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Indicators for assessing socioeconomic sustainability of bioenergy systems: A short list of practical measures

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ABSTRACT

Indicators are needed to assess both socioeconomic and environmental sustainability of bioenergy systems. Effective indicators can help to identify and quantify the sustainability attributes of bioenergy options. We identify 16 socioeconomic indicators that fall into the categories of social well-being, energy security, trade, profitability, resource conservation, and social acceptability. The suite of indicators is predicated on the existence of basic institutional frameworks to provide governance, legal, regulatory and enforcement services. Indicators were selected to be practical, sensitive to stresses, unambiguous, anticipatory, predictive, estimable with known variability, and sufficient when considered collectively. The utility of each indicator, methods for its measurement, and applications appropriate for the context of particular bioenergy systems are described along with future research needs. Together, this suite of indicators is hypothesized to reflect major socioeconomic effects of the full supply chain for bioenergy, including feedstock production and logistics, conversion to biofuels, biofuel logistics and biofuel end uses. Ten indicators are highlighted as a minimum set of practical measures of socioeconomic aspects of bioenergy sustainability. Coupled with locally prioritized environmental indicators, we propose that these socioeconomic indicators can provide a basis to quantify and evaluate sustainability of bioenergy systems across many regions in which they will be deployed.

1. Introduction

Sustainability is often considered to be the capacity of an activity to continue while maintaining options and the ability to meet needs of future generations (Bruntland, 1987). While the science of sustainability is evolving, its definition depends on local conditions and stakeholders. Because sustainability is not a "steady state" or fixed target, assessing it involves comparing the relative merits of different options, and achieving it allows for continued adjustment in response to changing conditions, knowledge, and priorities. Sustainability assessment requires an understanding of how dynamic processes interact under alternative trajectories and how interpretations depend on the priorities of stakeholders in a specific place and time. We propose a set of socioeconomic sustainability indicators for bioenergy. The target audience for use of sustainability indicators includes policy makers, business people, and other stakeholders in all stages of the supply chain from land managers or waste suppliers to those involved in logistics, conversion facilities and end users.

Indicators provide information about potential or realized effects of human activities on phenomena of concern. Indicators can be used to assess both the socioeconomic and environmental conditions of a system, to monitor trends in conditions over time, or to provide an early warning signal of change (Cairns et al., 1993). It is widely recognized that some socioeconomic indicators are related to environmental indicators (e.g., resource conservation) and that public acceptance depends on environmental impacts (MEA, 2005; Collins et al., 2011). Yet social and economic conditions are important on their own as well.

This manuscript builds from prior work proposing environmental indicators of bioenergy systems (e.g., McBride et al., 2011) and adds socioeconomic metrics. While this analysis is designed to be broad enough to apply to bioenergy, generally, the indicators were selected based on transportation biofuel production pathways. The analysis was designed to address three goals: to choose indicators that can be useful to decision makers, to select measures of sustainability that are applicable across the entire bioenergy supply chain, and to identify a *minimum* set of indicators. The proposed indicators are meant to be complementary to efforts designed to assess performance of transportation systems (e.g., Transportation Research Board, 2011).

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The first goal is to identify a set of socioeconomic indicators that can effectively support policy makers and planners. We seek clearly specified, science-based metrics that can, for example, support decisions about implementation and expansion of more sustainable bioenergy options over time. Reaching agreement on how to define and measure socioeconomic effects of bioenergy can facilitate constructive dialogue and comparison by providing a common platform to evaluate relative merits. The data collected for these indicators and the understanding they provide could support programs such as voluntary certification and emerging sustainability standards (van Dam et al., 2008; ISO, 2010). Furthermore, since the focus is on energy, the indicators should allow the comparison of bioenergy to other energy systems and the identification of preferred pathways and practices for energy provision. For this reason we attempt to include indicators that are pertinent to both biofuels and other energy pathways.

A second goal is to identify indicators that apply across the supply chain, including feedstock production and logistics, conversion to biofuels, biofuel logistics and biofuel end uses, as defined by the players at each stage. For example, growers and suppliers are the major actors in the feedstock production stage; the conversion stage involves biorefineries; and fuels users (including the public) are at the end-user stage. It is important to consider the components of the supply chain both individually and collectively.

The third goal is to identify a minimum set of indicators of socioeconomic aspects of sustainable bioenergy systems based on defined selection criteria. The lack of consistent application of selection criteria can undermine attempts to promote sustainability indicators by generating well-intended but cumbersome wish lists. Too many indicators and data requirements thwart effective adoption because of prohibitive costs and unacceptable technical or administrative burdens. Selecting a set of indicators that is both complete in scope (sufficient when taken as a suite) and parsimonious is difficult.

Social aspects of sustainable bioenergy involve preserving livelihoods and affordable access to nutritious food; guaranteeing the reliability of energy supply; and ensuring the safety of people, facilities, and regions. They also include using open and transparent participatory processes that actively engage stakeholders, establish obligations to respect human rights, and emplace a long-term sustainability plan with periodic monitoring.

Economic aspects of bioenergy sustainability involve maintaining viable production, distribution and consumption of goods and services. This concept addresses short and long-term profitability of feedstocks, interaction with technical advances in society, differential costs of production and transport of various fuels, and the accounting and distribution of costs and benefits. The economic sustainability perspective recognizes the exigencies of production decisions, which are influenced by the expected price for a product and perceived risks of production and management practices. The potential for co-products also can affect economic costs and benefits across the supply chain (Vlysidis et al., 2011). Thus, interactions with other markets including animal feed, fiber, and food are considered. Economic factors are influenced by government policies, technology, energy and feedstock prices, demand resulting from diverse energy uses, and environmental consequences.

Our review of proposed indicators for bioenergy sustainability illustrates four significant challenges: (1) the sheer number and complexity of indicators required to cover the breadth of sustainability; (2) the costs of applying the indicators; (3) a lack of data – both now and in the foreseeable future –that are required to effectively apply proposed indicators; and (4) open-ended or inconsistent definitions of indicators, units and methods of measurement, leading to wide-ranging outcomes and incomparable results. The growing field of research and policies associated with the sustainability of bioenergy systems builds on decades of work in sustainable forestry and agriculture. Many organizations have identified measures to document practices for more sustainable agriculture [e.g., the Millennium Ecosystem Assessment (MEA, 2005), the National Sustainable Agriculture Information Service (Earles and Williams, 2005), U.S. Department of Agriculture Natural Resources Conservation Service, and Dale and Polasky (2007)], forestry [Forestry Stewardship Council, United Nations Food and Agriculture Organization (FAO, 2011b), state-wide best practices, etc.], bioenergy feedstock production [e.g. FAO (2012), Mata et al. (2011)] and economic development (e.g., USAID, 1998). Our work builds from those efforts as well as consideration of the indicators proposed by the Roundtable on Sustainable Biofuels (RSB, 2011), Global Bioenergy Partnership (GBEP, 2011), Council on Sustainable Biomass Production (CSBP, 2011), and several other national and international efforts that are in the process of selecting sustainability indicators for bioenergy. For example, the International Organization for Standardization (ISO) is developing criteria for bioenergy sustainability with plans to release a draft standard by 2014.

While prior efforts have gone a long way toward defining terms and building consensus about the importance of addressing sustainability associated with energy production and use, none have provided a short list of practical measures that cover socioeconomic aspects of sustainability. For example, GBEP lists 16 social and economic indicators, but the corresponding methodology sheets specify 40 sub-indicators and discuss about 30 additional measurements (GBEP, 2011). The RSB enumerates over 100 indicators under seven socioeconomic principles, and full compliance may require additional measurements and analyses, depending on the circumstances. Furthermore, many proposed indicators lack precision in definitions and protocols necessary for consistent measurement or equitable comparison. After considering recent efforts to establish indicators, we propose substantially fewer.

The objective of this paper is to present a small set of clearly defined indicators that focus on socioeconomic effects of bioenergy systems and that are feasible to measure. We identify a core suite of 10 indicators that can support monitoring and characterization of major effects that many bioenergy systems have or are likely to have on social and economic sustainability. We identify six additional indicators: four that require further refinement to be consistently applied and two that complement economic perspectives. The indicators are organized under six categories: social well-being, energy security, external trade, profitability, resource conservation, and social acceptability (Table 1). Together with environmental indicators, these socioeconomic indicators are proposed as a basis for moving forward in testing, evaluating and implementing a standard set of sustainability indicators for bioenergy systems across diverse settings and scales.

2. Approach

2.1. Criteria for selecting sustainability indicators

Our selection of indicators of bioenergy sustainability is based on the availability of information about socioeconomic conditions for each category, on other efforts to identify sets of indicators, and on established criteria for selecting indicators. Dale and Beyeler (2001) analyzed existing literature on indicator selection to identify key criteria:

1. *practical* (easy, timely, and cost-effective to measure),
2. *sensitive* and responsive to both natural and anthropogenic stresses to the system,
3. *unambiguous* with respect to what is measured, how measurements are made, and how response is measured,
4. *anticipatory* of impending changes,