JRC Technical Notes

Estimate of GHG emissions from global land use change scenarios

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EUR 24817 EN - 2011

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JRC 64430

EUR 24817 EN
ISBN 978-92-79-20242-1
ISSN 1018-5593
DOI 10.2788/20453

Luxembourg: Office for Official Publications of the European Communities

Printed in Italy

Summary

This study follows the methodology developed by the JRC (2010) for estimating changes in greenhouse gas emissions from global land use changes due to increased biofuels demand, and applies the methodology to the output of global modelling calculations run by the International Food and Policy Research Institute (IFPRI).

In particular, this report focuses on the scenario recently published by IFPRI[1] that was based on the estimates of the National Renewable Energy Action Plans (NREAPs) of the EU Member States. In this scenario, a total 1st generation biofuels blend of 8.7%, with a spread bioethanol/biodiesel of 22%-78% (NREAP "full mandate") was assumed. In addition to the "full mandate", marginal calculations for 8 different feedstocks were also carried out.

For completeness of the analysis on IFPRI scenarios carried out in JRC 2010 report, Appendix 1 also reports the results of the methodology as applied to another scenario (the "8.6% mandate") published in the previous IFPRI report of 2010[2]: this scenario assumes a biofuels (1st generation) blend in total fuel consumption in 2020 of 8.6% with a spread bioethanol/biodiesel of 60%-40%.

Based on the outcomes of IFPRI economic modeling in the "NREAPs scenario", the increased biofuels demand will cause ILUC GHG emissions of about 36 gCO_2/MJ. This result also includes emissions from peatland drainage due to oil palm plantations mainly in Indonesia and Malaysia, which were not accounted in the original JRC methodology. The estimated peat emissions in unit of energy are 19.8 gCO_2/MJ, which represent the main contribution to total GHG emissions from LUC (about 55% of total emissions).

ILUC GHG emissions for 8 feedstocks (4 for ethanol and 4 for biodiesel) were also calculated. The results show that in general ethanol crops have lower ILUC impacts than oilseeds/biodiesel crops: emissions for ethanol feedstocks range from about 4 to 20 gCO_2/MJ, and for biodiesel feedstocks they range from about 36 to 60 gCO_2/MJ. These JRC results are in line with the emissions calculated by IFPRI.

Compared to the new (2011) study, the previous (2010) economic analysis carried out by IFPRI gave much higher estimations of land use change due to 8.6% biofuels consumption in 2020 ("8.6% scenario"), resulting in GHG emissions of about 54 gCO_2/MJ[3]. The contribution of peat emissions is about 3 gCO_2/MJ, which corresponds to only 5% of total emissions. The low share is due to the very limited oil palm expansion in the previous IFPRI economic analysis.

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[1] D. Laborde (2011) Assessing the Land Use Change Consequences of European Biofuel Policies and Their Uncertainties

[2] Al-Riffai et al (2010), Global Trade and Environmental Impact Study of the EU Biofuels Mandate.

[3] Many parameters have changed in the new run of MIRAGE model since the previous analysis, as clearly discussed in IFPRI 2011 report.

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Introduction

In 2009 and 2010, under request of the Commission's Directorate for Trade (DG TRADE), the International Food and Policy Research Institute (IFPRI) carried out an analysis of the impacts of EU Biofuels policy using the global computable general equilibrium model MIRAGE [Al Riffai et al, 2010] In this report, a biofuel blend of 5.6% in 2020 was assumed in the central scenario (corresponding to a change in biofuels demand of 2.3% (over the baseline) of EU 2020 transport fuels consumption), with a bioethanol/biodiesel share of 87%-13% respectively in the additional demand ("5.6% mandate"). The study also briefly analysed the effects on GHG emissions of different biofuels blends, in particular a share of 8.6% on total transport fuels consumption, corresponding to a change in demand in 2020 of 5.2% and a spread bioethanol/biodiesel of 60%-40% ("8.6% mandate").
Under request of the Commission, IFPRI made a new run of the MIRAGE model in 2011, with a central scenario based on estimates of EU biofuels consumption in 2020 resulting from the recently submitted National Renewable Energy Action Plans (NREAP-mandate). The full mandate of this scenario assumed a biofuels share of 8.7 % over total transport fuels consumption, corresponding to a change in demand of 5.7%, and a bioethanol/biodiesel share of 28%-72% respectively. In addition to this "full NREAP-mandate", IFPRI also assessed the Indirect Land Use Change (ILUC) effects caused by 8 separate feedstock crops [Laborde, 2011].

During 2010 the JRC developed a new methodology to estimate the GHG emissions resulting from global land use changes caused by the production of biofuels [JRC 2010a]. This study used as input data the cropland demands from the original "5.6% mandate" of IFPRI, and calculated the corresponding emissions from changes in soil carbon stocks and above- and belowground biomass carbon stocks (ABCS). .

This note presents the GHG emissions calculated by the JRC applying its methodology to the cropland demand calculated by IFPRI in the new "NREAP mandate" scenario and for the 8 feedstocks analysed by IFPRI. For completeness of the previous JRC study, GHG emissions from the old "8.6% mandate" are also estimated and reported in Appendix.

1 GHG emissions from IFPRI-MIRAGE "NRAP mandate"

1.1 "Full mandate"

Based on the results of the NREAPs delivered to the Commission in 2010, IFPRI assumed a total fuel consumption of 312 Mtoe in 2020, with a 1st generation biofuels share to meet the target of 27.2 Mtoe (8.7% of total fuel consumption). This, compared to a "no-policy" baseline in 2020 of 11.7 Mtoe of biofuels, corresponds to an increase in biofuels demand of 15.5 Mtoe (650 Million GJ). As for the previous "5.6%" and "8.6%" scenarios, Business as Usual (BAU) and Free-Trade (FT) scenarios were calculated[4].

1.1.1 Spatial allocation based on IFPRI economical demand

Table 1 and Table 2 present the changes in terms of land cover for both BAU and FT "NREAP full mandate" scenarios when the spatial allocation model is run under standard conditions as described by [JRC 2010a].

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[4] For further details about BAU and FT scenarios assumptions see IFPRI 2010 and 2011 reports

Table 1 : Land cover changes for NREAP Full Mandate BAU scenario

1000 ha	Cropland	Grassland	Closed Forest	Open Forest	Shrubland	Sparse
Brazil	307.88	-49.92	-87.70	-32.65	-134.92	-2.69
CAMCarib	13.20	-3.33	-6.12	-1.27	-2.24	-0.24
China	135.96	-33.88	-26.21	-22.41	-26.73	-26.74
CIS	408.11	-92.63	-146.20	-59.54	-77.14	-32.61
EU27	118.13	-12.12	-37.37	-7.91	-10.78	-49.95
IndoMalay	120.24	-11.30	-82.35	-9.61	-15.69	-1.28
LAC	152.40	-38.06	-35.73	-15.40	-59.73	-3.48
RoOECD	47.01	-5.06	-30.36	-3.23	-7.24	-1.11
RoW	161.67	-39.59	-43.43	-22.67	-35.65	-20.32
SSA	230.71	-41.45	-101.37	-29.86	-54.88	-3.16
USA	42.85	-17.96	-17.91	-2.48	-4.33	-0.17
World	**1738.16**	**-345.29**	**-614.76**	**-207.02**	**-429.34**	**-141.75**

Table 2 : Land cover changes for NREAP Full Mandate FT scenario

1000 ha	Cropland	Grassland	Closed Forest	Open Forest	Shrubland	Sparse
Brazil	486.62	-77.72	-168.17	-51.83	-184.25	-4.65
CAMCarib	11.77	-2.89	-5.50	-1.14	-2.01	-0.23
China	131.10	-32.55	-25.38	-21.64	-25.80	-25.73
CIS	389.57	-88.35	-139.29	-56.73	-73.46	-31.74
EU27	105.25	-9.76	-33.54	-7.21	-9.20	-45.54
IndoMalay	119.78	-11.23	-82.15	-9.55	-15.58	-1.27
LAC	156.83	-39.11	-37.16	-15.80	-61.22	-3.54
RoOECD	46.51	-3.96	-31.87	-2.64	-7.23	-0.81
RoW	155.27	-38.12	-42.67	-21.49	-34.15	-18.84
SSA	221.90	-39.84	-99.53	-28.40	-51.30	-2.83
USA	44.52	-18.47	-18.82	-2.57	-4.48	-0.18
World	**1869.11**	**-362.00**	**-684.08**	**-218.99**	**-468.68**	**-135.36**

1.1.2 Emissions from changes in above- and belowground biomass carbon stock

CO_2 Emissions from changes in ABCS based on Business as Usual (BAU) and Free-Trade (FT) NREAP scenarios at regional level are shown in Table 3 and Table 4.

The “IndoMalay” (Indonesia and Malaysia) and SSA (Sub-Saharan Africa) regions show some carbon savings instead of carbon emissions. This is explained by the fact that in these regions the economical demand resulting from IFPRI economic analysis indicates an important replacement of arable lands and “non-forest” land with oil palm plantations. The biomass carbon content per hectare of an oil palm plantation is much higher than the biomass carbon content per hectare of any arable or “non-forest” land and therefore the ABCS emissions in these regions are negative (i.e. sequestration occurs).

Table 3 : Emissions due to ABCS for NREAP Full Mandate BAU scenario

BAU	Surface (ha)	ABCS ($MtCO_2$)	ABCS (tCO_2/ha)
Brazil	307,875	65.65	213.25
CAMCarib	13,199	2.15	162.75
China	135,964	11.00	80.93
CIS	408,110	53.63	131.41
EU27	118,132	13.22	111.89
IndoMalay	120,238	-26.02	-216.41
LAC	152,402	28.42	186.48
RoOECD	47,007	20.52	436.46
RoW	161,673	15.04	93.04
SSA	230,711	-16.60	-71.94
USA	42,850	21.51	501.94
World	**1,738,162**	**188.52**	**108.46**

Table 4 : Emissions due to ABCS for NREAP Full Mandate FT scenario

FT	Surface (ha)	ABCS ($MtCO_2$)	ABCS (tCO_2/ha)
Brazil	486,618	108.16	222.27
CAMCarib	11,773	1.82	154.47
China	13,1101	10.63	81.07
CIS	389,569	51.10	131.18
EU27	105,249	11.84	112.50
IndoMalay	119,781	-25.58	-213.58
LAC	156,829	29.48	187.98
RoOECD	46,509	21.13	454.39
RoW	155,267	15.00	96.64
SSA	221,896	-17.56	-79.15
USA	44,520	22.50	505.50
World	**1,869,113**	**228.53**	**122.27**

1.1.3 Emissions from changes in soil C-stocks

Emissions from mineral soils (SOC) have been calculated following IPCC recommendations and the methodology already described in detail in the JRC report EUR 24483 [JRCa].

CO_2 Emissions from changes in soil C-stock based on Business as Usual (BAU) and Free-Trade (FT) NRAP scenarios at regional level are shown in Table 5. The changes in N_2O induced by the change in C-stock are also presented in the table.

The negative values for Brazil, CAMCarib (Central America and Caribbean), IndoMalay and SSA can also be explained by the important replacement of cultivated crops with perennial or semi-perennial crops (i.e. sugar cane and oil palm) in these regions. According to IPCC factors, perennial crops disturb the soils less and release less carbon than cultivated crops, bringing improvements in the C soil content.

Some important considerations must be made on this classification. In fact, substantial differences in soil organic carbon associated with sugar cane planting may occur, because in some sugar cane plantation areas all residues are (still) burned after harvest, while in others the residues are incorporated into the soil, thus bringing improvement in the soil C.

Certainly sugar cane can be considered as a perennial crop for biomass C stock change estimation (as done in the previous paragraph 2.1.2), but from the soil perspective the management technologies have a great influence. If fire is involved, then there is a small biomass input to the soil (or even none at all), and there is likely to be no organic matter build up or rather a decrease under fertilization. Under these circumstances, a conservative approach would suggest to assume sugar cane as an annual (cultivated) crop, with no build of Carbon in the soil and no substantial SOC changes.

However, following discussions with Brazilian experts and more recent literature publications (De Figueiredo et al, 2011) the practice of burning off the residues before cutting sugar cane is now being phased out, and "green harvest" where high amounts of residues are left on the soil surface is more often used, resulting in soil C accumulation. For these reasons, it was decided to apply the "more optimistic" assumptions rather than the conservative approach, using for sugar cane the LUC coefficients of "perennial crops", although we recognised that, whenever the management practices are not optimised to avoid burning fires, this may bring about relevant underestimations of SOC emissions.

The differences in terms of SOC (and N_2O) emissions resulting from the two different classifications are presented further below in the "sensitivity" paragraph in section 3.4.1.

Table 5 : Emissions due to change in mineral soil for NRAP Full Mandate BAU and FT scenario (Sugar Cane classified as perennial crop).

	BAU		**FT**	
$MtCO_2$	SOC	N_20	SOC	N_20
Brazil	-3.23	-0.35	-28.07	-3.15
CAMCarib	-0.61	-0.08	-0.15	-0.02
China	4.26	0.45	4.14	0.44
CIS	38.09	3.62	36.34	3.46
EU27	3.87	0.43	3.48	0.38
IndoMalay	-26.65	-3.15	-26.54	-3.14
LAC	6.34	0.73	6.61	0.76
RoOECD	0.78	0.08	0.56	0.06
RoW	7.74	0.95	5.88	0.72
SSA	-12.55	-1.39	-13.75	-1.54
USA	2.75	0.33	2.82	0.34
World	20.81	1.62	-8.69	-1.69

1.1.4 Peatland and organic soils

The estimation of CO_2 emissions from the conversion of peatland are not part of the method put forward by the JRC in the original 2010 report. They are also not included in the IPCC Tier 1 approach and no specific provisions are made in Commission Decision C(2010) 3751) other than that appropriate methods shall be used (Annex, 4.2).

For various technical and conceptual reasons for C emissions from peat the method of calculating changes in C-stock used for mineral soils are not applicable to peat. Instead, GHG emissions on peat are measured directly or by using a proxy. A simplification of the costly measurements is the use of default emission factors.

Default emission factors for cultivated organic soils are given in the IPCC Good Practice Guidance (GPG) for LULUCF in Table 3.3.5 (IPCC, 2003). The GPG provides default values for 3 climatic temperature regimes as follows:

Cold temperate	1.0 t C ha^{-1} yr^{-1} (or 3.7 t CO_2 ha^{-1} yr^{-1})
Warm temperate	10.0 t C ha^{-1} yr^{-1} (or 37 t CO_2 ha^{-1} yr^{-1})
Tropical / sub-tropical	20.0 t C ha^{-1} yr^{-1} (or 73 t CO_2 ha^{-1} yr^{-1})

In recent years more estimates of CO_2 emissions from peatland, based on subsidence rate or flux measurements, have become available, indicating higher values than the IPCC default value for agriculture on tropical peatland.

As discussed during the expert consultation organized by the JRC in November 2010[5], the most robust currently available empirical estimate of peat CO_2 emissions is **86 t CO_2 ha^{-1} yr^{-1}**, annualized over 50 years [Hooijer et al, 2011]. This number is the result of field studies with more than 800 subsidence / water depth measurement locations accompanied with CO_2 gas flux measurements, soil measurements, and other studies in selected locations. The estimates are also supported by CO_2 gas flux measurements of Jauhiainen et al (2011).

In terms of uncertainty range, the likely CO_2 emissions should be represented by the minimum and maximum values of 54 and 115 t CO_2 ha^{-1} yr^{-1}, for drainage depths of 0.6 to 0.85 m, respectively. The minimum value of 54 t CO_2 ha^{-1} yr^{-1} is the value suggested by the linear relationships of both Couwenberg et al. (2010) and Hooijer et al. (2006, 2010), and reported also in JRC ILUC modelling report [JRCb, 2010]. This is also the value used by IFPRI in its latest calculations. The upper value accounts for potentially higher CO_2 emissions due to higher peat C density in oil palm plantations, and is also closer to the median value of 110 t CO_2 ha^{-1} yr^{-1} predicted for drainage depth of 1.1 m.

In the estimation of emissions from extra land on peat several simplifications are applied:

- no extra land is allocated on peatland in areas of the cold and warm temperate climate regime;
- only oil palms are planted on peatland in the IndoMalay IFPRI region;
- 33% of all extra land for oil palm is on peatland[6].

Under these assumptions the task of calculating CO_2 emissions from peat due to the extra land demand from biofuels is straightforward:

$$\left(A^{PalmFruit}_{Scenario} - A^{PalmFruit}_{Reference}\right)\left[km^2\right] \times 0.33 \times 86\left[tCO_2 ha^{-1} yr^{-1}\right] \times 20\left[yr\right] \times 10^2\left[ha km^{-2}\right] \times 10^{-6}$$

Peat emissions estimated with the above assumptions, with the range min-MAX values, are reported in Table 6 below. For comparison, peat emissions estimated with IPCC default value are also included.

Table 6: Peat emissions from Oil Palm cultivation in Malaysia/Indonesia

$MtCO_2$	**PEAT** **(86 t CO_2 ha^{-1} yr^{-1})**	**Min** (54 t CO_2 ha^{-1} yr^{-1})	**MAX** (115 t CO_2 ha^{-1} yr^{-1})	**IPCC default** (73 t CO_2 ha^{-1} yr^{-1})
BAU	256.84	161.27	343.45	218.01
FT	255.17	160.22	341.22	216.60

1.1.5 Synthesis

Table 7, Table 8 and Figure 1 show the different sources of GHG emissions for the BAU and FT NREAP scenarios under the assumptions (for sugar cane and peat) discussed in the previous paragraphs annualized over 20 years (as requested by EU directives). It is evident from the figure that in both the scenarios, peat emissions represent the main contribution to total GHG emissions from LUC.

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[5] See JRC report no. 24816 EN "Critical issues in estimating ILUC emissions" [JRCa]

[6] Values taken from most recent literature publications and studies ([Miettinen and Liew, 2010], [Page et al, 2011]). Sources disagree on the exact fraction of existing oil palms that is on peatland (in some cases because of the different definitions of "peatland"). Some projections show that by 2025 oil palm and pulp wood plantations will cover more than 50% (10 Mha) of peatlands in Indonesia, although Tropical Peat research Laboratory claims lower figures (about 15% of peat in Indonesia).

Table 7 : Total emissions for NREAP Full mandate scenarios ($MtCO_2$)

$MtCO_2$	Surface (ha)	ABCS	SOC	N_2O	PEAT	Total
BAU	1,738,162	188.52	20.81	1.62	256.84	467.79
FT	1,869,113	228.53	-8.69	-1.69	255.17	473.32

Table 8 : Total annual emissions per Mega Joule for NREAP Full Mandate (gCO2/MJ/yr)

$gCO_2/MJ/y$	Shock (PJ)	ABCS	SOC	N_2O	PEAT	Total
BAU	649.00	14.52	1.60	0.12	19.79	**36.04**
FT	649.00	17.61	-0.67	-0.13	19.66	**36.47**

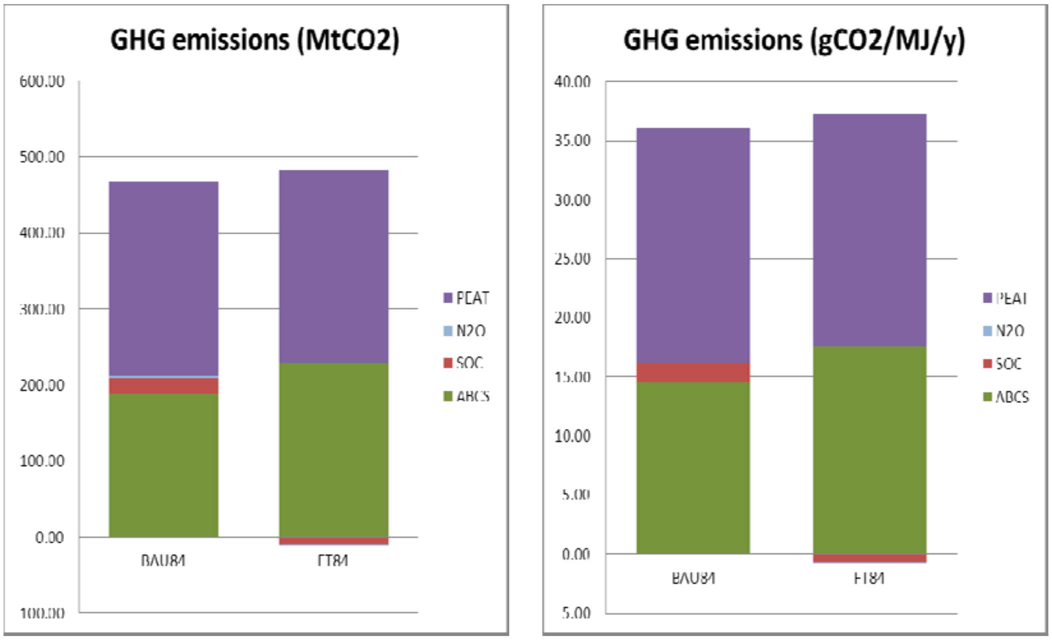

Figure 1: GHG emissions for NREAP BAU and FT Full mandate scenarios

1.2 Marginal “Crop-specific scenarios”

To get a better understanding of the possibility to differentiate the ILUC impacts between feedstock types, IFPRI also calculated the effects caused by an increase of 8 separate feedstock crops, four for bioethanol (wheat, maize, sugar beet and sugar cane), and four for biodiesel (oil palm, soybean, rapeseed and sunflower).

To compute a feedstock specific ILUC factor, the blending rate in the EU was increased by 0.5% (from 8.2 percent to 8.7 percent), and any increase in biofuel supply to match the new EU demand was generated only with one feedstock.

Emissions have been calculated from the output of the 9 IFPRI simulations:

- 1 pre crop simulation BAU79_1001_B1 (Full Mandate – 60 Million GJ),
- 8 feedstock simulations BAU79_1001_B1_XXXX (Marginal biofuel demand increase of 60 Million GJ met with XXXX feedstock)

1.2.1 Emissions from ABCS

Table 9 below presents the above and below-ground biomass carbon stock emissions (ABCS) generated by the shocks on the 8 feedstocks in the IFPRI analysis.

Table 9 : ABCS emissions using standard calculation for feedstock shocks

	Crop expansion Area (Ha)	Shock Million GJ	ABCS (Mt C)	ABCS ($MtCO_{2\ eq}$)	ABCS (gCO_2/MJ)
IFPRI B1 WHEAT	82,045	59.14	3.46	12.69	10.73
IFPRI B1 MAIZE	52,994	60.52	3.30	12.11	10.01
IFPRI B1 BEET	23,459	57.91	1.01	3.71	3.21
IFPRI B1 CANE	86,792	58.71	6.29	23.09	19.66
IFPRI B1 OIL PALM	128,511	65.12	-1.34	-4.91	-3.77
IFPRI B1 SOYBEANS	247,973	64.16	7.52	27.61	21.51
IFPRI B1 SUNFLOWER	306,296	62.52	8.72	32.00	25.59
IFPRI B1 RAPESEED	254,127	65.15	7.68	28.18	21.62

The negative value for the oil palm shock is due to the fact that one hectare of an oil palm plantation has a higher carbon content than one hectare of other cropland, grassland or sparse vegetation. In this oil palm scenario, there is an important replacement of low carbon content vegetation by oil palm trees and therefore a carbon stock saving instead of a carbon loss in term of ABCS ”emissions”.

1.2.2 Emissions from mineral soil

A range of SOC values is provided in this new analysis, representing different assumptions made on the farming practices and on the level of input used.
The IPCC methodology for the estimation of SOC emissions is based on 3 coefficients to account for changes in land use (Land Use factor, Management Factor and Input Factor)[7].

Management Factor (tillage practice): As explained in the JRC report, it is difficult to determine or deduce the level of tillage at global level. For these calculations, a constant management factor corresponding to full tillage was used.

Land Use Factor: crops are generally considered as long term cultivated. However, according to the indications in the Commission Decision 2010/335/EU[8], oil palm trees are considered perennial crops. Since this definition is not generally accepted and some studies (e.g. IFPRI, 2011) are considering oil palm trees as “long term cultivation”, SOC values are calculated for both the classifications.
For the reasons explained above in 2.1.3, sugar cane is also considered as a “perennial crop”. This generally brings an improvement in soil C stocks, but uncertainties in different management practices suggest considering also a “conservative” approach, assuming “no-build up” of C in the soil, i.e. cultivation of perennial crops doesn’t bring substantial improvement in the soils.
The highest (MAX) SOC values reported in this analysis considered oil palm/sugar cane as “long term cultivated”.

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[7] Intergovernmental Panel on Climate Change (IPCC) (2006) 2006 Guidelines for National Greenhouse Gas Inventories. Eggelstone, S., L. Buemdia, K. Miwa, T. Ngara and K. Tanabe (Eds.). IPCC/OECD/IEA/IGES, Hayama, Japan.

[8] COMM 2010/335/EU on “Guidelines for the calculation of land carbon stocks for the purpose of Annex V to Directive 2009/28/EC”

Input Factor: The choice of this factor (F_I) results from a combination of numerous assumptions, relative to fertilizer application, irrigation and multiple-cropping practices
Crop-specific SOC values reported in this note represent the variability of the Land Use and Input factors only under realistic assumptions for farming practices (medium of high inputs).

Results based on the different assumptions explained above are reported in .

Table 10.

Table 10: SOC emissions for the different feedstocks in IFPRI scenarios.

IFPRI Scenario	**Crop Expansion Area**	**CO_2 Emission Mineral Soil min – 20 years**	**CO_2 Emission Mineral Soil max – 20 years**	**Annual CO_2 Emission Mineral Soil min**	**Annual CO_2 Emission Mineral Soil MAX**
	Ha	*Mt CO_2*	*Mt CO_2*	*gCO2/MJ*	*gCO2/MJ*
IFPRI B1 WHEAT	82,045	3.96	4.2	3.34	3.55
IFPRI B1 MAIZE	52,994	2.13	2.7	1.76	2.23
IFPRI B1 BEET	23,459	-1.97	1.2	-1.70	1.04
IFPRI B1 CANE	86,792	-13.19	1.6	-11.24	1.36
IFPRI B1 OIL PALM	128,511	-9.53	8.9	-7.32	6.83
IFPRI B1 SOYBEANS	247,973	6.62	11.9	5.16	9.27
IFPRI B1 SUNFLOWER	306,296	16.71	22.0	13.36	17.59
IFPRI B1 RAPESEED	254,127	8.48	13.7	6.51	10.51

The differences between min-max values are significant for all oilseed scenarios. This is due to the larger contribution of palm oil in the biodiesel scenarios.

1.2.3 Peatland and organic soils

The resulting emissions of CO_2 from peat over 20 years for the IFPRI crop-specific scenarios are summarized in Table 11 (min and MAX values are also reported in brackets).

Table 11: CO_2 Emissions from Peat from Oil Palm Extension using Emission Factor of 86 t CO_2 ha^{-1} yr^{-1} for Cultivated Organic Soils

IFPRI Scenarios	**Extra Land**			**Emission in 20 years (min – MAX)***
	Total cropland change	Total Palm change	Palm change IndoMalay	
	Ha	*Ha*	*Ha*	***Mt CO_2***
IFPRI B1 WHEAT	82,045	11,790	5,580	3.2 (2.0 – 4.2)
IFPRI B1 MAIZE	52,994	10,410	4,220	2.4 (1.5 – 3.2)
IFPRI B1 BEET	23,459	11,040	4,810	2.7 (1.7 – 3.7)
IFPRI B1 CANE	86,792	2,040	1,050	0.6 (0.4 – 0.8)
IFPRI B1 OIL PALM	128,511	253,360	110,820	63.0 (39.5 – 84.1)
IFPRI B1 SOYBEANS	247,973	158,980	55,040	31.2 (19.6 – 41.8)
IFPRI B1 SUNFLOWER	306,296	91,320	35,060	19.9 (12.5 – 26.6)
IFPRI B1 RAPESEED	254,127	111,270	52,260	29.7 (18.6 – 39.7)

***Range min-MAX value has been calculated with peat emissions of 54 and 115 t CO_2 ha^{-1} yr^{-1} respectively**

The table indicates that the estimated emissions for extra land in the IndoMalay IFPRI region are considerable: for all oilseeds scenarios (apart from sunflower) the CO_2 emissions from extra land for oil palm on peat are higher than the maximum estimated value for mineral soils.
These calculations are a stark simplification of a complex issue of the degree to which the various crops are affected by the production of biofuels, the amount of extra land needed and the allocation of such crops.

1.2.4 Total emissions

Total annual GHG emissions (amortized over 20 years) resulting from the crop-specific scenarios are summarized in Table 8 below.

Table 12 : Total <u>Annual</u> emissions for different feedstock shocks

Annual emissions	**ABCS** $MtCO_2$	**SOC Min – MAX** $MtCO_2$	**N_2O** $MtCO_2$	**PEAT*** $MtCO_2$	**Total** $MtCO_2$	**Total gCO_2/MJ/yr**
IFPRI B1 WHEAT	0.63	0.20 – 0.21	0.022	0.16	1.01 - 1.02	**17.2 – 17.4**
IFPRI B1 MAIZE	0.60	0.11 – 0.14	0.011	0.12	0.84 - 0.87	**13.9 – 14.4**
IFPRI B1 BEET	0.19	-0.07 – 0.06	-0.007	0.14	0.25 - 0.38	**3.7 – 6.5**
IFPRI B1 CANE	1.15	-0.65 – 0.08	-0.074	0.03	0.46 - 1.19	**7.7 – 20.3**
IFPRI B1 OIL PALM	-0.25	-0.48 – 0.44	-0.056	3.15	2.36 - 3.28	**36.4 – 50.6**
IFPRI B1 SOYBEANS	1.38	0.33 – 0.60	0.036	1.56	3.31 - 3.58	**51.5 – 55.7**
IFPRI B1 SUNFLOWER	1.60	0.83 – 1.10	0.081	1.00	3.51 - 3.78	**56.2 – 60.4**
IFPRI B1 RAPESEED	1.41	0.42 – 0.69	0.045	1.48	3.36 - 3.63	**51.6 – 56.6**

***estimated using emission factor of 86 t CO_2 ha^{-1} yr^{-1}**

As explained in 2.2.2, the range of C stock values accounts for different assumptions on oil palm and sugar cane definition: lower SOC values when considering palm trees and sugar cane as perennial (with no burning fires used to burn residues of sugar cane after harvest), higher SOC values if palm trees are classified as “long term cultivated”, and using the conservative approach for sugar cane not bringing substantial soil improvements (which is equivalent to classifying it as cultivated crop from the soil carbon content perspective).
Figure 2 below compares JRC-SAM results with total GHG emissions calculated by IFPRI for the different feedstocks.

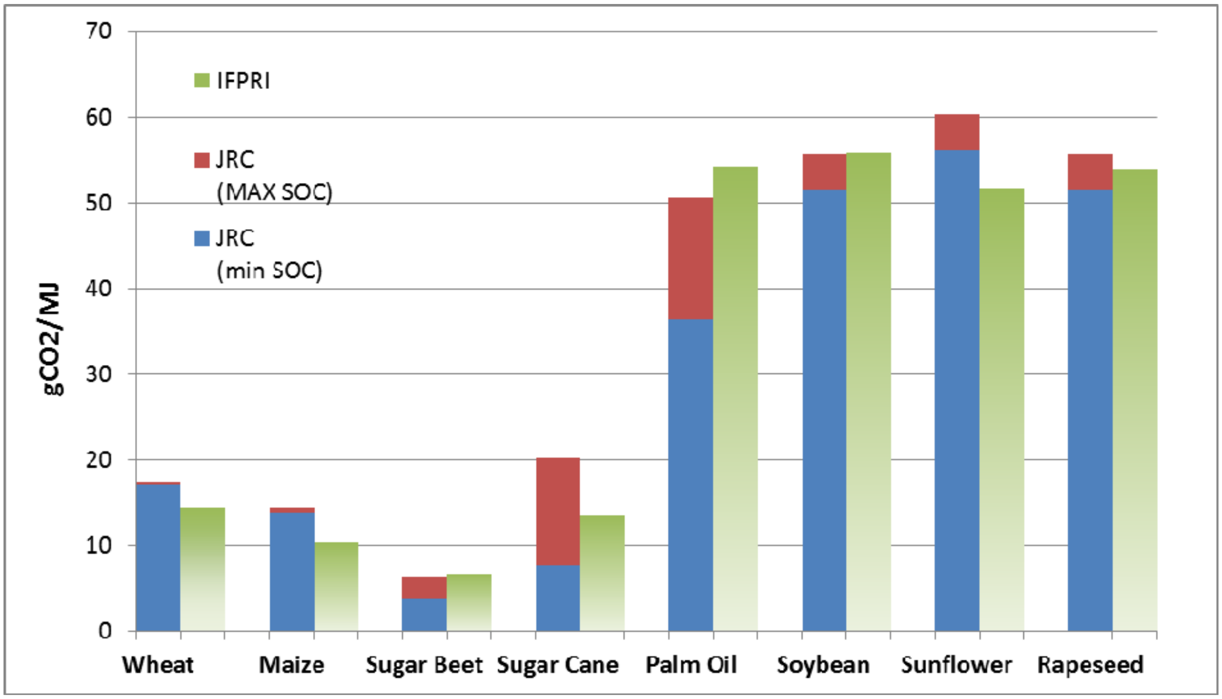

Figure 2: Comparison of total GHG emissions calculated with JRC-SAM and IFPRI methodology for the different feedstocks

Concerning the above mentioned assumptions on oil palm, peat emissions and sugar cane, IFPRI analysis considered oil palm trees and sugar cane as “long term cultivated”, and used an emission factor for cultivation on peat of 55 tCO2 ha-1 yr-1 (with the same assumptions as JRC concerning the amount of oil palm plantations on peatland – 33%)

2 Sensitivity analysis

A sensitivity analysis has been carried out on the IFPRI NREAP BAU “full mandate” scenario. In particular, GHG emissions have been calculated:

- assuming no cropland expansion on closed forests
- using a different land cover classification

These two assumptions mainly affect ABCS emissions, as shown in the following paragraphs.

2.1 Land cover changes for “no forest” and CDIAC scenarios

The proportion of forest converted to cropland to cater for the additional demand is one of the key parameters in GHG emissions calculations, due to the high carbon stock and potential emissions assigned to forests.

To give an indication of minimum emissions from cropland expansion that could be achieved, a specific processing configuration was used to determine the changes in GHG emissions under the assumption that no areas of closed forest (>30%) were converted (“No Closed forest” scenario).

Results of the spatial allocation of cropland expansion for the different classes are shown in Table 13.

Table 13: Land cover changes when cropland expansion on closed forest (>30% canopy) is prevented

1000 ha	Cropland	Grassland	Closed Forest	Open Forest	Shrubland	Sparse
Brazil	307.88	-70.61	0.00	-46.49	-186.80	-3.98
CAMCarib	13.20	-6.04	0.00	-2.40	-4.32	-0.43
China	135.96	-42.45	0.00	-28.47	-34.00	-31.04
CIS	408.11	-145.19	0.00	-99.31	-124.20	-39.40
EU27	118.13	-17.89	0.00	-12.80	-14.95	-72.50
IndoMalay	120.24	-35.83	0.00	-30.76	-48.95	-4.70
LAC	152.40	-51.08	0.00	-20.38	-75.97	-4.97
RoOECD	47.01	-12.73	0.00	-9.81	-19.08	-5.39
RoW	161.67	-54.09	0.00	-32.22	-49.76	-25.59
SSA	230.71	-75.00	0.00	-55.43	-94.78	-5.50
USA	42.85	-30.63	0.00	-4.41	-7.50	-0.31
World	**1738.16**	**-541.54**	**0.00**	**-342.50**	**-660.31**	**-193.81**

The Carbon Dioxide Information Analysis Center (CDIAC) (has proposed an alternative map for world distribution of biomass carbon in above and belowground living vegetation using the IPCC Good Practice Guidance for reporting GHG national inventories. It is interesting to compare the results in term of ABCS emissions that can be obtained when using the CDIAC datasets in the SAM methodology. The CDIAC calculations are based on GLC 2000 land cover map instead of GlobCover 2005 and use the carbon values calculated by Aaron Ruesch and Holly Gibbs[9] (“CDIAC” scenario). Results are shown in Table 14. Because of the characteristics of the spatial allocation model, the impact of the carbon values considered for mixed classes (as mosaic cropland, mixed forest or mosaic forest) can be important.

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[9] Aaron Ruesch and Holly K. Gibbs. 2008. New IPCC Tier-1 Global Biomass Carbon Map For the Year 2000. Available online from the Carbon Dioxide Information Analysis Center [http://cdiac.ornl.gov], Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Table 14 : Land cover changes when GLC2000 land cover dataset is used (aggregated according to CDIAC classification)

1000 ha	Cropland	Mosaic Cropland	Grassland	Sparse grassland	Broadleaf forest	Evergreen forest	Mixed Forest	Mosaic Forest	Shrubland
Brazil	307.88	-98.45	-72.02	-69.42	-56.64	0.00	-0.99	0.00	-10.35
CAMCarib	13.20	-0.07	-2.75	-0.19	-6.82	-0.93	-0.69	0.00	-1.75
China	135.96	-0.07	-52.97	-2.85	-37.51	-14.60	0.00	-0.27	-27.68
CIS	408.11	-115.14	-87.79	-127.45	-43.00	-8.58	-15.04	-2.22	-8.89
EU27	118.13	-4.88	-23.01	-12.10	-28.76	-14.13	-19.26	-0.89	-15.10
IndoMalay	120.24	-64.05	0.00	-2.07	-34.95	0.00	-2.73	-8.80	-7.63
LAC	152.40	-15.03	-26.05	-55.31	-30.17	-12.94	-4.09	-0.01	-8.79
RoOECD	47.01	-4.47	-2.14	-1.01	-25.57	-0.96	-5.28	-0.53	-7.04
RoW	161.67	-18.16	-7.56	-14.37	-49.18	-13.13	-2.21	-0.99	-56.07
SSA	230.71	-61.24	-15.69	-6.25	-89.92	0.00	-0.84	-23.49	-33.29
USA	42.85	0.00	-8.74	-0.64	-17.53	-8.58	-6.84	-0.04	-0.48
World	**1738.16**	**-381.56**	**-298.74**	**-291.67**	**-420.06**	**-73.85**	**-57.96**	**-37.24**	**-177.08**

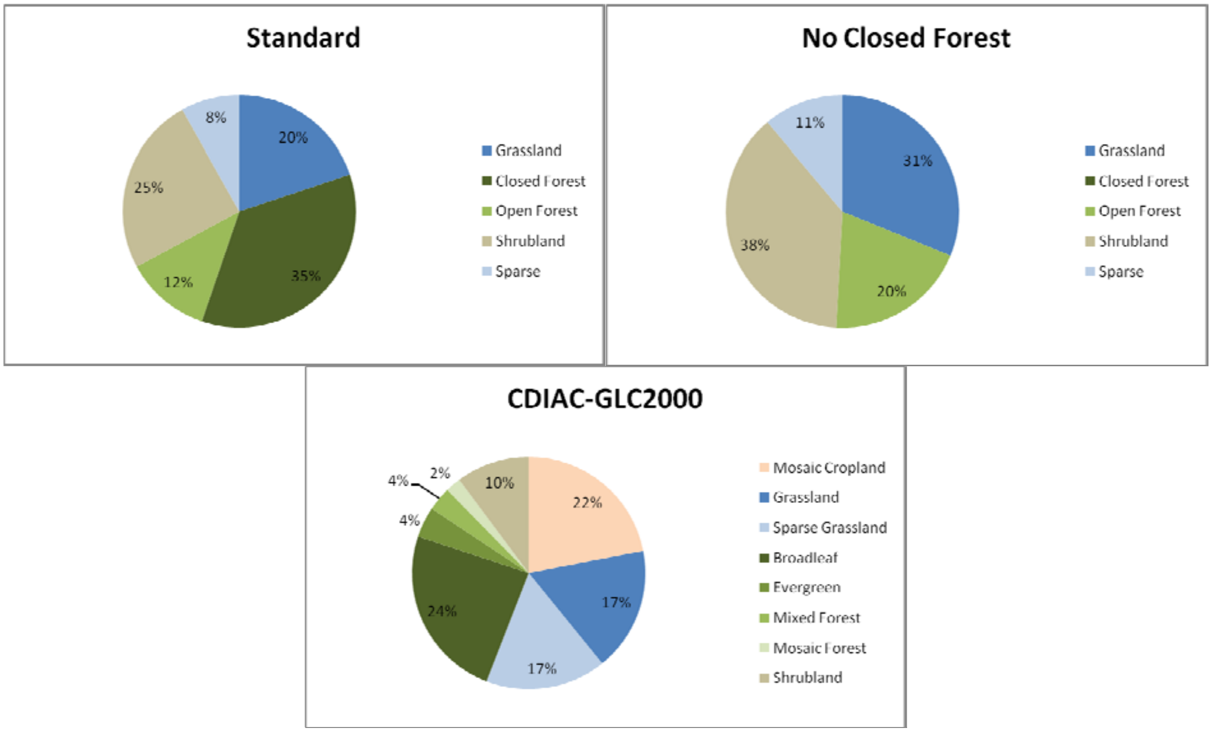

Figure 3: Comparison of land cover changes

2.2 ABCS emissions for “no forest” and “CDIAC” scenarios

The respective emissions in terms of Above and Below Ground Carbon stock changes are presented in Table 15 and Figure 4.

Table 15: ABCS emissions of the Standard, CDIAC and "No Closed forest" calculations in NRAP BAU scenario (Full Mandate)

	Standard		No Closed Forest		CDIAC-GLC2000	
BAU84	ABCS (MtCO2)	ABCS (tCO2/ha)	ABCS (MtCO2)	ABCS (tCO2/ha)	ABCS (MtCO2)	ABCS (tCO2/ha)
Brazil	65.65	213.25	34.85	113.21	51.17	166.19
CAMCarib	2.15	162.75	-0.81	-61.48	3.00	227.26
China	11.00	80.93	3.63	26.71	6.43	47.31
CIS	53.63	131.41	13.44	32.94	9.49	23.24
EU27	13.22	111.89	2.20	18.59	14.35	121.44
IndoMalay	-26.02	-216.41	-84.16	-699.96	-37.36	-310.74
LAC	28.42	186.48	15.29	100.33	26.02	170.74
RoOECD	20.52	436.46	-0.92	-19.66	16.55	352.06
RoW	15.04	93.04	-0.15	-0.94	23.05	142.55
SSA	-16.60	-71.94	-60.51	-262.29	12.29	53.25
USA	21.51	501.94	2.26	52.75	7.92	184.91
World	**188.52**	**108.46**	**-74.89**	**-43.08**	**132.89**	**76.46**

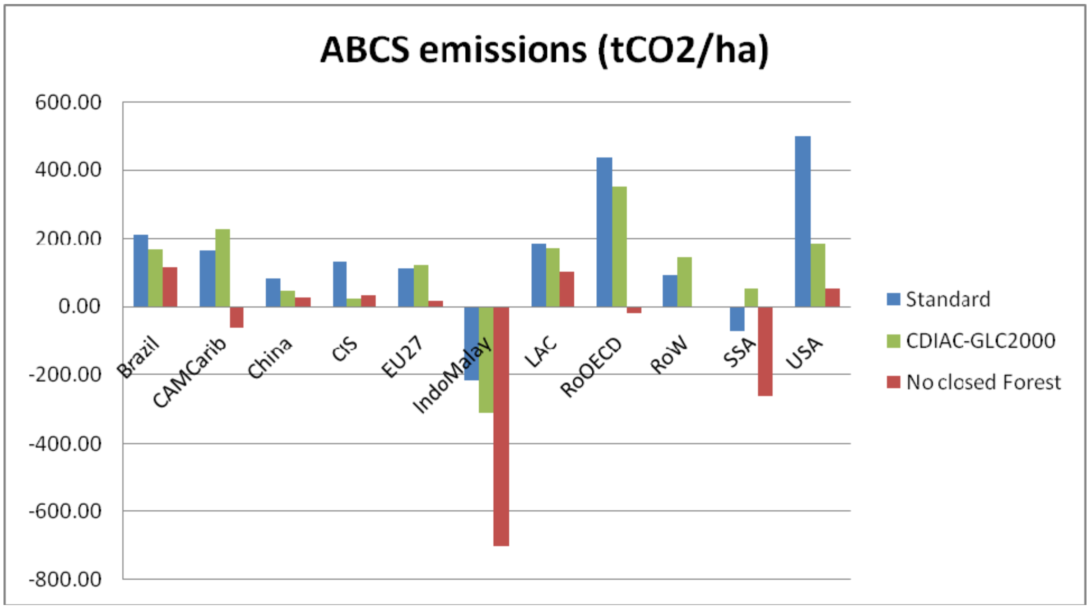

Figure 4: Comparison of ABCS emissions when using standard, CDIAC or “No closed forest” simulation.

The strong gain in carbon stock in the SSA and “IndoMalay” regions is due to the oil palm plantations. As explained above, if oil palm trees replace natural vegetation other than forest, then the biomass carbon stock will increase.

Globally, if no cropland expansion occurred on closed forest, there would be a GHG saving of about 65 tCO_{2eq} from ABCS.

The results of the “no forest” and “CDIAC” scenarios to the crop-specific runs are reported in Table 16, Table 17 and Figure 5 below.

Table 16 : ABCS emissions using “No Closed forest” calculation for feedstock shocks

	Surface	**Shock**	**ABCS**	**ABCS**	**ABCS**
	Ha	*Million GJ*	*Mt* CO_{2eq}	tCO_2/ha	gCO_2/MJ
IFPRI B1 WHEAT	82,045	59.14	1.53	18.69	1.30
IFPRI B1 MAIZE	52,994	60.52	1.64	30.97	1.36
IFPRI B1 BEET	23,459	57.91	-1.63	-69.50	-1.41
IFPRI B1 CANE	86,792	58.71	5.27	60.67	4.49
IFPRI B1 OIL PALM	128,511	65.12	-43.55	-338.90	-33.44
IFPRI B1 SOYBEANS	247,973	64.16	-10.97	-44.23	-8.55
IFPRI B1 SUNFLOWER	306,296	62.52	-3.51	-11.46	-2.81
IFPRI B1 RAPESEED	254,127	65.15	-8.17	-32.14	-6.27

Table 17 : ABCS emissions using CDIAC calculation for feedstock shocks

	Surface	**Shock**	**ABCS**	**ABCS**	**ABCS**
	Ha	*Million GJ*	*Mt* CO_{2eq}	tCO_2/ha	gCO_2/MJ
IFPRI B1 WHEAT	82,045	59.14	9.14	111.44	7.73
IFPRI B1 MAIZE	52,994	60.52	9.62	181.55	7.95
IFPRI B1 BEET	23,459	57.91	3.22	137.33	2.78
IFPRI B1 CANE	86,792	58.71	18.83	216.91	16.03
IFPRI B1 OIL PALM	128,511	65.12	-2.87	-22.37	-2.21
IFPRI B1 SOYBEANS	247,973	64.16	22.66	91.39	17.66
IFPRI B1 SUNFLOWER	306,296	62.52	5.09	16.61	4.07
IFPRI B1 RAPESEED	254,127	65.15	19.22	75.64	14.75

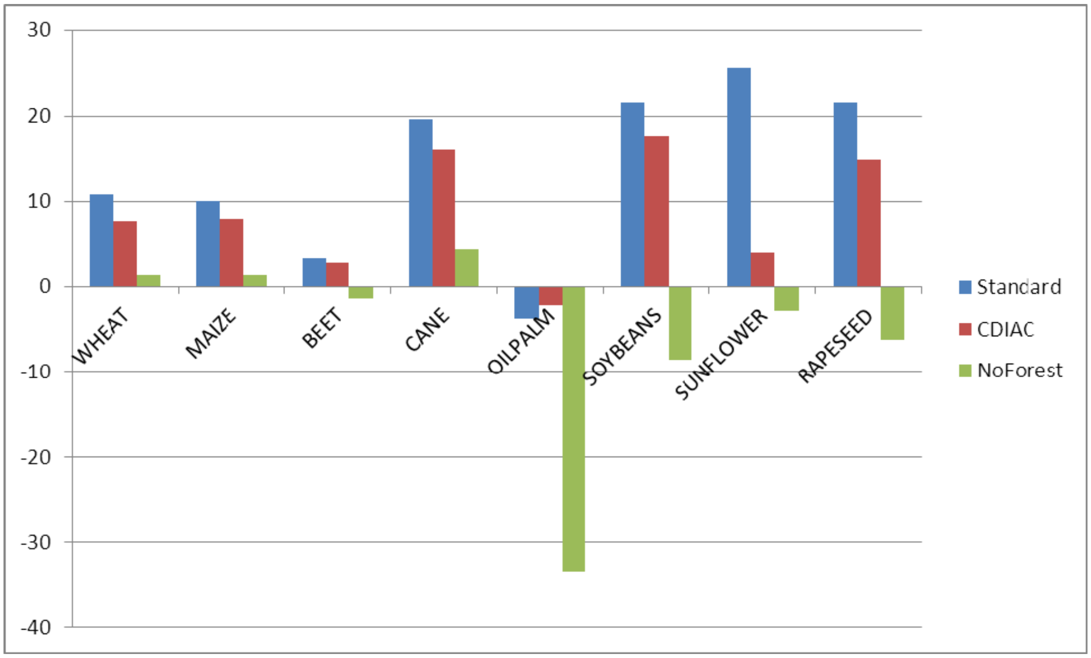

Figure 5 : Comparison of ABCS emissions for feedstock shocks using standard, CDIAC and “No Closed forest” calculations

2.3 SOC emissions for “no forest” scenario

While emissions from forest are significant for above and below ground biomass, when such areas are converted to cropland the changes in soil C are not of the same magnitude.
The global changes in soil C stocks from a configuration where the conversion of extra land excludes closed forest (>30%) to the IFPRI crop-specific scenarios is presented in Figure 6.

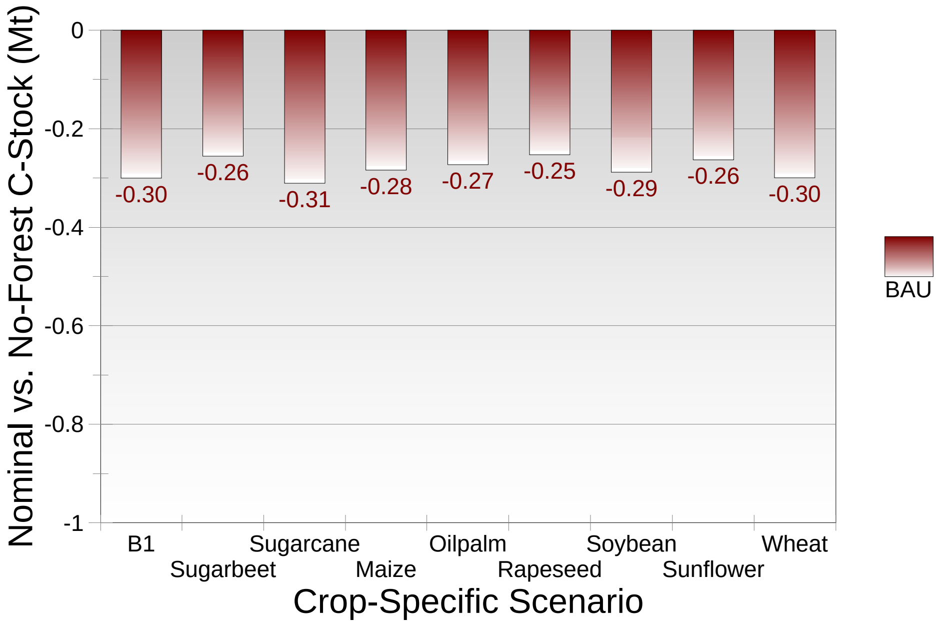

Figure 6: Change in Soil C-Stock from Restricted Conversion of Closed Forest to Unrestricted Conversion for IFPRI Crop- Specific Scenarios

Emissions from the soil are generally lower by 0.3 Mt C (1.1 Mt CO_2 eq) when excluding areas of closed forest from the conversion of land. This corresponds to a reduction in emissions from the soil of 1.4% for the B1 scenario.

2.4 Variation of Land Management factors

To better understand the impact of the land management factor, additional assumptions have been tested by:

- Changing the land use factor for sugar cane
- Considering a No tillage option for the land management factor
- Assessing the impact of different input factor assumptions

2.4.1 Variation in the land use factor of sugar cane

A perennial land use factor and a long term cultivated land use factor applied to sugar cane have been tested and the results are shown in Table 18 and Figure 6.
The last two columns indicate the emissions if sugar cane is considered as “semi perennial”. On average, sugar cane is planted 3 times in 20 years, so we estimate that the emissions released from

soil would be the emissions of the perennial assumption plus 3/20th of the difference between cultivated and perennial assumptions.

Table 18 : Variation in mineral soil emissions considering different assumptions on sugarcane land use factor

	Sugar Cane Cultivated		**Sugar Cane Perennial**		**Sugar Cane Semi-Perennial**	
MtCO2	SOC	N2O	SOC	N20	SOC	N20
Brazil	25.07	2.85	-3.23	-0.35	1.02	0.13
CAMCarib	0.51	0.06	-0.61	-0.08	-0.44	-0.06
China	3.95	0.41	4.26	0.45	4.22	0.44
CIS	38.09	3.62	38.09	3.62	38.09	3.62
EU27	3.87	0.43	3.87	0.43	3.87	0.43
IndoMalay	-27.14	-3.21	-26.65	-3.15	-26.73	-3.16
LAC	6.14	0.71	6.34	0.73	6.31	0.73
RoOECD	1.09	0.11	0.78	0.08	0.83	0.09
RoW	8.59	1.06	7.74	0.95	7.87	0.97
SSA	-10.81	-1.19	-12.55	-1.39	-12.28	-1.36
USA	2.75	0.33	2.75	0.33	2.75	0.33
World	**52.12**	**5.18**	**20.81**	**1.62**	**25.50**	**2.16**

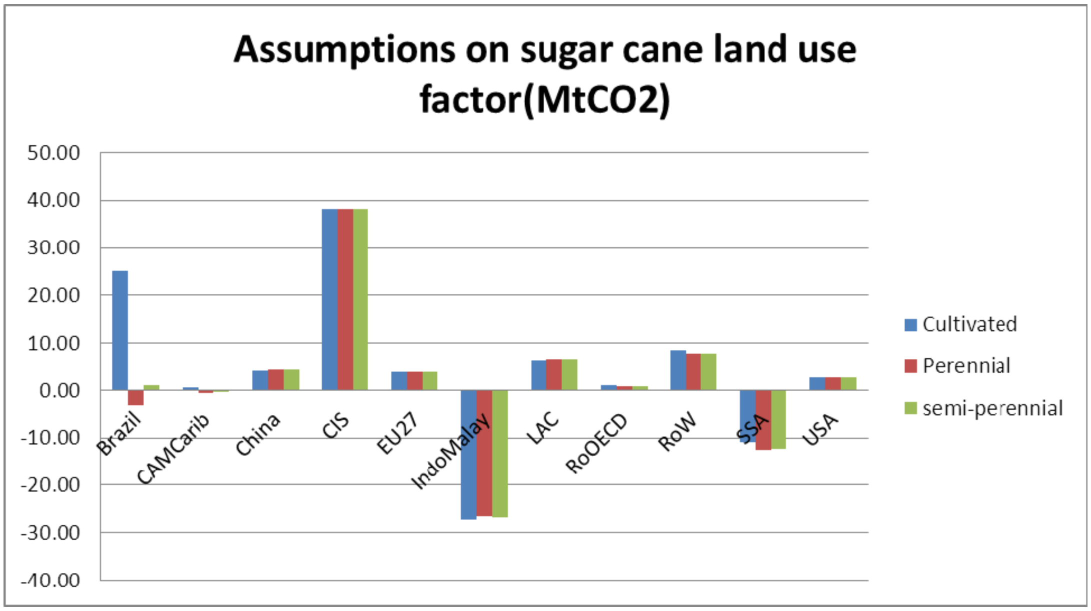

Figure 7: SOC emissions under different classifications of sugar cane NREAP BAU full mandate

2.4.2 Change in Management and Input factors

The figure below illustrates as an example the extreme GHG emissions that can be obtained under different input and management factors assumptions.
The Cropland input factor (F_I) tested in the figure are:

- Cropland F_I set to Low everywhere (Low)
- Cropland F_I set to Medium everywhere (Med)
- Cropland F_I set to High without manure everywhere (HNoM)
- Cropland F_I set to High with manure everywhere (HWM)

Figure 8 compares the results of the best estimate calculation (with the range of values obtained considering full tillage (blue bars) and no tillage (red bars)).
Land use factor is set to perennial for oil palm trees and sugar cane and long term cultivated for other type of crops.

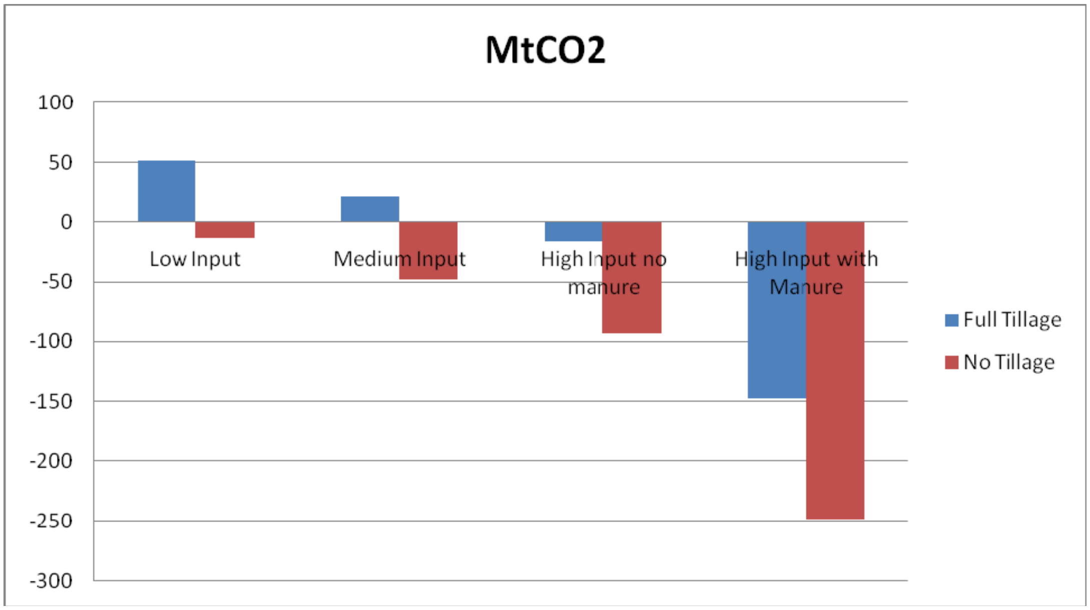

Figure 8: Comparison of emissions under different input factors and management practices – NREAP full mandate

Appendix 1: GHG emissions from IFPRI-MIRAGE “8.6% mandate”

1 Emissions from changes in above- and belowground biomass carbon stock

CO_2 Emissions from changes in ABCS based on Business as Usual (BAU) and Free-Trade (FT) 8.6% scenarios at regional level are shown in Figure 9 and Figure 10 below. The distribution of the LUC area over the different ecosystems is similar to the one calculated with the 5.6% scenario, and emissions increase linearly with the increase in area moving from the 5.6% to the 8.6% scenario, as shown in Table 19 (see for comparison the corresponding Figures 38 and 39 in JRC report n. 24483 [Hiederer et al, 2010] .

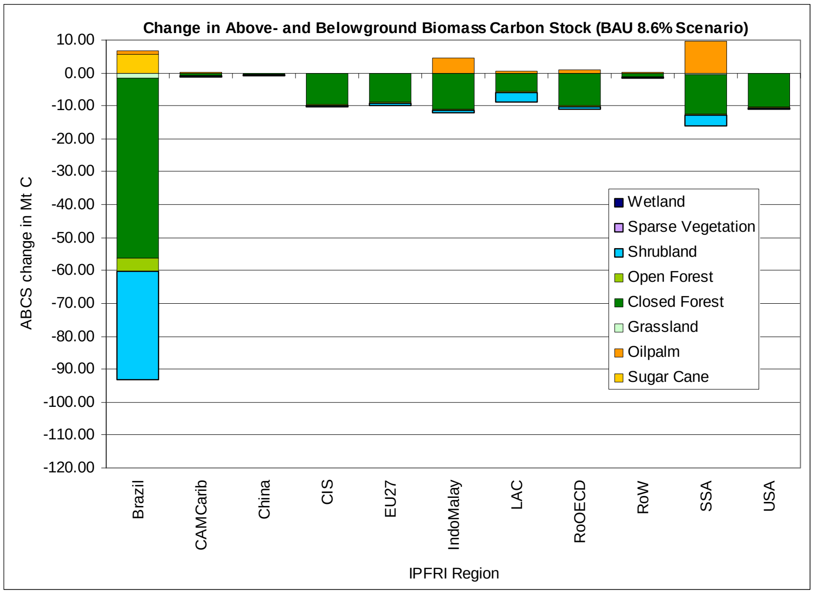

Figure 9: Change in Above- and Belowground Biomass Carbon Stock (Mt C) in Different Regions Based on Spatial Allocation of IFPRI 8.6% BAU scenario

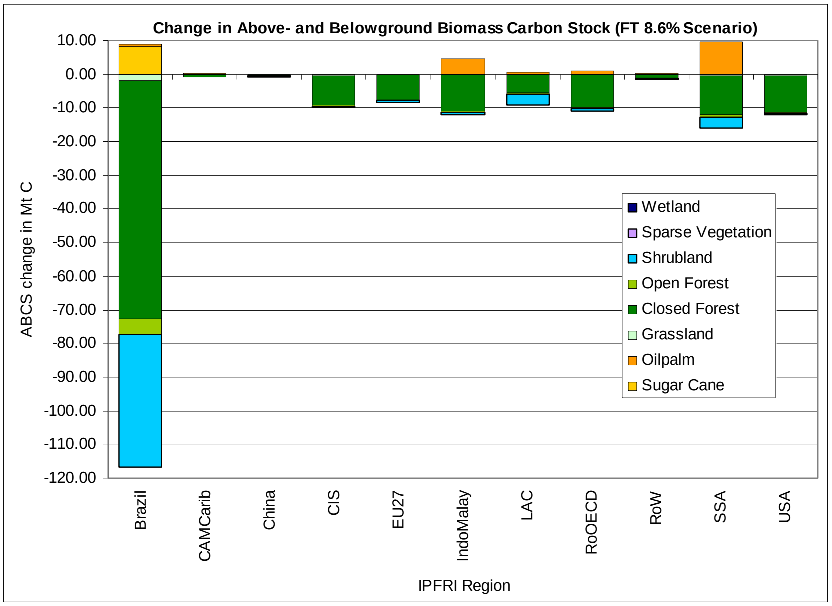

Figure 10: Change in Above- and Belowground Biomass Carbon Stock (Mt C) in Different Regions Based on Spatial Allocation of IFPRI 8.6% FT scenario

Table 19: Emissions from change in Above- and Belowground Biomass Carbon Stock Related to Biofuel Cultivation in 2020 by IFPRI Region (IFPRI 8.6% BAU Scenario)

	IFPRI BAU 8.6% SCENARIO	
	LUC area (ha)	**C stock change in Mt CO2**
Brazil	1424608	-318
CAMCarib	15605	-3
China	24280	-3
CIS	266243	-38
EU27	314650	-36
IndoMalay	83324	-28
LAC	158396	-31
RoOECD	107434	-37
RoW	39268	-5
SSA	240303	-24
USA	96216	-40
Global	**2770328**	**-563**

Table 20: Emissions from change in Above- and Belowground Biomass Carbon Stock Related to Biofuel Cultivation in 2020 by IFPRI Region (IFPRI 8.6% FT Scenario)

	IFPRI 8.6% FT SCENARIO	
	LUC area (ha)	**C stock change in Mt CO2**
Brazil	1748536	-395
CAMCarib	10214	-2
China	23153	-3
CIS	255415	-37
EU27	268848	-31
IndoMalay	83797	-28
LAC	160618	-31
RoOECD	104637	-37
RoW	33834	-5
SSA	231546	-23
USA	105073	-44
World	**3025671**	**-634**

Table 21: Comparison of ABCS emissions based on IFPRI MIRAGE 8.6% and 5.6% scenarios

	8.6% scenario			5.6% scenario		
	LUC area in ha	**Total CO2 emissions in Mt**	**CO2 emissions in t/ha**	**LUC area in ha**	**Total CO2 emissions in Mt**	**CO2 emissions in t/ha**
BAU	2,770,328	563	203	820,900	167	203
FT	3,025,671	634	210	975,890	210	215

1.1 Emissions from changes in changes in soil C-stock

The global changes in soil C-stock amounts to **31.5** Mt C for the BAU scenario (corresponding to 115.3 $MtCO_2$) and to **32.7** Mt C for the FT scenario (equivalent to 119.7 Mt CO_2).
The difference in emissions from the soil between BAU and FT scenarios is very small and results from the limited increase in extra land in the FT scenario of about 2,500 km^2 more than in the BAU scenario. A summary of the emissions of C from the soil is given in Table 22. Peat emissions (organic

soils) have been estimated assuming that 33% of cropland expansion in Malaysia and Indonesia occurs on peatlands and using the emission factor of 86 tCO_2/ha/yr).

Table 22: Changes in Soil C and CO_2 Emissions from the Soil on Extra Cropland for IFPRI 8.6% Scenario Data

IFPRI Scenario	Crop Expansion Area	C Stock Change	CO_2 Emission Mineral Soil	CO_2 Emission Organic Soil*
	Ha	*Mt C*	*Mt CO_{2eq}*	*Mt CO_{2eq}*
BAU 8.6	2,770,328	-31.5	115.3	42.6
FT 8.6	3,025,671	-32.7	119.7	42.9

* Assuming 33% of extra land in the “IndoMalay” IFPRI Region for oil palm on peat.

The results of the changes in soil C-stock (changes in C in mineral soils) by region are given in Figure 11.

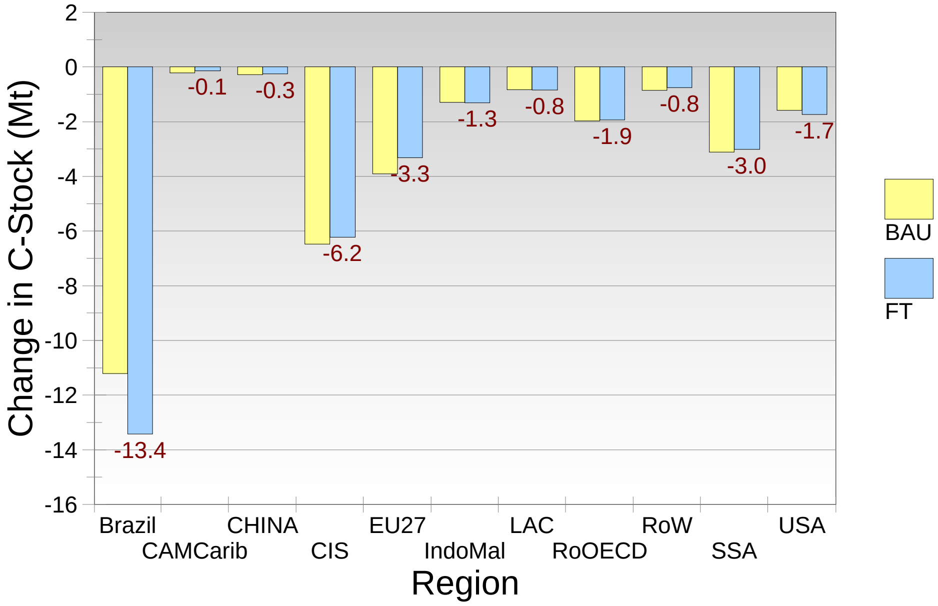

Figure 11: Changes in Soil C-Stock under IFPRI 8.6% Scenario, Business as Usual (BAU) and Free Trade (FT)

For both settings the main changes in C-stock are found for Brazil, followed by CIS (for this region the emissions slightly decrease from the BAU scenario to the FT scenario).

The largest increase in cropland area in Brazil is driven by sugar cane expansion, which is generally classified as “perennial crop” regarding SOC storage (for example Winrock international[10] or FAO[11]). According to Brazilian experts indications (see for example the comments sent by the Brazilian Sugar cane Industry Association (UNICA) to the Commission’s Consultation on Indirect Land Use Change impacts of biofuels) sugar cane is a semi-perennial crop with high carbon stocks[12]. However, semi-perennial crops are not appropriately reflected in the IPCC default values, and therefore sugar cane is more often considered as perennial.

Using a different classification for sugar cane as “long term cultivated” crop, soil C emissions would be much higher (respectively 31.5 Mt C for the BAU scenario and 38.1 Mt C for the FT scenario).

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[10] Winrock 2009. Harris, N. L., Grimland, S. and Brown, S. Land Use Change and Emissions Factors: Updates since Proposed RFS Rule;Winrock Emission Factors Docket. Report submitted to EPA.

[11] http://www.fao.org/docrep/u7600t/u7600t04.htm

[12] UNICA Comments to European Commission on Indirect Land Use Change Impact of Biofuels. Brussels, 29 October 2010

A graphical presentation of the changes in soil C-stock by country from the two scenarios is given in Figure 12.

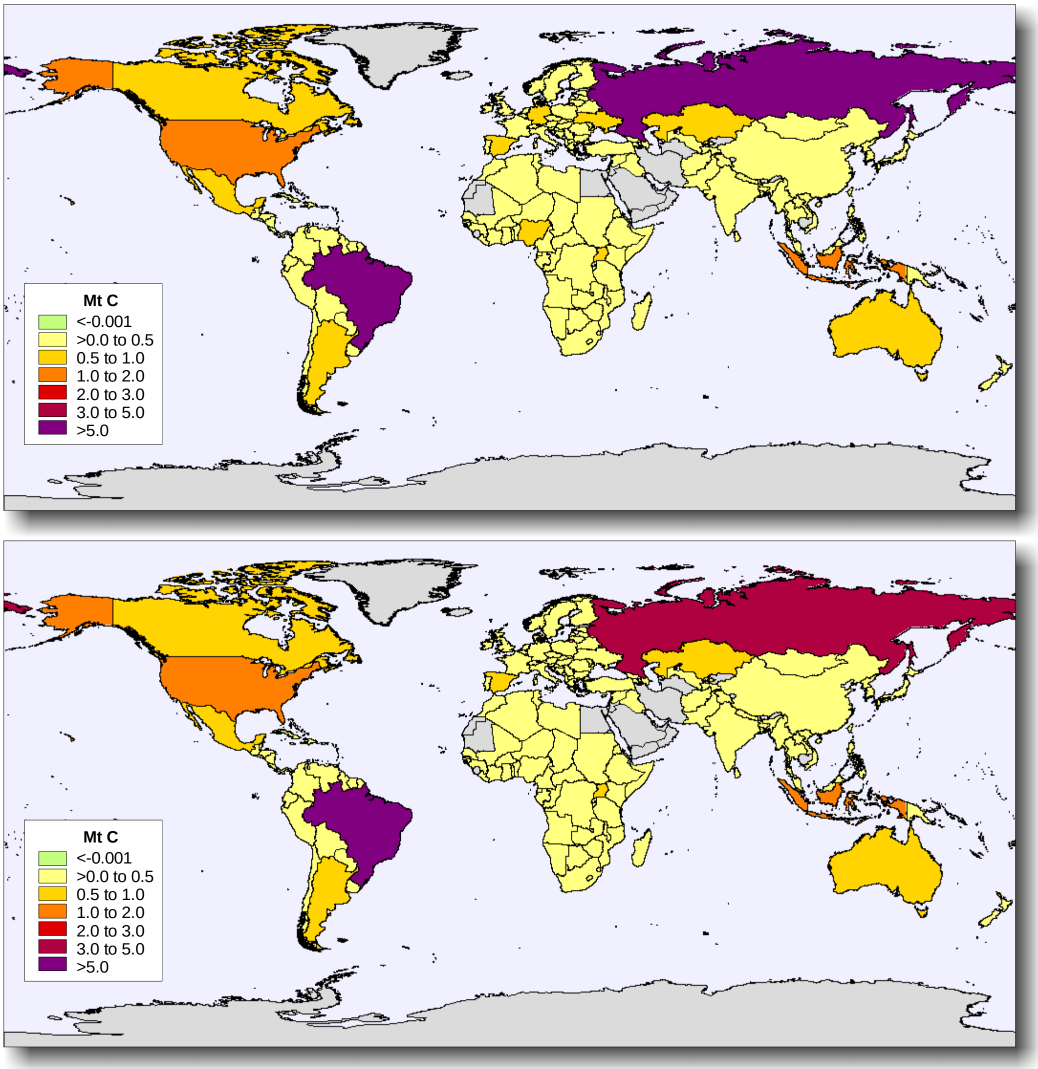

Figure 12: Distribution of Changes in Soil C-Stock by Country; IFPRI 8.6% scenario; Business as Usual (BAU) and Free Trade (FT)

The soil C emissions in Russia drop from 5.15 Mt C under the BAU scenario to 4.97 Mt C under the FT scenario. This results in a classification change and subsequent colouring of the areas in the maps.

1.2 N_2O soil emissions

N_2O soil emissions related to mineralized N were estimated as 12% of CO_2 emissions from loss of SOC. This simplified approach is justified by the finding of the calculations in the “5.6% scenario” in the JRC report, Figure 33: the ratio between N_2O (in CO_2 equivalent) and SOC emissions doesn’t vary much across the different regions, and the average value is 0.12. Results are indicated in Table 23 below. Considering the low values for N_2O emissions, this approximation brings negligible deviations from the results that could be obtained applying the detailed methodology.

Table 23: Global N_2O Soil Emissions over a Period of 20 Years Related to Mineralized N Resulting from Loss of Soil Organic Carbon due to Land Use Change in 2020

	N_2O Soil Emissions Related to Mineralized N Resulting from Loss of SOC	
	IFPRI-MIRAGE BAU	**IFPRI-MIRAGE FT**
	Mt CO_2eq	*Mt CO_2eq*
Global Total	**13.8**	**14.4**

1.3 Total emissions from IFPRI BAU and FT "8.6%" scenarios

Total GHG emissions resulting from extra land demand based on IFPRI-MIRAGE 8.6% scenario are summarized in Table 24 below.

Table 24: Total Greenhouse Gas Emissions from Changes in Soil and Biomass Carbon Stocks Induced by ILUC

Source	**IFPRI BAU**			**IFPRI FT**		
	Mt CO_2eq	*gCO_2/MJ*	%	*Mt CO_2eq*	*gCO_2/MJ*	%
Emissions from change in soil C stock*	152	12	21	157	13	20
N_2O emissions related to loss in soil C	13.8	1	2	14.4	1	2
Emissions from change in ABCS	565	41	77	635	46	78
Total GHG emissions from land use change	731	**54**		806	**60**	

*Including emissions from peat-lands in "IndoMalay" region.

The total emissions calculated from this "8.6% mandate" scenario from 2010 IFPRI study are considerably higher than total emissions resulting from the more recent 2011 "NRAP scenario" (about 36 gCO2/MJ, as shown in 2.1.5).

As explained by IFPRI (Laborde, 2011), there are important changes in 2011 "NRAP" study compared to the previous "8.6% mandate" (Al Riffai et al, 2010).

Although the size of the mandates in the two studies is almost the same (8.6% first generation biofuels share on total transport fuels), the 2011 study included several modifications to the model assumptions, as for example the treatment of co-products (higher substitution), the peatland emissions (higher factor), the land reallocation among crops (better calibration) and the dynamics of food demand (less elastic). But most importantly, in the new 2011 study most feedstocks benefit from the higher yields assumed in the baseline which helps to reduce the amount of land required to cope with additional crop demand and hence total emissions.

Appendix 2: Estimation of potential impacts on biodiversity resulting from IFPRI NREAP scenarios

According to the central scenario in the 'new' IFPRI model, the estimated additional cropland requirements globally amount to 17,000 km^2, mainly taking place in Commonwealth of Independent States (CIS), Sub-Saharan Africa and Brazil regions. New cropland is allocated by IFPRI estimating changes in the economic use of land, i.e. among forestry, cropland and pasture uses. The results of the IFPRI study showed that this new cropland is taken from pasture (42%), managed forest (39%), primary forest (3%) and savannah and grassland (16%), which will have biodiversity and wider environmental impacts.

A qualitative estimation of the impacts to biodiversity of land use changes calculated by IFPRI was made by the JRC using the Mean Species Abundance (MSA) values provided by the Global Biodiversity Model (GLOBIO 3)[13]. This model is built on a set of equations which link environmental drivers and biodiversity impacts. The environmental drivers used as input for GLOBIO3 are land-use change (including forestry), climate change, N deposition, harvesting, energy use etc.

Biodiversity is described in GLOBIO3 on the basis of the remaining mean species abundance (MSA) of original species, relative to their abundance in pristine or primary vegetation, which are assumed to be not disturbed by human activities for a prolonged period. MSA is therefore considered as the indicator for biodiversity.

The following table was extracted from Alkemade et al, 2009 and adapted to IFPRI land use classes to evaluate MSA values for the land use transitions (and LU classes) in IFPRI scenario.

IFPRI Land Use class	**Sub-category**	**Description**	**MSA$_{LU}$**	**SE**
Pasture		Grasslands where wildlife is replaced by grazing livestock	0.7	0.05
Managed Forest	Secondary forest	Areas originally covered with forest or woodlands, where vegetation has been removed, forest is re-growing or has a different cover and is no longer in use	0.5	0.03
	Agroforestry	Agricultural production intercropped with (native) trees. Trees are kept for shade or as wind shelter	0.5	0.06
Primary Forest		Minimal disturbance, where flora and fauna species abundance are near pristine	1.0	<0.01
Scrublands and grasslands		Grassland or scrubland-dominated vegetation (for example, steppe, tundra, or savannah)	1.0	<0.01
Cultivated and managed areas		High external input agriculture, conventional agriculture, mostly with a degree of regional specialization, irrigation-based agriculture, drainage-based agriculture*.	0.1	0.08

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[13] GLOBIO 3 is developed by a consortium made up of UNEP world Conservation Monitoring Centre (WCMC), UNEP/GRID-Arendal and the Netherlands Environmental Agency (PBL). [Alkemade et al, 2009]

* The JRC assumes land management factor for cropland as “medium or high input with manure” in its calculations. For consistency the same assumption is taken here.

For example, according to the MSA values in the table, a transition from pastureland (MSA 0.7) to cropland (MSA 0.1) will cause a loss of 86% of MSA.

An estimation of the total biodiversity loss which may result from IFPRI scenario has been calculated with a weighted average of MSA values for IFPRI land use changes as:

$$\mathit{Biodiversity\ loss}\ (\%) = \frac{\left[\sum_i (MSAi\ *\ \%i)\right]\ -\ MSA_{ca}}{\sum_i MSAi\ *\ \%i}$$

Where:

MSA_i = Mean Species Abundance of land use type i
$\%_i$ = % of land conversion according to IFPRI results
MSA_{ca} = Mean Species Abundance of cultivated and managed areas

Considering that 42% of new cropland will come from pasture, 39% from managed forest, 3% from primary forest and 16% from savannah and scrublands, this will result in a “weighted” MSA value of 0.68, and the transition to cropland will cause an 85.3% decrease in the MSA index in affected areas.

This result, in line with the conclusions of the GLOBIO3 study, shows that the extensive use of bioenergy crops will increase the rate in loss of biodiversity, and often the GHG reduction from biofuels production are insufficient to compensate for the losses due to land use change.

This analysis can only give a rough estimation of the potential impacts of land use change driven by increased biofuels demand to biodiversity. For future updates of the Spatial Allocation Methodology, the JRC will evaluate the possibility, in collaboration with the experts who developed the biodiversity maps, of also including in the SAM routine the MSA maps, in order to make a more precise assessment of the impacts on biodiversity in the different regions.

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European Commission

EUR 24817 EN – Joint Research Centre – Institute for Energy
Title: Estimate of GHG emissions from global land use change scenarios
Author(s): L. Marelli, F. Ramos, R. Hiederer, R. Koeble
Luxembourg: Office for Official Publications of the European Communities
2011 – 36 pp. – 21 x 29.7 cm
EUR – Scientific and Technical Research series – ISSN 1018-5593
ISBN 978-92-79-20242-1
DOI 10.2788/20453

Abstract

This study follows the methodology developed by the JRC (2010) for estimating changes in greenhouse gas emissions from global land use changes due to increased biofuels demand, and applies the methodology to the output of global modelling calculations run by the International Food and Policy Research Institute (IFPRI).

In particular, this report focuses on the scenario recently published by IFPRI that was based on the estimates of the National Renewable Energy Action Plans (NREAPs) of the EU Member States. In this scenario, a total 1st generation biofuels blend of 8.7%, with a spread bioethanol/biodiesel of 22%-78% (NREAP "full mandate") was assumed. In addition to the "full mandate", marginal calculations for 8 different feedstocks were also carried out.

For completeness of the analysis on IFPRI scenarios carried out in JRC 2010 report, Appendix 1 also reports the results of the methodology as applied to another scenario (the "8.6% mandate") published in the previous IFPRI report of 2010: this scenario assumes a biofuels (1st generation) blend in total fuel consumption in 2020 of 8.6% with a spread bioethanol/biodiesel of 60%-40%.

Based on the outcomes of IFPRI economic modeling in the "NREAPs scenario", the increased biofuels demand will cause ILUC GHG emissions of about 36 gCO_2/MJ. This result also includes emissions from peatland drainage due to oil palm plantations mainly in Indonesia and Malaysia, which were not accounted in the original JRC methodology. The estimated peat emissions in unit of energy are 19.8 gCO_2/MJ, which represent the main contribution to total GHG emissions from LUC (about 55% of total emissions).

ILUC GHG emissions for 8 feedstocks (4 for ethanol and 4 for biodiesel) were also calculated. The results show that in general ethanol crops have lower ILUC impacts than oilseeds/biodiesel crops: emissions for ethanol feedstocks range from about 4 to 20 gCO_2/MJ, and for biodiesel feedstocks they range from about 36 to 60 gCO_2/MJ. These JRC results are in line with the emissions calculated by IFPRI.

Compared to the new (2011) study, the previous (2010) economic analysis carried out by IFPRI gave much higher estimations of land use change due to 8.6% biofuels consumption in 2020 ("8.6% scenario"), resulting in GHG emissions of about 54 gCO_2/MJ. The contribution of peat emissions is about 3 gCO_2/MJ, which corresponds to only 5% of total emissions. The low share is due to the very limited oil palm expansion in the previous IFPRI economic analysis.

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