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A LIFE CYCLE ASSESSMENT OF RAPESEED OIL PRODUCED IN ROMANIA AS FUEL FOR DIESEL ENGINES

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ABSTRACT

In this paper is analysed the environmental performance of rapeseed oil (RO) from winter rape as fuels produced in Romania. The methodology used is life cycle assessment (LCA) and takes into consideration the influence of grain production and agroclimatic conditions. This study shows favourable results for RO when compared to diesel fuel, in the following impact categories: Abiotic depletion potential (ADP), Ozone layer depletion (ODP) and Photochemical ozone creation potential (POCP). Furthermore, the environmental performance of the biofuel can be improved by changing the type of fertilizer used.

KEYWORDS: rapeseed oil, life cycle assessment, greenhouse gases

1. INTRODUCTION

According to the Directive 2009/28/EC [1], the share of biofuel in the fuel used in transportation sector rises to a minimum 10% in every Member State in 2020. The directive wants to ensure that, as we expand the use of biofuels in the EU, we use only sustainable biofuels which generate a clear and net GHG saving and have no negative impact on biodiversity and land use [1], [2]. In this context it is necessary to assess the environmental performance of rapeseed oil produced in Romania.

This study focuses on environmentally assessing rapeseed oil production as a potential energy source. With this purpose we compiled agricultural production data for winter rape cultivated on 150 ha. from eastern Romania (Galati area).

Finally, the study compares the environmental performance of RO and an equivalent quantity of fossil diesel in order to demonstrate the viability of this energy source along with the fossil fuel.

2. METHODOLOGY

The plot selected for this study is 1 ha. of the total of 150 ha. cultivated with winter rape in the eastern Romania. In Table I are considered the main variables such as mean annual temperature, annual rainfall and average number of frost days.

The methodology used to analyse the environmental performance of B. napus cropping system was Life Cycle Assessment (LCA).This environmental tool is used to assess all environmental impacts associated with a product, process or activity by accounting for and evaluating resource consumption and emission [5], [6]. LCA is a methodology that follows the ISO 14040 guidelines [5], [6] and is divided into four steps: 1. Definition of goal and scope, 2. Inventory analysis, 3. Impact assessment, 4. Interpretation.

The environmental analysis was conducted using the software program SimaPro 7.3 by Pré Consultants.

3. LCA OF RO PRODUCTION BY MEANS OF B. NAPUS CROPPING SYSTEM

Table 1. Agroclimatic conditions of the studied area

Geo-coordinates	Mean annual temperature (°C)	Annual rainfall (mm)	Frost days (days*year^{-1})
45.53N, 28.08 E	10,7	420 – 430	92

A. Goal Definition

The aim of the study was to evaluate the environmental performance of winter rapeseed cropping system in order to determine if this energy crop is suitable for biofuel production. A specific goal of the present study is to evaluate the environmental impacts of RO and compare the results with conventional diesel.

B. Functional unit

In this study, the selected functional unit is the production of 1 kg. of RO. To compare the biofuel with fossil diesel on the basis of LHV, the equivalent quantity of fossil diesel of 870 g. is considered [3].

Table 2. Field Operation Experimental Data Used in the Assessment

Operation	Tractor	Implement				Inputs
	weight [kg.]		weight [kg.]	Operating rate [$h \cdot ha^{-1}$]	Fuel [$l \cdot ha^{-1} \cdot y^{-1}$]	
Soil tilling	9.000	plow	800	2	20	
Soil milling	9.000	mill	1.500	1	10.50	
Chisel pass	9.000	disc harrow	3.000	0.50	6	
Fertilizer application	4.000	spreader	1.200	0.50	2	500 $kg \cdot ha^{-1} \cdot y^{-1}$ NPK 15-15-15
Sowing	9.000	seeder	800	0.75	7.50	3.500 $kg \cdot ha^{-1} \cdot y^{-1}$ rape seeds
Herbicide application	4.000	Boom sprayer	3.000	0.25	2	1 $kg \cdot ha^{-1} \cdot y^{-1}$ Fusilade Forte
Insecticide application	4.000	Boom sprayer	3.000	0.25	2	0.15 $kg \cdot ha^{-1} \cdot y^{-1}$ Karate-Zeon
Harvesting	10.000			1	10	

C. Systems description

3.1. Rapeseed oil system

The energy crop system studied includes agricultural production, transport of inputs/outputs and oil extraction. The main stages analysed in the life cycle of rapeseed oil are represented in Fig. 1 and conventional diesel. The system includes all agricultural inputs and outputs, and their corresponding emissions, during the agricultural stage. Inputs are: all agricultural machinery, seeds, water from irrigation stage, fertilizers with their corresponding emissions, insecticides, herbicides. Transportation of agricultural machinery and other inputs from the farm to the land and back is also considered an input. Farmer transport stage includes a total number of 10 round trips [4].

Outputs are seeds and biomass bales. To obtain the final product, we have to consider the extraction of the vegetable oil phase and its refining.

The oil extraction yield is considered 97% taking into account the seed's oil content of 41% [7] – [9]. The outputs of these processes are meal and rapeseed oil [10]. The refinement of the vegetable oil is also taken into account. In this study meal is considered a co-product of rapeseed oil and its impact is subtracted from the systems total impact according to the allocation procedure selected.

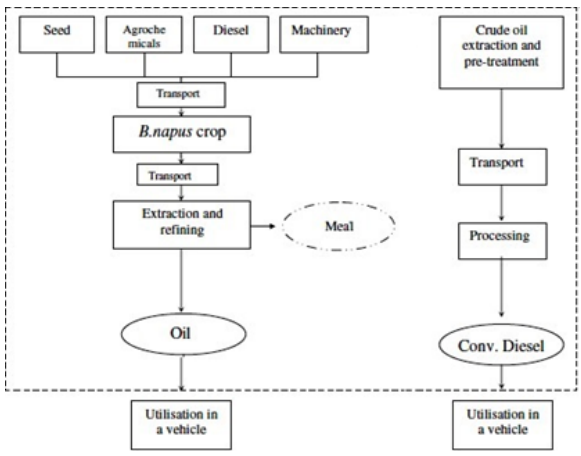

Fig. 1. Boundaries of the rapeseed oil production system, biodiesel production system and conventional diesel

Table 3. Environmental impact of one kg. of rapeseed oil

Impact category	UNIT	AGRICULTURAL STAGE			Transport stage	Conversion stage	Total
		Field works	Fertilizers production and use	Pesticides production and use	All transports	Oil extraction and refining	
ADP	g Sb eq	1,603	0,939	0,030	0,045	5,806	8,426
AP	g SO_2 eq	0,986	1,452	0,033	0,024	2,595	5,091
EP	g PO_4--- eq	0,428	0,392	0,009	0,006	2,929	3,767
GWP100	kg CO_2 eq	0,192	0,214	0,004	0,006	0,621	1,038
ODP	mg CFC-11 eq	0,018	0,013	0,002	0,001	0,061	0,096
HTP	kg 1,4-DB eq	0,232	0,115	0,004	0,001	0,480	0,834
FWAEP	kg 1,4-DB eq	0,080	0,040	0,000	0,000	0,494	0,616
MAEP	kg 1,4-DB eq	161,036	92,182	1,485	1,201	1082,322	1338,227
TEP	g 1,4-DB eq	4,469	0,930	0,010	0,013	10,760	16,182
POCP	g C_2H_4 eq	0,050	0,041	0,001	0,000	0,119	0,212

ADP: Abiotic Depletion Potential, AP: Acidification Potential, EP: Eutrophication Potential, GWP: Global Warming Potential, ODP: Ozone Layer Depletion Potential, HTTP: Human Toxicity Potential, FWAEP: Fresh Water Aquatic Ecotoxicity Potential, MAEP: Marine Aquatic Ecotoxicity Potential, TE: Terrestrial Ecotoxicity Potential; POCP: Photochemical Oxidation Potential.

3.2. Diesel system

The reference system used to compare all fuels consists of production and transportation of diesel to a refinery. Crude oil extraction and transportation from the petrol field to refinery are the main stages of the system.

3.3. Allocation procedure

To compare the three production systems is necessary to focus on the main function which is fuel for diesel engines production. Therefore the environmental impact of the co-products is subtracted from rapeseed oil system and biodiesel system. Thereby, from the rapeseed oil system it has been subtracted the impact of soymeal production [9] and from the biodiesel system it has been subtracted the impact of glycerin produced from propane gas [9], [11].

3.4. Quality of data

The rapeseed production system uses field data collected from a survey carried out during 2012 agricultural year, such as fertilizers, insecticides, herbicides, seed application dose, type of machinery used and operating rate, diesel fuel consumption. The data for generalized and standardized production processes for agrochemicals, tractors and implements along with data related to the life cycle of the fuel (production, distribution and consumption) were taken from the Ecoinvent database [12].

In Table II are presented the information used for the compilation of the agricultural inventory. The data related to oil extraction factor of 41% has been taken from bibliography [9], as well as oil conversion factor to biodiesel of 0.97.

4. RESULTS

The classification and characterization method used was CML 2 baseline 2000 [13].

4.000 kg. of rapeseeds is the average production of the studied parcel. This corresponds to approximately 1.591 kg. oil. This result has been used to analyze the environmental performance of the biofuel.

In this paper we calculated the relative magnitude of different contributors to all impact categories to compare the three fuels.

Figure 2a and 2b present the impact in all ten impact categories of the agricultural stage of rapeseed.

The environmental impact of rapeseed oil production system is shown in Table III. The results are then compared with diesel production sys-tems environmental impact which is presented in Table IV.

Table 4. Environmental impact of 0.870 kg of diesel

Impact category	Unit	Total
ADP	g Sb eq	20
AP	g SO_2 eq	5
EP	g PO_4--- eq	0,5
GWP100	kg CO_2 eq	0,41
ODP	mg CFC-11 eq	0,40
HTP	kg 1,4-DB eq	0,40
FWAEP	kg 1,4-DB eq	0,03
MAEP	kg 1,4-DB eq	270,51
TEP	g 1,4-DB eq	1,70
POCP	g C_2H_4 eq	0,30

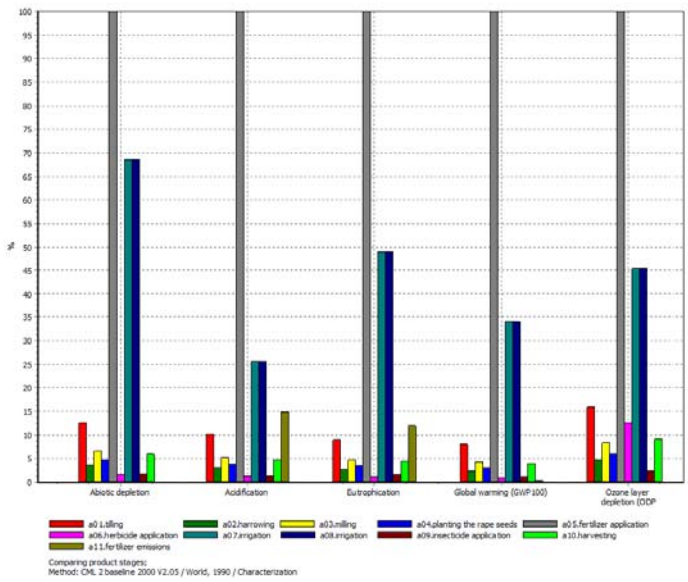

Fig. 2a Impact assessment agricultural stage

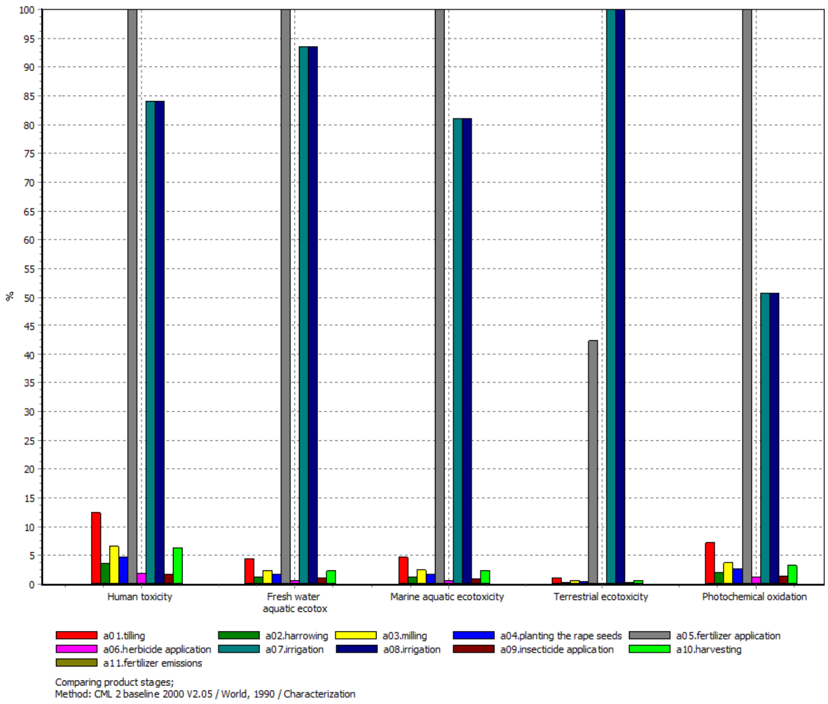

Fig. 2b Impact assessment agricultural stage

4.1. Contribution of the life cycle stages to the total environmental impact for RO

In the case of rapeseed oil the results show that the extraction and refining of the oil is the activity with the biggest impact in all impact categories, with a contribution between 50,97% and 80,87%. Field works contribute to the total impact as the second most impacting activity.

4.2. Comparison of the total environmental impact between rapeseed oil and diesel

When compared with diesel fuel, rapeseed oil shows better results in three impact categories: Ozone Layer Depletion Potential is reduced by 76%, Abiotic Depletion Potential by 57,87% and Photochemical Oxidation Potential is reduced with 29,33%.

5. AKNOLEDGEMENTS

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6. REFERENCES

[1] ***, *Directive 2009/28/EC on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. 2009.04.23.* Official J Eur Union 2009.

[2] **Carles, M., et. al.**, *A life cycle assessment of biodiesel production from winter rape grown in Southern Europe*, Biomass and Bioenergy, Volume 40, May 2012, Pages 71-81, ISSN 0961-9534, 10.1016/j.biombioe.2012.02.003.

[3] **Mittelbach M, Remschmidt C.**, *Biodiesel the comprehensive handbook*. Boersedruck (Austria): Ges.m.b.H; 2005.

[4] **Gasol CM, Gabarrell X, Anton A, Rigola M, Carrasco J, Ciria P, et al.** *Life cycle assessment of a Brassica carinata bioenergy cropping system in Southern Europe*. Biomass Bioenerg 2007; 31:543e55.

[5] ***, *International Standard Organization. ISO 14044: environmental Management – Life cycle assessment – requirements and guidelines*; 2006. Genoa, Switzerland.

[6] ***, *International Standard Organization. ISO 14044: environmental Management – Life cycle assessment – Principles and Framework*; 2006. Genoa, Switzerland.

[7] **Bernesson, S., Nilsson, D., Hansson, PA.,** *A limited LCA comparing large- and small-scale production of ethanol for heavy engines under Swedish conditions*. Biomass Bioenergy 2006;30(1):46e57.

[8] **Salvia, J.,** *Agronomic Engineering in Institute of Agrofood research* (IRTA). Advicer of Koipesol Spain. Personal Communication by Oral Communication and email in April of 2007.

[9] **Bernesson, S., Nilsson, D., Hansson, P.A.,** *A limited LCA comparing large- and small-scale production of rape methyl ester (RME) under Swedish conditions*. Biomass Bioenergy 2004;26(6):545e59.

[10] **Lecho´n, Y., Cabal, H., de la Ru´a, C., Izquierdo, L., Sa´ez, R.M.,** *Ana´lisis de Ciclo de vida de Combustibles alternativos para el Transporte. Fase II: ana´lisis de Ciclo de Vida comparativo del Biodie´sel y del Die´sel*. Madrid (Spain): Centro de Publicaciones Secretarı´a Te´cnica. Enviroment Spanish Ministry; 2006.

[12] **Nemecek, T., Heil, A., Huguenim, O., Meier, S., Erzinger, S., Blaser, S.** *In-Life cycle inventories of agricultural production systems.* Du¨nderdorf (Switzerland): Swiss Centre for Life Cycle Inventories. Final report ecoinvent 2000. Available from: www.ecoinvent.ch; 2003.