INDICATING AND ASSESSING SUSTAINABILITY OF BIOMASS (FOR BIOFUEL) PRODUCTION ON FAMILY FARMS

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Abstract
Sustainability is an overwhelming theme within the ongoing biofuels discussions. Sustainability has also proven an important topic within agricultural systems research. The role of family farmers producing biomass for biofuel is an important part of the sustainability question. A review of the current biofuel discussions is combined with a review of the scientific literature concerning sustainable agriculture. This provides a useful basis for discussion and recommendations regarding assessment of sustainability of family farms producing biomass for biofuel. Interpreting sustainability with structured indicator selection frameworks and acknowledging scales and levels can be taken from the scientific literature. The biofuels discussions have produced an extensive and comprehensive list of sustainability issues. Indicators relating to these issues remain general. For assessment of production of biomass by family farmers it is important to develop indicators that are coherent with adaptive and site-specific management as well as being practical for farmers. This necessarily requires identification of the most relevant issues for assessment. These issues must account for diversity between individual farmers and between farmers and plantations. This is a question of perspective which is related to understanding the multiple scales and levels at which processes underlying sustainability issues are acting.

1. Introduction

Actual and potential production of biomass for biofuels is currently a hot topic fuelling many international, national and local discussions. Many of these discussions are ongoing and the topic of sustainability is a major feature within. Naturally, these discourses are playing out in a variety of arenas including governments, institutions, industries and scientific communities (FAO, 2008; Bindraban *et al.*, 2009; Ewing and Msangi, 2009). There is consensus that sustainability must be addressed. There is also a significant movement towards certification schemes as a way of guaranteeing the sustainability of production (Lewandowski and Faaij, 2006). Attempts at devising such schemes raise difficult questions regarding identification of sustainability issues and standards and then how to measure performance against these standards (van Dam *et al.*, 2008). Besides sustainability related to biofuel, sustainability related to agricultural systems (generally) is a topic spanning the scientific literature roughly since the Brundtland Report in 1987. Defining sustainability and in turn measuring and monitoring sustainability have proven equally tricky and controversial (Dumanski *et al.*, 1998).

The role of family farmers producing biomass for biofuel is an important part of such discussions about the sustainability of biofuel production. It is important to grant special consideration to the context of family farmers by acknowledging that production of biomass by family farmers is distinct to biomass production on plantations for example. Important considerations are the notorious diversity in terms of management between family farmers (eg. Tittonell *et al.*, 2005) and the socio-economic conditions under which family farmers function (eg. Blazy *et al.*, 2009). Thorough clarification of these type of distinctions in the

biofuel discussions is currently lacking and the consequences of this for identifying sustainability issues and monitoring sustainability outcomes remain to be seen.
It is acknowledged that the scientific literature about sustainability and sustainability discussions about biofuels do not exist in isolation. However, there is scope to articulate the similarities and differences between these two discourses, particularly with specific attention towards family farmers. The aim of this paper is to review farming systems literature concerned with sustainability as well as to review ongoing dialogues about the sustainability of biofuel production. These reviews will be undertaken with specific attention towards family farms. The reviews will be compared and contrasted then synthesised as a set of recommendations towards assessment of sustainability of family farmers producing biomass for biofuel.

2. Farming systems and sustainability

2.1 Sustainability indicators

Two defining aspects of indicators for sustainability assessment are that indicators, "…can be used to evaluate or assess different types of impacts…" and that, "indicators should be relevant for a specific context, policy and/or user group" (Bezlepkina *et al.* 2006).

These two aspects can be further clarified by considering selection and use of 'sustainability indicators'.

Selecting a set of indicators can be considered an implicit use and is related to the above-mentioned relevance aspect of the definition. Indicator selection is essentially a learning process that enables decisions about which parts of a broad and unstructured problem will be granted specific attention. For example, sustainable biomass for biofuel production by smallholder or family farmers is a broad and unstructured challenge consisting of many inter-related issues. It is clear that selection of indicators is not a scientific question alone. Indicators are situated at an interface between science and politics in that they serve to translate scientific knowledge into useable knowledge as well as to translate public discussion into knowledge production and use (Turnhout *et al.*, 2007). This implies the importance of both 'scientific' and 'political' considerations for indicator selection for both general and context-specific outcomes.

Using a set of indicators implies that they are part of an integrated assessment in that they are a means to answer some specific research questions (ie. to assess or evaluate impacts). Therefore indicators will be tangible and perhaps quantifiable; such as outputs from a simulation model, a measurable property or an empirical relationship.

Preceding the term indicator with 'sustainability' requires some discussion about interpretation of the term sustainability. From the many existing definitions, a few key points will be used in this paper. Sustainability implies more than indefinite existence into the future. Sustainability is a holistic concept that embraces a systemic interpretation of processes and functions within a system. It requires simultaneous consideration of ecological, social and economic dimensions of a system. Given the multi-faceted nature of sustainability, it is not a prescriptive term, it is site-specific and perspective is an important determinant of what can be deemed sustainable.

2.2 Indicator selection frameworks (ISF)

Formalisation of an indicator selection exercise is often referred to as an 'indicator selection framework' (ISF). Examples of ISFs with respect to agricultural systems demonstrate a range

of different approaches. This diversity of approaches is largely due to different emphasis on scientific and political considerations and to different interpretations of sustainability.

It is useful to distinguish between hierarchically organised and linearly organised frameworks. A hierarchical framework consists of levels with different degrees of generality/specificity. A common example of a hierarchical framework places indicators below criteria which are in turn below principles. Principles are broad and over-arching, criteria are more specific and indicators even more so. Linearly organised frameworks are usually described as Pressure-State-Response or Driving Force-State-Response frameworks (PSR or DSR). An advantage of a hierarchically organised framework is the holistic nature while the PSR or DSR approach allow explicit focus on individual processes within the system. Based on current literature review, the hierarchical approach appears dominant.

ISFs can also be categorised along a continuum with system-based and content-based at each end (von Wiren-Lehr, 2001). System-based approaches focus on general functions or processes of a system as a whole while content-based approaches focus on specific (usually discipline based) aspects of the system (van Cauwenbergh *et al.*, 2007). While a purely system-based approach is potentially most generic, this type of approach is most difficult to apply.

The conceptual basis of an ISF is demonstrative of the type of approach. Lopez-Ridaura *et al.* (2005) developed a system-based framework based on five properties considered fundamental to sustainability. These were productivity, stability, resilience, reliability and adaptability. By contrast, the starting point for a content-based framework might include concepts such as goals. Within the SEAMLESS project a framework was developed upon the conceptual basis of *ultimate goals of policies, process for achievement* and *means* organised within environmental, economic and social domains (Alkan Olsson *et al.*, 2009). Further, an example that is located between these extremes is the SAFE framework (van Cauwenbergh *et al.*, 2007). This scheme begins with the multi-functions of agro-ecosystems (from de Groot *et al.*, 2002) again organised within environmental, economic and social domains.

Regardless of the underlying concepts within an ISF, the desired endpoint is a set of indicators that will serve a practical purpose. There are a number of challenges associated with this aim common to the variety of approaches. Niemeijer and de Groot (2008) provide a comprehensive review of these type of issues and indeed there is an array of 'criteria' for sound indicator selection (Fernandes and Woodhouse, 2008). These issues range from; practicalities such as indicators should be specific, measureable and achievable (Schomaker, 1997) to: considerations about temporal and spatial scales of applicability (NRC, 2000) to: policy relevance (OECD, 1999) and to: the link between the indicator, management practices and production (Pannel and Glen, 2000).

2.3 Scales and levels

The multi-faceted nature of sustainability is intertwined with the need to address issues about scales, levels and context. The current dialogues concerning biofuels and a family farming systems perspective invite discussion in greater detail.

Scale refers to the quantitative or analytical dimensions of the phenomenon being studied (Gibson *et al.*, 2000). Spatial, temporal, jurisdictional and institutional scales are some of the

examples provided by Cash *et al.* (2006). These examples demonstrate that while spatial and temporal dimensions are most commonly associated with scale, human dimensions are also used to define scales. Level refers to the position along a particular scale (Gibson *et al.*, 2000; Cash *et al.*, 2006) and is considered to be a discrete unit of analysis (Ewert *et al.*, 2006). This implies that the distinction between scales and levels is most relevant when discussing hierarchical scales.

There are many discussions about scales and levels in the context of natural resource management. It is difficult (perhaps impossible) to separate this discussion from that of context, the political process and governance. For example, Giller *et al.* (2008) discuss how changes at a local level can be dependent on processes occurring at higher levels. Examples of these processes are prices set at international levels and infrastructure affecting or determining possible farmer response. This example highlights the fact that a natural resource management problem faced by a farmer requires analysis at multiple scales and levels which necessarily includes multiple disciplines and perspectives. An initial application of this discussion is the clear need to define the scales and the levels at which sustainability indicators will be assessed and acknowledging that there will certainly be more than one.

Most existing ISFs deal with scales and levels to the point of defining a scale and a number of levels at which specific indicators will be assessed and allowing for the fact that a set of indicators can be tailored to a specific situation.

Examples of levels within scales for indicators in the literature are; parcel, farm and landscape (van Cauwenbergh *et al.*, 2007); field, farm, region and market (Alkan Olsson *et al.*, 2009); farm household, community, municipality, sub-region and region (Lopez-Ridaura *et al.*, 2005). Defining these scales and levels is largely pragmatic in that the issue of concern determines which level or levels are analysed. It is evident that the definition of these scales includes a mixture of ecological and socio-economic quantities. For example, a parcel might be a homogeneous piece of land measured in hectares where as a field has boundaries that were created by a farmer, a municipality involves political boundaries and a market involves economic boundaries. The work of Lopez-Ridaura *et al.* (2005) effectively demonstrate how some stakeholder objectives are consistent between levels such as productivity yet some objectives are unique to individual levels. For example, to increase diversity of activities is important at the farm household level but neither at the community or regional level. On the other hand, reducing deforestation is an objective at the regional level but not at the farm or community level.

3. Sustainability of biofuel production (ongoing dialogues)

3.1 Defining sustainability issues

Different actors such as farmers, companies, civil society organisations, non-government organisations, governments, and experts (including academics) are participating in the sustainable-biofuels discussions. Some significant international initiatives concerned with sustainable production of biofuels are the roundtables. There is the Roundtable on Sustainable Biofuels (http://cgse.epfl.ch/page65660.html), the Roundtable on Sustainable Palm Oil (http://www.rspo.org/default.aspx) and the Roundtable on Responsible Soy Association (http://www.responsiblesoy.org/). These are multi-stakeholder platforms uniting representatives from the above-mentioned actors. Besides these coalition-type initiatives, national and transnational governments have also made their voices heard (eg. the

Netherlands, the UK, the European Union). Contributions are also being made by somewhat more specialised groups such as COMPETE with an Africa focus (http://www.compete-bioafrica.net/) and by organisations such as the United Nations.

Progress towards governing the sustainability of biofuel production is overwhelmingly a number of hierarchical frameworks regarding sustainability principles and criteria. For some of these frameworks sustainability themes (a level above principles) is included and in some cases progress towards indicators has already been made. It is useful to also consider some less structured frameworks and reports that refer to sustainability visions or standards.

Within these frameworks it is evident that significant effort has been invested in formulation of the "most important sustainability issues" and corresponding assertions. There is some diversity in terms of the level at which these issues are formulated (ie. themes, standards, visions, principles or criteria). However, there is generally consensus regarding many of the assertions as they appear purposefully general.
Table 1 provides some insight into the major issues represented by a selection of the main frameworks and reports.

Elaboration of these issues listed in
Table 1 has occurred to different extents depending on the particular framework. For example, the Cramer Criteria includes themes, principles, criteria and indicators, the Roundtable on Responsible soy includes principles, criteria, indicators and guidance but the Roundtable on Sustainable Biofuels (a more recent initiative) has so far proposed principles and criteria. Similar to the sustainability issues, the sustainability criteria are also particularly general and difficult to disagree with. For example, with respect to a few different frameworks the issue of biodiversity is formulated into criteria such as: *habitats of rare and endangered species must be maintained; cultivation must take place on land cleared before a certain date; status of rare and endangered species must be identified and their conservation taken into account and; no deterioration of biodiversity*. Moving beyond these types of statements towards tangible and practical indicators that can be monitored or measured remains a subjective exercise.

3.2 A family farming perspective on sustainability issues
The wide range of standards demonstrated in
Table 1 highlight the vastness of issues that multi-stakeholder perspectives bring to light. Specific issues are more relevant to specific stakeholders and furthermore, specific issues emerge dominant within different contexts.

Family farmers as specific stakeholders and as producers of biomass within a variety of contexts (environmental and socio-economic) receive some attention within the biofuels discussions. Often reference to small scale versus large scale production alludes to this distinction within the discussions. For example, the Roundtable of Responsible Soy's contribution to environmental impacts mention that assessments should be appropriate to the scale of operation.

The contribution from the WWF notes the importance of position along spatial and temporal scales. A spatial scope (local, regional or global) and a temporal scope (short, medium or long

–term) are assigned to each of the sustainability standards. For example, 'minimisation of soil erosion and degradation' is considered a regional and local issue with a short to medium –term time horizon. This is an acknowledgement of the many different interpretations of sustainability. A particularly relevant sustainability issue also demonstrating this is

greenhouse gas (GHG) emissions. The desire to reduce GHG emissions has been an important driver behind global promotion of biofuels as a sustainable alternative to fossil fuels. However, when evaluating sustainability of production of biomass for biofuels at the level of a farmer, GHG emissions is not necessarily the most important sustainability issue.

Table 1 Identifying the “most important sustainability issues” through analysis of some major sustainability frameworks and reports produced by roundtables, governments and NGOs. Each row within this table refers to an issue that was raised within the frameworks. An ‘X’ indicates which issues have been identified within each framework or report.

10 sustainability standards proposed by the WWF (Fritsche *et al., 2007*)	Cramer Criteria (Cramer *et al.*, 2007)	UN Energy paper (UN-Energy, 2007)	Roundtable for Responsible Soy (RTRS, 2008)	Roundtable for sustainable Palm Oil (RSPO, 2007)	Roundtable on Sustainable biofuels (RSB, 2008)	COMPETE visions guiding bioenergy development in Africa (Yamba *et al.*, 2008)
Clarification of land ownership	X		X	X	X	
Avoid negative impacts from landuse change (including indirect impacts)	X		X	X	X	
Priority for food supply and food security	X	X			X	X
No additional negative biodiversity impacts	X	X	X	X	X	
Minimization of greenhouse gas emissions	X	X	X	X	X	
Minimization of soil erosion and degradation	X	X	X	X	X	
Minimization of water use and avoidance of water contamination	X	X	X	X	X	
Improvement of labor conditions and workers rights	X		X	X	X	
Ensuring a share of proceeds (local prosperity and rural development)	X		X	X	X	X
Avoiding human health impacts		X		X		
Additonal issues identified in the discussions						
Air quality	X		X	X	X	
Energy services for the poor		X				X
Effect on national economy (budget, trade)		X				
Energy security		X				X
Legal compliance			X	X	X	X
Community relations (including consultation)			X		X	
Transparency				X		
Long term financial viability				X	X	

Modernisation of agricultural practices						X
Achieve Millennium Development Goals						X
Transition from traditional to modern biomass						X

3.3 Defining sustainability indicators

Progress in terms of indicator development for assessment against sustainability standards or criteria remains quite general. From the frameworks mentioned above, existing indicators largely consist of statements referring to the type of information that would be useful, suggestions for compliance with existing regulations and suggestion for implementing management plans. This is evident in Table 2 for the example of sustainable soil management proposed by the Cramer Criteria and the Roundtable on Responsible Soy Association. In both these examples the indicators are qualitative, means-based and leave significant scope for interpretation. This is consistent between most of the schemes.

3.4 A family farming perspective on sustainability indicators

The means or ability for family farmers to use the proposed sustainability indicators is a concern that has received some attention in the discussions. It is acknowledged that if a certification scheme is implemented there is the potential for unintended exclusion of family farmers from the market. The cost of compliance is the main reason for this potential exclusion. In order to reduce compliance costs, the Roundtable for Sustainable Palm Oil suggests a group certification approach. This implies that a group of farmers rather than individual farmers could be certified. The Cramer Criteria and most of the other schemes reinforce the value of this idea. Group certification for organic and fair trade are successful examples of smallholder/family farmers engaging in group certification.

The idea that family farmers could use different indicators (compared to plantations for example) for the same issues is a possibility that has not been thoroughly investigated. The Roundtable on Responsible Soy implies this possibility by mentioning that monitoring procedures need to be scale dependent. This approach could also potentially reduce compliance costs.

Table 2 Indicators with regards to sustainability of soil management

	Indicators
Cramer Criteria	Relevant national and local regulations must be complied with, with respect to: • Waste management; • The use of agrochemicals (fertilizers and pesticides); • The mineral system; • The prevention of soil erosion; • Environmental impact reporting; • Company audits. At least the Stockholm convention (12 most harmful pesticides) must be complied with, also where national legislation is lacking.
Roundtable on Responsible Soy	• There is a soil quality (physical, chemical and biological) and erosion management plan – appropriate to the location and scale of production – which is being implemented. • Monitoring – appropriate to scale of production – is in place. • Producers must demonstrate knowledge of techniques to maintain soil fertility and must be implementing this in practice.
Various scientific literature (Eg. Kibblewhite *et al.*, 2008; Sanchez *et al.*, 2003; Stoorvogel and Smaling, 1998)	• Bulk density • Aggregate stability • pH • Cation Exchange Capacity • Soil Organic Matter (fractions) • nutrient balances • earthworms • N-fixers

	• Pest control populations • Nutrient depletion

Table 3 Managing and monitoring sustainability issues at different levels within an organisational hierarchy of a farming system producing biomass for biofuels

	(field)	(farm)	(region)	(country)	(globe)
Priority for food supply and food security	• Management such as fertilizer • Monitoring such as crop yields	• Management such as crop rotations • Monitoring such as household nutrition	• Monitoring such as food prices	• Management such as subsidies • Monitoring such as food prices	• Monitoring such as food prices
Minimisation of soil erosion and degradation	• Management such as contours and soil amendments • Monitoring such as crop yields	• Management such as crop sequences • Monitoring such as farm yields	• Monitoring such as sediment loads in catchments		

4. Farming systems literature and sustainability of biofuels discussions

4.1 The importance of perspective when defining sustainability issues

There is agreement between the farming systems and the biofuel-specific discussions about sustainability being a complex concept with many interpretations. Evidence is presented in
Table 1 demonstrating that the sustainability of biofuel production is related to a multitude of issues. This multitude of issues is a result of the many perspectives involved in the biofuels discussions. It is useful to use scale (as discussed in Section 2) for interpretation of these perspectives manifesting as different issues.

Table 3 presents five levels along a hierarchical scale. In this example, the farm level can be considered a system on its own or as a combination of subsystems from lower levels (fields) or as a subsystem of higher levels (region, country, globe). Distinctions can be made between these levels in terms of which processes can be managed and/or monitored. This approach can provide some insight into the levels at which certain sustainability issues can be monitored and the levels at which certain sustainability issues can be managed.

Using two examples taken from
Table 1, it is demonstrated that one sustainability issue manifests itself at different levels under different guises. In the case of food security, crop yields at the field level and a household meeting its nutritional requirements at a farm level contrast with food prices at the higher levels. As well, management of this issue is dependent on the level such that it is an agronomic issue at the farm and field level but an economic issue at higher levels. These types of differences are also demonstrated for the example of soil management. This exercise serves to exemplify why sustainability issues differ depending on perspective (in this case perspective is represented as levels within a hierarchy) and why assessment of sustainability must take this into account.

4.2 The importance of perspective when defining sustainability indicators

Table 2 allows for comparison between the type of indicators generally accepted within the scientific literature regarding sustainable soil management and those proposed within the biofuels discussions. This serves as an example demonstrating that the scientific literature tends to emphasise a quantitative approach and favours effect-based indicators. In contrast the outcome from the biofuels discussions favour qualitative and means-based indicators. This difference is related to different motivations behind using indicators. It has previously been discussed in the literature that when enforcement plays a role cheaper, means-based indicators will be chosen as opposed to effect-based indicators. On the contrary effect-based indicators are preferred when an indicator should guide change or provide insight into best practice (van der Werf and Petit, 2002). This reinforces the discussion about the context of a sustainability assessment. Not only do questions differ regarding different sustainability issues but how to answer these questions differ depending on why and who is asking the questions.

5. Concluding remarks

The literature concerning sustainability of farming systems and particularly about indicators shows that for assessment of a multi-dimensional concept such as sustainability a structured framework for selection of indicators is useful. Variations on a hierarchical structure that begins with principles and follows with criteria and indicators, as well as some disciplinary bias such as considering ecological, economic and social spheres or management goals are demonstrated in the literature. It is demonstrated that a degree of tension between theoretical and practical interpretations of sustainability exist but it is necessary that indicators are practical in ways such as specific, measureable and achievable. Finally, considering scales and levels is a dominant theme within the literature. This is because sustainability issues frequently transcend disciplines and individual levels within a system.

The discussions about sustainability of biofuels reinforce that sustainability is a multi-dimensional concept. Many of the sustainability discussions have been structured using hierarchical frameworks including principles, criteria and indicators. The diversity of stakeholders concerned with the sustainability of biofuel production clearly matches the diversity of sustainability issues. Diversity in terms of indicator development does not necessarily acknowledge as many perspectives. Most indicators are quite general such as simply referring to existing laws and regulations.

With respect to the role of family farmers producing biomass for biofuel in a sustainable way there are some important considerations. As mentioned in a number of the ongoing discussions costs need to be considered if a certification scheme is in place then group certification is certainly a feasible option. This review of the literature and the biofuel discussions informs a couple of important points. These are particularly related to the value of scales and levels for understanding the possible contexts and perspectives of family farmers. In summary it is important to:

- Choose a subset of issues (from those already identified) that are most relevant to farmers in terms of management and outcomes. This requires explicit understanding of the processes underlying each sustainability issue.
- Choose indicators that are specific and measureable. This requires a combination of means- and effect-based indicators such that management choices can adapt and remain site-specific.

Acknowledgements

Funding for this work is provided by the Netherlands Organisation for Scientific Research (NWO).

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