Assessing Sustainability of Agricultural Systems: Evidence from a Conjoint Choice Survey

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Selected paper prepared for presentation at the Southern Agricultural Economics Association Annual Meetings

Mobile, Alabama, February 4-7, 2007

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Abstract

This study identifies a list of economic, social, and ecological agricultural sustainability attributes based on experts' opinions. Next, the attributes are used in a conjoint choice experiment which enables direct extraction of the relative impact of the attributes and attribute levels on individual respondents' perception of overall sustainability.

Introduction

Modern agriculture relies heavily on the use of natural resources to achieve high returns. This trend has created environmental and social pressure and has led to a general realization that a transition is required towards more sustainable production practices. The emergence of sustainable agriculture in the late 1980s and the public debate over its economic viability brought the need for the comprehensive assessment of the performance of various conventional and alternative agricultural production systems (Ikerd, 2006) requiring a quantitative approach for the assessment of sustainability.

In agricultural sustainability studies, farmers are often classified as sustainable based on their organizational affiliations and use of specific production practices, which could be viewed as an oversimplification (Taylor, 1993). A holistic appraisal of sustainability should integrate its ecological, economic, and social dimensions (Becker, 1997; Van Calker et al., 2006). Thus, some operational composite measure of sustainability incorporating its different dimensions is required (Rigby, Howlett, and Woodhouse, 2000).

The objective of this study is to identify a comprehensive list of economic, social, and ecological sustainability attributes and to estimate their relative importance for individuals' perceptions of overall sustainability. We build upon previous studies on the identification and development of ranking procedures for sustainability attributes for various branches of agriculture (Van Calker et al., 2005; Taylor et al., 1993; Rigby et al., 2001). More specifically, we seek to develop a set of sustainability attributes covering all land related agricultural production and to employ a new method to estimate the relative impact of the individual attributes on overall sustainability. Experts in a variety of sustainability areas representing research institutions, governmental agencies, and non-governmental environmental and farmer organizations were interviewed to identify the list of possible sustainability attributes. A survey using the conjoint choice methodology was administered to asses the relative impact of the identified sustainability attributes on the composite sustainability measure.

General Components and Attributes of Sustainability

There is an ongoing debate over the definition of sustainable development. The commonly accepted definition, "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Bryndtland, 1987), as well as other definitions, gives rise to various interpretations of sustainability (Van Calker et al., 2005). In this study, we rely on the perceptions of a heterogeneous group of experts in different areas of sustainability, as well as farmers, to identify attributes essential to sustainability of agricultural production systems.

A series of individual and group discussions were organized with experts in a variety of sustainability areas (hereafter, "experts") representing research institutions, governmental agencies, non-governmental environmental and farmer organizations. Expert selection process took into account their competence evaluated though their professional activities and publications to ensure the diversity of expertise and opinions.

After consulting the experts, a list of attributes important for sustainability of agricultural production systems was identified (figure 1). Following Van Calker et al. (2005), the attributes were grouped under four general sustainability components: economic, internal social, external social, and ecological. Economic component includes attributes relevant to a farmer's ability to continue his farming business (i.e. economic viability of production). First of all, a farm should be profitable over time to be sustainable. It should also be able to maintain its productivity indefinitely in the future by relying more on own inputs and capital which would make it less vulnerable to external market fluctuations. A farmer has also to comply with various governmental regulations which may results in additional costs associated with time spent to gain an understanding of new regulations, production adjustments in response to regulation requirements, purchase of new inputs and equipment, and workers' training.

Social components of sustainability view people in three distinct roles: as producers, consumers, and members of civil society (Ikerd, 2006). The responsibility of agriculture to consumers is to provide adequate quantities of safe food at reasonable cost. Because people not only consume agricultural products but are also involved in production, sustainable agriculture should provide sufficient employment opportunities in local communities and create safe and comfortable work environment. Finally, people need positive relationships with other people within family, community, or entire nation.

Following Van Calker et al. (2005), we introduce a distinction between internal and external social sustainability attributes. Internal social sustainability relates to work conditions and safety for the farm operator and workers. A farm that will discontinue current sustainable practices in the future could not be considered sustainable. The continuity of the farm within the family is also considered.

External social component relates to the societal concerns about the impact of agricultural production on human and animal welfare and consists of a number of very different attributes. Safety of agricultural products depends on production procedures used on-farm. Product flavor and nutritional value are determined primarily by the chosen variety or breed: farmers who market their produce on the local markets often choose varieties with improved nutrition and taste, while the farmers who sell nation-wide choose easily transported varieties. Impact on the local economy is capturing permanent and seasonal jobs created on farm and a share of farm income that will be spent locally contributing to the local economy and creating additional jobs. Animal welfare and health issues relate to the extent to which farm animals can adapt without suffering to the environments designed by humans. Recently, increasing attention is given to farmland aesthetics (see Van Mansvelt and Stobbelaar 1997). Farms that are visually attractive create positive externality for local communities affecting local property values and attracting tourists. In addition, continuous research is done by universities, governmental agencies, and private companies to develop more sustainable production, and farmers are direct beneficiaries of such information. Farmers may become educators themselves by organizing farm tours, sharing experiences with other farmers, and getting actively involved in different social organizations. Finally, on-farm public recreational opportunities, such as hunting, fishing, hiking, corn maze, etc., would provide opportunities for farm income diversification.

The ecological component includes attributes relevant to the impacts of production on ecosystem. The emphasis is on sustainable farming systems as living systems that would be regenerative, capable of renewing themselves, and maintaining their productivity and vitality indefinitely (Ikerd, 2006). To achieve this, it is necessary to select production practices that contribute to the ecological health of the soil, surrounding water resources, air, atmosphere, plants, and animals.

Relative Impact of Sustainability Attributes

Design of the Survey Instrument

A survey using a conjoint analysis methodology was designed to estimate the relative impact of different economic, social, and ecological attributes on sustainability. The survey is nine-page long. At the beginning, the purpose of the survey and short details of the survey procedure are explained and four general sustainability components are introduced, followed by the section designed to extract relative impact information. Respondents are referred to one of the general sustainability components at a time starting with economic, followed by internal and external social, and concluded with ecological component. Attribute relative impact information for each general sustainability component is obtained in two different ways. First, respondents are asked to directly allocate 100 points among proposed attributes. This procedure has an advantage comparing to simple attribute ranking used by Van Calker et al. (2005). It results in the relative importance information based on cardinal scale; while in the case of ranking only ordinal information is obtained. Second, conjoint choice experiments are presented to the respondents where they have to choose between two hypothetical sustainability profiles. The survey is concluded by a section where some demographic information is collected.

The choice experiments enable the estimation of the relative impact of different economic, social, and ecological attributes on sustainability. Each choice experiment presents to the respondent two hypothetical sustainability profiles, and they then select the profile they consider more sustainable. Profiles represent various combinations of the levels of different sustainability attributes. An example is presented in Appendix A. Each survey contains eight choice experiment questions, two for each general aspect of sustainability: economic, internal social, external social, and ecological. Tables 1, 2 and 3 define attribute levels where each attribute can take two possible values representing low and high attribute levels. Attribute levels and question wording were developed in consultations with the experts.

The SAS statistical software package was used for the experimental design. Full factorial design, which consists of all possible combinations of the levels of attributes, results in 64 (2^6) possible economic sustainability profiles, 16 (2^4) internal social sustainability profiles, 128 (2^7) external social sustainability profiles, and 256 (2^8) ecological sustainability profiles. Given the great number of attributes, especially of external social and ecological sustainability, it would be very hard to present all possible profiles to the respondents. Therefore, fractional factorial design is generated by selecting a subset of full factorial design excluding two profiles for which all of the attributes take high/low levels (such profiles would be dominant/dominated in the choice experiment). The SAS software optimizes the D-efficiency score aimed at a balanced and orthogonal design (Kuhfeld, Tobias, and Garratt, 1994).

For each of the general components, a fractional factorial design consisting of 48 profiles was created. This number of profiles is selected because it is sufficient for full identification of a model consisting of an intercept, main effects, and two-way interactions for the ecological sustainability component which has the greatest number of attributes. Next, these fractional factorial design profiles are paired to create choice experiments in a way that would allow each attribute level occur equally often in each choice experiment for balanced design. As a result, 24 choice profiles are created for each general sustainability component. Twelve different versions of the survey are created, each containing two randomly selected choice experiments for each general sustainability aspect. The 12 versions were randomly administered to the respondents.

Survey Administration

Survey participation was limited to people who are familiar enough with the concept of agricultural sustainability to be able to make judgments. Three potential respondent groups were identified: farmers, consumers, and individuals who work for a university, governmental agency, or non-governmental organization in the area relevant to agricultural sustainability. While selecting potential survey respondents, we attempted to cover possible diversity in opinions. For example in the case of farmers, we contacted both conventional and alternative farmers in different production areas.

"Paper and pencil" survey was administered in November and December of 2006. Some respondents were approached during specialized farmer meetings: Sustainable Agriculture Conference, Mid-Atlantic Dairy Grazing Conference, Organic Grains Panel, and Southeast Vegetable and Fruit Expo. The remaining respondents, with the majority representing universities, governmental agencies, and NGOs, were mailed a survey with preaddressed and stamped return envelopes. A total of 420 surveys were distributed resulting in 95 completed surveys with a response rate of 23 percent.

The average survey respondent is 46 years old, has completed 16 years of formal education, and is a member of a household consisting, on average, of 2.6 persons with 0.7 persons being under 18, and having a yearly household income of $72,093. Seventy four percent of all respondents were male. Forty two percent of respondents indicated farming or farm labor as their primary link to agriculture, 38 percent of respondents work for the university, government, or non-governmental organization in the area of agricultural sustainability, 6 percent of respondents are agricultural suppliers/processors, and 14 percent of respondents do not have any specific link to agriculture and identified themselves as consumers.

Choice Experiment Decision Model Based on Multivariate Utility Function

In choice experiments, respondents are presented with two hypothetical sustainability profiles A and B, out of which they have to select the more sustainable one. The utility of respondent *i* associated with a profile *j* (*j*=A or B) can be represented as:

$$U_{ij} = \boldsymbol{\beta}'\mathbf{x}_{ij} + \varepsilon_{ij}, \quad (1)$$

where $\boldsymbol{\beta}$ is a vector of parameters to be estimated, $\mathbf{x}_{ij}$ is a vector of attributes of profile *j* presented to respondent *i*, and ε_{ij} is the stochastic portion of the utility function.

Respondent *i* would select profile A over profile B if $U_{iA} > U_{iB}$. Assuming that non-stochastic portion of the utility function is a linear function of the parameters, and the error disturbances ε_{ij} have independent Type I extreme value distribution with a cumulative distribution function $exp(-exp(\varepsilon_{ij}))$, the probability of choosing profile j is

$P(j) = \frac{exp(\boldsymbol{\beta}'\mathbf{x}_{ij})}{\sum_j exp(\boldsymbol{\beta}'\mathbf{x}_{ij})}$ leading to the conditional logit model (Greene, p.720).

Results and Discussion

Estimation results of the conditional logit model enable us to identify attributes that are important for sustainability and their relative impact. In the estimation procedure, sustainability attributes were coded as 1, if a certain attribute reaches high (desirable) value, or 0, if an attribute is at low (undesirable) value. Therefore, since all attributes are presented on a common scale, estimated coefficient on sustainability attributes can be used directly to extract their relative impact on economic, social, or ecological sustainability. For example, the relative impact of long-run profit prospects on economic sustainability is calculated as the coefficient on this attribute divided by a sum of all statistically significant coefficients on economic sustainability attributes.

Estimation was conducted using the conditional logit procedure available in the SAS statistical software package. Estimation results for economic, social, and ecological sustainability attributes are presented in tables 4, 5, and 6, respectively. The results indicate that the respondents identified long-run profit prospects, reliance on purchased inputs, and extent of governmental regulation as attributes most important for economic agricultural sustainability since the coefficient on these attributes are statistically significant at 1 or 5 percent significance levels (table 4).

Table 4 also presents relative impact information for economic sustainability attributes indicating that the relative impact of long-run profit prospects is equivalent to 59 percent of the total impact of all economic attributes, the relative impact of the reliance on purchased input is 19 percent, and the relative impact of the extent of governmental regulation is 22 percent.

The coefficients on internal social sustainability attributes are all statistically significant at the 1 percent significance level (table 5). Respondent identified mental stress level as the most important attribute with its relative impact equivalent to 39 percent of the impact of all internal social sustainability attributes. Safety of product to consumers, product nutrition, quality, and taste, impact of production on local economy, and utilization of information by a farmer were identified as important for external social sustainability (table 5), with consumer product safety having the greatest impact (52 percent). Finally, soil, surface and groundwater quality, solid waste management, and emission of greenhouse gasses are identified as important for ecological sustainability (table 6), with the solid waste management being the most important attribute for ecological sustainability (29 percent).

These results represent a preliminary analysis of the relative impact of various economic, social, and ecological attributes on sustainability. Future research will investigate whether there are any differences in the relative impact values estimated for different groups of respondents, for example, farmers, university professional, and consumers. Also, some demographic variables, such as age or education, might play an important role in the ranking of attributes. In addition, we will compare attribute relative impact information obtained from the choice experiments and those directly stated by respondents.

The proposed approach presents an effective informational tool for management decisions of farmers as well as regional and national efforts aimed at monitoring the sustainability of agricultural production systems. The results could also be used as a marketing tool by farmers and an informational source for consumers. In addition, this approach provides policy makers with a method to reduce complex sustainability information to a simpler format that could be used in the decision making process. Finally, it is important to mention that this approach is general enough to be adapted to evaluate and monitor sustainability of production in other economic sectors.

References

Becker, B. 1997. "Sustainability Assessment: A Review of Values, Concepts, and Methodological Approaches." Issues in Agriculture Series, CGIAR. Available at www.worldbank.org/html/cgiar/publications/issues/issues10.pdf.

Brundtland, G. 1987. *Our Common Future.* WCED. Oxford, UK: University Press.

Greene, W.H. 2003. *Econometric Analysis*, 5th ed. New Jersey: Prentice Hall.

Ikerd, J. 2006. "Economic Analysis and Multiple Impact Valuation Strategies." In C. Francis, R. Poincelot, and G. Bird, eds. *Developing and Extending Sustainable Agriculture:A New Social Contract.* Binghamton NY: Haworth Food and Agricultural Products Press. Pp.109-140.

Kuhfeld, W., R. Tobias, and M. Garratt. 1994. "Efficient Experimental Design with Marketing Research Applications." *Journal of Marketing Research* 31:545-557.

Rigby, D., D. Howlett, and P. Woodhouse. 2000. "A Review of Indicators of Agricultural and Rural Livelihood Sustainability." Centre for Agricultural Food and Resource Economics (CAFRE), University of Manchester. Working Paper 1. Available at http://les.man.ac.uk/ses/research/CAFRE/indicators/wp1.pdf.

____, P. Woodhouse, T. Young, M. Burton. 2001. “Constructing a Farm Level Indicator of sustainable Practice.” *Ecological Economics* 39:463-478.

Taylor, D., Z. Mohamed, M. Shamsudin, M. Mohaydin, and E. Chiew. 1993. “Creating a Farmer Sustainability Index: A Malaysian Case Study.” *American Journal of Alternative Agriculture* 8:175-184.

Van Calker, K., P. Berentsen, G. Giesen, and R. Huirne. 2005. “Identifying and Ranking Attributes that Determine Sustainability in Dutch Dairy Farming.” *Agriculture and Human Values* 22:53-63.

____, P. Berentsen, C. Romero, G. Giesen, and R. Huirne. “Development and Application of Multi-Attribute Sustainability Function for Dutch Dairy Farming Systems.” *Ecological Economics* 57(2006):640-658.

Van Mansvelt, J. and D. Stobbelaar, eds. 1997. “Landscape Values in Agriculture: Strategies for the Improvement of Sustainable production.” *Agriculture, Ecosystems and Environment* (Special Issue) 63:83-253.

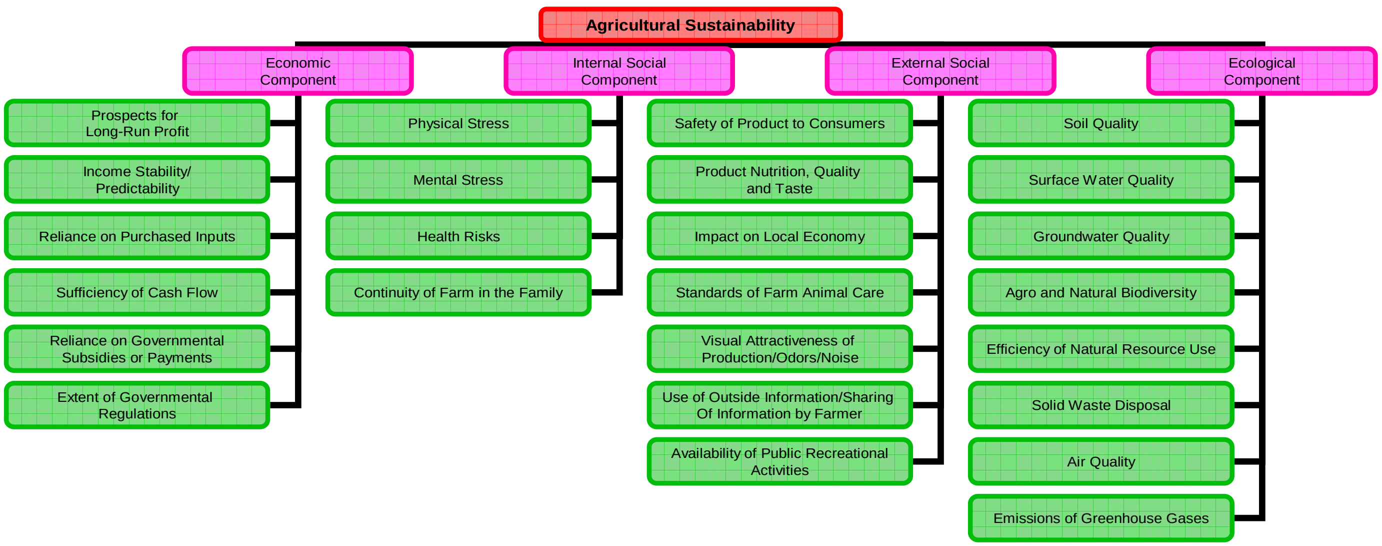

Figure 1. Attributes of Agricultural Sustainability

Table 1. Economic Sustainability Attributes' Levels

	High Attribute Level	**Low Attribute Level**
Prospects for long-run profit	Good prospects	Odds are against long-run profits
Income stability/predictability in the short-run in comparison with other opportunities	More stable/more predictable	Less stable/less predictable
Reliance on purchased inputs (fertilizers, pesticides, fuel) and borrowed capital	Moderately reliant	Highly reliant
Sufficiency of cash flow to cover operational expenses on time	More than enough	May require borrowing
Reliance on governmental subsidies or payments (governmental programs)	Not required	May be required
Extent of governmental regulations	Easy to comply	Difficult to comply

Table 2. Social Sustainability Attributes' Levels

	High Attribute Level	**Low Attribute Level**
Internal Social Attributes		
Physical stress level	Moderate	High
Mental stress level	Moderate	High
Existence of known health risks	Safe	Potential risk involved
Farm will remain in the family after farmer retires	Yes	No
External Social Attributes		
Safety of product to consumers	Safe	Potential risk involved
Product nutrition/quality/taste	Enhanced	Not enhanced
Impact of production on local economy	Relatively large	Relatively small
Standards of farm animal care	Outstanding	Comply with established norms
Visual attractiveness of production/prevention of unpleasant odors and noise	Considered pleasant by most people	Considered unpleasant by some people
Farmer uses outside information and/or shares own information about production with others	Farmer uses/shares information	Farmer depends on own knowledge
Public recreational activities are made possible (hunting, fishing, corn maze, ecotourism)	Yes	No

Table 3. Ecological Sustainability Attributes' Levels

	High Attribute Level	**Low Attribute Level**
Soil quality (physical, chemical, and biological condition)	Enhanced	Maintained, not enhanced
Surface water quality (streams, rivers, lakes)	Safe	Potential risk involved
Groundwater quality (wells)	Safe	Potential risk involved
Agro and natural biodiversity (species richness)	Enhanced	Not enhanced
Efficiency of natural resource use (water, energy)	High	Low
Disposal of solid waste	Properly disposed/recycled	Improperly disposed
Air quality	Safe	Potential risk involved
Emissions of greenhouse gases	Reduced	Not reduced

Table 4. Estimation Results and Relative Impact Estimates of the Economic Sustainability Attributes

	Parameter Estimate	**Attribute Relative Impact**
Prospects for long-run profit	1.68*** *(0.26)*	0.59
Income stability/predictability in the short-run in comparison with other opportunities	-0.04 *(0.22)*	
Reliance on purchased inputs (fertilizers, pesticides, fuel) and borrowed capital	0.54** *(0.25)*	0.19
Sufficiency of cash flow to cover operational expenses on time	0.12 *(0.22)*	
Reliance on governmental subsidies or payments (governmental programs)	0.35 *(0.22)*	
Extent of governmental regulations	0.61*** *(0.24)*	0.22

Note: Asterisks (***, and **) indicate coefficients significantly different from zero at α=0.01 and α=0.05, correspondingly. The first number is the coefficient and the number in parentheses, its standard error. N=162.

Table 5. Estimation Results and Relative Impact Estimates for the Social Sustainability Attributes

	Parameter Estimate	Attribute Relative Impact
Internal Social Attributes		
Physical stress level	0.70*** *(0.22)*	0.18
Mental stress level	1.47*** *(0.24)*	0.39
Existence of known health risks	0.68*** *(0.22)*	0.18
Farm will remain in the family after farmer retires	0.93*** *(0.24)*	0.25
External Social Attributes		
Safety of product to consumers	2.02*** *(0.28)*	0.52
Product nutrition/quality/taste	0.89*** *(0.28)*	0.23
Impact of production on local economy	0.42* *(0.26)*	0.11
Standards of farm animal care	0.26 *(0.26)*	
Visual attractiveness of production/prevention of unpleasant odors and noise	0.18 *(0.24)*	
Farmer uses outside information and/or shares own information about production with others	0.54** *(0.24)*	0.14
Public recreational activities are made possible (hunting, fishing, corn maze, ecotourism)	-0.01 *(0.25)*	

Note: Asterisks (***, **, and *) indicate coefficients significantly different from zero at α=0.01, α=0.05, and α=0.10, correspondingly. The first number is the coefficient and the number in parentheses, its standard error. N=165 for internal social sustainability attributes, and N=174 for external social sustainability attributes.

Table 6. Estimation Results and Relative Impact Estimates for the Ecological Sustainability Attributes

	Parameter Estimate	Attribute Relative Impact
Soil quality (physical, chemical, and biological condition)	0.44* *(0.28)*	0.09
Surface water quality (streams, rivers, lakes)	1.05*** *(0.30)*	0.22
Groundwater quality (wells)	1.31*** *(0.34)*	0.27
Agro and natural biodiversity (species richness)	0.39 *(0.32)*	
Efficiency of natural resource use (water, energy)	0.38 *(0.27)*	
Disposal of solid waste	1.39*** *(0.33)*	0.29
Air quality	0.29 *(0.29)*	
Emissions of greenhouse gases	0.64** *(0.32)*	0.13

Note: Asterisks (***, **, and *) indicate coefficients significantly different from zero at α=0.01, α=0.05, and α=0.10, correspondingly. The first number is the coefficient and the number in parentheses, its standard error. N=144.

Appendix A. Choice Question Example

In your opinion, which of the following production system is more economically sustainable?

Production System A ( ) Production System B ( ) Don't know ( )

	Production System A	**Production System B**
Prospects for long-run profit	Odds are against long-run profits	Good prospects
Income stability/predictability in the short-run in comparison with other opportunities	More stable /more predictable	Less stable /less predictable
Reliance on purchased inputs (fertilizers, pesticides, fuel) and borrowed capital	Highly reliant	Moderately reliant
Sufficiency of cash flow to cover operational expenses on time	May require borrowing	May require borrowing
Reliance on governmental subsidies or payments (governmental programs)	Not required	May be required
Extent of governmental regulations	Easy to comply	Difficult to comply