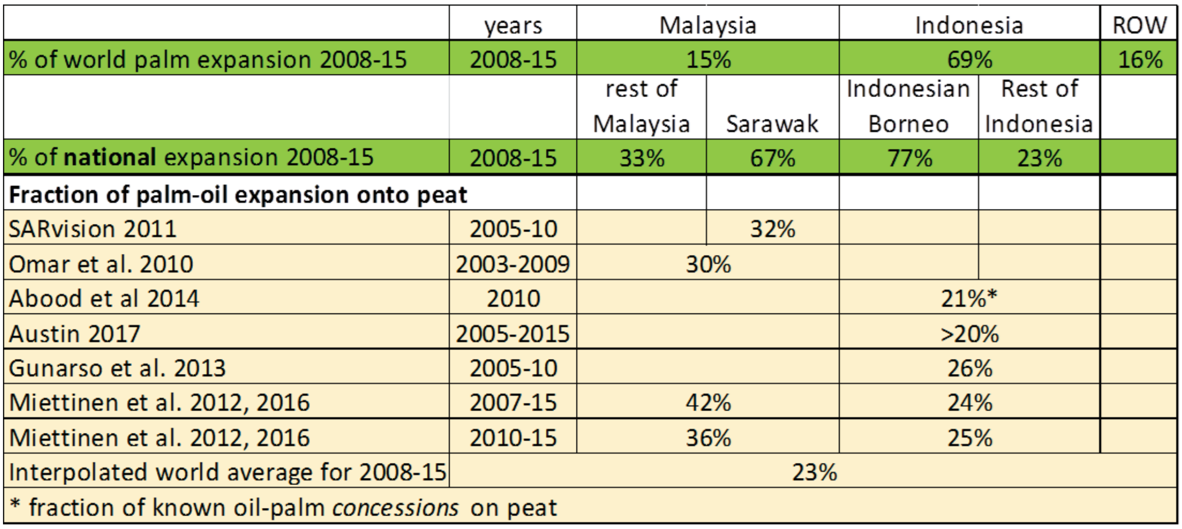
Instead of using satellite images to identify the previous land-cover where Indonesian palm oil plantations expanded, [Austin et al. 2017] referred to land-use maps issued by the Indonesian Ministry of Environment and Forestry. They found that only about 20% of the land used for the expansion of industrial palm oil in 2005-15 had been classified as "forest" on those maps five years before. Their definition of forest specifies >30% canopy cover (instead of >10% in the Directive), and does not include scrub, which would sometimes qualify as forest under the definition of the Directive. A further 40% of the palm oil expansion occurred on land-use categories that included scrub. For these reasons, it is considered that [Austin et al 2017]'s figure of 20% expansion onto forest in 2010-2015 is likely to be an underestimate for the purpose of this report.

JRC estimate of percentage of palm oil expansion onto forest for rest-of-the-world				
	year of expansion	Latin America	Africa	rest Asia
% of world palm oil expansion 2008-15	2008-15	9%	3%	5%
Furumo and Aide 2017	2001-15	20%		
Maaijard et al. 2018			6%	
Vijay et al. 2016	2013	21%	6%	4%
weighted average for ROW	2013	13%		

As shown in the table, lower shares of expansion into forest are reported for the rest of the world. Weighting the results for Latin America, Africa and the rest of Asia (excluding Indonesia and Malysia) an average share of expansion of palm oil plantations into forest of 13% was derived.

Overall, taking into account the results from the regional studies on palm oil expansion into high-carbon stock land in Malysia and Indonesia and evidence for such expansion in the rest of the world the world-average share of palm oil expansion onto forest of 45% proposed by [Vijay et al 2016] can be considered a good estimate.

Fraction of oil-palm expansion onto peat



	years	Malaysia		Indonesia		ROW
% of world palm expansion 2008-15	2008-15	15%		69%		16%
		rest of Malaysia	Sarawak	Indonesian Borneo	Rest of Indonesia	
% of **national** expansion 2008-15	2008-15	33%	67%	77%	23%	
Fraction of palm-oil expansion onto peat						
SARvision 2011	2005-10		32%			
Omar et al. 2010	2003-2009	30%				
Abood et al 2014	2010			21%*		
Austin 2017	2005-2015			>20%		
Gunarso et al. 2013	2005-10			26%		
Miettinen et al. 2012, 2016	2007-15	42%		24%		
Miettinen et al. 2012, 2016	2010-15	36%		25%		
Interpolated world average for 2008-15	23%					
* fraction of known oil-palm *concessions* on peat						

[Abood et al. 2014] found that 21% of known Indonesian palm oil concessions were located over peatlands, and 10% over deep peat (>3 metres), which is supposed to be protected from drainage under a 1990 Indonesian government decree. From 2000-2010, they reported 535 kha of peat-swamp forest were lost on Indonesian palm oil concessions, which is 33% of the palm oil expansion on concessions.

[Miettinen et al. 2012, 2016] analysed high-resolution satellite images to track the spread of mature palm oil plantations onto peatland at times between 1990 and 2015. They used the JRC's European Digital Archive of Soil Maps to identify peat areas and report that between

2007 and 2015 palm oil plantations expanded 1089 kha onto Indonesian peatland and 436 kha onto Malaysian peatland. Dividing by the increase in mature palm oil area in that time period[4], gives a share of 24% palm oil expansion onto peat in Indonesia, and 42% in Malaysia. For the latest period they report, 2010-2015, the corresponding figures are 25% and 36%.

The Malaysian Palm Oil Board published a study of palm oil [Omar et al. 2010], based on GIS identification of palm oil cultivation, and a soil map from the Malaysian Ministry of Agriculture. They report that the percentage of palm cultivation on peat in Malaysia grew from 8.2% in 2003 to 13.3% in 2009, corresponding to 313 and 666 kha respectively. In the same period, their data show the total area of palm oil expanded from 3813 to 5011 kha, so the fraction of that expansion that was on peat was 30%.

[SARvision 2011] found that from 2005 to 2010, 535 thousand hectares of peat-forest were cleared inside the boundaries of known palm oil concessions in Sarawak, the Malaysian province where most palm oil expansion takes place. This corresponds to about 32% of the increase in palm oil harvested area in that time[5]. This misses peat-forest loss for palm oil outside concession boundaries, and any conversion of peatland that was not forested at the time of conversion.

[Gunarso et al. 2013] report an anomalously low fraction of palm oil expansion on peat in Malaysia (only 6% between 2000 and 2010, according to their supplementary information). This is far below any other estimate, even from the Malaysian sources, so it was discounted[6].

For Indonesia, [Gunarso et al. 2013]'s supplementary data show 24% of palm oil expansion between 2005 and 2010 was onto peat-swamp, and this only rises to ~26% if the conversion from peat swamp via "bare soil"are included.

[Austin et al. 2017] report that the fraction of Indonesian palm oil expansion onto peat remained at ~20% for all the time-periods they studied (1995-2015), without any correction for "bare soil". The reason why Austin's results are lower than others is the use of the "BBSDLP[7]" peat map from the Indonesian Ministry of Agriculture (H. Valin, private communication, 5 December 2018). The BBSDLP map does not include areas with less than 0.5 m depth of peat[8], and this is partly why it shows 13.5% less peat area than maps from Wetlands International, which themselves probably underestimate peat area by about 10-13%, according to ground surveys. [Hooijer and Vernimmen 2013].

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[4] Miettinen et al only counted mature palm areas, so in this case it is appropriate to divide by mature palm area rather than total planted area. Data from US Department of Agriculture Foreign Agricultural Service on "harvested area" was used, which in fact refer to "mature planted area", and have been checked against other data such as oil-palm seedling sales. Data from FAO are less useful because, for example, they reflect temporary reductions in harvested area in 2014/15 due to flooding in Malaysia.

[5] *Planted*-area data for that area and time period could not be found.

[6] [Gunarso et al. 2013] hint at an explanation: they only identified planting on peat if the land was wet peat-swamp five years before; if it was already drained, it became another land-use type, such as "bare soil". Converting swamp to palm oil requires not only tree clearance but also the construction of a dense network of drainage channels, and soil compaction, which prolongs the time before oil-palm trees can be identified on satellite pictures. Thus, whereas in Peninsula Malaysia (with little peatland) no oil-palm expanded onto bare soil in 2005-10, in Sarawak, 37% expansion was onto "bare soil". Furthermore, there is a high rate of conversion from peat-swamp to "agroforestry and plantations", and then from "agroforestry and plantations" to oil-palm in successive 5-year periods, so in addition perhaps early-stage oil-palm plantations were mistaken for agroforestry or plantations of other crops.

[7] BBSDLP is the Indonesian Center for Research and Development of Agricultural Land Resources.

[8] 0.5m of tropical peat contains about 250-300 tonnes of carbon per hectare, which will almost all be released in the first decade after drainage.

Quantitative data for the fraction of palm expansion onto peatland in the rest of the world is not available. From 2008-15, 9% of palm oil expansion was in Latin America, 5% in the rest of Asia and 3% in Africa. There are considerable areas of tropical peat in South America, especially in Peru, Bolivia, Venezuela and along the Amazon, but these are not significant production areas of palm oil. However, the world's largest tropical peat swamp is in the Congo basin. There, already at least one huge palm oil concession, of 470 kha (e.g. 10% of the entire area of palm oil in Malaysia), has been granted, and it lies 89% on peat [Dargie et al. 2018]. The fear is that as production growth in SE Asian countries slows, more investment will flow into developing palm oil on peatlands in Africa and Latin America.

Placing the most weight on the results of [Miettinen et al. 2012, 2016], which can be considered as the most advanced pieces of scientific literature, and assuming zero peatland drainage for palm in the rest of the world, gives an interpolated weighted average estimate of 23% expansion of palm oil onto peat for the whole world between 2008 and 2011.

Sugar cane

More than 80% of global sugar cane expansion took place in Brazil from 2008 to 2015.

[Cuypers et al. 2013] estimated that 36% of world sugar cane expansion between 1990 and 2008 was onto land that was previously forest. However, that is likely an over-estimate for the purposes of the analysis: deforestation was allocated between forestry, expansion of pasture, and expansion of different crops, at *national scale*. Little deforestation was attributed to pasture land, because it hardly showed any *net* expansion; by contrast, sugar cane expanded greatly and therefore received a high allocation of the national deforestation. However, the *regions* of Brazil where sugar cane expanded mostly do not overlap with areas of high deforestation, and this was not considered in the analysis of [Cuypers et al. 2013].

[Adami et al. 2012] reported that only 0.6% of sugar cane expansion in the Centre-South of Brazil went onto forest between 2000 and 2009. Although the region accounted for about 90% of world sugar cane expansion in that time period, there was some expansion in other regions of Brazil not covered by this study.

[Sparovek et al. 2008] agreed that in 1996-2006 sugar cane expansion in the Brazilian Centre-South was almost entirely onto pasture or other crops (as there is very little forest left in that region); however, another 27% of expansion occurred in "peripheral" areas around and inside the Amazon biome, in the Northeast and in the Atlantic Forest biome. In these peripheral regions, there was a correlation between forest loss per municipality and sugar cane expansion. However, no figures on the share of expansion onto forest are given in the paper.

As a result no adequate quantification of deforestation by sugar cane could be derived from the literature.

Maize

Cereals are not usually thought of as causing deforestation, because most production is in temperate zones where deforestation is generally modest. However, maize is also a tropical crop, often grown by smallholders, and also often rotated with soybeans on large farms. And a disproportionate part of maize expansion happens in tropical regions where deforestation is more common and carbon-intensive.

% of world maize harvested area expansion 2010-15	
China	29.8%
Brazil	11.6%
Angola	10.5%
Nigeria	9.8%
Argentina	8.9%
Russian Federation	7.0%
Mali	3.1%
Mexico	1.7%
Cameroon	1.6%
other (mostly developing) countries	16%
WEIGHTED AVERAGE YIELD 2010-15 (t/ha)	3.935

The expansion in China was concentrated onto marginal land in the North-East of the country [Hansen 2017], which one supposes to be mostly steppe grasslands rather than forest. The expansion in Brazil and Argentina could be assigned the same % deforestation as soy in Brazil.[Lark et al. 2015] found that, of US maize expansion between 2008 and 2012, 3% was at the expense of forest, 8% shrubland and 2% wetlands. Nevertherless, it is difficult to make a global estimate without looking into detail at what is happening in each country.

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ANNEX 2

GIS ANALYSIS

1.

Method

In order to estimate deforestation and related emissions associated with the expansion of biofuel crops since 2008 into areas with a tree canopy cover density greater than 10 %, a geospatial modelling approach was used to combine a deforestation map from Global Forest Watch (GFW) with crop type maps from MapSPAM and EarthStat. Further details of the approach are summarized below, and data sources used in the analysis are listed in the Table below. The analysis was undertaken using a pixel size of approximately 100 hectares at the equator.

Data Sources

Crop Data

At present, globally consistent maps showing the expansion of all individual biofuel crops through time are not available, although research is ongoing to achieve this for palm oil and soybean through the interpretation of satellite imagery. For this analysis, we relied on two sources for single-year, single-crop maps: MapSPAM (IFPRI and IIASA 2016), which captures the global distribution of 42 crops in the year 2005[9], and EarthStat (Ramankutty et al. 2008), which maps crop and pasture areas in the year 2000. Both sources of crop data result from approaches that combine a variety of spatially-explicit input data to make plausible estimates of global crop distribution. Data inputs include production statistics at the scale of administrative (subnational) units, various land cover maps produced from satellite imagery, and crop suitability maps created based on local landscape, climate and soil conditions.

Given the lack of up-to-date global maps for individual crops as well as the lack of consistent information about their expansion through time, a major assumption used in our analysis is that total deforestation and associated GHG emissions occurring within an area since 2008 can be allocated to a specific crop based on each crop's proportional area relative to the total agricultural land area, including pasture, present in the same pixel of the crop map.

Deforestation Data

Published maps of global annual tree cover loss derived from Landsat satellite observations, available on Global Forest Watch for years 2001 through 2017, formed the basis of our deforestation analysis. The tree cover loss data are available at a 30-meter resolution, or a pixel size of 0.09 hectares. The original tree cover loss data of Hansen et al. (2013) do not distinguish permanent conversion (i.e., deforestation) from temporary loss of tree cover due to forestry or wildfire. Therefore, for this analysis we included only the subset of tree cover loss pixels that fell within areas dominated by commodity-driven deforestation, as mapped at a 10-kilometer resolution by Curtis et al. (2018)[10]. Thus areas where other drivers, such as forestry or shifting agriculture, are dominant were excluded from analysis. Within the commodity-driven deforestation class, only pixels with a percent tree cover above 10 percent were

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[9] Updated MapSPAM data for the year 2010 were released on January 4, 2019, just after this analysis was completed.

[10] Work is ongoing to update the Curtis et al. (2018) study to show dominant drivers for post 2015 tree cover loss years.

considered for analysis, with "percent tree cover" defined as the density of tree canopy coverage of the land surface in the year 2000. Given the specific criteria included in RED2 (see "b" and "c" in Background above), analysis results were disaggregated into deforestation for the years 2008 through 2015 for areas with greater than 30 percent tree cover and areas with 10-30 percent tree cover.

Curtis et al. (2018) point out that multiple forest loss drivers may be present within a landscape at any given time, and the dominant driver may vary in different years during the 15-year study period; their model assigned only one dominant driver that contributed to the majority of tree cover loss within that landscape during the study period. One assumption used in this analysis was that all tree cover loss within areas dominated by commodity-driven deforestation was for the expansion of new agricultural areas. This assumption would tend to over-estimate the effect of commodity-crops in those pixels. On the other hand, agriculture may also be expanding in areas dominated by shifting agriculture or forestry; other classes from the Curtis et al. (2018) map that were excluded from our analysis. This implies that the method could under-estimate the deforestation due to crops. However, the footprint areas of the nine crops included in this analysis fell primarily into the commodity-driven deforestation class, and therefore crop areas outside this class were assumed to have small area ratios (see Crop Allocation Model section below) and therefore the contribution of these areas to the final totals should be small.

Peatland Data

Peatland extent was defined using the same maps as Miettinen et al. 2016, who mapped changes in land cover from 1990 to 2015 in the peatlands of Peninsular Malaysia, Sumatra and Borneo. For Sumatra and Kalimantan, Miettinen et al. (2016) included peat from the Wetlands International 1:700,000 peatland atlases (Wahyunto et al. 2003, Wahyunto et al. 2004), where peat was defined as follows: "soil formed from the accumulation over a long period of time of organic matter such as the remains of plants". Peat soil is generally waterlogged or flooded all year long unless drained." As outlined in Wahyunto and Suryadiputra (2008), the peatland atlases in turn compiled data from a variety of sources which primarily used imagery (satellite, radar, and aerial photography data), as well as survey and soil mapping, to map peat distribution. For Malaysia, peat from the European Digital Archive of Soil Maps was used (Selvaradjou et al. 2005).

An analysis specific to deforestation from palm oil expansion in peat soils was undertaken due to the importance of peat in this biofuel crop's overall land use and GHG footprint. Using industrial palm oil expansion data from Miettinen et al. 2016, the area of tree cover loss that occurred before the year of known palm oil expansion from 2008 through 2015 was estimated.

GHG Emissions Data

Emissions from deforestation since the year 2008 were estimated as the loss of carbon from the aboveground biomass pool. Emissions are expressed in units of megatons of carbon dioxide (Mt CO_2).

Emissions from aboveground biomass loss were calculated by overlaying the map of tree cover loss (from 2008 through 2015) with a map of aboveground live woody biomass in the year 2000. The biomass map, produced by Woods Hole Research Center and derived from satellite and ground observations, is available on Global Forest Watch. All biomass loss was assumed to be "committed" emissions to the atmosphere upon clearing, although there are lag times associated with some causes of tree loss. Emissions are "gross" estimates rather than "net" estimates, meaning that the land use after clearing, and its associated carbon value, was not considered. The carbon fraction of aboveground biomass was assumed to be 0.5 (IPCC 2003) and carbon was converted to carbon dioxide using a conversion factor of 44/12, or 3.67. One advantage of using a pixel-based forest biomass map with continuous values, rather than assigning categorical carbon stock values to different land cover types (e.g., forest, shrubland, IPCC Tier 1 values, etc.) is that the data used for estimating biomass loss is completely independent of the choice of land cover map used to estimate land cover change.

Emissions associated with other carbon pools, such as belowground biomass (roots), dead wood, litter and soil carbon, including peat decomposition or fires, were excluded from the analysis.

Analysis Extent

The extent of the global analysis was defined by overlaying the commodity-driven deforestation map (Curtis et al. 2018) with the biofuel-relevant crops of interest (palm oil, coconut, wheat, rapeseed, maize, soybean, sugar beet, sunflower and sugar cane). Only pixels that were included in one of the nine crops of interest and that touched the commodity-driven deforestation class were considered in the analysis.

Crop Allocation Model

Total deforestation and emissions within a given 1-kilometer pixel were allocated to different biofuel crops of interest based on the proportion of each crop present in the pixel (“Crop X”, e.g. soy) relative to the total area of agricultural land in the pixel, defined here as the sum of cropland and pasture land. In this way, each biofuel crop’s relative contribution to the pixel’s total agricultural footprint served as the basis for allocating its associated deforestation and GHG emission footprint.

Because a single, globally consistent and up-to-date map of agricultural land disaggregated by crop type was not readily available, we applied a two-step process to approximate each biofuel crop of interest’s relative role in deforestation and emissions in a given location (Eq. 1). In the first step, we used crop data for the most recent year available (MapSPAM, Year 2005) to calculate the ratio of Crop X to total cropland within a pixel. In the second step, we used EarthStat data (Year 2000) to calculate the ratio of total cropland to total pasture+cropland within a pixel. (EarthStat data were used because MapSPAM does not include maps of pasture land, and the expansion of pasture land also plays a role in deforestation dynamics.) Combining these two steps made it possible to approximate the relative contribution of Crop X to the total agricultural footprint within a given pixel, albeit using different data sources from different time periods.

Equation 1:

$$\frac{MapSpam\ Crop\ X\ (2005)}{MapSPAM\ total\ crop\ area\ (2005)} \times \frac{Earthstat\ total\ crop\ area\ (2000)}{Earthstat\ total\ crop + pasture\ area\ (2000)} = \frac{Crop\ X}{crop + pasture}$$

Final Calculations

Once the crop allocation maps were created for each biofuel crop of interest, we multiplied the total deforestation and GHG emissions by the proportion of Crop X in each 1- kilometer pixel, and calculated global summary statistics disaggregated by deforestation and emissions occurring on land with greater than 30 percent tree canopy density and on land with 10-30 percent tree canopy density.

The GIS results show the deforestation observed during the 8 calendar years 2008 to 2015, which associated with different crops. To see what % of the crop expansion is associated with deforestation, the total area of deforestation during these years was divided by the corresponding increase in crop area. To take into account that a crop can still cause deforestation even when the overall global crop area declines but expands in some countries, the shares were calculated based on the *gross* increase in global crop area, which is the sum of the increases in crop area in countries where it did not shrink.

Further, data on harvested areas was adjusted to obtain information on planted areas: for annual crops, the increase in crop area was assumed to be the same as the increase in harvested area. For (semi-)permanent crops, the fraction of the crop area, which is not harvested because the plants have not yet reached maturity, was taken into account. Sugar cane needs to be replanted about every five years, but there are only four harvests, as it is still immature after the first year. Oil-palm is replanted about every 25 years and bears fruit in the last 22 years.

For most crops, the database [FAOstat 2008] was used, which shows the area harvested by calendar year. Only for palm oil, data from [USDA 2008] was chosen, because it reports data on all mature palm oil areas, including in years where harvesting was impeded by flooding. The database also includes more countries for this crop.

Table: Summary of Data Sources in WRI GIS-analysis.

Dataset	**Source**
Forest and Peat Extent	
Tree Cover 2000	Hansen et al. 2013
Peatlands	Miettinen et al. 2016
Deforestation	
Tree Cover Loss	Hansen et al. 2013 (+ annual updates on GFW)
Commodity-driven deforestation	Curtis et al. 2018
Palm oil Expansion, 2000-2015 (for estimation of deforestation on peat)	
Indonesia, Malaysia	Miettinen et al. 2016
GHG Emissions	
Aboveground Biomass	Zarin et al. 2016
Crop and Pasture Extent Data	
MapSPAM (physical area)	IFPRI and IIASA 2016
EarthStat	Ramankutty et al. 2008

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