THE LAND USE CHANGE IMPACT OF BIOFUELS CONSUMED IN THE EU

Quantification of area and greenhouse gas impacts

COMPLEMENTARY SCENARIOS BY 2030

Report for the European Commission, Energy Directorate

by the International Institute for Applied Systems Analysis (IIASA)

4 October 2016 – Final version

Author: Hugo Valin (IIASA)

Project number: ENER/C1/2015-438/2

Table of Contents

1. Introduction

The impact of biofuel policy on land use has been subject to much scrutiny over the past years. In particular, understanding the role of "indirect land use change" (ILUC) emissions on the final GHG emission balance of biofuels has been at the core of recent EU policy development, with the new ILUC directive in 2015. To support the analysis of the impact of biofuels, a consortium composed of Ecofys, IIASA and E4tech published in 2015 an extensive study based on the GLOBIOM-EU model developed at IIASA ("2015 ILUC study" in the following). This study provided detailed potential impacts of various biofuel feedstock uses on land use and their GHG emissions. This report also considered some policy scenario by 2020, with various feedstock mix assumptions, based on information available at the time where the study was conducted, i.e. 2013-2014.

The present report comes as a complement to the 2015 ILUC study. It provides a set of updated scenario results to improve the representation of the biofuel composition from the former "EU 2020 mix" scenarios. It also expands the period considered to 2030 to consider some post-2020 possible evolutions in the contribution of food-based biofuels.

More specifically, this report explores three alternative scenarios for biofuels by 2030 using the GLOBIOM-EU model, as previously improved for the ILUC 2015 study.[1] The first scenario considers continuation of the current use of food crops for biofuels after 2020. The second scenario looks at an alternative partial phase-down of the use of food crop based biofuels ("food biofuels" in the following) after 2020, down to the 2008 level at the horizon 2030. The feedstock mix between biodiesel and ethanol is then considered to the mix in 2008. A third scenario considers a similar phase down, but where the share of biodiesel in the food based biofuels is reduced to 60%. These scenarios are compared to a baseline where biofuels are kept at their level of 2008, before the adoption of the Renewable Energy Directive (2009).[2]

2. Scenario description

2.1. One baseline and three scenarios

We represent in the model three different developments by 2030.

- **Baseline:** the model baseline is built on the same assumptions as the 2015 ILUC study (see Section 2 of the corresponding report). In particular, this scenario considers no further development of biofuels beyond the 2008 level, as no EU biofuel policy is considered (initial level of 9.8 Mtoe is kept fixed, which represents 3.2% of EU transportation fuel demand in 2010, (3.4% in 2020 and 3.9% in 2030 according to fuel demand projections).[3] The baseline serves as a

---

[1] Project ENER/C1/428-2012, LOT 2.

[2] The set-up of the baseline and scenarios slightly differs from that used in the 2015 ILUC study. Differences in assumptions are documented in Appendix.

[3] Note that in the 2015 ILUC study, level was kept fixed as percentage of the transportation fuel consumption. Here, for a more consistent representation of the phase down scenario, we keep the absolute level of biofuel

counterfactual scenario. It contains the background assumption on which amount of biofuels would be consumed in absence of binding EU and MS policies (the Renewable Energy Directive and its implementation in MS).

- **Status quo scenario:** this scenario reproduces the historical development of biofuel consumption in the EU Member States following the adoption of the Renewable Energy Directive in 2008. The 2020 level is projected by taking into account most recent data on current development and current policy implementations, including the ILUC Directive from 2015. It therefore differs from the scenarios analyzed in the 2015 ILUC study.
  In the Status quo scenario, the 10% target on renewable energy is reached mainly through first and second generation biofuels contribution (8.2%), but the energy equivalent is only 6.5% due to the double-counting of advanced biofuels. Renewable electricity complements biofuels to match the 10% target. First generation biofuels reach 4.8% of EU fuel transportation by 2020, and remain below the 7% cap on food biofuels. Second generation biofuels are representing 1.7% of the final energy demand before double-counting. However, only 42% of advanced biofuels are considered to come from land-based feedstocks in 2020 (perennial grasses, short rotation coppice and cereal straw).[4] The remaining part is considered to be supplied from used cooking oil and animal fats which are not represented in the model (ILUC directive Annex IX, part B). Therefore, only 5.5% of final energy demand for transportation, corresponding to land-using biofuel consumption, is implemented in the model for 2020. The support to biofuels (e.g. mandates in MS) thereafter is assumed to remain at the same level between 2020 and 2030 and the contribution of the different feedstocks in the biofuel portfolio unchanged. Due to the decrease of fuel consumption in the transportation sector, the share of food-based biofuels increases from 4.8% to 5.5% by 2030.
- **Phase down scenario:** this scenario is based on the Status quo scenario until 2020. However, after 2020, it is considered that the contribution of food biofuels in the EU bioenergy policy is reduced (for example through lowering the "cap" on food based biofuels) and the incorporation level is decreased to 9.8 Mtoe i.e. to the same absolute level of feedstock demand as in the baseline scenario. This represents a share of 3.9% of the fuel transportation in transport. The share of biodiesel in the food based feedstock mix is 83%, as in 2008.
- **Phase down biodiesel scenario:** this scenario is similar to the previous "phase down" scenario. However, the share of food based ethanol and biodiesel assumed in 2030 now differ from the baseline. They represent 60% for biodiesel and 40% for ethanol. The feedstock mix for biodiesel and for ethanol is unchanged compared to the "phase down" scenario.

The different levels of biofuel demand assumed per scenario are summarized in Table 1 below. More details are also provided in appendix.

---

consumption constant in the baseline. As a consequence, returning to 2008 level in the scenarios is equivalent to returning to the baseline level in 2030. Future shares are calculated based on the fossil fuel projections in transportation from the European Commission based on the PRIMES model (EUCO27 scenario).

[4] Other feedstocks from annex IX Part A of the 2015 ILUC Directive are not considered here.

Table 1. Assumptions on biofuel use for each of the scenario explored in this note

Scenario name	Biofuels incorporation level in EU transportation fuel (before double counting)		
	2010	2020	2030
Baseline	9.8 Mtoe food-based (83% biodiesel, 2008 level)		
Status quo	13.3 Mtoe food-based (79% biodiesel, 2010 level)	13.9 Mtoe food-based (75% biodiesel) 2.1 Mtoe lignocellulosic	13.9 Mtoe food-based (75% biodiesel) 2.1 Mtoe lignocellulosic
Phase-down	13.3 Mtoe food-based (79% biodiesel, 2010 level)	13.9 Mtoe food-based (75% biodiesel) 2.1 Mtoe lignocellulosic	9.8 Mtoe food-based (83% biodiesel) 2.1 Mtoe lignocellulosic
Phase-down biodiesel	13.3 Mtoe food-based (79% biodiesel, 2010 level)	13.9 Mtoe food-based (75% biodiesel) 2.1 Mtoe lignocellulosic	9.8 Mtoe food-based (60% biodiesel) 2.1 Mtoe lignocellulosic

2.2.Feedstock mix in the different scenarios

The composition of feedstocks within the different food-based and lignocellulosic biofuels categories is presented in Figure 1 and determined on the basis of the following criteria:

- For 2010, the historical consumption shares are used.
- For 2020, the shares of ethanol feedstocks follow the same assumptions as in the 2015 ILUC study. The shares of biodiesel have been updated to reflect most recently available data on use of vegetable oils. The case of palm oil consumption being subject to large uncertainty across data source (USDA, FO Lichts, FEDIOL), we consider a mid-point at 2 Mt of palm oil (about 25% of vegetable oils converted to biodiesel in the EU) as our reference. This level is in the middle of the distribution of commonly reported statistics (1.4 Mt according to USDA, 2.9 Mt according to FEDIOL on average on 2013-2014) and close to other industrial sources.[5]
- For 2030, the same shares as in 2020 are considered for the Status quo scenario, whereas the 2010 shares are used in the baseline and the Phase down scenarios. In the standard "Phase down", the shares of ethanol and biodiesel in the food-based biofuel mix is unchanged (83% biodiesel). In the "Phase down biodiesel" scenario, the share of biodiesel is decreased to 60%. As for feedstocks contribution within the fuel categories, the only difference in the feedstock mix is related to soybean use, which is capped at the consumption level of 2020 (2010 level was higher than 2020). The gap is filled by rapeseed oil consumption.

[5] The consumption share also takes account of 0.6 Mt of biodiesel imports in 2015 (USDA), 60% of which are assumed coming from Southeast Asia.

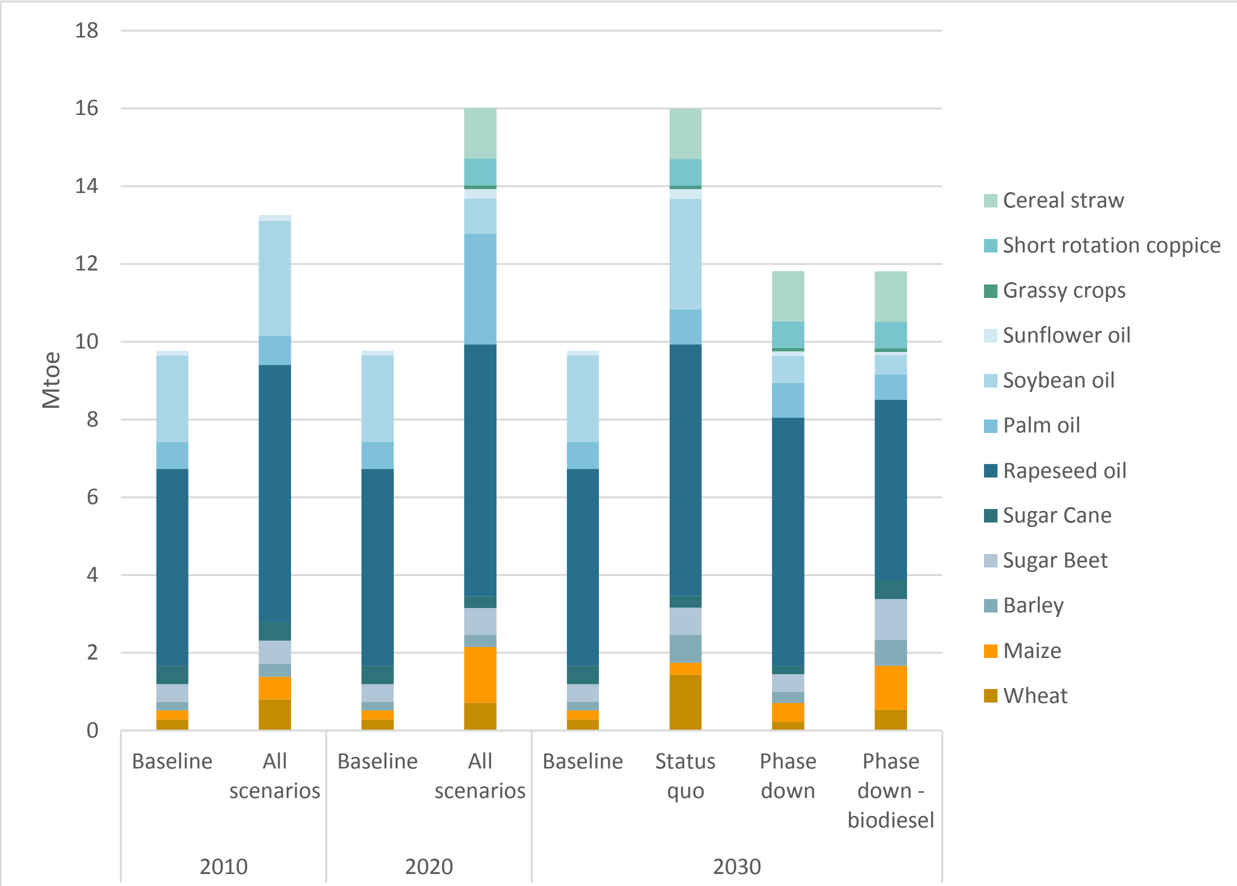

Figure 1. Level of biofuel consumption in the EU28 for land based biofuels for the different scenarios. See graph in percentage in Appendix.

3. Methodology for LUC value calculation

We follow for the calculation of LUC emissions the following approach:

1) Cumulative emissions for the baseline and each scenario are calculated on the period 2008-2030 to account for the full differences across the various developments.[6]

2) Difference between the scenarios and the baseline are divided by the 20-year reference period and by the difference in land-based biofuel energy use in 2020 to derive an estimate in gCO_2/MJ.[7]

[6] In line with the ILUC Directive, the accounting of emissions for the ILUC calculation in the EU is to be performed on a period of 20 years. The time window to assess the policy should therefore be 2008-2028, to properly account for the effect of the policy. However, because GLOBIOM is running on 10-year time steps, emissions are accounted until the year 2030. This however does not lead to inconsistency because no further policy changes are considered between 2028 and 2030. See appendix for more details on the emission calculations.

[7] We do not consider here the potential indirect land use change effect of non-land based biofuels as these are not represented in the models. Even if some feedstocks such as used cooking oil or animal fat do not require land for their production, they can have some impact on land use by substitution effect across feedstock uses (e.g. their decrease consumption for combustion is replaced by some vegetable oils).

The LUC value calculated following these steps therefore represent the emissions associated to the biofuels entered in use under the EU directive after 2008. The impact of these biofuels can be different from those from biofuels produced before 2008, as the land use impacts of biofuels can be expected to be non-linear in response to the size of the shock, but also its timing, and the composition of the portfolio. For instance, if biofuel demand increases more slowly than yield increase from technical change, extra production should be possible on the same area of land. As the shock becomes bigger however, more land has to be used: once domestic land reserve is converted to production, remaining impacts are then more largely diverted to some other adjustment sources (demand decrease, international relocation of production).

Emissions sources that are considered for the LUC calculation of this report are as follows:

- natural vegetation conversion (above and below-ground living biomass carbon)
- natural vegetation regrowth on abandoned land (above and below living-biomass carbon)
- agricultural vegetation above and below living-biomass carbon (weighted by their period of coverage)
- soil organic carbon in mineral soil
- soil mineral carbon oxidation through peatland drainage

More details on the LUC emissions calculation methodology can be found in appendix and in the ILUC 2015 study.

4. Results

4.1. Land use and GHG emissions

The **Status quo scenario** leads to an expansion of 1.8 Mha for cropland in the European Union (including 0.3 Mha of short rotation coppice) and to 0.6 Mha of cropland expansion in the rest of the World, by 2020, with 0.1 Mha at the expense of forest. Expansion of cropland at global level occurs at the expense of grassland (-1.1 Mha), abandoned land (-0.9 Mha) and other natural vegetation (0.4 Mha). Deforestation increases in Southeast Asia (-0.6 Mha) due to palm oil demand, but decreases in Latin America (by 0.6 Mha) due to decreased demand for soybean cakes and oil, which leads to a zero net deforestation. The cropland area requirement remains broadly stable between 2020 and 2030 (from 2.3 to 2.5 Mha) and land use displacement keep similar patterns. Overall, the scenario leads to additional cumulated emissions over 20 years of 330 MtCO_2-eq by 2030, in which peatland emissions account for 540 MtCO_2-eq and foregone sequestration 110 MtCO_2-eq. Land use emissions lead to a net negative flow of -10 MtCO_2-eq. Plantations act as a sink with -300 MtCO_2-eq. Soil organic carbon removes 10 MtCO_2-eq to the balance. With a reference period of 20 years used for the calculation, this represents a LUC value of 64 gCO_2-eq/MJ/yr.

This value above is slightly lower than the ones found in the 2015 ILUC study (97 and 79 gCO_2/MJ for the EU 2020 biofuel mix without and with 7% cap). This is driven by i) the relatively small contribution of food based biofuels in the overall biofuel mix (4.8% in 2020): when comparing the Status quo scenario to the baseline in 2020, food based biofuels represent only 64% of the additional biofuels consumed, whereas it was 87% in the "EU 2020 Mix" scenario (97 gCO_2/MJ) and 65% in the "EU 2020 Mix + 7% Cap" scenario (79 gCO_2-eq/MJ) of the 2015 ILUC study; ii) the larger share of ethanol feedstocks in the additional demand (44%) compared to the ILUC 2015 Mix scenarios (29% for "EU 2020 Mix" and 32% for "EU 2020 Mix + 7% Cap"); iii) the smaller contribution of imported vegetable oils among biodiesel feedstocks: palm and soybean oil represent in the Status quo scenario 35% of the additional vegetable oil consumed, whereas it was 54% in the "EU 2020 Mix" and 59% "EU 2020 Mix + 7% Cap" scenarios of the ILUC 2015 study.

The **Phase down scenario** follows a similar development as the Status quo scenario by 2020. Once the contribution of first generation biofuels to the mandate is decreased, the extra area required drops in 2030 from 2.5 Mha in Status quo to only 0.8 Mha, reallocated to food and feed use. As a result, 1.5 Mha of the extra cropland required in 2020 are reverted to abandoned land and other natural vegetation. The GHG emissions generated after 2020 are therefore much lower than in the Status quo scenario (+100 $MtCO_2$-eq compared to the baseline, instead of +290 $MtCO_2$-eq in the Status quo scenario). However, emissions on the period 2020-2030 remain positive because peatland emissions from 2008-2020 are not completely compensated through the land use decrease (decrease from 540 to 370 $MtCO_2$ in cumulated emissions). However, a number of emissions sources show negative flows on the period 2020-2030: avoided deforestation through the food sector reduces emissions by 140 $MtCO_2$-eq and foregone sequestration emissions are reduced by around 60 $MtCO_2$-eq on the 2020-2030 period, compared to the status quo. At the same time, palm plantations area expansion is shifted closer to the baseline level, which decreases sequestration by 180 $MtCO_2$-eq. Overall, the cumulated emissions of the phase down scenario are 140 $MtCO_2$-eq by 2030, in which peatland emissions account for 370 $MtCO_2$-eq. This represent a GHG saving of 37 gCO_2/MJ achieved on the period 2020-2030 compared to the status quo scenario, which means the net LUC value for the entire policy would be reduced to 27 gCO_2-eq/MJ. The phase down therefore succeeds to mitigate a part of the emissions from the biofuel policy.

In an overall expanding world crop system with net-land take for food production being much higher than for that biofuels, a reduction in the use of food biofuels, induced through e.g. a phase-down of the cap, frees up crop land for food production. It thus reduces LUC emissions caused by the previous expansion of cropland through EU policy. This "avoided LUC" is taken into account in the phase-down scenario. However, we observe here that the phase down does not compensate for all past emissions, in particular due to the past peatland emissions. Indeed, the stock of mineral carbon being depleted only after many decades, draining peatland earlier does not displace the timing of emissions that would be later triggered off by extra food demand. It increases instead the overall emissions achieved at a given date in the medium term.[8] Therefore, the "avoided LUC" effect through food use only partly compensates here the past biofuel use emissions.

The **Phase down biodiesel scenario** leads to improved GHG emissions outcome. When increasing the share of ethanol in the phase down mix to 40%, cropland needs even further decrease by 0.5 Mha globally by 2030 compared to the standard phase down. This impacts positively the GHG emission

[8] In the very long run, emissions could be considered displaced, but depending on peat depth, this would not occur before 50 or even 100 years. The only way to recover the emissions would be to rewet the drained peatland, which would however jeopardize the food production for plantations.

balances. On the period 2020-2030, natural vegetation reversion on abandoned land leads to 30 $MtCO_2$-eq of additional carbon sequestration compared to a phase down with unchanged feedstock mix. Soil organic carbon sequestration increases by an extra 40 $MtCO_2$-eq due to less cultivated land. Overall, the period 2020-2030 leads to a net emission flow of 40 $MtCO_2$-eq to be compared to 100 MtCO2-eq in the previous phase down set-up. This corresponds to savings of 47gCO_2-eq/MJ achieved on the 2020-2030 period and the final ILUC value is then reduced overall to a net 17gCO_2-eq/MJ for the entire policy.

The results on the cumulated GHG emission and LUC values impacts of the different scenarios are summarized in Table 2, and the decomposition across sources is provided on Figure 1. The underlying net global land use changes are displayed in Figure 3 for each scenario.

Table 2. Cumulated GHG emissions on 20 years and impact associated to the three scenarios

<table>
<tr><th>Scenario</th><th>Biofuel demand of EU 2020 policy</th><th>Total emissions 20 years ($MtCO_2$-eq)[a]</th><th>Gross ILUC value of EU 2020 mix (gCO_2/MJ)[b]</th><th>Repaid CO_2 debt 2020-2030 (gCO_2/MJ)</th><th>Net effect (gCO_2/MJ)</th></tr>
<tr><td>Status quo</td><td rowspan="3">6.2 Mtoe (261 PJ)</td><td>330</td><td rowspan="3">64</td><td>0</td><td>64</td></tr>
<tr><td>Phase down</td><td>140</td><td>-37</td><td>27</td></tr>
<tr><td>Phase down biodiesel</td><td>90</td><td>-47</td><td>17</td></tr>
</table>

[a] GHG emissions results are rounded up due to the inherent uncertainties margins in the carbon pool levels. Gross ILUC value is estimated using the unrounded model estimate (334 $MtCO_2$-eq), divided by 20 years and by the 261 PJ of biofuel demand.
[b] The gross value of the EU 2020 mix only corresponds to the average ILUC for the biofuel demand coming in addition to the baseline level. It does not inform on the ILUC of biofuels produced before 2008.

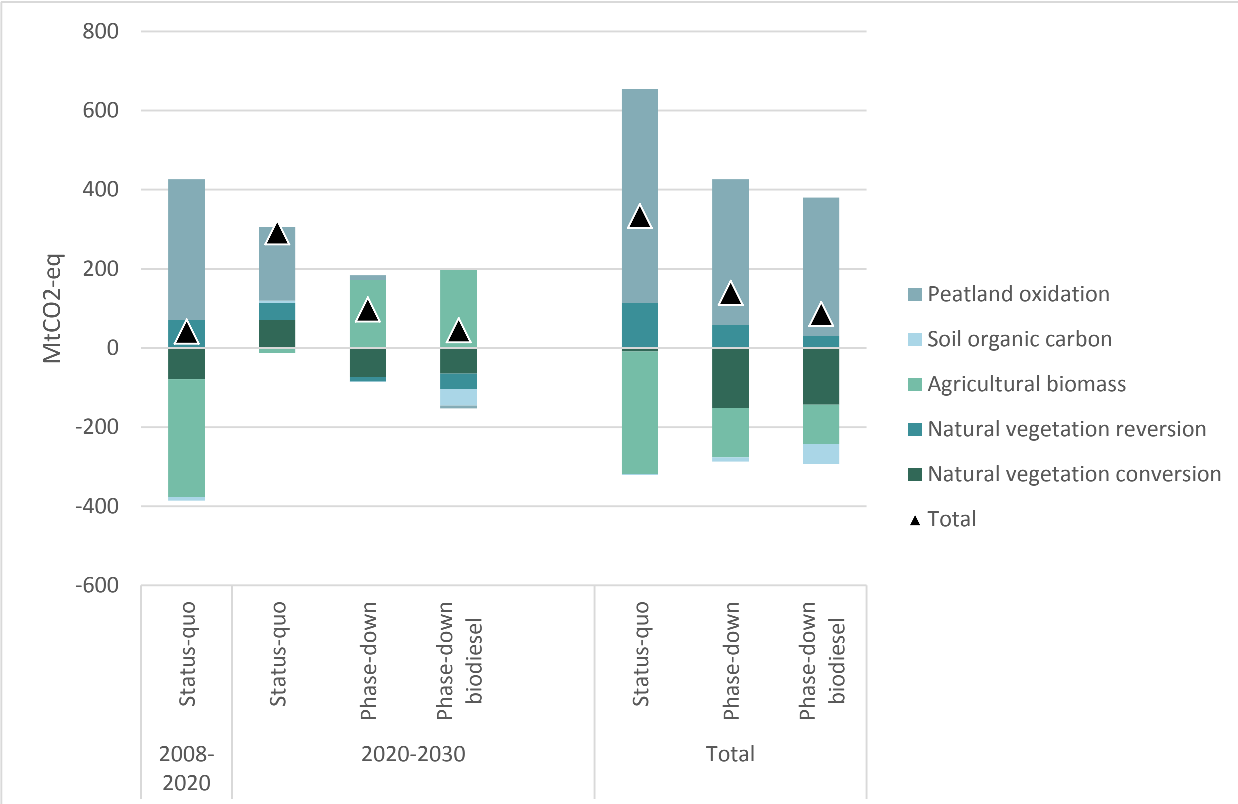

Figure 2. Cumulated GHG emissions for each scenario over the 2008-2020 and the 2020-2030 periods.

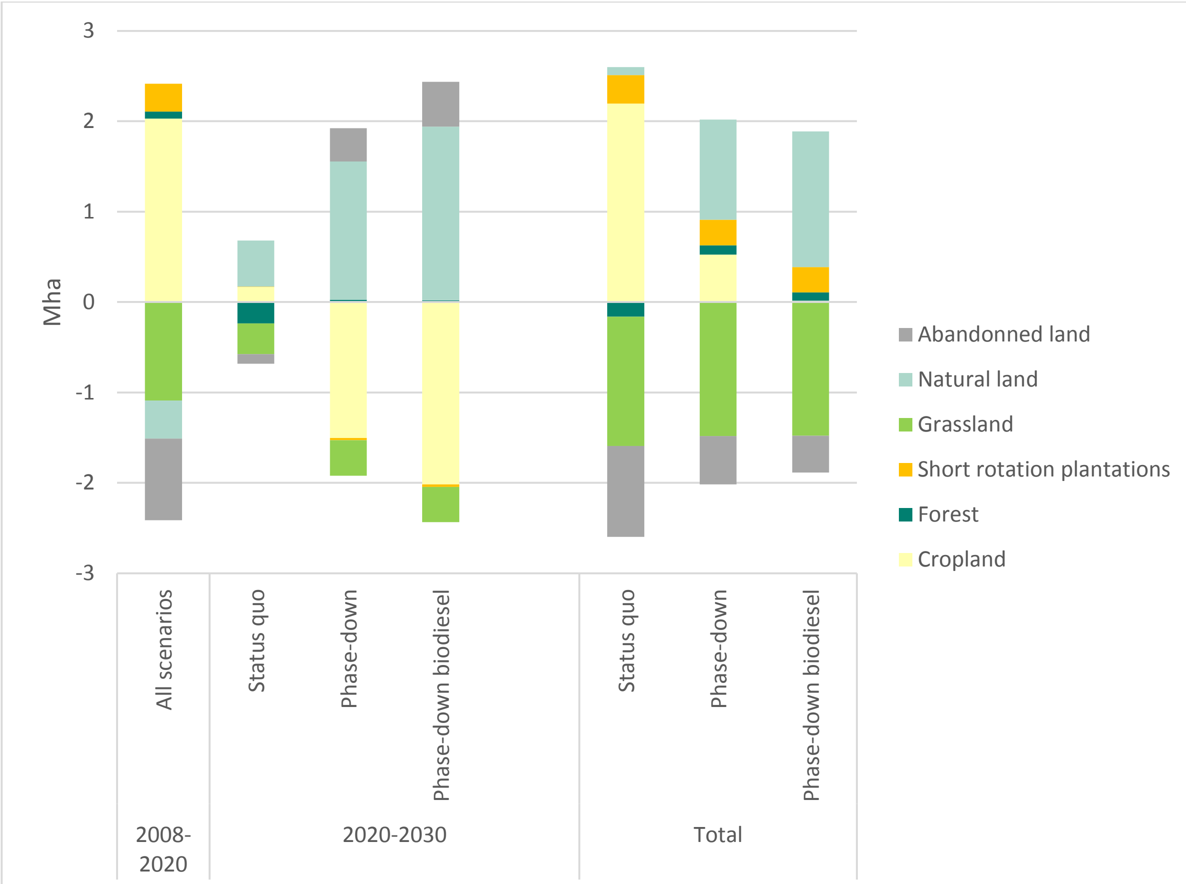

Figure 3. Change in land use for the different scenarios and time steps, compared to the baseline (Mha).

4.2. Market responses to the phase down and phase down biodiesel scenarios

The Phase down and Phase down biodiesel scenarios considered above lead to notable changes for the EU markets that we analyze in this section, taking as a benchmark the Status quo scenario in 2030.

The Phase down scenario is characterized by a decrease in cereal production mostly in the EU, compared to the Status quo scenario (Table 3). As biofuel demand decreases, a part of the maize is recycled as feed (2.2 Mt out of 5.8 Mt of not consumed feedstock for biofuels) or exported (0.3 Mt). In the case of wheat, only 0.3 Mt out of the 2.4 Mt of feedstock dropped from biofuel consumptions are going to feed instead or exported. As a result, maize harvested area decreases by 420 kha and wheat by 380 kha in the EU by 2030, compared to the Status quo. Production of DDGS decreases by 2.4 Mt and requires replacement by oilseed meals, mainly from soybean. As a result, production of soybean increases by 1.5 Mt globally, and consumption as feed in the EU increases by 1.3 Mt (soybean meal having higher protein content, less soybean is required per unit of DDGS). In comparison, impact on the oilseeds markets in the EU remain more limited, because we do not consider in the Status quo scenario a strong increase of EU oilseeds compared to the baseline. Therefore, the phase down scenario hardly affects the demand for oilseeds in the EU, whereas adjustments on palm oil are more notable with a 2.3 Mt decrease in production globally).

Table 3. Change in market balances for oilseeds under the Phase down scenario compared to the Status quo scenario in 2030

	Production world (1000 t)	Production EU (1000 t)	Harvest EU (1000 ha)	Consumption EU (1000 t)	Food EU (1000 t)	Biofuel EU (1000 t)	Feed EU (1000 t)	Other Use EU (1000 t)	Net trade (1000 t)
Maize	-3941	-3232	-423	-3568	6	-5772	2178	19	336
Maize DDGS	-1703	-1703	0	-1697	0	0	-1697	0	-6
Wheat	-2164	-2037	-383	-2165	-4	-2355	194	-1	128
Wheat DDGS	-692	-692	0	-694	0	0	-694	0	1
Barley	-349	-349	-106	-349	19	-466	80	18	0
Barley DDGS	-137	-137	0	-137	0	0	-137	0	0
Sugar beet	-4729	-4729	-70	-4729	99	-4848	-6	26	0
Sugar beet pulp	-267	-267	0	-267	0	0	-267	0	0
Rapeseed	-159	-76	-10	-91	0	0	-7	-84	15
Rape meal	-83	-47	0	-43	0	0	-43	0	-4
Rape oil	-61	-36	0	-98	3	-101	-1	2	62
Soybean	1481	62	25	248	0	0	-3	251	-186
Soybean meal	1179	200	0	1348	0	0	1348	0	-1148
Soybean oil	279	45	0	4	2	0	0	2	41
Sunflower	-367	-4	-1	100	0	0	-3	103	-105
Sunflower meal	-192	56	0	95	0	0	95	0	-39
Sunflower oil	-162	46	0	-157	4	-159	-2	1	203
Palm oil	-2319	0	0	-2558	0	-2566	0	8	-2558

When looking at the Phase down biodiesel scenario, the impacts are distributed differently across the markets (Table 4). Harvested area in the EU28 is still decreased (-1 Mha) but more wheat is produced (+8 Mt) compared to the status quo scenario, as well as more sugar beet (+0.9 Mt). These production increases are achieved to the detriment of maize (-2.8 Mt, to rebalance the feedstock mix closer to the baseline mix) and rapeseed, the production of the latter falling by 3.3 Mt, which represent a harvested area decrease of 0.9 Mha. Other regions of the world are also affected by a decrease in maize (-2.1 Mt) and rapeseed (-1.2 Mt). Significant changes also occur on the meal market, as cereals DDGS and rapeseed meal are replaced by soybean meals. Rapeseed and rapeseed oil are exported to compensate for the demand decrease from the biofuel sector (+0.6 Mt and +0.4 Mt respectively), as well as sunflower oil (0.4 Mt) and soybean oil (+0.3 Mt) due to the oversupply of oil on the domestic market. Imports of soybean meal in the EU increases by 1.8 Mt compared to the status quo, in order to substitute the previously produced rapeseed and sunflower meals. The impact on the palm oil sector is also particularly large, with a drop of 2.6 Mt in palm oil production following the decreased demand of palm based biodiesel.

Table 4. Change in market balances for oilseeds under the Phase down biodiesel scenario compared to the Status quo scenario in 2030

	Production world (1000 t)	Production EU (1000 t)	Harvest EU (1000 ha)	Consumption EU (1000 t)	Food EU (1000 t)	Biofuel EU (1000 t)	Feed EU (1000 t)	Other Use EU (1000 t)	Net trade (1000 t)
Maize	-5004	-2865	-386	-3415	7	-4289	847	20	550
Maize DDGS	-1265	-1265	0	-1262	0	0	-1262	0	-3
Barley	-679	-1457	-187	-738	-56	-287	-383	-12	-718
Barley DDGS	376	376	0	375	0	0	375	0	1
Sugar beet	867	867	248	867	19	1100	-249	-3	0
Sugar beet pulp	-137	-137	0	-137	0	0	-137	0	0
Wheat	8054	8054	142	8054	566	6986	358	143	0
Wheat DDGS	384	384	0	384	0	0	384	0	0
Rapeseed	-4532	-3329	-865	-3959	0	0	1	-3959	629
Rape meal	-2546	-2220	0	-2211	0	0	-2211	0	-8
Rape oil	-1914	-1685	0	-2083	51	-2201	38	30	398
Soybean	1964	38	10	204	0	0	-2	206	-166
Soybean meal	1551	165	0	1929	0	0	1929	0	-1764
Soybean oil	366	37	0	-272	9	-296	2	12	309
Sunflower	-719	-36	-32	226	0	0	-2	227	-262
Sunflower meal	-378	123	0	194	0	0	194	0	-71
Sunflower oil	-317	101	0	-254	-75	-195	35	-18	355
Palm oil	-2613	0	0	-2733	3	-2795	0	59	-2733

These changes in market balances are reflected in EU domestic price changes. Impacts are relatively limited on the cereal markets because quantities involved by the shocks are relatively small compared to the overall production in the EU (65 Mt for maize and 123 Mt for wheat). However, changes on the oilseed markets are much larger. In the Status quo scenario, the demand for vegetable oil increases but at the same time, prices decrease due to a composition effect across the oilseed used. Indeed, the deficit in soybean cakes leads to a relative oversupply of oil as more rapeseed and sunflower are produced to replace the cakes (the oil versus cake ratio is higher for rapeseed and sunflower than for soybean). This leads to a relative decrease in the price of vegetable oil, accentuated by the more important share taken by palm oil.

In the Phase down scenario and even more in the Phase down biodiesel scenario, vegetable oil demand decreases for all oilseeds and prices decrease further (-6.5% and -16.3% respectively). It is no surprise that the drop in prices is large considering that consumption of vegetable oils accounts for EU biofuels account for 9 Mt in the baseline for a total market size of 22 Mt for these four types of oils. The effect of the phase down on protein meals is also remarkable, with an increase in meal prices of 11.4% to 16.8%, a consequence in particular of the decreased production of rapeseed meals.

Table 5. Change in market prices in the EU in the different scenarios compared to the baseline.

Percent	Status quo	Phase down	Phase down biodiesel
Maize	2.5	0.8	0.3
Wheat	-2.4	-2.5	-0.7
Barley	-1.2	-1.8	0.1
Sugar beet	1.8	1.3	0.2
Rapeseed	6.2	5.4	-5.2
Soya	-2.1	-1.9	-2.1
Sunflower	0.5	0.4	0.6
Vegetable oils	-4.6	-6.5	-16.3
Protein meals	8.8	11.4	16.8

5. Conclusion

The land use change and GHG emissions impact of biofuel consumed in the EU is highly dependent on the feedstock use. In the ILUC 2015 study, the differentiation of these impacts had been highlighted and various scenarios explored by 2020. In this report, we looked at the impacts of some complementary feedstock mix by 2030, updating our assumptions by using more recent data on the market structure and different possible developments after 2020.

Our analysis confirms that emissions from the policy are significant, although the feedstock mix can play an important role in the overall results. Changing the mix, in particular by updating the attainable target to 2020 and decreasing the scope for further expansion of imported oilseed leads to slightly lower impacts when compared to the 2015 ILUC study (64 gCO_2-eq/MJ). These results are however conditional to the contribution of some advanced biofuels to the final mix. Among sources of emissions, peatland emissions associated to palm oil expansion remain the most important source to mitigate. Uncertainly related to this source of emissions should be kept in mind when analyzing the results.

Phasing down the mandate after 2020 could in principle lead to a neutralization of the past impact if the food demand expansion were to replace the use of land formerly used for biofuel demand (“avoided

ILUC"). However, although the emission level is found to be decreased (27 gCO_2-eq/MJ), it does not lead to a zero emission impact, because the additional emissions from peatland emitted before 2020 cannot be compensated through a simple phase down. Price impacts of the Phase down scenario are relatively moderate in our results compared to the baseline, because the expansion considered by 2020 is relatively modest (4.8%, with almost half of the contribution through a catching up of the ethanol sector). When increasing the share of ethanol in the feedstock mix to 40%, the shock size is decreased even further at 17gCO_2/MJ, due to the better performance of ethanol feedstocks.

Phasing down the mandate also lead to remarkable impacts on the EU agricultural markets. Oilseed market structure is changed with a larger share of vegetable oils coming from EU domestic production and lower market prices, whereas the protein meal market relies more on imports of soybean meals with higher prices. Socio-economic implications of the phase down scenarios for the different EU agricultural sectors are not assessed in this study and would need to be investigated in more details to balance the benefits and costs associated to these scenarios.

6. References

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 for the European Commission, Project ENER/C1/428-2012, LOT 2, Ecofys, IIASA & E4tech.

Appendix

1) Decomposition of the 10% target across the different feedstocks in the baseline and the three scenarios

In the scenarios analyzed in this study, we focus on the feedstocks that are represented in GLOBIOM to derive the land use change and GHG emission impacts of the biofuel mix. However, our scenarios fit in a broader target related to the 2009 Renewable Energy Directive that sets to 10% the share of renewable energy that EU Member States need to incorporate in the transportation fuel demand (RES-T target).

Two sources of renewable energy are therefore omitted in the scenarios above and illustrated in Figure A 1. The first type of fuel omitted are the advanced biofuels of type B, which include used cooking oil and animal fat. The second type of fuel is renewable electricity. These sectors are not represented in GLOBIOM, therefore we only account for conventional, food based, biofuels and advanced biofuels of type A (which include grassy crops, cereal straw and short rotation coppice).

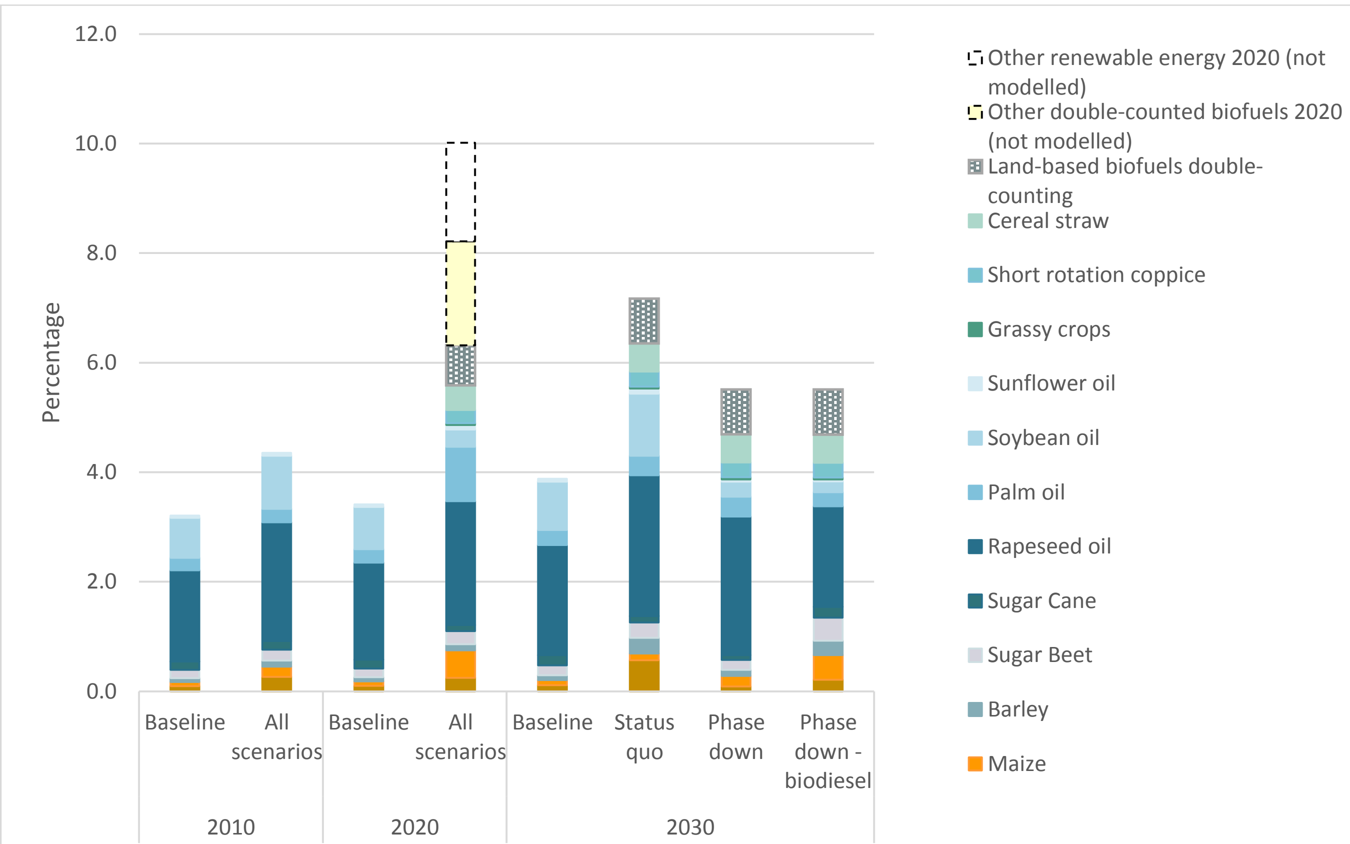

Figure A 1. Decomposition of the RES-T target across the different feedstocks for each scenario.

The level of the different feedstocks in each scenario (corresponding to Figure 1) is detailed in Table A 1 below. The table also provides more clarity on the changes to the baseline associated to each scenario (right hand-side).

Table A 1. Detail of biofuel demand per feedstock and scenario (Mtoe).

Mtoe	**2010**		**2020**	**2030**			**Diff to baseline 2030**		
	Baseline	**Status quo**	**Status quo**	**Status quo**	**Phase down**	**Phase down biodiesel**	**Status quo**	**Phase down**	**Phase down biodiesel**
Wheat	0.3	0.8	0.7	0.7	0.2	0.5	0.4	0.0	0.3
Maize	0.2	0.6	1.4	1.4	0.5	1.1	1.2	0.2	0.9
Barley	0.2	0.3	0.3	0.3	0.3	0.7	0.1	0.1	0.5
Sugar Beet	0.5	0.6	0.7	0.7	0.5	1.1	0.2	0.0	0.6
Sugar Cane	0.5	0.5	0.3	0.3	0.2	0.5	-0.2	-0.3	0.0
Rapeseed oil	5.1	6.6	6.5	6.5	6.4	4.6	1.4	1.3	-0.5
Palm oil	0.7	0.7	2.8	2.8	0.9	0.6	2.1	0.2	0.0
Soybean oil	2.2	3.0	0.9	0.9	0.7	0.5	-1.3	-1.5	-1.7
Sunflower oil	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.0	0.0
Total conventional	**9.8**	**13.3**	**13.9**	**13.9**	**9.8**	**9.8**	**4.2**	**0.0**	**0.0**
Grassy crops	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Short rotation coppice	0.0	0.0	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Cereal straw	0.0	0.0	1.3	1.3	1.3	1.3	1.3	1.3	1.3
Total advanced	0.0	0.0	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Total GLOBIOM	**9.8**	**13.3**	**16.0**	**16.0**	**11.8**	**11.8**	**6.2**	**2.1**	**2.1**

2) Modelling assumptions and differences with the 2015 ILUC Quantification Study

For the present analysis, we use the version of GLOBIOM developed and improved for the assessment of the impact of first generation biofuels. The baseline used for this model version differs however from the ILUC 2015 study in the following respect:

- Demand for solid biomass was updated to the last 2015 EU Reference baseline to 2050.
- Demand for final energy demand in 2020 in transport was updated to the EUCO30 baseline
- EU biofuel policy mix was updated to take account of last market development, as reflected in the Status Quo scenario
- Level of biofuel consumption in the baseline was kept fixed at 2008 level in absolute quantity to best represent the assumptions of the phase down scenario (return to 2008 level should represent a negative shock comparable to the positive shock of the policy). Similarly, level of biofuel demand in the Status Quo is the same in 2020 and 2030.

3) Calculation approach for 20 years LUC values

Following the approach of the 2015 ILUC study, we account in the present assessment for 20 years of emissions following the introduction of biofuels. Implementation of the RED policy is represented on the expansion of biofuel consumption on the period 2008-2020. This corresponds in GLOBIOM to two time steps: 2010 and 2020. Emissions associated to each period 2000-2010 and 2010-2020 are calculated at the time-step ending the period. Therefore, the model calculates emissions the same way independently on whether biofuels are considered introduced in 2011 or in 2019 within the period. To account for 20 years of emissions, the development of land use change is then analyzed up to 2030. The first decade of emissions associated to the biofuel consumption target corresponds to cumulated emissions reported in the year 2010 for feedstocks deployed between 2010, and in the year 2020 for feedstock deployed after 2010. The second decade of emissions are accounted in the next time step, i.e. 2020 or 2030.

More specifically, emissions are estimated as follows depending on the source:

- Living biomass emissions (natural land and agricultural land) are released immediately after the land use change adjustment following the shock. Therefore the LUC value for living biomass is calculated by difference between the scenario and the baseline at the end of each time-step, after division of the stock difference by 20 years.
- Soil organic carbon are annual emission flow depending on land management transitions. In a first approximation, the equilibrium of C stock after a change in management can be considered reached after a period of 20 years (IPCC Tier 1). In the present accounting approach, we always consider that the equilibrium is reached. The difference between equilibrium stock changes in the scenario and the baseline is allocated fully to the end of the period where the management change takes place. This means that we consider all the 20 years soil organic carbon release associated to expansion of cropland in the status quo scenario, and the phase down scenario, after equilibrium.

- Natural vegetation reversion occurs progressively over time, as forest regrows on some suitable land made available. When difference in land use patterns between the scenario and the baseline leads to abandoned land, 10 years of vegetation regrowth is accounted for at the end of each period. But because full forest regrowth takes several decades, the accounting on this source/sink is only partial. As the accounting is stopped here in the time step 2030, 20 years of foregone sequestration are accounted for in the status quo scenario, and 10 years of forest regrowth are considered after the phase-down taking place in 2030. Considering longer time period would lead to difference balances in both scenarios as more forest regenerates.
- Peatland emissions occur on an annual basis on drained peatland resulting from areas planted with palm trees. These emissions occur for long period of time (many decades, until full depletion of the C stock in the peat. Annual emissions are calculated by looking at the differences between palm plantation areas in the scenario and the baseline. Because we only account here for 20 years of emissions, peat emissions associated to plantation expansion over the period 2000-2010, both accounted in time-step 2010 and in 2020, are not considered for the time step 2030. Accounting for longer time period for emissions would not change the results on peatland emissions, because LUC values are to be expressed in annual flows, therefore the 20 year accounting period for cumulated emissions is thereafter divided by the same 20 years.

More information on the representation of the GHG accounts within the ILUC version of GLOBIOM is available in the 2015 ILUC study.

4) Land use change patterns across scenarios

Table A 2. Land use change between the scenarios and the baseline for each time step (1000 ha)

	1000 ha	All scenarios 2008-2020	Status quo 2020-2030	Phase down 2020-2030	Phase down biodiesel 2020-2030
EU28	Cropland (w/o coppice)	1446	64	-891	-1331
	Short rotation coppice	307	9	9	6
	Cropland Total	*1753*	*73*	*-883*	*-1325*
	Grassland	-137	-28	-1	-9
	Abandoned land	-728	-140	325	468
	Forest	0	0	0	0
	Other natural vegetation	-887	94	559	866
Latin America	Cropland (w/o coppice)	-581	481	666	661
	Short rotation coppice	1	0	0	0
	Cropland Total	*-580*	*481*	*666*	*661*
	Grassland	-266	-447	-652	-625
	Abandoned land	0	0	0	0
	Forest	593	51	69	44
	Other natural vegetation	253	-85	-83	-81
Southeast Asia	Cropland (w/o coppice)	857	316	-517	-625
	Short rotation coppice	0	-12	-12	-12
	Cropland Total	*857*	*304*	*-529*	*-638*
	Grassland	-278	40	198	200
	Abandoned land	0	0	0	0
	Forest	-626	-255	-13	4
	Other natural vegetation	47	-89	344	434
Rest of the World	Cropland (w/o coppice)	308	-695	-761	-721
	Short rotation coppice	0	9	-21	-23
	Cropland Total	*308*	*-686*	*-782*	*-744*
	Grassland	-410	97	63	45
	Abandoned land	-173	34	41	26
	Forest	108	-34	-31	-28
	Other natural vegetation	167	588	710	702
World total	Cropland (w/o coppice)	2030	166	-1504	-2017
	Short rotation coppice	308	6	-25	-29
	Cropland Total	*2338*	*172*	*-1529*	*-2046*
	Grassland	-1091	-338	-393	-389
	Abandoned land	-901	-105	366	494
	Forest	75	-238	25	19
	Other natural vegetation	-421	509	1530	1921