THE SUSTAINABILITY OF BRAZILIAN ETHANOL - AN ASSESSMENT OF THE POSSIBILITIES FOR CERTIFIED PRODUCTION

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ABSTRACT: In this article the environmental and socio-economical impacts ethanol production from sugarcane in the state of São Paulo (Brazil) are evaluated. Subsequently, an attempt is made to determine to what extent these impacts are a bottleneck for a sustainable and certified ethanol production. 17 environmental and socio-economic areas of concern are analysed. Four parameters are used to evaluate if an area of concern is a bottleneck: (1) the importance of the area of concern, based on the severity of the impact and the frequency of which an aspect is mentioned in the literature as an area of concern, (2) the availability of indicators and criteria, (3) the necessity of improvement strategies to reach compliance with Brazilian and/or (inter)national legislation, standards, guidelines and sustainability criteria, and (4) the impact of these improvement strategies on the costs and potential of ethanol production. The availability of data allowed for the calculation of these costs for 12 criteria; the results indicate an increase of the production costs by 36% compared to convential ethanol production. In total 14 areas of concern are classified as a minor or medium bottleneck. Two possible major bottlenecks are the protection of biodiversity and the production of food resulting from the competition for land with (the expected increase in) sugarcane production. Genetically modified cane is another (potential) major bottleneck considering the potentially large benefits and disadvantages, both which are at this moment highly uncertain.
Keywords: perennial rhizomatous grassess, environmental aspects biomass production and conversion, costs.

1 INTRODUCTION

Biomass is receiving more and more attention as a renewable (green or CO_2 neutral) energy source. This goes especially for bioethanol, of which Brazil the world's largest producer and exporter with an estimated share of 48% and 60%, respectively.

A perquisite for the large-scale production and trade of bioethanol is that production and trade take place in a sustainable way. This means that the production and trade should be beneficial with respect to the *social well being of the people* (people), the *ecosystem* (planet) and the *economy* (profit).

The goal of this study is to evaluate the environmental and socio-economical impacts of the production of ethanol from sugarcane in the state of São Paulo (Brazil)[1]. Further, an attempt is made to determine to what extent these impacts are a bottleneck for a sustainable and certified ethanol production.

The nature of this work is exploratory; further research is required to reduce gaps in knowledge in combination with stakeholder consultation to reach consesus on what is sustainable.

2 APPROACH

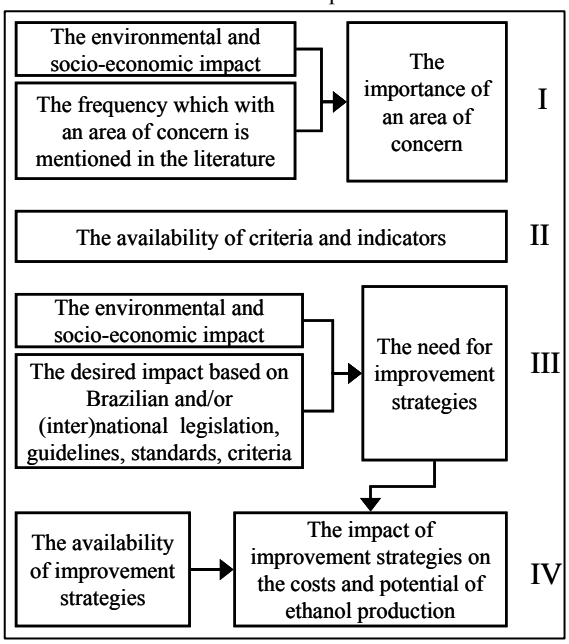
2.1 Selection of areas of concern and case study region

17 areas of concern are selected based on a review of the literature about the environmental and socio-economic impacts of ethanol production and based on a list of areas of concern that are relevant for the production and trade of bioenergy that have been identified by Lewandowski and Faaij [16]. São Paulo (SP) in Brazil is chosen as case study, because SP is the world's most important ethanol producing region, with a share of 35% of the total production.

2.2 Identification of bottlenekcs

Four criteria are used to determine if an areas of concern is also a bottleneck of a sustainable and certified ethanol production (I to IV in Figure 1).

Figure 1. The four criteria (I to IV) that are used to determine if an area of concern is a bottleneck for a sustainable and certified ethanol production.



Four aspects are included: (I) Importance of the area of concern, which is evaluated taking into account the severity of the impact which is determined by looking at the impact on the ecosystem or on human welfare and based on an assessment of the frequency of which an

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aspect is mentioned is the literature as problematic. (II) The availability of indicators and criteria. (III) The necessity of improvement strategies. This is determined by taking into account the difference between present situation or the situation that is expected in the future and the desired situation, and also the availability of the desired improvement strategies. (IV) The impact of improvement strategies on the costs and potential of ethanol production. Each aspect is valued and given a corresponding point, following the division in row 1 of Table I. The sum of the points of the four aspects determines the conclusion to what extent an area of concern is a bottleneck for certification, whereby three levels are distinguished: minor (the sum is 4-6), medium (7-9 points) and major (10-12 points).

3 RESULTS

Table I given an overview of the final results. 14 areas of concern are classified as a minor or medium bottleneck. Some issues require improvements, but these can be realised at relatively limited additional costs, see Figure 1. Three areas of concern are classified as a (potential) major bottlecks. The increasing demand for land for sugarcane production could result in competition with the use of land for the protection of biodiversity and for food production. Also the application of genetically modified sugarcane is judged as a potential bottleneck. A selection of results is presented in more detail below. For more detailed results and for references see {Smeets, 2007 #795; Smeets, 2006 #690}.

Table I. The extend to which area area of concern is a bottleneck for a sustainable and certified ethanol production in SP.

Aspect		I Importance of the area of concern: High = 3 Medium = 2 Low = 1	II Availability of indicators and criteria: Low = 3 Medium = 2 High = 1	III Necessity of improvement strategies: High = 3 Medium = 2 Low = 1	IV Impact of improvement strategies on costs and potential: High = 3 Medium = 2 Low = 1	Conclusion: level to which extend an area of concern is a bottleneck
Ecological areas of concern						
1	Water use	2	1	2	1	minor
2	Water pollution	3	1	2	1	medium
3	Protection of biodiversity (present/future)	1/3	3	1/3	1/3	minor/major
4	Soil erosion	2	2	2	1	medium
5	Fertilizer use	2	1	2	1	minor
6	Genetically modified organisms	3	3	1	3	major
7	Sugarcane burning	2	1	1	1	minor
8	Greenhouse gas emission and energy balance[a]	3	2	1	1	medium
Socio-economical areas of concern						
9	Competition with food production	2	3	2	3	major
10	Employment	3	1	1	1	minor
11	Income distribution	1	1	2	1	minor
12	Land tenure	1	1	1	1	minor
13	Wages	2	1	2	1	minor
14	Working conditions	3	1	2	1	medium
15	Child labour	3	1	2	1	medium
16	Social responsibility and benefits	2	2	2	n/d	medium
17	Competitiveness	3	1	1	1[1]	minor

[a] Excluding additional costs resulting from compliance with sustainability criteria.

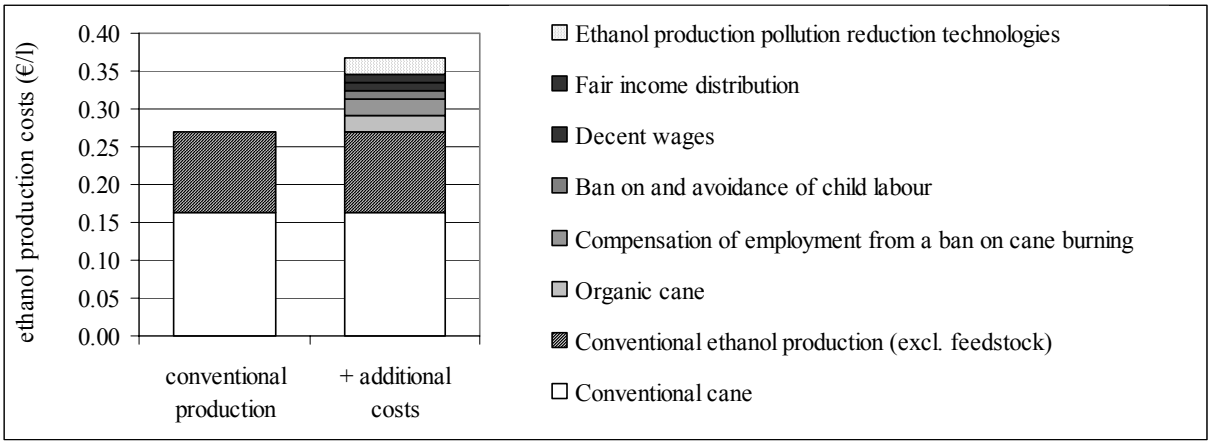

Figure 2. The costs of improvement strategies to reduce or avoid any negative impacts compared to the costs of conventional ethanol production in SP.

3.1 Water and soil

Water use, water pollution, soil erosion and fertilizer use are issues that are classified as a minor or medium bottleneck. Improvements are required, but effective improvement strategies can be implemented at limited additional costs (Figure 1). For example, the São Fransisco sugar mill in São Paulo produces organic cane (no use of fertilisers, herbicides, pesticides and fungicides; mechanical harvesting without cane burning). Ethanol made from organic cane is 8% more expensive than conventional ethanol. Another important issue is the wastewater from ethanol production. The appliction of wastewater treatment facilities increase the costs of ethanol by another 8%.

3.2 Sugarcane burning and employment

Sugarcane burning is the burning of the leaves and tops of the cane before harvesting in the field to reduce the costs of harvesting and transportation. The most important disadvantages of cane burning are the (potentially) harmfull emissions and the damage to forests, infrastructure and to the cane stalks. Legislation has recently been implemented in Brazil that includes the gradual phasing out of cane burning, resulting in a complete ban in 2031. A reduction in cane burning is generally accompanied by the replacement manual harvesting system by mechanical harvesting, resulting is unemployment. Full mechanised harvesting would reduce the direct employment in cane production by more than 60%. Compensation via unemployment benefits would increase the costs of ethanol by 8%.

3.3 Greenhouse gas emission and energy balance.

Ethanol from sugarcane has a higher greenhouse gas emission reduction potential per hectare and a lower energy input to energy output balance compared to other biofuels. Key parameters are the sugarcane yield, the ethanol production efficiency, the type of technology that is used for cogeneration of electricity, the harvesting system (mechanical harvesting without cane burning vs. manual harvesting with cane burning), see Table II. The results show that substantial improvements can be realised.

The results exclude long-distance transportation. The transportation of the ethanol from the SP (São Sebastião harbour) to the EU (Rotterdam), followed by 500 km inland transportation by truck decreases the energy output to input ratio from 7.8 to 5.6 and increases the GHG emissions from 263 to 510 kg CO_2 m^{-3} ethanol 256 kg CO_2 m^{-3} to 503 kg CO_2 m^{-3} ethanol, in case of the present average situation and partial cane burning.

The results also exclude the impact of CO_2 emissions from changes in the soil carbon content. A large fraction of the sugarcane plantations are established on pastures, which results in a decrease of the soil carbon content, thus lead to CO_2 emissions. Data are not available, except for one modelling excercise that indicates an increase of the CO_2 emissions from 263 to 510 kg CO_2 m^{-3} ethanol 256 kg CO_2 m^{-3} to 503 kg CO_2 m^{-3}. Changes in land use that are induced by sugarcane production (see also the following section) and the resulting changes in soil carbon content require further analysis.

3.4 Biodiversity and food production

Biodiversity and food production are both classified as a (potential) major bottleneck. Both issues are frequently mentioned in literature as an area of concern.

Most sugarcane plantations are established on agricultural land and thus there is a (potential) direct impact on food production. The area of sugarcane is 17% of the total area of land in São Paulo and this is projected to increase to 30% in 2015. Undernourishment is a problem in Brazil, but is relatively limited problem in SP, and undernourishment is caused by poverty and not a lack of domestic food production potential. We conclude that the impact of sugarcane production on food production is probably limited, particularly considering the large areas of (potentially) suitable agricultural land in Brazil. Accurate data to verify this conclusion are however not available.

The area of agricultural land (including sugarcane plantations) increases at the expense of the area under natural vegetation cover and this trend is expected to continue during the coming decades. Existing legislation is insufficiently strict to prevent this conversion. An important biodiversity hotspot are the cerrado (savanne) regions in the Center-South. Sugarcane production takes place closeby and in these areas, see Figure 2. The cerrados are also an important source of new agricultural land. The (potential) indirect and induced effects of sugarcane production could result in a shift of food production towards or into these areas. These indirect and induced effects are difficult to quantify due to lack of data.

We conclude that the impact of sugarcane production on biodiversity and food production are probably limited, but considering the importance of these issues, that safeguards and improvement strategies are required. A problem hereby is that generally accepted and practically

Table II. The greenhouse gas emissions (in kg CO_2 equiv. m^{-3} ethanol) and energy output to input ratio of ethanol production from cane in São Paulo in various situations, including key parameters as the assumed yield (t ha^{-1} y^{-1}), ethanol production efficiency (l t^{-1}).

	Yield	Ethanol production efficiency	Electricity cogeneration technology level	Energy output to input ratio[a]		Greenhouse gas emissions[a]	
				partial cane burning	no cane burning	partial cane burning	no cane burning
	(t ha^{-1} y^{-1})	(l t^{-1})	(-)	(-)	(-)	(kg m^{-3})	(kg m^{-3})
Present - worst case	55	80	1	5.5[a]	5.2[a]	498[a]	402[a]
Present - average case	69	86	1	7.8[a]	7.3[a]	263[a]	174[a]
Present - best case	82	92	1	10.7[a]	9.7[a]	72[a]	-12[a]
Future	100	114	1	14.5[a]	13.6[a]	186[a]	160[a]
Future	100	114	2	20.6[a]	21.6[a]	-114[a]	-277[a]
Future	100	114	3	30.1[a]	34.5[a]	-576[a]	-975[a]

[a] Reference system: recently installed fossil fuel capacity

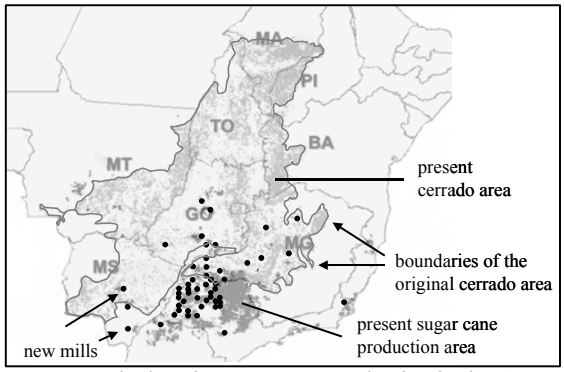

Figure 3. The location sugarcane production in the Center-South in relation to the cerrado (savannah) area.

applicable indicators and criteria are not available. The same goes for improvement strategies, particularly those that are related to the indirect/induced effects. In theory the efficiency of food production can be increased substantially, which could reduce the pressure on land. Various studies indicate that under existing socio-economic conditions these changes are not likely to happen.

3.5 Child labour

Child labour is a widespread phenomenon in Brazil, but the occurance of child labour in sugarcane and ethanol production is limited compared to other agricultural activities. The Brazilian legislation is in line with the internationally accepted standards of the International Labour Organisation (ILO), but law enforcement is weak. Additional criteria seem appropriate to ensure that the legal requirements are met. Existing certification systems cane be used. The (theoretical) costs to prevent child labour by means of compensating parents for the loss of family income from child labour and by means of compensating parents for the costs of education is calculated to increase the ethanol costs by 4%.

3.6 Wages

Average wages in sugarcane production are above the minimum wage and are higher than most other crops. Yet, higher wages seem desirable, because wages may still be insufficient for a decent standard of living: the 'net minimum wage necessary' for a family of four of circa 4.6 times the minimum wage, based on one wage earner. An average cane cutter earns 1.8 times the minimum wage during the maximum of 8 month harvesting season and this equals 1.2 times the minimum wage after reallocation over the entire year. A complicating factor is that temporary workers are sometimes required to pay unrealistically much for transportation, housing and/or food. If we assume an increase of the wages of the unskilled labour used in harvesting of an arbitrary 50%, than the total costs of ethanol increase by 4 %.

4 DISCUSSIOIN AND CONCLUSIONS

Biodiversity and competition with food production and genetically modified organisms are potential bottlenecks for a sustainable and certified ethanol production. The areas biodiversity and competition with food production have in common that the indirect and induced impacts are potentially significant, indicators and criteria are need to be developed and the costs are possible high. Genetically modified cane is at this moment not used, but could become a bottleneck considering the potentially large benefits and advantages, although both are highly uncertain.

We acknowledge that the analysis in this article is based on a subjective assessment and evaluation of the different areas of concern and on incomplete information. The further development of a practically applicable and generally accepted certification system requires additional work on:

1. Data collection. There is a lack of region-specific, up-to-date information about many areas of concern.
2. Methodology development. There is a need for more accurate methodologies, indicators and criteria to estimate the indirect and induced impacts of ethanol production, which are particularly relevant for the impact on employment, biodiversity and food security, but in principle also for other issues. This goes also for the development of improvement strategies.
3. Stakeholder consultation. There is no consensus about the definition of the term sustainability. Consequently, stakeholder discussions are necessary to reach consensus about the criteria and to create support for a certification system.

A complete report (2006) and journal article (2007; in preparation) about this research are also available and can be obtained from: www.chem.uu.nl -> publications, or send an e-mail to the author (e.m.w.smeets@uu.nl).