Field to Market: The Keystone Alliance for Sustainable Agriculture

Environmental Resource Indicators for Measuring Outcomes of On-Farm Agricultural Production in the United States

First Report, January 2009

Executive Summary

(Full report available online at http://keystone.org/spp/env-sustain_ag.html)

Background. Nearly all estimates of future demand for agricultural goods suggest a need to double agricultural production by 2050, if not before, in order to maintain adequate supplies for a growing world population that will use its expanding income to diversify diets with more meat, dairy, fruits and vegetables.[i] *Field to Market: The Keystone Alliance for Sustainable Agriculture* believes this increased production must be accomplished in a manner that does not negatively impact – and actually improves – overall environmental and societal outcomes. Field *to Market* is a collaborative stakeholder group of producers, agribusinesses, food and retail companies, and conservation organizations that are working together to develop a supply-chain system for agricultural sustainability. The group was convened and is facilitated by The Keystone Center, a neutral, non-profit organization specializing in collaborative decision-making processes for environment, energy, and health policy issues.

As an initial step, the group has defined sustainable agriculture as meeting the needs of the present while improving the ability of future generations to meet their own needs by focusing on these specific, critical outcomes:

- Increasing agricultural productivity to meet future nutritional needs while decreasing impacts on the environment, including water, soil, habitat, air quality and climate emissions, and land use;
- Improving human health through access to safe, nutritious food; and
- Improving the social and economic well-being of agricultural communities.

It is within this context that the group is developing metrics to measure the environmental, health, and socioeconomic outcomes of agriculture in the United States. These metrics will ultimately comprise a Sustainability Index that will facilitate quantification and identification of key impact areas and trends over time, foster productive industry-wide dialogue, and promote continued progress along the path toward sustainability. The national-scale environmental resource indicators presented here are a first step in these larger efforts, which are summarized visually in Table I.I. Table I.I lists the kinds of components that we believe are critical for a complete sustainability index that measures outcomes for a full range of products and practices. The table includes the national scale outcomes that we have modeled to date (the shaded cells) as well as the additional environmental, health, and socioeconomic outcomes at national,

regional and local scales that we plan to model in the future. Our future plans and objectives for developing international scale metrics have not yet been defined.

Table I.I. Components of a Complete Sustainability Index. *Field to Market* has produced metrics for measuring environmental outcomes at the national scale (shaded cells). Specific socio-economic and health and safety outcomes are given as examples only; future work will determine which outcomes can be measured within these broad categories, as well as how they can be applied at different scales.

	Environmental Outcomes							Social and Economic Outcomes									Health and Safety Outcomes	
	Land Use	Soil Loss	Water Use	Water Quality	Energy Use	Climate Impact	Biodiversity	Producer Income	Labor	Productivity	Competing Land and product uses	Rural Character and Quality of Life	Availability	Post Harvest Loss	Consumer Demand	Return of Value to Producers	Nutrition (access to calories, etc)	Safety
International Scale																		
National Scale	x	x	X		x	x				x								
Regional Scale																		
Local Scale																		

Methods Overview. The environmental resource indicator metrics presented here represent a first step in these efforts. Using publicly-available data, national-scale metrics are developed to measure outcomes for five environmental indicators: land use, soil loss, irrigation water use, energy use, and climate impact (greenhouse gas emissions). The metrics are applied to quantify environmental outcomes for four commodity crops –corn, cotton, soybeans, and wheat—produced through agricultural practices in the United States.

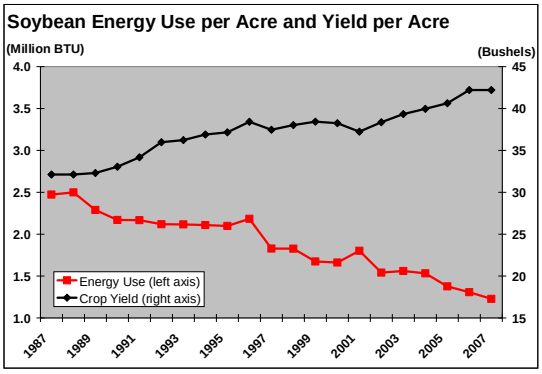
The national scale was chosen as a starting point for benchmarking the overall environmental performance of particular crops. We believe that national level environmental indicators can

provide perspective and prompt industry-wide dialogue that is ultimately relevant to more localized investigations and efforts. We have focused upon the four commodity crops because they constitute a majority of agricultural crops currently harvested in the United States. An outcomes-based approach was selected because it can provide an inclusive mechanism for considering the actual impacts and sustainability of diverse agricultural products and practices.

We recognize that water quality and biodiversity are key environmental areas of concern for agriculture, and we will need to develop metrics to measure the successes and continued challenges for these areas. In this report, we provide an overview of our progress to-date in developing a water quality indicator.

Results Overview. Results are presented for the years 1987-2007. The results for each indicator (land use, soil loss, water use, energy use, and climate impact/carbon emissions) are displayed for each crop in two formats: 1) Resource indicator (use or impact) per acre and crop productivity (yield) per acre (Figure I.Ia), and 2) "Efficiency" indicators showing resource indicator (use or impact) per unit of output, benchmarked to the year 2000 (Figure I.I.b). Total annual use or impact indicators are also presented as an appendix. We believe that all approaches are valuable, as resource use or impact indicators can show change over time independent of yield, and efficiency measures – resource indicator measures over output – can show change in use or impact over time relative to our ability to meet productivity demands. A summary of efficiency indicator results for each crop is also presented in a spidergram that demonstrates the change in "footprint" over time of all of the efficiency indicators (Figure I.II).

a)



b)

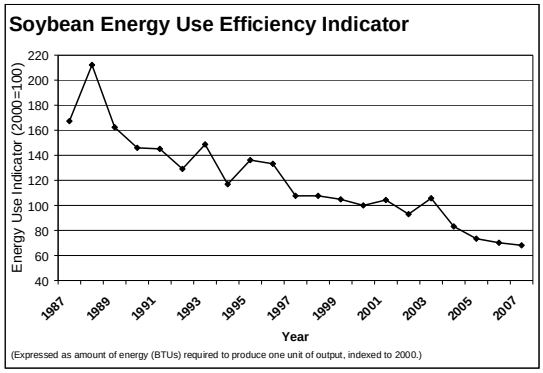
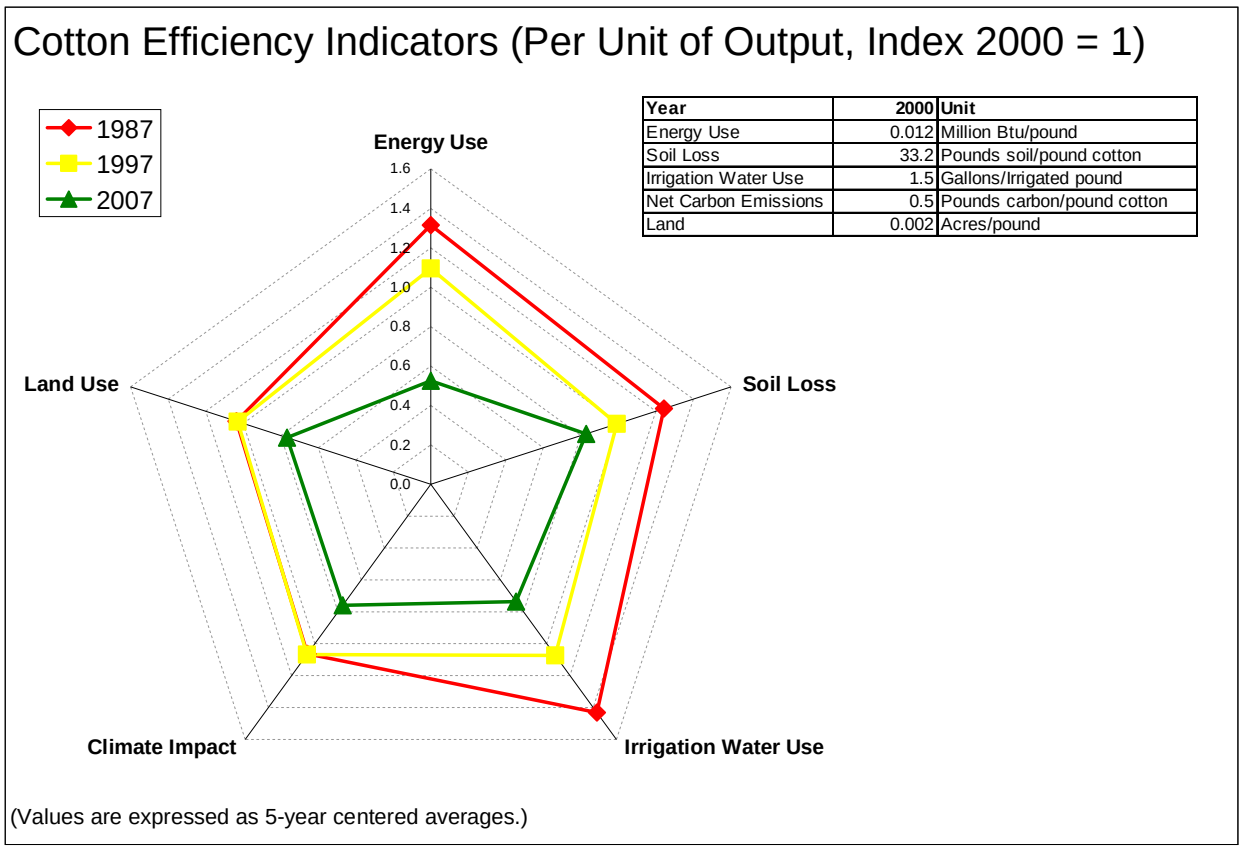


Figure I.I. Examples of Indicator Charts: **(a)** Per acre resource use or impact and per acre productivity and **(b)** Resource efficiency (resource use/ unit of output, indexed to the year 2000)



Year	2000	Unit
Energy Use	0.012	Million Btu/pound
Soil Loss	33.2	Pounds soil/pound cotton
Irrigation Water Use	1.5	Gallons/Irrigated pound
Net Carbon Emissions	0.5	Pounds carbon/pound cotton
Land	0.002	Acres/pound

Figure I.II. Summary of Cotton Efficiency Indicators

Discussion and Conclusions. The group anticipates that the approaches presented in this report can be refined to better measure impacts on natural resources in addition to the efficiency of use of the resource. The group also anticipates that these approaches can be adapted to quantify environmental outcomes for other crops and agricultural products and be inclusive of a full range of agricultural technologies and practices ranging, for example, from organic to conventional methods. This expectation must be tested through case studies, and the methods must be revised as necessary for other crops and scales, as well as when additional data becomes available. Table I.II conceptualizes our understanding of what each of our current metrics does and does not do, the metrics' potential scalability, and areas for future improvement.

Table I.II. Evaluation of Environmental Resource Indicators and their effectiveness as metrics for environmental sustainability outcomes at various scales. The five metrics presented here are believed to be relevant (assuming appropriate available data) at national, regional, and local scales. Land Use, Water Use, and Energy Use indicators measure the efficiency of resource use, while soil loss and climate impact measure actual impact on the natural resource in question. In most cases, the data utilized is not confounded by non-agricultural sources of stressors. Agricultural inputs such as nutrients and pesticides are accounted for in the Energy Use and Climate Impact indicators. Examples of ideas for future areas of improvement are also provided.

Resource Indicator	Type of Measure of Sustainability Outcomes		Scalability (based on appropriateness of use of other available data)			Data confounded by other (non-agricultural) sources of stressors?	Ag Inputs Included? (i.e. nutrients, pesticides)	Areas of Improvement
	Efficiency of Use of Resource	Impact on Natural Resource	National	Regional	Local (grower)			
Land Use	Yes	No	Relevant	Relevant	Relevant	No	NA	
Soil Loss	No	Yes (soil loss specific)	Relevant (data specific to cropland)	Relevant	Relevant	No	NA	Incorporate 2007 data when available through NRI.
Water Use	Yes	No	Relevant	Relevant	Relevant	No	NA	Look for and utilize state level data with greater reporting frequency.
Energy Use	Yes	No	Relevant	Relevant	Relevant	No	Yes	Current approach may not capture energy efficiency improvement over time; include seed production energy.
Climate Impact	No	Yes	Relevant	Relevant	Relevant	Yes – geographic (climate and soil)	Yes	Could be improved with better energy efficiency data over time, possible improvements in the method of fertilizer application analysis, inclusion of NO_2 and CH_4, and also by incorporating better measurement or estimation of soil organic carbon sequestration for alternative tillage practices and crop rotations (as they become available).

This report does not define a benchmark level for sustainability, and thus cannot conclude whether we have achieved "sustainability" in agriculture or how far we might have to go. However, the environmental resource indicators provide tools by which to describe progress or

lack of progress at the national scale in terms of total environmental impacts as well as resource efficiency. They also provide a context for further focusing in on specific challenges and regions and generating processes for achieving continuous improvement.

It is too soon in this process to draw major conclusions about this data. This report marks our first step in establishing some benchmarks and baselines for overall performance. However, we can begin to see some positive trends emerge and also identify areas where we would like to see see stronger trends and continuous improvement. Gains in productivity (yield) per acre over the past decade in most of the crops have generally improved overall efficiency of resource use. Soil loss trends (both per acre and per unit of output) have improved significantly in all crops. In addition, corn has seen modest to significant improvements in water use per acre and in water use, energy use, and carbon emissions per bushel. Cotton and soybeans are making progress in reducing irrigated water use, energy use, and carbon emissions per acre and per unit of output. Wheat's energy use per bushel has decreased, its water use per bushel has remained relatively flat, and its carbon emissions per acre and bushel have seen larger increases. In the future, we hope to better understand the relationship between outcomes trends and the practices and other factors that are driving them. This understanding will enhance our ability to achieve improved outcomes performance.

We view this work as a first step toward developing a complete Sustainability Index. In the future, *Field to Market* will continue to develop and improve metrics for measuring environmental, health, and socioeconomic outcomes at a variety of scales, as we build consensus on an overall methodology for doing so (See Table I.I). We recognize that other stakeholders must be engaged to develop these indicators. The focus of these future indicators will be on outcomes rather than practices, policies, or technologies. The group will utilize these current and future measures to further communicate about and define sustainability and develop practices to promote continuous improvement throughout the agricultural supply chain.

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[i] FAO. (2006). World agriculture: towards 2030/2050. Rome: Food and Agriculture Organization. http://www.fao.org/ES/esd/AT2050web.pdf