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Consequential life cycle assessment of the environmental impacts of an increased rapemethylester (RME) production in Switzerland

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ABSTRACT

Arable land is a constrained production factor – particular in Switzerland. Merely 45% of the consumed crops are produced domestically. Hence, the additional cultivation of rape for producing methyl ester is assumed to substitute crops used for food production. Consequently, Switzerland has to face the decision either to use the arable land for food production and import fuels or to produce fuel from rape and import the displaced food. Using Consequential Life Cycle Assessment (CLCA), the environmental consequences have been assessed if rape for energetic utilization substitutes rape used as edible oil or barley used as animal fodder. The study shows, that displacing food production by RME production in Switzerland can reduce total GHG emissions, when GHG-intense soy meal from Brazil is substituted by rape and sunflower meal, which is a co-product of the vegetable oil production. On the other hand, an increased production of vegetable oils increases various other environmental factors, because agricultural production of edible oil is associated with higher environmental impacts than the production and use of fossil fuels. In summary, the environmental impacts of an increased RME production in Switzerland rather depend on the environmental scores of the marginal replacement products on the world market, than on local production factors.

1. Introduction

Driven by scarcity of fossil fuels and climate change the idea of using renewable energy is attracting interest both in the Swiss public eye and in the industry. Fuels made from biomass – so-called biofuels – are currently the most important form of renewable energy in road transportation and are supposed to play a role in reducing greenhouse gas emissions (GHG) and decreasing our dependency on fossil fuels at least over the short to medium term [1,2]. Despite the potential of biofuels on reducing GHG emissions, the environmental impacts of producing biofuels are manifold ranging from nutrient outwash to biodiversity loss [3]. These direct environmental impacts have been investigated extensively in various Life Cycle Assessment (LCA) studies [4–6]. Because the production of biofuels is land intensive, the environmental impacts of biofuels are strongly intertwined with other uses of land like nature conservation [7], supply of food [8] and production of biomaterials [9]. For a sound assessment of the total environmental impacts of producing biofuels, it is therefore necessary to address also indirect impacts, which take place outside of the value chain of biofuels.

The goal of this study is to assess the direct and indirect environmental impacts when Switzerland substitutes one percent of its annual diesel consumption by the domestic production of RME. We used consequential LCA (CLCA) to quantify the direct and indirect environmental impacts resulting from an increased production of RME in Switzerland.

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2. Methodology

2.1. Consequential LCA

LCA is a method for analyzing and assessing environmental impacts of a material, product or service along its entire life cycle [10]. Two main approaches are distinguished: the attributional and the consequential approach. The approaches differ with respect to system delimitation and the use of average versus marginal data.

Attributional LCA (ALCA) is defined by its focus on describing the environmentally relevant physical flows to and from a life cycle and its subsystems [11]. Within an ALCA, the system investigated is limited to a single full life cycle from cradle to grave. Hence, co-production has to be treated by applying allocation factors. Furthermore, the attributional approach uses average data in order to attribute the average environmental burdens for producing a unit of the product in the system [11].

Consequential LCA (CLCA) is defined by its aim to describe how environmentally relevant flows will change in response to possible decisions [11]. In contrast to ALCA, the system within a CLCA is not limited to one life cycle. The consequential approach uses system enlargement to include the life cycles of the products affected by a change of the physical flows in the central life cycle. Hence, allocation is avoided. According to this, marginal instead of average data is used within the consequential approach. Marginal data is represented by the product, resource, supplier or technology, which is the most sensitive to changes in demand. Economic value criteria are used to identify the marginal products.

2.2. System enlargement for assessing consequences

In addition to the changes in the main life cycle, this paper distinguishes two stages of consequences that are both handled by system enlargement: consequences (A) driven by the usage of constrained production factors and (B) driven by the changed outputs of multifunctional processes.

(A) An increase/decrease use of a resource will cause a change in the availability of the respective resource for other life cycles [11]. For example, a shift of rape oil from edible oil-consumption to RME production in Switzerland could decrease the availability of edible oil domestically. Since the overall demand for the oil is assumed to be stable, the lack of edible rape oil in Switzerland will be compensated for by additional imports of the marginal oil on the world market.

(B) The consequences driven by co-products stemming from multifunctional processes are considered as well. Ekvall and Weidema have defined rules for system enlargement driven by multifunctional processes [11]. Furthermore, Weidema determined how to handle the environmental burdens of additional or avoided production processes [12]. For example, the increasing production of rape oil for energetic use will lead to a corresponding growth of rape meal, which is a co-output of rape oil production. Given that the primary function of rape meal is feeding animals, it is likely that the increasing amount will substitute the marginal animal fodder on the world market which is most sensitive to changes in demand. In this study, soybean meal from Brazil is used as the most sensitive animal fodder. Consequently, the additional amount of rape meal is assumed to reduce the import and production of soybean meal in Brazil. In this case, the system is enlarged to the soybean production affected.

2.3. Assessing land use changes

The increase/decrease in the availability of agricultural products induces changes on the agricultural level. Corresponding effects to an increased demand for a specific crop are expansion, displacement and intensification [13].

Expansion is defined by the transformation of a specific land type like natural area or fallow land into arable land. In order to assess the effects of expansion, the marginal land, i.e. the land which will be transformed first, has to be identified.

Intensification increases the yield per hectare. Hence, no additional land is transformed. However, the increase in yield is caused by an increase of inputs per hectare, e.g. of water, energy and nutrients, which again can increase the environmental burdens of a given area.

Displacement substitutes one crop with another and is primarily assumed to occur in countries which face physical and also regulatory constraints [13].

As long as crops are displaced, the effect of displacement trickles through the overall global agricultural system until it is balanced by intensification and expansion. In theory, all displacement, intensification and expansion steps must be taken into account in order to ascribe the consequences of an increased cultivation to the energy crop of interest. In practice this is simply not possible. Based on this insight, different approaches have been used to simplify the assessment of consequences. For instance Kløverpris [13] uses a dynamic-economical model based on the Global Trade Analysis Project (GTAP) to determine the possible consequences on the agricultural stage. Another approach developed by Schmidt [14] is to cut off short and mid term changes and instead focus on the long term marginal supplier of a specific crop. In an increasing market the long term marginal supplier is the unconstrained supplier with the highest increase in production and lowest long term marginal production cost [12].

3. Scope

3.1. Goal and functional unit

The goal of this study is to assess the direct and indirect environmental impacts when Switzerland substitute one percent of its annual diesel consumption by the domestic production of RME. Using the method of consequential LCA, two future systems are analysed and compared: one where the current developments unfolds, i.e. Diesel is further imported, one where RME is increasingly produced.

In order to compare both scenarios, the functional unit is defined as “one MJ fuel given at regional storage in Switzerland (CH)”. Consequently, both scenarios must fulfill these functions.