WFL Publisher
Science and Technology
Meri-Rastilantie 3 B, FI-00980
Helsinki, Finland
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Journal of Food, Agriculture & Environment Vol.12 (2): 1353-1355. 2014
www.world-food.net

Indirect land-use change effects of biodiesel production: A case study for Poland

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Received 26 February 2014, accepted 7 April 2014.

Abstract

The European Commission proposed amendments to the Directive 98/70/EC and Directive 2009/28/EC, which call for the inclusion of indirect changes in land use (iLUC) to the estimated volume of greenhouse gas (GHG) emissions within the life cycle of transportation biofuels. The paper investigates possible emissions reductions in the life cycle of biodiesel (FAME) according to six scenarios with special focus on iLUC. Including iLUC for rapeseed biodiesel production in Poland results in GHG emission reduction lower than the required 50% starting from January 2017. However, in some rapeseed growing regions, at least 50% emission threshold can be achieved when reduced tillage (małopolskie, opolskie, pomorskie and zachodniopomorskie) or no-tillage (małopolskie, opolskie, podkarpackie, pomorskie, śląskie and zachodniopomorskie) is applied. All these regions are located in temperate moist climate region, which is combined with higher level of soil organic carbon sequestration compared to dry climate.It was estimated that when including iLUC in the calculations of greenhouse gas emissions, the agricultural sector in Poland can produce 548 thousand ton of rapeseed, which meets the Directive 2009/28/EC sustainability criteria (50% GHG emission reductions), under the condition that improvement of agricultural management (soil carbon accumulation) will occur. This production can supply 202 thousand tons of FAME, which would amount to 33% of transport fuel from renewable energy sources by 2020, according to National Renewable Energy Action Plan. After 2020, the additional amount of transportation fuels required by the Directive 2009/28/EC will have to be derived from another biofuels or renewable energy sources.

Key words: iLUC, greenhouse gas, emission reduction, rapeseed, biodiesel, RED.

Introduction

The European Commission proposed amendments to the Directive 98/70/EC and Directive 2009/28/EC (RED), which call for inclusion of indirect changes in land use (iLUC) to the estimated volume of GHG emissions within the life cycle of transportation biofuels [1]. iLUC takes into consideration complementary emission, which will significantly increase the total volume of GHG emissions in the biofuel lifecycle and at the same time it decreases the biofuels emission savings compared to conventional liquid fuels [2-6].

The threshold limitations for GHG emissions for biofuels, as required by the currently applied provisions of Directive 2009/28/EC, are at least 50% and will become effective from 01.01.2017 [7]. Furthermore, the amended Directive assumes biofuels emission saving target at least 60% for installations starting production effectively from 01.07.2012 and at least 50% for installations operating before 01.07.2012 [1].

Materials and Methods

iLUC: Biofuel feedstock may be produced on land directly converted from another land use status to agricultural land. It can lead to significant GHG emissions, named direct land use change (dLUC), which have to be included in the overall calculation of greenhouse gas emissions of particular biofuel, in order to determine if it meets the sustainability criteria [1, 7]. However, if the biofuels feedstock is instead cultivated on existing agricultural land, it may, then displace another crop production, and some of which ultimately may lead to conversion of another land into an agricultural land. This indirect land-use change can also lead to additional emissions which is called iLUC.

According to the European Commission, the proposed iLUC factor value for oilseed crops is 55 g CO_2 eq. MJ^{-1} of biofuel and should be included in the calculation of biofuels GHG emissions from 2021 [1].

Climate: The climate in Poland, (in accordance to the decision from the European Commission), has been accessed as cold temperate dry and moist [8]. This climatic classification is spatially inaccurate as it derives from maps covering the entire globe. A more detailed map developed by Faber *et al.* [9] is shown in Fig. 1.

The classification of individual administrative regions (voivodeships, NUTS-2) to climate regions is shown in Table 1. The classification has a significant impact on the amount of soil organic carbon sequestration under crops; therefore, it will influence the calculation of GHG emissions in the life cycle of crop-based biofuels. Further analyses are based on the climate classification according to IUNG-PIB data (Table 1). JRC data show different climatic classification for three regions.

Carbon sequestration: Soil organic carbon (SOC) sequestration was estimated taking into account improved agricultural management, the reduced tillage (reduced soil disturbance) and no-tillage (cultivation without ploughing) with varying amounts of crop residues left in the field (carbon input) [10]. In accordance with the requirements of the EC decision [10], the estimate of the SOC stocks took into account the climate (temperate dry and

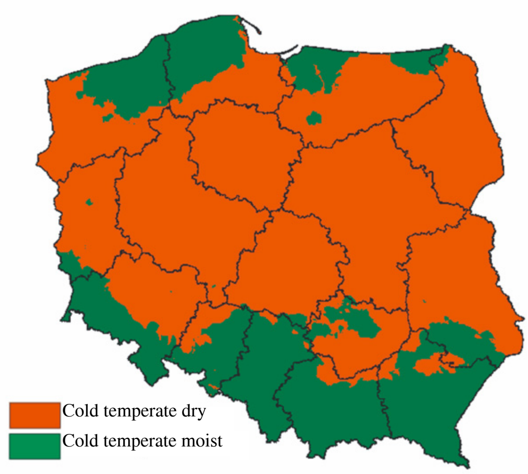

Figure 1. Climatic regions of Poland [9].

Table 1. The type of climate in the voivodeships of Poland.

Voivodeship (NUTS-2)	Temperate climate	
	IUNG-PID [9]	JRC EC [8]
Dolnośląskie	S	S
Kujawsko-pomorskie	S	S
Lubelskie	S	S
Lubuskie	S	S
Łódzkie	S	S
Małopolskie	W	W
Mazowieckie	S	S
Opolskie	W	W
Podkarpackie	W	W
Podlaskie	S	W
Pomorskie	S/W	W
Śląskie	W	W
Świętokrzyskie	S	W
Wielkopolskie	S	S
Warmińsko-mazurskie	S	W
Zachodniopomorskie	S/W	S/W

S - temperate dry; W - temperate humid.

humid), soil type (high clay activity mineral), land cover (agricultural land) and the field management (agricultural land). All data are typical for Poland.

Greenhouse gas emissions reduction: The reduction of GHG in the life cycle of biofuels compared to conventional fuels were estimated in accordance with the requirements of Directive 2009/28/EC (Annex V) using BIOGRACE 4b public [11]. Emissions from crop cultivation and biofuel processing, transport and distribution were included. In the estimates of agricultural emissions, the voivodeship's averages of crop production technology from 1,218 rapeseed growing farms were used [12]. The other emission parameters for biodiesel (processing, transport and distribution) were assumed as the EU average. For the biofuel processing plant, natural gas was selected as the processing fuel.

The study presents the results of 96 simulations of greenhouse gas emission reductions in the life cycle of biodiesel produced from rapeseed in Poland.

Scenarios: The GHG attributed to iLUC (55 g CO_2 eq. MJ^{-1} FAME) and soil organic carbon (SOC) sequestration, both affect the overall GHG reduction in the lifecycle of biofuels. Six scenarios were reviewed to evaluate the impact:

- Scenario 1. Reduction of GHG emission without SOC sequestration (conventional cultivation, full tillage);
- Scenario 2. Reduction of GHG emission without SOC sequestration, iLUC taken into account;
- Scenario 3. Reduction of GHG emission including SOC sequestration the application of simplified cultivation scheme (reduced tillage);
- Scenario 4. Reduction of GHG emission including SOC sequestration with the application of direct sowing (no-tillage);
- Scenario 5. Reduction of GHG emission including SOC sequestration with simplified cultivation, iLUC taken into account;
- Scenario 6. Reduction of GHG emission including SOC sequestration with direct sowing, iLUC taken into account.

Results and Discussion

The results of the analyses show that the introduction of iLUC factor lowers the currently achieved reduction in biofuels versus fossil fuel emission to a level close to zero (wherever the value is negative, the biodiesel emission is larger than that of conventional fuel) (Table 2).

Results for NUTS-2 are following:

- The reduction of GHG emissions (GHG emission savings) combined with biofuels, including iLUC, in all voivodeships are lower than 50% (scenario 2);
- Achieving the threshold reduction in the GHG emission of 50% is possible under scenario 5 in the podkarpackie and śląskie voivodeships; close to achieving this level are małopolskie, opolskie, pomorskie and zachodniopomorskie voivodeships (all in the cold temperate moist climate region);
- Achieving the threshold reduction of emission of 50% is possible under scenario 6 in małopolskie, opolskie, podkarpackie, pomorskie, śląskie and zachodniopomorskie voivodeships (cold temperate moist climate region).

The situation for biodiesel production is much worse compared to bioethanol, and it is forecasted that in some EU countries, the fulfilment of national indicative targets shall be substituted

Table 2. GHG emission reduction in the life cycle of rapeseed biodiesel with leaving harvest residues in the field.

Factor	Unit	Improved crop management	Min. *	Max. **	Average ***
iLUC	t CO_2 ha^{-1} r^{-1}	x	2.2	2.7	2.5
C sequestration	t CO_2 ha^{-1} r^{-1}	x	0.5	1.9	1.0
GHG emission reduction	%	Scenario 1	32	42	37
		Scenario 2	-6	3	-2
		Scenario 3	47	92	64
		Scenario 4	64	113	82
		Scenario 5	9	54	26
		Scenario 6	25	74	43

* Min - NUTS-2 in the cold temperate dry climate region; ** Max - NUTS-2 in the cold temperate moist climate region; *** Average for Poland.

by bioethanol or other biofuels of low iLUC. In Poland, the potential production of rapeseed is limited to voivodeships located in the mild-wet climate. With the optimistic assumption that the entire rapeseed production from these voivodeships could be used for biodiesel, the amount of rapeseed would be of 548 thousand tonnes, which corresponds to FAME volume of 202 thousand tonnes (Table 3). However, in order to estimate more realistic potential, the raw material availability shall be counted as 50% of the volume of total production, which means that the above values should be reduced by half. Analyses conducted by IUNG-PIB show that some voivodeships presented in Table 3 will not increase their volume of production. On the other hand, increased efficiency in the rapeseed cultivation is expected to occur particularly in the south and southeast part of Poland.

Table 3. Maximum volume of rapeseed production for biodiesel in voivodeships with mild-wet climate.

Voivodeship (NUTS-2)	2010 rapeseed production (thousand tons)[13]
Małopolskie	11.1
Opolskie	231.2
Podkarpackie	35.3
Śląskie	37.2
Pomorskie	83.5
Zachodniopomorskie	150.0
Total	548.3*

* Provides for total FAME production of 201 908 t year^{-1}.

Application of the improved crop management will increase the organic carbon sequestration in the soil, much more in the area of Poland with the temperate moist climate rather than the temperate dry (Fig. 1).

Conclusions

Including iLUC in rapeseed biodiesel production in Poland results in GHG emission reduction lower than the required 50% starting from January 2017. However, in some regions of rapeseed cultivations at least 50% of emission threshold can be achieved when reduced tillage (małopolskie, opolskie, pomorskie and zachodniopomorskie) or no-tillage (małopolskie, opolskie, podkarpackie, pomorskie, śląskie and zachodniopomorskie) is applied. All these regions are located in temperate moist climate region, which is combined with higher level of SOC sequestration compared to temperate dry climate. Based on the results achieved, it was found that including iLUC in the calculations of greenhouse gas emissions can give in Poland total production of 548 thousand tons of rapeseed, which meets the sustainability criteria of the Directive 2009/28/EC (50% GHG emission reductions) if improvement of agricultural management (soil carbon accumulation) will occur. This production can supply 202 thousand tons of FAME which would cover 33% of transport fuel from renewable energy sources by 2020 according to National Renewable Energy Action Plan.

Acknowledgements

The studies have been supported by National Science Centre within the projects N N313 759240.

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