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Note from the field

Standardized and simplified life-cycle assessment (LCA) as a driver for more sustainable biofuels

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ABSTRACT

The assessment of environmental impacts along the life cycle of biofuels is a complex and resource-demanding task that cannot be afforded by small producers in developing countries. Therefore, certification schemes bear the risk that small and independent producers will be locked out and the market for sustainable biofuels will be dominated by international investors and large-scale plantations. However, many environmental impacts of various production chains of biofuels and feedstocks are already known. This knowledge has been used to create a web-based questionnaire for a "Sustainability Quick Check for Biofuels" (SQCB, http://www.sqcb.org). SQCB reduces the need for user entries to the most relevant and best-known parameters of the biofuel production chain. Based on this user input, a specific inventory is automatically modelled and linked to background data. SQCB then calculates the environmental impact assessment and checks the results against sustainability criteria. Since the results are calculated immediately, key environmental factors can be interactively analyzed. One major goal of the SQCB is to support the market entrance for local biofuel producers, given that strengthening local stakeholders is a key driver for empowering rural communities in development countries.

1. Introduction

A major driver for current political support being given to the biofuels market is the supposed environmental benefit. Biofuels appear to be carbon neutral, while decreasing the dependence on oil-producing regions and generating new income for farmers [1]. However, results from current life-cycle studies demonstrate that the greenhouse gas savings of conventional biofuels are usually small. The reasons for that are the carbon intensity of their cultivation and fuel production [2]. Moreover, environmental impacts such as ecotoxicity, eutrophication or biodiversity are usually higher for biofuels than for fossil fuels [3]. In addition, the negative effects of biofuels predominate if carbon and biodiversity loss due to direct [4] and indirect [5] land transformation are considered in the full life cycle of biofuels. Certification schemes could be an efficient approach to ensure the sustainable production of biofuels by keeping environmental and social impacts within certain limits.

Certification schemes based on best practice guidelines are already in place for forest products [6] and palm oil [7]. For biofuels, sustainability certification is more complex, as both agricultural and industrial processes may be relevant, and as greenhouse gas emissions occur along the full product life cycle. Nowadays, various certification schemes are under development such as the UK Renewable Transportation Fuel Obligation (RTFO) [8,9], the Swiss mineral oil tax redemption for sustainable biofuels [10], the European CEN-standard [11], or the voluntary criteria of the Roundtable on Sustainable Biofuels (RSB) [12].

Although the general principles of sustainable biofuel production are relatively easy to define, it is quite challenging to derive a sound framework that is able to characterize environmental and social impacts in an adequate way. Environmental impacts occur in all stages of the biofuels value chain, while transforming the land needed, while producing and applying fertilizers and pesticides, while cultivating energy crops, while producing the biofuel, while transporting it to the gauging station and while using it in the car. Some environmental impacts are only caused by specific process steps, e.g. nutrient leaching is mainly induced by agricultural activity. However, most pollutants are generated in many different steps of the value chain. The most prominent pollutant of this type is fossil CO_2 which is generated in nearly every unit process of the full value chain of a biofuel (Fig. 1).

However, adequate assessment of the environmental impacts that occur throughout the life cycle is a complex task; this task is often solved differently by the different institutes involved.

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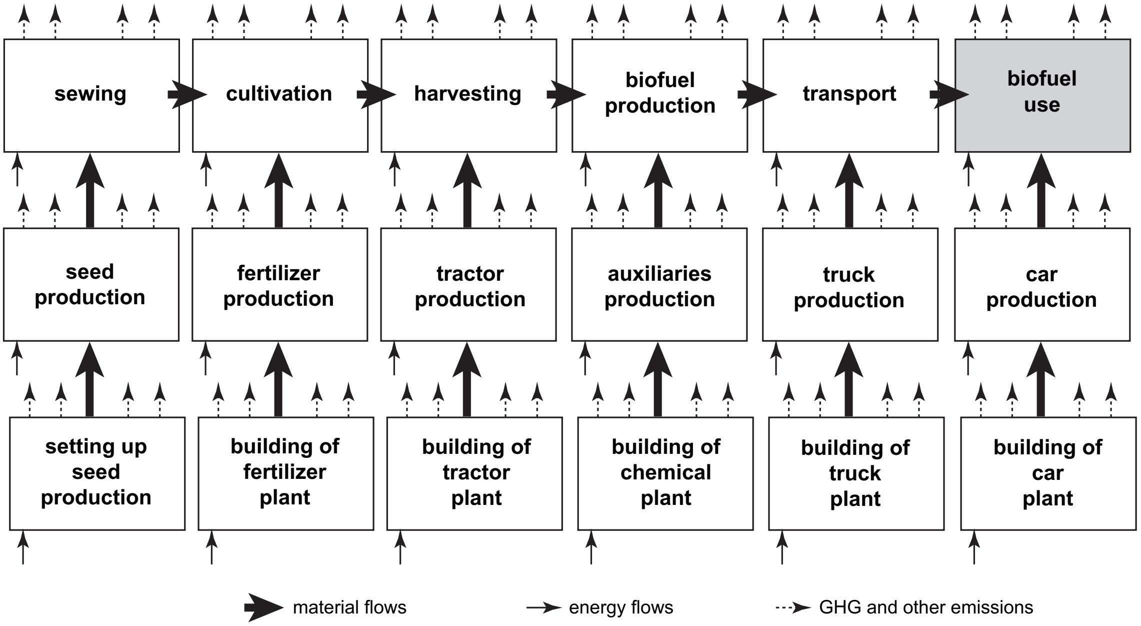

Fig. 1. Schematic flow diagram of material flows, energy flows and pollutant emissions in the biofuel production chain. In LCA all flows are related to the reference flow, in this case one unit of biofuel use (grey box), e.g. 1 vehicle km.

Unsurprisingly that makes projects more resource demanding, a requirement that many small and medium enterprises cannot afford, especially those in developing countries. Furthermore, results do not lend themselves well to comparison. Therefore, certification schemes which do not specifically target small and independent producers bear the risk that such producers will be locked out, and the market for sustainable biofuels will be dominated by international investors and large-scale plantations [13].

On the other hand, many environmental impacts of various production chains of biofuels have already been evaluated [14], and knowledge of the factors critical for sustainable production is available [15]. Such knowledge can be combined in a web-based questionnaire for rapidly assessing individual pathways of biofuels on an LCA basis. Such a “Sustainability Quick Check for Biofuels” (SQCB) [16] has been developed to compare the resulting environmental impacts of specific biofuels with the requirements of the Swiss mineral oil taxation law, in order to facilitate the entry of small producers from developing countries to the Swiss market. This paper describes the concept and implementation of the SQCB and discusses its potential impacts on the global trade in sustainable biofuels.

2. Methodology

The life-cycle assessment of a biofuel consists of two main assessment steps, (1) the modelling of the life-cycle inventory by quantifying all relevant flows of materials and energy along the value chain and (2) the environmental impact assessment that evaluates the impacts of all materials and energy flows. The inventory modelling is resource intensive because usually only key factors of the agricultural and technical processes are known and not the environmental flows themselves. For example, a farmer knows in detail the types and amounts of fertilizers he is applying and the respective yield of his crop, but he does not know the amount of phosphate leaching to the groundwater or the diffusion rate of N_2O from his field to the atmosphere (Fig. 2 upper part). Therefore SQCB reduces the need for user entries in the cases of the most relevant and best-known parameters of the biofuel production chain. Based on this questionnaire, a specific inventory is automatically modelled and linked with background data to a full life-cycle inventory. SQCB then calculates the environmental impact assessment and checks the results against sustainability criteria (Fig. 2 lower part).

2.1. Simplifying user entry

Although the life cycle of biofuels is influenced by a large number of factors, only a few of them have much relevance to the overall environmental impact assessment. It has been demonstrated that the environmentally most relevant step is cultivation [14] followed by the processing of the biofuel, while the transport of the fuel is of minor importance. A sensitivity analysis on the agricultural step shows that the most relevant factors for the greenhouse gas emissions are agricultural N_2O emissions and CO_2 from land transformation. For the calculation with the Swiss method of ecological scarcity [17] the most relevant factors are nitrate emissions in groundwater, phosphorus in river water, heavy metal and pesticide emissions in soil (Fig. 3). Consequently, the questionnaire of the SQCB focuses strongly on data entry for the agricultural step (mineral and organic fertilizers, pesticide use, irrigation, yield, former land use).

2.2. Automated inventory modelling

Calculation of the agricultural emissions is based on the ecoinvent report on bioenergy [18], direct CO_2 emissions caused by land transformation are based on a simplified implementation of the tier one methodology of the IPCC-guidelines [19]. For nitrate and phosphate leaching, new simplified models have been developed [16]. For the fuel production, most inventory data is taken from the ecoinvent database and data entry is limited to energy and chemical consumption, efficiency, and co-product allocation. No data entry is needed for assessing the inventory data of transporting the fuel to the customer and of using the fuel. Both stages are autonomously modelled using ecoinvent data [20].

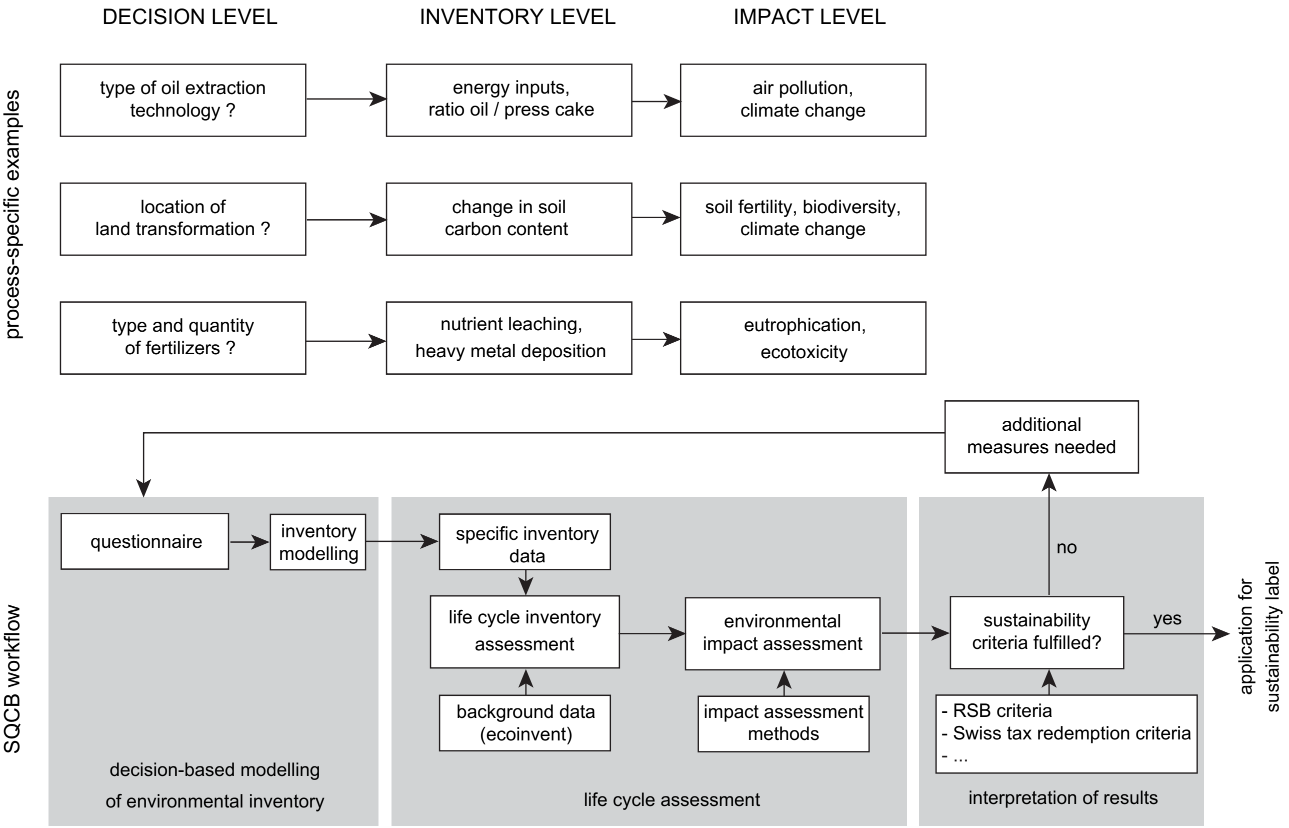

Fig. 2. Upper part: process-specific information that is available to decision makers (decision level), that results from an environmental inventory (inventory level) and from an environmental impact assessment (impact level). Lower part: scheme of environmental impact modelling in the SQCB.

2.3. Benchmarking with sustainability criteria

The global warming potential (GWP100) and total environmental impacts [17] are calculated and graphically compared to an average biofuel reference path and to a fossil reference. The SQCB indicates whether the results of the overall environmental impacts and of the greenhouse gas emissions comply with the requirements of the Swiss law on mineral oil tax. The SQCB also shows in a detailed way the environmental impacts of the cultivation and processing steps. Furthermore, the user can vary the data entry and get more insight into the key drivers for the environmental impacts of his biofuel value chain.

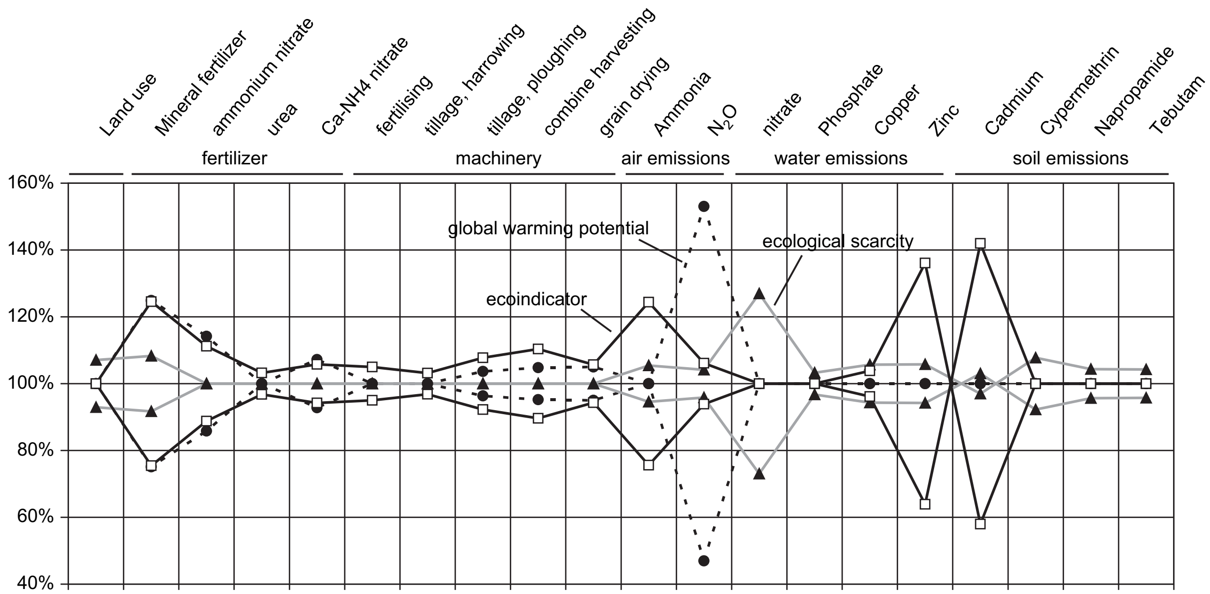

Fig. 3. Sensitivity of the agricultural step taking soybean production in Brazil as example. The dotted line shows the effect on greenhouse gas emissions of doubling or setting the parameter to zero, the grey line shows the equivalent effect on the total environmental impact in ecopoints [17], the black line in eco-indicator-points [21].

3. Outlook

The SQCB allows a user to make a quick assessment of the environmental impacts of individual value chains of biofuels without the need to conduct a time and resource-intensive life-cycle assessment study. Background data and modelling approaches are consistent within the SQCB. Therefore the tool allows a user to make a comparison of different production paths, which is not possible for LCA studies based on different goal and scope definitions. Because the results are calculated immediately, SQCB can be used interactively. This enables the user to understand the influence and interaction of different decisions and factors on the environmental performance of his biofuel value chain. For example, by varying individual factors, the user can observe the changes in the overall impact assessment and get insights into the key factors in his biofuel chain. Besides its value for stakeholders in the biofuels industry, SQCB could also be of didactical interest and used for capacity building on sustainable biofuels production.

However, the simplified modelling approach limits the applicability of the SQCB to value chains similar to the reference chain in the tool. For example, complex biorefineries with multiple co-products and feedstocks cannot be modelled in this framework. Furthermore, in-depth know-how on land transformation, cultivation and fuel processing of the specific biofuel chain is needed for an accurate environmental impact assessment. SQCB must therefore be seen as a rapid screening that gives a first estimate on the overall sustainability and potentially critical factors of a biofuel production chain. On this basis the user can decide if he should invest in a sustainability certification or if major project revisions have to be implemented first.

The modularity of the SQCB allows the user to add more fuel paths or implement more result analysis functions. If the ongoing field testing of SQCB based on the Swiss biofuel regulation is successful, the adaptation of the SQCB to other certification schemes such as the RSB will be explored and implemented wherever possible.

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