doi:10.2489/jswc.68.1.1

Shifts in farmer uncertainty over time about sustainable farming practices and modern farming's reliance on commercial fertilizers, insecticides, and herbicides

L.W. Morton, J. Hobbs, and J.G. Arbuckle

Abstract: Nitrogen (N) is critical for maintaining crop yields; however, current agricultural management practices are major contributors to high levels of N and other agricultural chemicals leaking into neighboring water bodies thereby limiting the achievement of sustainability goals for water resources. Changes in farmer beliefs over time about sustainability goals and production inputs reveal increasing uncertainty about the connection between sustainability and their practices. Inference from a multinomial model analysis of farmer beliefs from 1989 to 2002 shows increasing odds of being uncertain about whether use of sustainable farming practices help maintain the natural resource base. Almost 29% of the population of a 2002 random sample survey of Iowa farmers was uncertain about sustainable farming practices compared to 18.8% in 1989. Further, farmers were increasingly uncertain over time as to whether modern farming relies too heavily upon commercial fertilizers, insecticides, and herbicides. In 2002, 14.5% of farmers, compared to 8.4% in 1994 and 5.7% in 1989, were uncertain about whether heavy reliance on commercial fertilizers was a sustainability problem. Multinomial logistic regression models examining responses to various farming practices reveal that the ratio of disagree/agree increases over time and is influenced by total corn and soybean acres farmed, net of farmer age, and weather conditions. Models of uncertainty controlling for age and weather conditions show increasing farmer uncertainty about sustainable farming practices; natural resource base maintenance; and whether modern farming relies too heavily on commercial fertilizers, insecticides, and herbicides.

Key words: commercial fertilizers—farmer beliefs—herbicides—sustainable farming practice

Sustainability of agriculture suggests endurance into the future (McIsaac 1994). Uncertainty related to climate change and the increasing demands for food, fiber, forage, and biofuel present significant challenges to agriculture's capacity to assure future food security and protection of the environment (SWCS 2011). Farming practices that reduce soil erosion and mitigate loss of excess nitrogen (N), herbicides, and other chemicals into proximate water bodies are central to achieving sustainable agricultural systems (National Research Council 2010).

The goal of sustainability is a socially determined outcome first explicitly codified by USDA in the Food, Agriculture, Conservation, and Trade Act of 1990 (Beachy 2010). The 1990 Farm Bill statutorily defines sustainable agriculture as an "integrated system of plant and animal production practices having a site-specific application that will, over the long term, satisfy human food and fiber needs; enhance environmental quality and the natural resource base upon which the agriculture economy depends; make the most efficient use of nonrenewable resources and on-farm resources and integrate, where appropriate, natural biological cycles and controls; sustain the economic viability of farm operations; and enhance the quality of life for farmers and society as a whole" (Food, Agriculture, Conservation, and Trade Act of 1990; Gold 2007).

Efforts to achieve sustainability imply a dual interest or multiutility approach (Chouinard et al. 2008; Bishop et al. 2010; Sheeder and Lynne 2011) to farming that balances economic, social, and environmental goals in ways that assure both viability of farm operations and protection of the natural resource base. To date, however, societal commitment to sustainability in agriculture has focused more on enhancing productivity and efficiency and less on addressing negative environmental externalities (National Research Council 2010). This societal emphasis on the productivity and efficiency components of sustainability is reflected in a similar attitudinal bias among farmers and other agricultural stakeholders who tend to give higher priority to the productivity-related dimensions of agricultural sustainability than the environmental (Herndl et al. 2011).

Nationally, about 18% of US total land area in the lower 48 states is cropland (357 million ac [144 million ha]) (USDA NRCS 2009). There are a number of key factors that over the past forty years have characterized the "modernization" of farming and crop production in the United States. These include (1) a steady rise in the concentration or dominance of a few field crops, (2) productivity increases, (3) increased adoption of technologies and larger equipment which enable producers to manage more acres within one operation, and (4) a production shift to larger farms and a decrease in the number of small commercial farms (Bechdol et al. 2010; Gardner 2002; National Research Council 2010; MacDonald 2011). Corn, soybeans, wheat, cotton, rice, sorghum, and barley oat represent 75% of crop value produced by 40% of US farms (Bechdol et al. 2010). Corn yields increased from an average 3.4 Mg ha^{-1} (55 bu ac^{-1}) in 1960 to 10.4 Mg ha^{-1} (165 bu ac^{-1}) in 2009 (Bechdol et al. 2010). According to Censuses of Agriculture (1982 to 2007), 16,000 farms in 1982 had at least US$1 million in sales (expressed in 2007 dollars), but by 2007, 55,000 farms had at least US$1 million in sales and accounted for 59% of all farm sales (MacDonald 2011). The increase in the largest farms' share of sales contrasts with that of small commercial farms (sales of US$10,000 to US$250,000), which fell by 40% from 1982 to 2007 (MacDonald 2011).

Lois Wright Morton is professor of sociology, **Jon Hobbs** is a doctoral candidate, and **J. Gordon Arbuckle** is assistant professor of sociology at Iowa State University, Ames, Iowa.

The steady increase in farm size and number of farms with more than US$1 million in annual sales has been enabled to a large degree by more extensive use of synthetic fertilizers and herbicides inputs. These inputs, particularly fertilizers and pesticides, have allowed specialized monoculture of grain crops and spectacular gains in yield and labor productivity (Bechdol et al. 2010; McDonald 2011). Nitrogen is a major plant nutrient and the single most important input a farmer can control to increase crop yields (Ribaudo 2011). In the United States today, most row crop systems use pesticides along with other practices to manage weeds, insects, and disease to prevent crop yield or quality losses (Osteen and Livingston 2006). United States farmers typically spend over US$10 billion annually for commercial fertilizers, with corn production accounting for over 40% of all commercial fertilizer used (Daberkow and Huang 2006). Agricultural pesticide expenditures reached an all-time high of US$9 billion in 1997 to 1998, followed by US$8.3 to US$8.5 billion in 2002 to 2004 with herbicides accounting for two-thirds of those expenditures (Osteen and Livingston 2006).

This input-driven yield enhancement has come at a cost of increasing dependence on inputs, however. While use of commercial fertilizer and other chemical inputs has essentially stabilized in recent years, crop yields, especially with corn, are heavily reliant on such inputs (Daberkow and Huang 2006; Osteen and Livingston 2006). Thus, most large-scale, specialized grain producers are almost completely dependent on purchased inputs.

While productivity enhancement goals have largely been met over the last decades, lack of progress on the environmental side of the agricultural sustainability equation has created increasing levels of conflict over natural resource degradation. In the Corn Belt, these conflicts are centered mainly on water quality concerns as the negative impacts of soil loss, sedimentation, and excessive phosphorus (P) and N compounds on ecosystems and natural balances are widespread (USEPA 2009; Ribaudo 2011). The US Environmental Protection Agency has specified sustainability goals related to water resources as improved water quality achieved through reductions in N runoff and soil erosion from agricultural landscapes that contribute to hypoxic conditions in water bodies. United States Geological Survey findings reveal that agricultural sources contribute more than 70% of the N delivered to the Gulf of Mexico by way of the Mississippi River Basin (Alexander et al. 2008). Based on data from 1992 to 2003, 13% of US streams and 20% of groundwater wells have nitrate concentrations greater than the drinking water standard of 10 mg L^{-1} (10 ppm) (Heinz Center 2008). In May of 2011, the Mississippi and Atchafalaya rivers discharged 64,000 t (70,547 tn) of N into the northern Gulf of Mexico, nearly twice that of normal conditions, resulting in an estimated 35% increase over average May N levels in recent decades (NOAA 2011).

The tension between increased productivity and concern about nonpoint source pollution points to an imbalance in the sustainability equation. On one hand, farmers are responding effectively to societal and market signals to increase yields and have employed purchased inputs to greatly enhance productivity (Gardner 2002). However, on the other hand, there is a mounting demand for improved environmental performance and reduction of impacts, especially those associated with use of agrichemicals. Farmers thus face a structural paradox: even as productivity has become more a function of input use and less a function of labor, thereby increasing dependence on inputs, many of those same inputs are also increasingly implicated as drivers of environmental degradation.

In this research, we examine changes between 1989 and 2002 in farmers' beliefs about agricultural sustainability and their perceptions of the relationships between farming practices and maintenance of the natural resource base. Of particular interest are shifts in farmers' attitudes toward modern agriculture's reliance on inputs, such as commercial fertilizers, insecticides, and herbicides, as farm size increased during this time period. We posit that increase in farm size represents greater dependency on external inputs and an acceleration of the agricultural treadmill of production articulated by Cochrane (1993), which could make economic survival and viability a more dominant concern than water quality. The agricultural treadmill is characterized by specialization in one or two commodity crops which are not differentiated in the marketplace; thus, farmers have little control over market price when they choose to sell. Because the commodity price is the same for all farmers, those farmers who aggressively adopt new technologies that result in lower production costs and higher yields relative to other farmers will earn more profits. However, once yield-enhancing technologies are widely used, the competitive advantage is lost to the early adopter and the increase in supply lowers prices for all farmers. To survive, farmers must continually adopt new technology, expand their operations over more acres, or both, and the cycle repeats itself. Once on this agricultural treadmill, it may become very difficult to incorporate sustainability goals and conservation management unless they add value to the production process.

While managing for sustainability is a dual motive or multiutility (Chouinard et al 2008; Bishop et al. 2010; Sheeder and Lynne 2011) process that integrates both self-interest profit goals and collective conservation motives, the farmer who is on the agricultural treadmill is likely to find it very challenging to break the cycle of external input dependency and manage for the environmental impacts of those inputs. One way to manage or reconcile the tension between environmental values and production goals is to realign the priority assigned to the environmental values and move it to an uncertainty or less important cognitive category (Burke 1991; Burke and Stets 2000; McGuire 2010). Thus, the more dependent on inputs farmers become in order to meet productivity goals, the more environmental goals may seem at odds with or not relevant to those production and economic goals and the further the farmers move away from a multiutility approach to management decisions. The objective of this research is to assess, in the context of increasing scale and input dependence in agriculture, farmers' attitudes toward sustainable farming and input use over time and, in particular, the relationship between changes in those attitudes and individual farm size.

Materials and Methods

Data. Our data were drawn from the Iowa Farm and Rural Life Poll (IFRLP), an annual, longitudinal panel survey of Iowa farmers. We examine three questions that were presented in the 1989, 1994, and 2002 surveys. The question sets were introduced in the survey through the heading, "Opinions on Modern Agricultural Practices," and the following introductory sentence: "There is increasing public concern about the safety

Table 1
Summary statistics for key variables in the Iowa Farm and Rural Life Poll.

Variable	Year	Sample size	Strongly disagree (%)	Somewhat disagree (%)	Uncertain (%)	Somewhat agree (%)	Strongly agree (%)
Sustainable farming practices	1989	2,028	2.1	10.4	18.8	47.9	20.8
	1994	1,997	3.8	11.7	22.3	45.2	17.0
	2002	1,902	3.7	8.5	28.5	41.6	17.6
Commercial fertilizers	1989	2,045	3.7	14.6	5.7	42.6	33.4
	1994	2,008	8.1	23.2	8.5	39.8	20.4
	2002	1,912	5.6	18.2	14.5	41.5	20.1
Insecticides and herbicides	1989	2,044	3.3	13.0	5.3	38.5	39.9
	1994	2,010	8.0	22.4	8.4	38.0	23.2
	2002	1,908	6.3	19.2	14.1	38.3	22.1

Table 2
Covariates used in multinomial logistic regression models. Descriptive statistics for each covariate for each year are included.

Covariate	Description	Year	Minimum	Mean	Maximum
Row crop acres	Total row crop acres, truncated at 5,000	1989	0	287	4,275
	= corn acres owned + corn acres rented	1994	0	323	2,700
	+ soybean acres owned + soybean acres rented	2002	0	377	5,000
Age	Centered age	1989	–27	2.7	40
	= age – 50	1994	–28	4.7	41
		2002	–32	8.5	41
Growing degree days	Scaled growing degree days from previous year	1989	–0.30	0.20	0.87
	$= \frac{\text{county-specific growing degree days} - 3{,}000}{1{,}000}$	1994	–1.12	–0.45	0.25
		2002	–0.63	–0.04	0.73

of some modern agricultural practices. What is your opinion of these statements?" The statements read as follows (short descriptive name in parentheses):

- Increased use of sustainable farming practices would help maintain our natural resources (Sustainable Farming Practices)
- Modern farming relies too heavily upon commercial fertilizers (Commercial Fertilizers)
- Modern farming relies too heavily upon insecticides and herbicides (Insecticides and Herbicides).

Participants were asked to rate their level of agreement or disagreement with the three items on a scale from Strongly Disagree (1) to Strongly Agree (5). The middle points on the scale were Somewhat Disagree (2), Uncertain (3), and Somewhat Agree (4).

Responses on the first item were generally affirmative, but trended toward less agreement over time. In 1989, 69% of farmers expressed some agreement that "sustainable farming practices" would contribute to the maintenance of natural resources (table 1). By 2002, that figure had dropped ten points—to 59%. Attitudes toward use of commercial fertilizer and insecticides and herbicides followed a similar, though even more pronounced, declining trend. In 1989, 76% of farmers agreed with the statement, "modern farming relies too heavily on commercial fertilizers," and 78% agreed that modern farming was too reliant on insecticides and herbicides. By 2002, only 62% of farmers expressed agreement with the former position and 60% with the latter.

Three covariates (table 2) expected to be associated with farmer attitudes are included in our models, farm size and two control variables. Farm size is measured by total corn and soybean (the dominant cropping system in Iowa) planted acres owned and rented in the previous year and represents farm scale and input dependence. The IFRLP sample data show farm size increasing over the 1989 to 2002 period, from a mean of 116 ha (287 ac) of row crops in 1989, to 131 ha (323 ac) in 1994, to 153 ha (377 ac) in 2002 (table 2). In addition, there is substantial variability in farm size in all years. Age and growing degree days (GDD) are control variables. Younger farmers may have different attitudes; for example, they may more readily embrace modern practices. Growing degree days reflect the previous season's weather, which may influence respondent responses. Growing degree days are computed from temperature data from the National Weather Service Cooperative Observer Network. Data from over 90 National Weather Service Cooperative sites across Iowa were linked to IFRLP respondent county codes to provide approximate local weather information at the individual level. As shown in table 2, age and GDD have been centered and scaled. The centering allows more meaningful interpretation in regression modeling. For example, centering the GDD variable by subtracting a constant allows a regression intercept to reflect an average year's weather (3,000 GDD) versus a year with zero GDD, which is uninterpretable. Scaling the covariates (dividing by a constant) can positively impact the performance of the computational routines used to estimate the parameters. Scaling gives the covariates similar variability. Ultimately, centering and scaling do not change the technical results but allow for easier estimation and interpretation. The following sections present the results of two multinomial modeling approaches that assess attitude changes in the sample population over time and model the relationships between farm size and attitudes toward input use and sustainable practices over time.

Analytical Approaches: Multinomial Modeling. We use two types of statistical models to analyze our data. The first approach addresses overall changes in the population over time, and the second approach incorporates the relationship between attitudes and farm size. It is unclear how the uncertain category may fit into an ordering of the response categories, so our analysis considers these as nominal categories. A basic statistical framework for responses from discrete categories is a multinomial distribution model. The multinomial distribution is characterized by a set of population-level proportions associated with each response category. Our analysis consists of two variations of the multinomial model; it first considers a time-varying population-level model and then a logistic regression model that incorporates covariate and individual effects.

Approach 1: Population-Level Multinomial Model. The population-level multinomial model assumes that at a given point in time the distribution of responses to each of the three survey items of interest is multinomial. Since there are five response options, this distribution consists of five fixed proportions that characterize the population of Iowa farmers. Using the data from each year's sample, we wish to estimate these population proportions and assess potential differences across years.

A Bayesian analysis is used here for inference on the population proportions. The Bayesian approach requires prior distributions that reflect previous knowledge about the unknown parameters, which are the multinomial proportions for each year in this model. The prior distribution is combined with the observed data to yield the posterior, or postdata, distribution, which provides inference for the parameters of interest.

If the data analyst desires that the data have greatest impact on the inference, a vague or diffuse prior distribution can be chosen. For multinomial proportions, the Dirichlet distribution is a convenient prior distribution, both mathematically and for interpretation. The Dirichlet parameters can be thought to represent "prior counts" for the response categories. Thus, the prior knowledge can be summarized in terms of a predata sample size and the anticipated responses in each category (Gelman et al. 2004). One noninformative Dirichlet prior assigns a prior count of 1 to each category. This prior distribution is used for the analysis of the 1989, 1994, and 2002 IFRLP data.

When a Dirichlet prior is adopted with a multinomial data model, the resulting posterior distribution for the set of multinomial proportions is also a Dirichlet distribution. In addition, the posterior distribution for a single category's proportion is a beta distribution. Summaries of these distributions, such as their means and extreme quantiles, provide point estimates and measures of uncertainty for the parameters of interest. This approach is applied separately to the three years of data for each of the three survey items of interest.

Approach 2: Multinomial Logistic Regression. Approach 1 helps provide a broad picture of the population at different points in time. The second modeling approach extends the investigation to include the relationship between attitudes and covariates of interest. Further, some subjects remain in the survey for multiple years; in fact, a portion of the sample presented here participated in 1989, 1994, and 2002. Multinomial logistic regression modeling with random effects is a comprehensive modeling approach that allows responses by the same individuals over time to be related statistically and specific investigation of the relationships between farm size/dependence on inputs and attitudes toward those inputs and sustainable practices related more generally.

First, the five response options are collapsed into three. Denote $y_{i,t,}$ as the response to an item by subject i in year t. The possible responses are identified in the following way:

$$y_{i,t} = \begin{cases} 0 \text{ if subject } i \text{ chooses Uncertain in year } t \\ -1 \text{ if subject } i \text{ chooses Somewhat Disagree} \\ \quad \text{or Strongly Disagree in year } t \\ 1 \text{ if subject } i \text{ chooses Somewhat Agree or} \\ \quad \text{Strongly Agree in year } t\,. \end{cases}$$

Then, this individual-specific random variable follows a multinomial distribution characterized by three proportions: $P_{i,t,0}$, $P_{i,t,-1}$, and $P_{i,t,1}$. These individual- and time-specific proportions can now be made functions of covariates. One common approach for incorporating the covariate information is through a multinomial logit (Hartzel et al. 2001). The logit is simply the logarithm of the odds ratio between the proportions for two categories. When the categories are nominal, the generalized logit can be used. This requires one of the categories to be defined as a baseline, and a logistic regression is then constructed for each category relative to the baseline. Taking the uncertain category as a baseline, the two components are then

$$\log\left(\frac{P_{i,t,-1}}{P_{i,t,0}}\right) = x'_{i,t}\alpha_{t,-1} + Z_{i,-1}$$

$$\log\left(\frac{P_{i,t,1}}{P_{i,t,0}}\right) = x'_{i,t}\alpha_{t,1} + Z_{i,1}.$$

The vectors $x_{i,t}$ denote known individual-level covariates for each year and include coding for an intercept. As defined above, these covariates are total corn and soybean row crop acres, representing farm size and serving as a proxy for input dependence; farmer age; and GDD, representing weather conditions for the prior growing season.

The multinomial logit model includes the time-specific coefficients $\alpha_{t,-1}$ and $\alpha_{t,1}$, which are associated with the covariates and reflect the population effect for each covariate (including an intercept) for each year. In addition, the model includes the individual-specific effects $Z_{t,-1}$ and $Z_{t,1}$. Noting that these effects vary from individual-to-individual but do not vary with time, these effects capture the tendency of an individual to respond consistently at all times. Since some respondents participated in two or all three of the 1989, 1994, and 2002 IFRLPs, their responses over time may be related, and these effects attempt to account for that. Following Hartzel et al. (2001), these individual effects are assumed to be random variables with a multivariate normal distribution.

As with the first approach, inference for the multinomial logit model is achieved through a Bayesian analysis. Prior distributions include Gaussian distributions for $\alpha_{t,-1}$ and $\alpha_{t,1}$ and an inverse Wishart distribution for the covariance parameters of the individual effects. Unlike the first approach, this model is completely specified for the entire collection of data for all three years. Therefore, only a single analysis is required instead of separate analyses by year. For this model, Markov Chain Monte Carlo techniques (Gelman et al. 2004) are used to sample from the posterior distributions of the parameters.

The posterior distributions for the regression coefficients $\alpha_{t,-1}$ and $\alpha_{t,1}$ will guide quantitative inference and interpretation. Specifically, the coefficients corresponding to total row crop acres will reveal tendencies in farmer opinions as a function of farm size. Comparing coefficients across years will reveal relevant time trends. This can be done both for the covariates' coefficients and the intercept terms since changes in the intercepts may reflect systematic population shifts in opinions.

Results and Discussion

We use these two approaches to examine the relationship between increasing farm size/dependence on purchased inputs and the degree to which farmers believe that (1) reliance on chemical inputs is problematic and (2) increased use of sustainable practices would lead to improved natural resource outcomes. The declines in proportion of farmers who agreed with those statements are linked to shifts in uncertainty and disagreement over time. The Bayesian approach to statistical inference relies on the posterior, or postdata, distribution, which mathematically combines the prior distribution with the model for the observed data. The posterior distribution is an actual probability distribution. Instead of computing parameter estimates, the center of the posterior distribution indicates the most likely values of the parameter. Instead of computing a standard error, the spread of the posterior distribution reflects the uncertainty about the parameter. The posterior distribution can be summarized graphically by plotting its histogram, or probability density function, or numerically by computing measures of center and spread such as the mean and an interval between two quantiles. This interval is known as a credible interval, a Bayesian confidence interval. The graphical and numerical summaries are both used in the results that follow.

Approach 1: Population-Level Multinomial Model. The Bayesian analysis of the population-level multinomial model can be summarized by looking at the posterior distribution of the multinomial proportions for each response category. Results for the sustainable practices and commercial fertilizers items are briefly presented here. The characteristics of the posterior distribution can be summarized visually through a plot of its probability density function. Figure 1 illustrates the posterior distributions for the sustainable farming practices item for each year and response category. The somewhat agree category is the most popular in all three years, with all three posterior distributions concentrated between 0.4 and 0.5 (i.e., between 40% and 50% of the population). However, there is a noticeable shift in this category's posterior distribution over time, moving from near 0.5 in 1989 to 0.4 in 2002. An opposite and even more pronounced shift is observed for the uncertain response category, which moves from a center under 0.2 in 1989 to over 0.3 in 2002. These shifts indicate that over time there is increasing uncertainty that increased use of sustainable practices would help maintain natural resources.

Figure 2 illustrates the posterior distributions for the commercial fertilizers item. It shares a similar trend in the uncertain category with the sustainable practices item, moving from a proportion less than 0.1 in 1989 to around 0.15 in 2002. There was a significant decline in the population proportion for the strongly agree category from 1989 to 1994 and complementary increases in both the strongly disagree and somewhat disagree categories. However, the posterior distributions for somewhat disagree suggest that the population proportion is highest in 1994 before moderating slightly in 2002.

The posterior distribution can also be summarized numerically, with its mean characterizing the distribution's center and credible intervals describing the spread, which represents uncertainty. The credible interval uses specific percentiles of the posterior distribution; for example, a 95% credible interval is the interval between the posterior distribution's 2.5 and 97.5 percentiles. Table 3 presents the posterior means and 95% credible intervals for the sustainable farming practices item for each year. The posterior means for somewhat agree, uncertain, and somewhat disagree peak in 1989, 2002, and 1994, respectively. The posterior distribution of the difference in proportions across years reveals that all categories saw some significant changes with time, with the proportion uncertain increasing significantly from 1989 to 1994 and from 1994 to 2002. Table 4 presents the means, credible intervals, and tests for the commercial fertilizers item. The agree categories combine for three-fourths of the population in 1989, and this proportion falls to around 60% in subsequent years, with upticks in somewhat disagree in 1994 and uncertain in 2002. Posterior density plots, means, and credible intervals for the insecticides and herbicides survey item follow a similar pattern as commercial fertilizers (not shown). These results reveal an increasing proportion of farmers shifting away from agreement and an increase in uncertainty about modern farming relying too heavily on commercial fertilizers, insecticides, and herbicides.

Approach 2: Multinomial Logistic Regression. The multinomial logistic regression model offers a more refined investigation while controlling for demographic and environmental factors as well as handling the richness of the available data. Specifically, the individual random effects realistically account for the relatedness of multiple observations across time for the same individual. While the random effects provide some useful interpretation for specific individuals, the initial focus is on the fixed predictors and their behavior over multiple years. As before, quantitative inference can be drawn from the posterior distributions of the model parameters. One strategy for identifying important predictors in a Bayesian analysis of a regression model is to single out the coefficients whose posterior credible intervals do not contain zero.

Tables 5, 6, and 7 summarize the posterior distributions for the coefficients in the multinomial logistic regression models for each of the three survey items, respectively. Each model has *two* coefficients for each combination of year and covariate. There are two coefficients for each combination to reflect two different odds ratios; the first corresponds to the odds of disagree to uncertain, and the second represents the odds of agree to uncertain. This complexity warrants some discussion of the interpretation of the coefficients. The intercept coefficients represent the log odds when the other covariates are zero, which would be for a farmer with no row crop acres (e.g., a livestock producer) who is 50 years old and experienced average weather conditions. A positive disagree/uncertain intercept indicates that the disagree response is relatively more likely than an uncertain response for this no-row crop acres farmer. The coefficients for crop acres, age, and GDD then reflect the change in the odds of disagree to uncertain as a function of the covariate. As an example, if the crop acres coefficient is positive (negative) for disagree/uncertain, then larger producers are increasingly more (less) likely to choose disagree over uncertain. The discussion of specific results is focused on the crop acres

Figure 1
Posterior density plots for each response category for the sustainable farming practices item: (a) strongly disagree, (b) somewhat disagree, (c) uncertain, (d) somewhat agree, and (e) strongly agree.

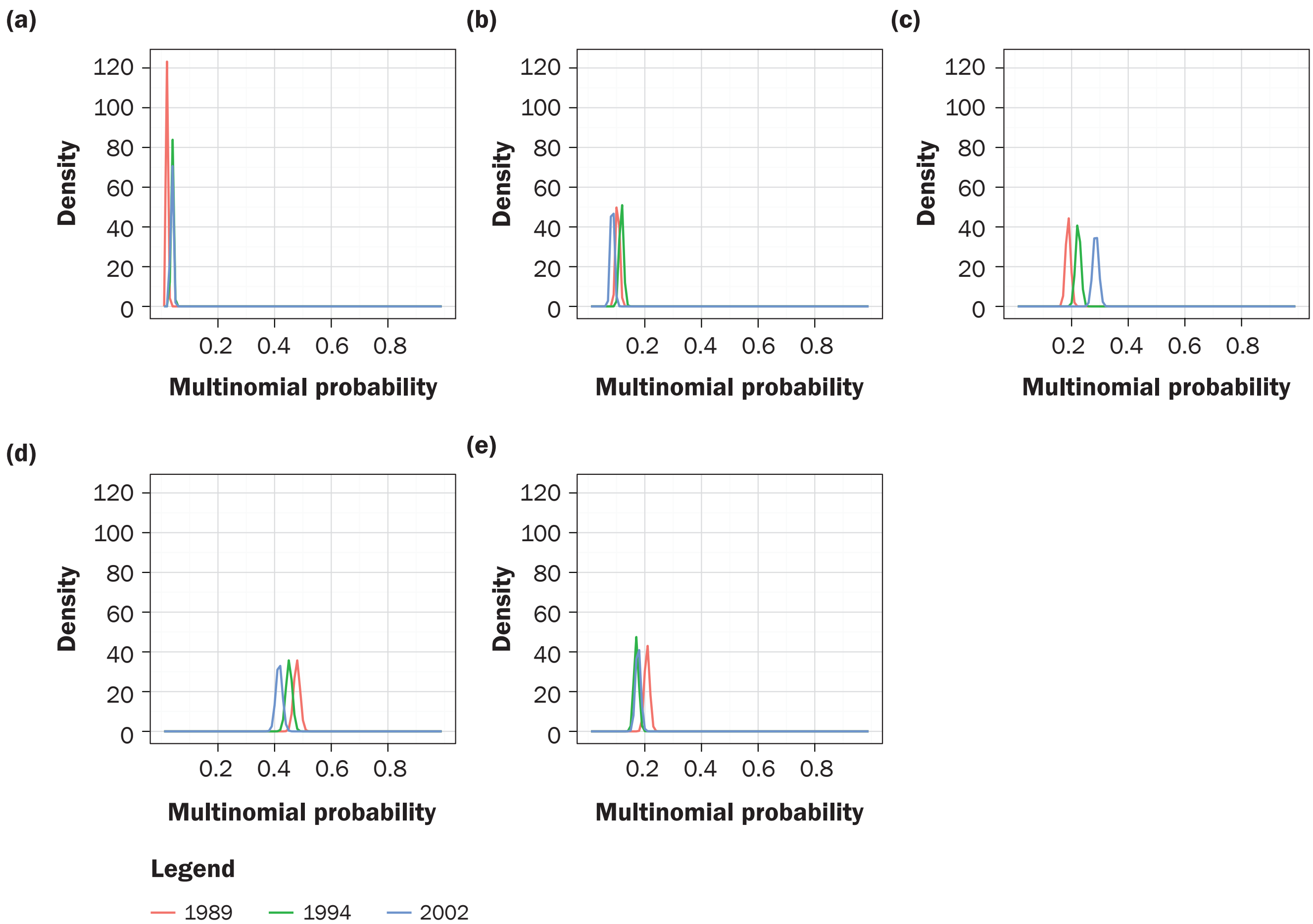


Table 3
Posterior means and credible intervals for multinomial proportions for the sustainable farming practices item. The final column indicates years that are significantly different with a posterior probability of at least 0.99. For example, a notation of 1989 < 1994 indicates that the proportion for 1989 is significantly smaller than for 1994.

Category	1989	1994	2002	Significantly different
Strongly disagree	0.021 (0.015, 0.028)	0.038 (0.030, 0.047)	0.037 (0.030, 0.047)	1989 < 1994; 1989 < 2002
Somewhat disagree	0.104 (0.091, 0.118)	0.117 (0.104, 0.132)	0.085 (0.073, 0.099)	2002 < 1994
Uncertain	0.188 (0.171, 0.205)	0.223 (0.205, 0.242)	0.285 (0.265, 0.306)	1989 < 1994 < 2002
Somewhat agree	0.479 (0.457, 0.500)	0.451 (0.429, 0.473)	0.416 (0.394, 0.438)	2002 < 1989
Strongly agree	0.208 (0.191, 0.226)	0.170 (0.154, 0.187)	0.176 (0.159, 0.193)	1994 < 1989; 2002 < 1989

Figure 2
Posterior density plots for each response category for the commercial fertilizers item: (a) strongly disagree, (b) somewhat disagree, (c) uncertain, (d) somewhat agree, and (e) strongly agree.

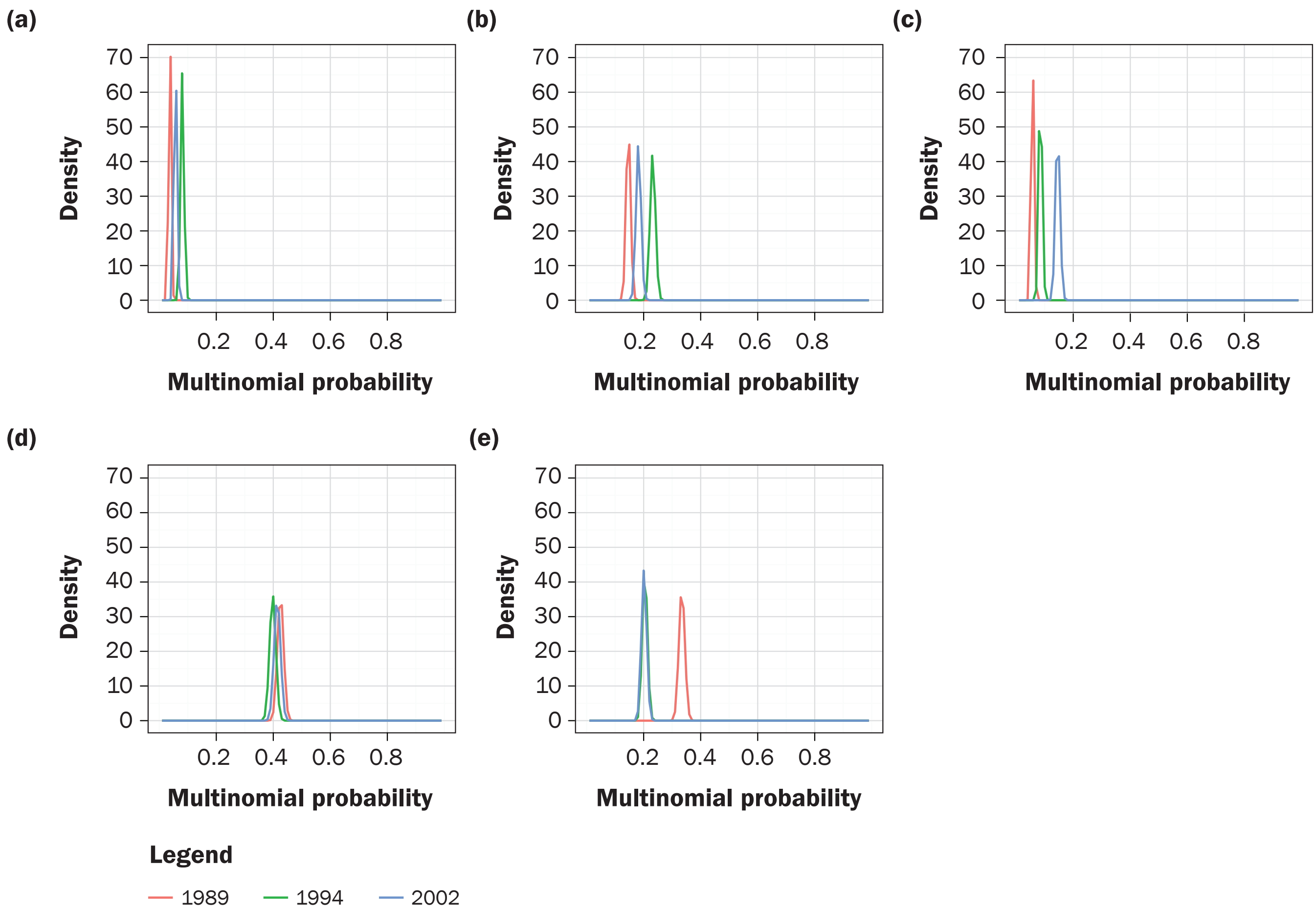


Table 4
Posterior means and credible intervals for multinomial proportions for the commercial fertilizers item. The final column indicates years that are significantly different with a posterior probability of at least 0.99. For example, a notation of 1989 < 1994 indicates that the proportion for 1989 is significantly smaller than for 1994.

Category	1989	1994	2002	Significantly different
Strongly disagree	0.037 (0.029, 0.046)	0.081 (0.069, 0.093)	0.057 (0.047, 0.068)	1989 < 2002 < 1994
Somewhat disagree	0.146 (0.132, 0.162)	0.232 (0.214, 0.251)	0.182 (0.165, 0.200)	1989 < 2002 < 1994
Uncertain	0.057 (0.047, 0.068)	0.085 (0.073, 0.098)	0.145 (0.132, 0.161)	1989 < 1994 < 2002
Somewhat agree	0.425 (0.404, 0.447)	0.398 (0.377, 0.419)	0.414 (0.392, 0.437)	
Strongly agree	0.334 (0.314, 0.355)	0.204 (0.187, 0.222)	0.201 (0.184, 0.220)	1994 < 1989; 2002 < 1989

Table 5
Posterior means and credible intervals for multinomial logit fixed effect parameters for the sustainable farming practices item. Significant coefficients are bolded.

Year	Coefficient	Disagree/uncertain	Agree/uncertain
1989	Intercept	−1.00 (−1.41, −0.61)	1.70 (1.45, 1.97)
	Crop acres	**0.00095 (0.00039, 0.00152)**	−0.00027 (−0.00075, 0.00022)
	Age	−0.010 (−0.027, 0.006)	−0.002 (−0.013, 0.010)
	GDD	0.05 (−0.74, 0.82)	−0.05 (−0.62, 0.54)
1994	Intercept	−0.88 (−1.32, −0.46)	1.37 (1.08, 1.66)
	Crop acres	**0.00102 (0.00054, 0.00152)**	**−0.00072 (−0.00116, −0.00029)**
	Age	−0.006 (−0.021, 0.009)	0.001 (−0.010, 0.012)
	GDD	0.26 (−0.34, 0.84)	−0.27 (−0.72, 0.17)
2002	Intercept	−1.39 (−1.76, −1.04)	1.01 (0.80, 1.23)
	Crop acres	**0.00040 (0.00008, 0.00072)**	**−0.00005 (−0.00077, −0.00022)**
	Age	0.002 (−0.014, 0.018)	0.010 (−0.001, 0.021)
	GDD	0.38 (−0.27, 1.04)	0.31 (−0.15, 0.78)

Note: GDD = growing degree days.

Table 6
Posterior means and credible intervals for multinomial logit fixed effect parameters for the commercial fertilizers item. Significant coefficients are bolded.

Year	Coefficient	Disagree/uncertain	Agree/uncertain
1989	Intercept	0.66 (0.08, 1.27)	3.47 (2.97, 4.02)
	Crop acres	**0.00082 (0.00012, 0.00156)**	**−0.00128 (−0.00196, −0.00055)**
	Age	−0.006 (−0.027, 0.015)	0.013 (−0.006, 0.031)
	GDD	0.10 (−0.89, 1.10)	0.14 (−0.74, 1.06)
1994	Intercept	0.96 (0.44, 1.54)	2.52 (2.04, 3.05)
	Crop acres	**0.00150 (0.00086, 0.00216)**	**−0.00114 (−0.00180, −0.00047)**
	Age	−0.006 (−0.023, 0.011)	0.022 (0.006, 0.038)
	GDD	0.45 (−0.23, 1.14)	−0.01 (−0.65, 0.63)
2002	Intercept	0.03 (−0.36, 0.44)	1.82 (1.49, 2.19)
	Crop acres	**0.00055 (0.00022, 0.00091)**	**−0.00087 (−0.00122, −0.00052)**
	Age	0.001 (−0.015, 0.016)	**0.021 (0.008, 0.035)**
	GDD	−0.04 (−0.68, 0.57)	−0.46 (−1.02, 0.11)

Note: GDD = growing degree days.

coefficients, which reflect farm size/input dependence, and the change of the intercepts across years, which reflect time trends in attitudes.

Table 5 gives posterior means and 95% credible intervals for the multinomial logistic regression coefficients for the sustainable farming practices item. The farm size coefficients are positive and significant in all years for disagree/uncertain (bolded). Similarly, the crop acre coefficients are consistently negative for agree/uncertain (bolded). Overall this suggests that as farm size/input dependence increases, farmers are more likely to disagree and less likely to agree that increased use of sustainable practices would help maintain natural resources. Coefficients for age and growing degree days are not significant, although the age coefficient for agree/uncertain increases from 1989 to 2002. The disagree/uncertain intercepts for the sustainable practices item exhibit noticeable changes over time. The coefficient is largest in 1994 and drops significantly in 2002, another indication of the peak in disagreement in 1994 and movement toward uncertainty in 2002 for the population as a whole. The intercept for agree/uncertain decreases substantially both from 1989 to 1994 and from 1994 to 2002, revealing the increasing uncertainty regarding sustainable farming practices.

The posterior distributions for the multinomial logistic regression coefficients for the commercial fertilizers (table 6) and insecticides and herbicides (table 7) items show similar patterns. Farm size coefficients are significant for both disagree/uncertain (positive) and agree/uncertain (negative). Together these results indicate a general tendency for farmers with larger operations to disagree that modern farming relies too heavily on commercial fertilizers, insecticides, and herbicides. Both of these items show slightly significant coefficients for age in 1994 and 2002, indicating that older farmers are more likely to agree that modern farming relies too heavily on fertilizers,

Table 7
Posterior means and credible intervals for multinomial logit fixed effect parameters for the insecticides and herbicides item. Significant coefficients are bolded.

Year	Coefficient	Disagree/uncertain	Agree/uncertain
1989	Intercept	0.62 (0.03, 1.23)	3.78 (3.27, 4.30)
	Crop acres	0.00045 (–0.00024, 0.00118)	**–0.00170 (–0.00238, –0.00102)**
	Age	–0.005 (–0.027, 0.017)	0.003 (–0.017, 0.022)
	GDD	0.33 (–0.70, 1.34)	0.10 (–0.83, 1.03)
1994	Intercept	0.79 (0.28, 1.32)	2.27 (1.80, 2.76)
	Crop acres	**0.00160 (0.00094, 0.00229)**	**–0.00089 (–0.00155, –0.00023)**
	Age	–0.007 (–0.024, 0.011)	**0.020 (0.004, 0.036)**
	GDD	0.26 (–0.41, 0.93)	–0.52 (–1.16, 0.11)
2002	Intercept	0.21 (–0.19, 0.59)	1.83 (1.50, 2.18)
	Crop acres	**0.00038 (0.00005, 0.00072)**	**–0.00081 (–0.00116, –0.00047)**
	Age	0.007 (–0.009, 0.022)	**0.018 (0.004, 0.032)**
	GDD	0.03 (–0.61, 0.66)	–0.36 (–0.93, 0.20)

Note: GDD = growing degree days.

insecticides, and herbicides. Changes in the intercepts are also evident for both items.

Figure 3 offers a complementary view of the results from the multinomial logistic regression models. The actual population proportions for the disagree, uncertain, and agree categories can be computed for chosen values of the covariates using the model coefficients. It depicts the behavior of these proportions as a function of the total crop acres for all three items, as suggested by the Bayesian analysis, for all three years. The transition from agree to disagree with increasing farm size is evident in all years. The other striking feature is the noticeable increase in the uncertain proportion over time, reaching a maximum for all survey items in 2002.

Summary and Conclusions

Over the 13-year course of this study, the relationship between farmer attitudes and farm size is pronounced and present in all years. The regression models identify two key results, the first being a strong relationship between attitudes and farm size and the second being the practically population-wide shifts over time. Further, there is a substantial shift from "I think it matters" to "I am unsure." In general, farmer agreement with the statements that (1) sustainable farming practices are needed to protect the natural resource base and (2) modern farming relies too heavily on commercial fertilizers, insecticides, and herbicides declined over the period, while uncertainty and disagreement increased, indicating that farmers in general are becoming less convinced that sustainable practices are needed to protect the natural resource base over time.

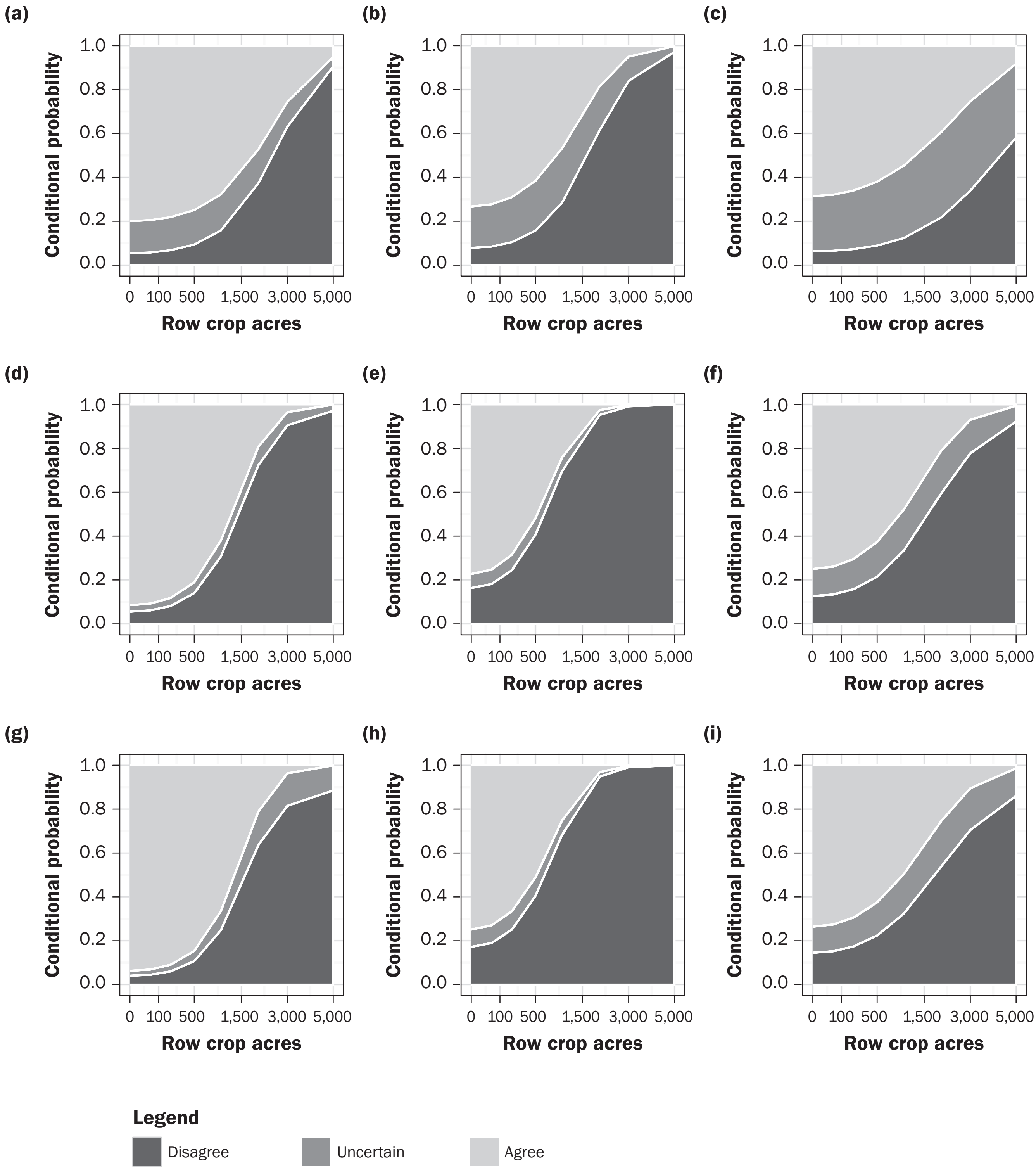
Further, we find that increasing farm scale, which we view as an indicator of increased reliance on inputs, was associated with greater likelihood that farmers would be uncertain or disagree that (1) sustainable practices help maintain the natural resource base and (2) modern farming relies too heavily on commercial fertilizers, insecticides and herbicides, regardless of age and weather conditions. These findings suggest a growing breach between farmer perceptions about the inputs that they depend on and expert assessments that changes in practices are necessary to achieve environmental quality and maintain the natural resource base upon which the agricultural economy depends. Although US Environmental Protection Agency and other agencies and organizations have found excess N and other chemicals from agriculture to be major contributors to water impairment, our findings indicate that farmers, especially those with larger-scale crop production, have become less concerned about overreliance on the nutrients and chemicals that are the source of this impairment.

Our data do not tell us why this shift is happening and what the social-psychological or biological drivers might be. Dual motive theories suggest there are multiple public and private interests that influence how farmers resolve the ongoing tension between economic self interests, and empathic, shared social interests (Chouinard et al. 2008). Burke's (1991) identity control model provides valuable insight into how farmer personal, role, and social identities are integrated, compared and adjusted to maintain/change the current identity standard. Increasing farm size is likely a proxy for a set of farmer characteristics of those who have successfully managed to survive and thrive through management of inputs and technologies that have allowed them to remain on the agricultural treadmill. McGuire et al. (2012) research applying identity control theory as a feedback mechanism to farmer activation (or not) of conservation identities shows promise in explaining variations along the continuum from productionist interest only to the coproduction of ecosystem services in conjunction with commodity productivity. It is also apparent that during the 1989 to 2002 period weather conditions were not strongly associated with issues of sustainability or modern farming practices.

Studies of sustainability and sustainable agriculture find competing and conflicting definitions and interpretations of the term sustainability (McIsaac 1994). These "appear to be rooted in fundamentally different worldviews and value systems" (McIsaac 1994). The results of this study, which indicate increasing uncertainty of farmers about sustainability, may reflect a gradual attitudinal shift in order to reconcile competing worldviews and external pressures to address soil and water quality concerns along with reaching for higher productivity goals. The strong association between increases in farm size/input dependence and tendency to disagree that more sustainable practices are needed and use of commercial fertilizer and other chemical inputs is not problematic

Figure 3

Posterior mean multinomial probabilities as a function of total corn and soybean acres and year for each of the three survey items studied: (a) sustainable farming practices, 1989; (b) sustainable farming practices, 1994; (c) sustainable farming practices, 2002; (d) commercial fertilizers, 1989; (e) commercial fertilizers, 1994; (f) commercial fertilizers, 2002; (g) insecticides and herbicides, 1989; (h) insecticides and herbicides, 1994; and (i) insecticides and herbicides, 2002.



suggests that farmers with larger operations that plant more row crops—precisely those operations that tend to use the most fertilizers and chemicals—are becoming less concerned about potential problems associated with their use.

Modern agriculture has accomplished unprecedented productivity in affordable food, feed, and fiber for domestic consumption and global export (Gardner 2002). USDA Economic Research Service analysis of US farm productivity over time reveals a steady 158% monotonic rise in output and productivity from 1948 to 2008 (National Research Council 2010). However, in 2006 only about 35% of US crop acres receiving N were implementing all three recommended N management criterion for rate, timing, and method that provide some measure of protection to the natural resource base (Ribaudo 2011). Nitrogen-related ecosystem problems will persist until farmers perceive that their practices and agricultural inputs affect the natural environment.

Does this mean that modern agriculture is the barrier to achieving sustainable agriculture? Not necessarily; the answer is more complex. Although the science of how excessive N and other agricultural chemicals affect our ecosystem has grown, examination of the market mechanisms, policies, and institutional structures that underlie the process of the agricultural treadmill have lagged behind. Current public policies incentivize short-term productivity and efficiency goals at the cost of long term environmental impacts (National Research Council 2010). The concept of sustainability is dynamic and a politically and socially constructed goal (National Research Council 2010; Beachy 2010). While there is considerable divergence about how to accomplish sustainability along the continuum of various agricultural systems, there is general agreement that sustainable is a "good" goal much like being a good steward of the land is part of most farmers' identity (National Research Council 2010). However, the sustainable goal must be rebalanced to include not just economic profitability and productivity but also the environmental impacts on water and other natural resources if productivity is to be assured into the future. Science has an essential role to inform public decisions and rulemaking, such as the provision of the farm bills, the water quality protection legislation, and subsequent amendments. Science can predict likely outcomes of different agricultural management decisions under varying soil and slopes types and variable weather conditions of extreme drought or wetness. Science can also tell us whether agricultural producers are moving toward sustainability goals or away from them.

However, science alone is not enough; it must be accompanied by strategies that increase farmer awareness, knowledge, understanding and motivation (Morton 2011). We must develop policies that rebalance the sustainability equation and devise interventions and technologies that support producer goals of economic profitability and management efficiency congruent with personal and societal values and goals for environmental quality. Agriculture is at a pivotal point in terms of consumer demand for multifunctional sustainable agricultural systems—systems that balance environmental performance, economic factors, and social factors alongside high production yields (National Research Council 2010). The practice of farming does not exist in isolation but is part of a broader human culture that values and attempts to sustain many things (McIssac 1994).

The vagueness, uncertainty, and lack of a common definition of sustainability should not deter us from pursuing this important goal. McIsaac (1994) calls for humility in the search for sustainability, a vigorous but open-minded debate and deliberation, and reminds us that the biosphere is interconnected. Farmers and policy makers must find ways to reconcile the discontinuity between current management practices and public findings of the externalities to the environment that their practices create (Morton 2011).

This study has a number of limitations. The data were collected from Iowa farmers and are not generalizable to all farmers. Over time, participant attrition has necessitated periodic inclusion of new random samples of farmers drawn from the list maintained for the agricultural census. When surveys are mailed to new samples, many respondents who have very small acreages, do not farm, and do not consider themselves farmers, even though they are defined as such by the USDA, decline to participate. Thus, over time the IFRLP has become biased toward larger-scale farmers. While this bias toward larger-scale farmers might be seen as a liability for some research efforts, for this study it is considered an asset because larger-scale farms operate a disproportionate amount of acreage and thus have a greater impact on soil and water conditions. Our findings are more likely to represent attitudes and opinions of traditional row crop farmers in the Midwest than other regions or types of production systems.

We recognize that much of the variance in attitudes about input dependence and sustainable practices remains unexplained. Although our approach allowed us to track the changes in attitudes over time, we cannot with confidence tie these changes in attitudes to potential changes in conservation behavior. However, evidence from other studies (Prokopy et al. 2008; Sheeder and Lynne 2011) indicates that concern can be a precursor to action. Such research has examined the tension between profit motive (measured as farm size and expansion plans [Bishop et al. 2010]) and prosocial, proenvironmental behavior. Evidence that declines in concern about the impacts of input use are correlated with increases in farm size suggests that profit motive may be on the rise and proclivity to engage in conservation behavior on the decline. The fact that shifts in attitudes are occurring more acutely among large-scale farmers, who farm a disproportionate amount of land, should be cause for concern among the conservation community.

There are likely other variables, structural (e.g., prices and markets) and cognitive (e.g., dual interests, farmer identity, and perceptions of risk), that are influencing farmer changes in perceptions over time about the strength of the connection between sustainability of natural resources and the inputs used for agricultural production. These variables are important if public policies are to successfully incentivize shared responsibility for the environmental impacts of cultivated cropping systems. Our data are insufficient to address these questions, and additional research is needed to better understand the underlying sources of the shift in beliefs about sustainable farming.

A final note regarding our results is warranted. As noted in the introduction, much of the recent growth in agricultural productivity has been gained from more efficient use of agricultural inputs (Fuglie et al. 2007). As input prices have soared in recent years (Duffy 2011), it is likely that farmer motivation to use inputs even more efficiently is also increasing. Extension and other entities that work with farmers could appeal to farmers' commitment to efficiency by focusing on retention of nutrients on the farm and other management efficiencies that wring more productivity out of inputs. However, this approach does not help the farmer step off the treadmill of production and may not rebalance the environmental component of sustainability. Incorporation of the dual-interest framework (Sheeder and Lynne, 2011) helps to frame and articulate this tension between the agricultural treadmill/profit motive/productivity side of the sustainability equation and the collective/conservation/shared-interest side. Overall, we find support for this framework, in that the changes in attitudes over time seem to be indicative of a shift toward a privileging of productivity and a de-emphasis of the more collective, shared ecosystem aspects of sustainability. The dual interest framework seems to work well in explaining these shifts in attitudes regarding sustainability, especially among larger-scale farmers. A critical question that remains—one that requires more research and extension attention—is how to improve the balance between the farm-level productivity and collective-level environmental dimensions of sustainability.

Acknowledgements

This research funded in part by the Iowa Agriculture and Home Economics Experiment Station at Iowa State University and the USDA National Institute of Food and Agriculture Integrated Water Program, Heartland Regional Water Coordination Initiative 2008-51130-19526. Data sources include Iowa Farm and Rural Life Poll and Iowa Environmental Mesonet. Weather data were accessed from the National Weather Service Cooperative Observer network archive on the Iowa Environmental Mesonet, available at http://mesonet.agron.iastate.edu.

References

Alexander, R.B., R.A. Smith, G.E. Schwarz, E.W. Boyer, J.V. Nolan, and J.W. Brakebill. 2008. Differences in phosphorus and nitrogen delivery to the Gulf of Mexico from the Mississippi River Basin. Environmental Science & Technology 42(3):822-830.

Beachy, R.N. 2010. Science and sustainability: The emerging consensus. BioScience 60(6):406-407.

Bechdol, E., A. Gray, and B. Gloy. 2010. Forces affecting change in crop production agriculture. Choices: The Magazine of Food, Farm, and Resource Issues 25(4).

Bishop, C.P., C.R. Shumway, and P.R. Wandschneider. 2010. Agent heterogeneity in adoption of anaerobic digestion technology: Integrating economic, diffusion, and behavioral innovation theories. Land Economics 86:585-608.

Burke, P.J. 1991. Identity processes and social stress. American Sociological Review 56(6):836-849.

Burke, P.J., and J.E. Stets. 2000 Identity theory and social identity theory. Social Psychology Quarterly 63(3):224-237.

Chouinard, H.H., T. Paterson, P.R. Wandschneider, and A.M. Ohler. 2008. Will farmers trade profits for stewardship? Heterogeneous motivations for farm practice selection. Land Economics 84(1):66-82.

Cochrane, W.W. 1993. The Development of American Agriculture: A Historical Analysis. Minneapolis, MN: University of Minnesota Press.

Daberkow, S., and W. Huang. 2006. Nutrient management. *In* Agricultural Resources and Environmental Indicators, chapter 4.4, 2006 Edition/EIB-16. Washington, DC: USDA Economic Research Service.

Duffy, M. 2011. Historical Costs of Crop Production. File A1-21. Ames, IA: Iowa State University Extension.

Food, Agriculture, Conservation, and Trade Act of 1990, Public Law 101-624, Title XVI, subtitle A, section 1603 in the United States Code. http://www.nationalaglawcenter.org/farmbills/#90.

Fuglie, K.O., J.M. MacDonald, and E. Ball. 2007. Productivity Growth in US Agriculture. EB-9. Washington, DC: USDA Economic Research Service.

Gardner, B.L. 2002. American Agriculture in the Twentieth Century: How It Flourished and What It Cost. Cambridge, MA: Harvard University Press.

Gelman, A., J.B. Carlin, H.S. Stern, and D.B. Rubin. 2004. Bayesian Data Analysis. Boca Raton: Chapman & Hall/CRC.

Gold, M.V. 2007. Sustainable Agriculture: Definitions and Terms. Special Reference Briefs Series No. SRB 99-02. Beltsville, MD: National Agricultural Library. http://www.nal.usda.gov/afsic/pubs/terms/srb9902.shtml/.

Hartzel, J., A. Agresti, and B. Caffo. 2001. Multinomial logit random effects models. Statistical Modeling 1:81-102.

Heinz Center. 2008 The State of the Nation's Ecosystems 2008: Measuring the Lands, Waters and Living Resources of the United States. The H. John Heinz III Center for Science, Economy, and the Environment. Washington, DC: Island Press.

Herndl, C.G., J. Goodwin, L. Honeycutt, G. Wilson, S.S. Graham, and D. Niedergeses. 2011. Talking sustainability: Identification and division in an Iowa community. Journal of Sustainable Agriculture 35:436-461.

MacDonald, J.M. 2011. Why are farms getting larger? The case of the US. Paper presented at the annual meeting of the German Association of Agricultural Economists, Halle, Germany, September 28, 2011.

McGuire, J., L.W. Morton, and A. Cast. 2012. Reconstructing the good farmer identity: Changing attitudes and behaviors through environmental performance-based management. Agriculture & Human Values. June 20, published online, doi: 10.1007/s10460-012-9381-y.

McIsaac, G. 1994. Introduction. *In* Sustainable Agriculture in the American Midwest, chapter 1, eds. G. McIsaac and W.R. Edwards. Urbana, IL: University of Illinois Press.

Morton, L.W. 2011. Citizen Involvement. *In* Pathways for Getting to Better Water Quality: the Citizen Effect, eds. L.W. Morton and S.S. Brown, 15-28. New York, NY: Springer.

NOAA (National Oceanic and Atmospheric Administration). 2011. Major flooding on the Mississippi River predicted to cause largest Gulf of Mexico dead zone ever recorded. Washington, DC: National Oceanic and Atmospheric Administration. http://www.noaanews.noaa.gov/stories2011/20110614_deadzone.html/.

National Research Council. 2010. Toward Sustainable Agricultural Systems in the 21st Century. Committee on Twenty-first Century Systems Agriculture, Board on Agriculture and Natural Resources, Division on Earth and Life Sciences. Washington, DC: National Research Council of the National Academes, The National Academies Press.

Osteen, C., and M. Livingston. 2006. Pest management practices. *In* Agricultural Resources and Environmental Indicators, chapter 4.3, 2006 Edition/EIB-16. Washington, DC: USDA Economic Research Service.

Prokopy, L.S., K. Floress, D. Klotthor-Weinkauf, and A. Baumgart-Getz. 2008. Determinants of agricultural best management practice adoption: Evidence from the literature. Journal of Soil and Water Conservation 63(5):300-311, doi:10.2489/jswc.63.5.300.

Ribaudo, M. 2011. Reducing agriculture's nitrogen footprint: Are new policy approaches needed? Amber Waves (September) Feature. Washington, DC: USDA Economic Research Service. http//www.ers.usda.gov/AmberWAves/September11/Features/NitrogenFootprint.htm/.

Sheeder, R.J., and G.D. Lynne. 2011. Empathy conditioned conservation: Walking-in-the-shoes-of-others as a conservation farmer. Land Economics 87:433-452.

SWCS (Soil and Water Conservation Society). 2011. Position Statement on Climate Change and Soil and Water Conservation. Ankeny, IA: Soil and Water Conservation Soicety, Board of Directors. http://www.swcs.org/documents/filelibrary/climate/SWCS_Climate_Position_Statement_751_46C025478C4CA.pdf.

USDA Natural Resources Conservation Service (USDA NRCS). 2009. Summary Report: 2007 National Resources Inventory. Ames, IA: Natural Resources Conservation Service, Washington, DC, and Center for Survey Statistics and Methodology, Iowa State University.

USEPA (United States Environmental Protection Agency). 2009. Nitrogen and phosphorus pollution. http://www.epa.gov/nutrientpollution/.