Translating scientific knowledge on bioenergy sustainability to a wider public: the Sustainability Quick Scan

J.W.A. (Hans) Langeveld[a] and Elske van de Fliert[b]

[a]*Biomass Research, P.O. Box 247, Wageningen, the Netherlands; hans@biomassresearch.eu*
[b]*Zero-e, Amersfoort, the Netherlands*

Abstract: *Biofuels can replace fossil fuels, reduce GHG emissions while offering opportunities to generate income for smallholders but may compete with nature or food production for land, water and other inputs. Identification of innovative ways to combine bioenergy and food, feed or fiber production requires efficient tools to evaluate production chains using technical, environmental and socio-economic data. Alternative chains can be evaluated using Life Cycle Assessments (LCA), but these encounter problems related to systems boundary definition, input allocation and limited data availability. This study utilizes the 'sustainability quick scan' to evaluate biogas production using co-fermentation digestion in the Netherlands and bioethanol production for smallholders in Sulawesi (Indonesia). Residue application in co-fermentation does not require crop land and may reduce nitrate leaching, but has modest economic results while removal of residues may deplete soil organic matter. Production of ethanol for cooking in Sulawesi can reduce soil erosion and save firewood. Large scale production using sugar cane provides more ethanol and GHG reduction but competes with food production. Small scale production based on sugar palm juice does not compete for land or water but requires additional organic material and labour. Impacts on prosperity and wellbeing depend on income generated by ethanol sales compared to income loss from rice sales. It is concluded that the use of a multi-dimensional model for evaluation of biofuel sustainability can solve problems of unbalanced data availability and weigh outcomes of different disciplines. Spiderweb figures may suggest more accuracy than is available.*

Introduction

Realization of the potential for bioenergy production may lead to adverse environmental and socio-economic impacts. It should be avoided that expanding bioenergy feedstock production competes with food and nature for valuable inputs including land and water while the position of local inhabitants – farmers, laborers and other – should be preserved. Different frameworks have been developed to determine sustainable production and use of bioenergy feedstocks that is socially acceptable. In the Netherlands, production standards have been formulated by the Cramer Commission (2007). Generally, there is an accepted view that expansion of bioenergy production should not lead to increased degradation of forests or other valuable natural ecosystems, show sufficient potential to reduce greenhouse gas (GHG) emissions and meet certain requirements for legal and social standard performance.

Under the present debate on bioenergy potentials and the impact of production on food prices and deforestation, there is a striking lack of scientific evaluations of bioenergy production chains. Consequently, the debate tends to be incomplete and unbalanced. One of the questions that remain mostly unanswered is what changes should be made in the design of (potential and existing) production chains in order to combine sufficient GHG emission reduction with economic, social and legal performances acceptable to the public. Developing such options will need empirical data plus solid procedures for using them in an effective evaluation process.

The most commonly applied evaluation approach is the Life Cycle Assessment (LCA). At present, however, large differences exist between alternative LCA studies as to the methods applied, discussion focussing on how to define systems boundaries and to allocate inputs consumed during the production process among main- and by-products. Consequently, it is difficult to compare the outcome of such studies. While the issue of systems boundaries and allocation is discussed in several reports and papers, problems related to limited data availability, poor data quality and lack of suitable evaluation procedures are attracting less attention. This holds especially for non-technical aspects of bioenergy production, including economic, social and legal impacts. It was demonstrated by Msimuko et al. (2007) who compared existing criteria and certification schemes with criteria for sustainable biofuel production defined by the Cramer commission (Table 1). Criteria to address competition with food or contribution to prosperity or wellbeing generally are the least developed.

A comprehensive approach ('sustainability quick scan') for the evaluation of bioenergy production chains has been presented by Langeveld et al. (2010). In the current paper, we provide two applications of this approach, providing a qualitative (semi-quantitative) assessment of chain performance along six axes of sustainability. The first application relates to the production of biogas in co-fermentation digestion units on livestock farms in the Netherlands, while the second refers to bioethanol production for smallholder cooking on the island of Sulawesi (Indonesia).

Methodology[1]

Application of the quick scan comprises a three-step approach. In the first step, we identify options for bioenergy development, describing development routes and assessing their sustainability. This step comprises the definition of two development scenarios. Main aim is to articulate alternative bioenergy development routes. This is done by describing the scenarios in some detail, including activities related to biomass production (land use, crop cultivation), potential impacts for (availability of) natural resources (land, water), impact for local land and food prices, and social and economic consequences.

In the second step, sustainability aspects of each development scenario are assessed using all types of available data. Finally, in the last step, the scenarios are evaluated by comparing their performance along six sustainability axes: (i) reduction of GHG, (ii) impact on biodiversity, (iii) competition for natural resources, (iv) impact on local food and land prices, (v) impact on local prosperity and economic development, and (vi) impact on wellbeing. The score of a given scenario along any of the axes is the aggregated effect of all activities in the bioenergy production chain, thus including crop cultivation and transport, biomass conversion and its distribution to end-users. It depends on impacts of these activities for natural resources (availability, quality), local food production and price, biodiversity in the production area as well as changes in social and economic conditions.

The outcomes are presented in radar figures which depict scenario performance on each of the six sustainability dimensions. For each case study, two figures are presented.

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[1] This section is based on Langeveld et al. (2010).

Table 1. Grading of all standards for the selected criteria. Source: Msimuko et al. (2007).

Standards	*GHG emissions*	*Environment*	*Biodiversity*	*Social well-being*	*Competition with food*	*Economic prosperity*	*Traceability & crop management*	(total "scores")
SQF 1000	1	1	0	1	1	0	2	6
SQF 2000	0	1	0	1	1	0	1	4
EUREPGAP	2	2	2	1	0	0	2	9
ISO 14001	1	1	0	1	0	0	1	4
SAN	0	2	1	1	0	1	1	6
FLO	0	1	1	1	0	1	0	4
FSC	1	1	2	2	1	1	2	10
SA8000	0	0	0	1	0	0	0	1
Eugene	1	1	0	0	0	0	0	2
Cerflor	0	1	1	2	0	2	2	8
EU regulation 2092/91	1	2	2	1	0	0	2	8
USDA NOP	0	2	2	1	0	0	2	7
IFOAM	1	2	2	2	0	2	2	11
ILO	0	1	1	1	0	0	0	3
EMAS	2	2	2	1	0	0	0	7
ETI	0	0	0	1	0	0	0	1
Green Gold Label	0	1	1	1	0	0	1	4
RSPO	0	1	1	1	1	1	1	6
RTRS	1	1	1	1	0	1	0	5
(total "scores")	11	23	19	21	4	9	19	

0	not included	criterion is *not* described
1	partly included	criterion is described *partly*
2	included	criterion is described *extensively*

Results

Case 1: Biogas production from crop residues[2]

In the first case, we compare the production of biogas in the Netherlands along two production routes. In the first scenario, biogas is produced in fermentors filled with animal manure plus biomass from energy crops (silage maize) cultivated especially for this purpose. Maize biomass in the Netherlands often is added to improve biogas production of manure. Anaerobic fermentation, conversion of organic material by micro-organisms into methane and carbon dioxide under oxygen-free conditions, is occurring spontaneously in animal intestines but will continue after the manure has been collected in the stable. Organic matter in manure, however, has limited digestibility (30-40%) as most degradable materials were removed in the animal.

Maize, the major crop in co-fermentation in the Netherlands is providing high methane yields at relatively low costs. Alternatively, crop residues (with exception of straw) can be used to provide biomass for the co-fermentation process as long as they provide sufficient dry matter. Methane yields are less than those of manure/maize mixtures, but the lack of production costs leads to suitable economic outcomes although under current conditions biogas production and use is not competitive. Further, using residues in co-fermentation may deprive them from other applications including ploughing in order to maintain soil fertility (organic matter). In some cases, however, this

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[2] This case has been taken from Langeveld et al. (2010).

ploughing is a major contributor of nitrate losses to the ground (and drinking) water through a process called leaching.

Thus, using crop residues in biogas production adds to biogas production and replacement of fossil use while no extra land or inputs are required (which would be the case if energy crops would have be cultivated). Further, the quality of groundwater may be improved. No negative effects may be expected for local biodiversity, food production or land prices, but there is the risk that soils are deprived from sufficient organic matter to compensate losses of mineralization.

A comparison of biogas production using energy crops versus gas from co-fermentation of crop residues (Figure 1) suggests that energy crops are less efficient in GHG reduction (depicted by a blue line lying closer to the centre of the figure). Their cultivation has more repercussions for biodiversity, increases competition for natural resources, and may lead to higher food and land prices. Their economic performa.

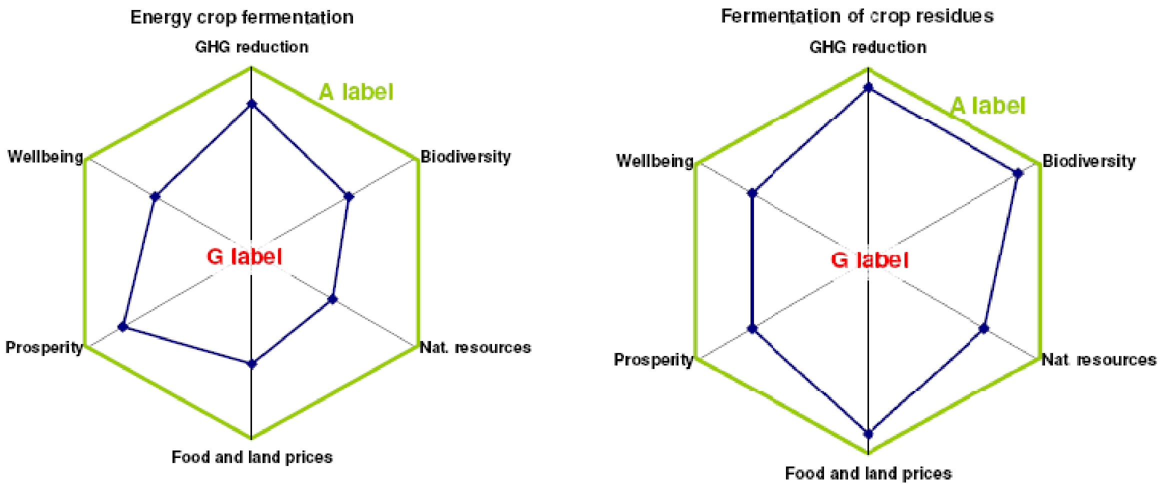

Figure 1. Sustainability labeling of biogas production from energy crops (left) and from crop residues in the Netherlands (right). High scores are depicted by blue lines far out of the center of the figure (near the green lines).
Source: Langeveld et al. (2010)

Case 2: Large vs small scale bioethanol in Indonesia

The second case discusses bioethanol production on the island of Sulawesi (Indonesia). Smallholders here are facing a manifold of problems including soil erosion and deterioration of crop yields (rice). Shortages of firewood force household to spend more and more time in collecting wood for the open cooking fires while cutting trees is adding to the erosion problem. As chimney facilities are lacking, in house air quality is poor and respiratory problems are common. Under these conditions, production of cheap and clean non-fossil cooking fuels like bioethanol may help to stop wood cutting and improve health conditions at little or no economic cost.

Ethanol may be produced along two alternative lines. In the first scenario, sugar cane is cultivated and collected in a large scale ethanol processing facility. The second scenario discusses small scale decentralized ethanol conversion form sugar palm, a local crop found mostly on steep hill slopes. Cultivation of sugar cane may go at the extent of rice production, as it requires fertile and level land. Such land is scarce and there is little room for area expansion. Some fertilization (mainly nitrogen) will be required while the crop may compete (again) with rice for limited irrigation water. High crop yields are expected to generate surplus ethanol that can be sold on the market. This may generate extra cash that can compensate for loss of rice sales.

Alternatively, sugar palm juice may be converted into alcohol in local, small scale, distillation units. Ethanol yields will be lower but lack of long transportation requirements and low (fertilizer, chemical) inputs will lead to more favourable GHG emission reduction levels. Sugar palm trees do not compete for land (being located on slopes) and can play a role in erosion control (Mogea et al., 1991). Although some organic material will be needed to feed energy demands of distillation units, the impact of this type of ethanol production is expected to have less impact on the demand for natural resources and on food and land prices. Decentralized production units further would have the advantage that valuable nutrients remain in the region while pollution problems caused by massive deposition of vinasse is not necessary. Labour demand for sugar palm juice harvesting, however, can be considerable.

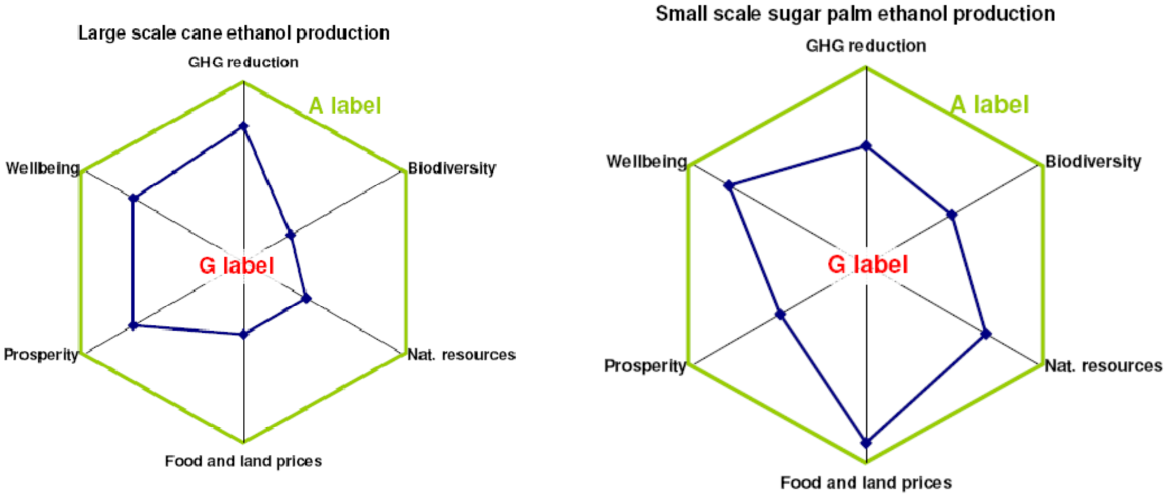

Figure 2. Sustainability labeling of large scale (sugar cane, left) and small scale (sugar palm, right) bioethanol production in Sulawesi. High scores are depicted by blue lines far out of the center of the figure (near the green lines).

Discussion

We presented two examples of bioenergy production where two alternative scenarios can be evaluated and compared. Using crop residues in co-fermentation units in the Netherlands does not require land allocated to (energy) crop cultivation while, still, biogas yields can be considerable. Reduction of nitrate leaching is one of the major advantages, but (depending on costs for land and inputs on the one hand and electricity produced from biogas on the other hand) economic results may lag behind. There is also the risk that removal of large amounts of crop residues in the long run leads to depletion of soil organic matter.

Production of ethanol for smallholder cooking in Sulawesi can help to prevent further problems of erosion and firewood shortages. Two scenarios have been evaluated. Large scale ethanol production using sugar cane provides higher ethanol production levels and GHG emission reduction levels but will compete with food (rice) production for valuable resources (land, water). Thus, the risk exists that food and land prices will rice. Small scale ethanol production may, alternatively, be done with juice from sugar palms, a local crop already in use that is found mostly on hilly slopes where it helps to control soil erosion. Under this scenario, there is no competition for land or water although some organic material will be needed to provide energy for distillation. Impacts on prosperity and wellbeing of either scenario will depend on the potential to generate income from ethanol sales compared to potential income loss (from rice sales, labour).

Both examples demonstrate the way the quick scan facilitates a systematic comparison of alternative energy development scenarios. Data used in the analysis can include both scientific and non-scientific data, representing technical and social disciplines while the use of sustainability labels and spiderweb figures allows processing of data and factual knowledge so that it can be applied in a multi-dimensional evaluation. The outcome (figures) facilitates communication with stakeholders such as policy makers, researchers, companies and NGOs.

It is not easy to obtain sufficient objective and high qualitative quantitative data that are needed for this type of analysis. We have been able to obtain a considerable amount of data for the Netherlands and Sulawesi, but in other cases data availability can hamper the quality of the evaluation outcome. As a rule, data on economic, social and legal aspects of biofuel (ethanol) production tend to be scarce and incomplete.

The use of a multi-dimensional model for information collection and analysis of land use change impacts — including social, economical and legal (non-technical) — has advantages as well as disadvantages. Bringing all kind of sustainability elements into one figure offers the opportunity to simultaneously judge all dimensions including those that usually receive less attention in the debate. This can facilitate decisions making on (improved) bioenergy production systems and their related land use practices. The method might be better able to overcome unbalances in data availability, but requires a weighing of sustainability aspects which have completely different characters. Presenting results in radar figures, further, may suggest more accuracy than actually is available.

The outcome of this study suggests that biomass production may locally coincide with other forms of land use in sophisticated and well-balanced production systems. This has been discussed in detail elsewhere. Langeveld et al. (2010) suggest that identification of innovative ways to combine bioenergy and food, feed or fiber production will need efficient tools to evaluate entire production chains including technical, environmental and socio-economic data. Systematic collection and analysis of data on different dimensions of alternative bioenergy scenarios facilitates a comprehensive evaluation effects that bioenergy can have. This helps policy makers to define how bioenergy can help to reduce GHG emissions and fossil dependency while not threatening nature conservation, food production or social equality. The strong visual and schematic representation of the outcome helps to represent a broad range of impacts of a given solution in a systematic and comprehensive way.

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