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Elicitation of Subjective Beliefs: A Pilot study of farmers' nitrogen management decision-making in Central Iowa

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Abstract

In the spring of 2014, we conducted a survey of Iowa crop producers to (1) learn about common nutrient management practices, and (2) to elicit farmers' subjective beliefs about the weather and crop growth uncertainty they face when making nutrient management decisions. The survey is part of a larger study that seeks to uncover the subjective or perceived relationship between nitrogen application practices, e.g., quantity, timing, application method, and crop yield outcomes. This paper provides a rationale for measuring subjective beliefs in the context of decision making under uncertainty and discusses specific design elements of the 2014 survey instrument. We provide summary statistics for the information that was gathered and discuss lessons learned from the pilot study.

Disciplines

Agricultural and Resource Economics | Agricultural Economics | Economics

Elicitation of Subjective Beliefs: A Pilot Study of Farmers’ Nitrogen Decision-making in Central Iowa

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1 Introduction

In the spring of 2014, we conducted a survey of Iowa crop producers to (1) learn about common nutrient management practices, and (2) to elicit farmers’ subjective beliefs about the weather and crop growth uncertainty they face when making nutrient management decisions. The survey is part of a larger study that seeks to uncover the subjective or *perceived* relationship between nitrogen application practices, e.g., quantity, timing, application method, and crop yield outcomes. This paper provides a rationale for measuring subjective beliefs in the context of decision making under uncertainty and discusses specific design elements of the 2014 survey instrument. We provide summary statistics for the information that was gathered and discuss lessons learned from the pilot study.

1.1 Background

Measurement of subjective beliefs and expectations has been incorporated in studies of school choice and returns to schooling (Dominitz and Manski, 1996; Jensen, 2010; Zafar, 2013; Arcidiacono et al., 2012; Stinebrickner and Stinebrickner, 2014), subjective income expectations (Dominitz and Manski, 1996, 1997b; Dominitz, 2001), perceptions of economic insecurity (Dominitz and Manski, 1997a; Manski and Straub, 2000; Campbell et al., 2007), subjective health expectations (Delavande, 2008; Delavande and Kohler, 2009, 2012), consumption and investment decisions (Dominitz and Manski, 2004; Gouret and Hollard, 2011), and energy choices (Blass et al., 2010; Allcott, 2013). Recent developments in elicitation methods have also been successful in eliciting subjective expectations in developing countries where populations are generally less educated and with illiterate respondents (Attanasio, 2009; Delavande et al., 2011a,b; Delavande, 2014).

Belief elicitation methodology is broadly categorized as indirect or direct. Indirect methods use responses to a question or choices based on a task designed to infer a respondents’ degree of uncertainty. The most popular indirect methods include the Gambling Method, Bid Method, Lottery Method, Odds Method, Weighting Method, Ranking Method, Visual Counter Method and Smoothing Method. Although indirect methods are believed to be the easiest for respondents to understand and use (Winkler (1967); Chesley (1978)), a common critique is that the interplay of an

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individual's risk attitude with the perceived uncertainty might influence the response and choices made by the respondent in the assessment of subjective probability (Chesley (1978))².

Direct methods measure subjective beliefs by, as the name suggests, asking respondents directly to report the likelihood of outcomes or to assess and report probabilities. Two common methods for measuring subjective probabilities are used. In the first approach probability intervals are elicited, in which respondents are presented with a range of possible outcomes and are asked to report the likelihood that the outcome falls within specified intervals, e.g. the respondent may be asked to report the likelihood that the value of the random variable will lie below a threshold value. This has been referred to as *Percent Chances* format by Manski (2004) and more recently termed as the *Subjective Probability Interval Estimate* or *SPIES* method by Haran et al. (2010), which is the terminology we will be using for our method hereafter. The second approach is the fractile method, which asks respondents to identify one or more points on the support of a subjective distribution that match particular likelihood outcomes, e.g., the respondent may be asked to name the 95th percentile value of the support of their subjective likelihood that of a random event. Direct methods of probability elicitation have the advantage that they do not require the researcher to pre-commit to a particular distribution support or functional forms in analyzing responses.

While some researchers believe the SPIES method performs better than fractile approaches, (Winkler, 1967; Ludke et al., 1977; Chesley, 1978), there is no consensus. Further, evidence is lacking as to which method is cognitively simpler for respondents to use: the fractile method requires only equally likely responses (Chesley, 1978) but might be more difficult than the SPIES method because one-half of the distribution is disregarded (Huber, 1974). Also, it may be difficult for respondents to assess small probabilities using the fractile method because it produces relatively tight subjective distributions, particularly in the tails. The fractile method is subject to error accumulation if the median is elicited inaccurately because all successive fractiles build on the median (Winkler, 1967; Hampton et al., 1973; Schaefer and Borcharding, 1973; Seaver et al., 1978; Alpert and Raiffa, 1982).

An increasingly important issue in the elicitation of subjective beliefs is over-precision, which is a form of overconfidence whereby respondents believe they have more control over random outcomes, or underestimate the range of possible outcomes than is objectively warranted. Recent research has linked the finding of overprecision to the elicitation method (Haran et al., 2010). Under the SPIES approach, respondents are asked to report likelihoods over a wide distribution support. The SPIES method may help the respondent think about all possible outcomes and thereby reduce the inclination to overlook and underweight low-probability outcomes, i.e., outcomes that fall in the tails of the subjective distribution under investigation.

Subjective beliefs of decision-makers under uncertainty plays an important role in agricultural economics research. Attempts to elicit and incorporate farmers' subjective beliefs into models and analysis are fairly rare. Exceptions include studies that measure beliefs about yield loss due to crop disease or adverse weather (Carlson, 1970; Pingali and Carlson, 1985; Menapace et al., 2013), subjective yield, price and income expectations (Grisley and Kellogg, 1983; Clop-Gallart and Juárez-Rubio, 2007), subjective beliefs about optimal nitrogen applications (SriRamaratnam et al., 1987), and beliefs about weather impacts (Sherrick et al., 2000; Sherrick, 2002). These studies

²For a detailed discussion of these methods and their comparison, please look at (Winkler, 1967; Hampton et al., 1973; Ludke et al., 1977; Chesley, 1978; Norris et al., 1990)

have relied on indirect methods of probability elicitation or fractile approaches, an exception being (Sherrick et al., 2000; Sherrick, 2002) which uses both a fractile and inverse CDF approach.

In 2014, we developed and administered a pilot survey instrument to measure the subjective beliefs of farmers regarding the nitrogen management practices they use on their cropped fields. The survey incorporated the latest methodological advances from the above cited literature. The SPIES methodology was employed. Seventy seven farmers participated in the study. Section 2 describes the procedures that were used to develop the survey instrument and administration of the survey to Iowa farmers. Summary statistics of survey responses are reported in section 3. We discuss the lessons that were learned in the pilot study in section 4. Concluding remarks are presented in section 5.

2 Survey Instrument Development and Administration

We developed a draft survey in spring of 2014. A focus group meeting was held with six farmers in February of 2014. The final web-based version of the survey was completed in the summer of 2014. The survey questions are presented in an Appendix.

We conducted focus group meetings with local producers and agronomists to ensure survey questions were interpreted as intended and that the coverage of response options was reasonable. The survey was revised based on the feedback. A concern raised in the focus group is the importance of maintaining producers anonymity, particularly because the survey asked producers to reveal production practices. Anonymity of the responses was achieved with the help of the cooperative firm that facilitated the list of potential participants. Participant names and contact information was maintained by the coop firm. The researcher team was provided with number IDs that could not be traced to individual producers. Survey participants received a signed confidentiality agreement by ground mail (the agreement also appeared with the online survey instrument and is shown in an appendix). As is common in survey studies, respondents who completed the survey were compensated for their time (Dominitz and Manski, 1996; Delavande, 2008; Arcidiacono et al., 2012; Zafar, 2013). The coop firm managed the allocation of compensation crediting each producer who completed the survey \$50 on their coop account.

The survey involved human participants. Exemption from requirements of the human subject protections regulations was obtained via the Institutional Review Board (IRB) at the Iowa State University, IRB ID 14-245.

Invitations to participate in an online Qualtrics survey were mailed from the cooperative to approximately 500 of their farmer-members. Each producer used a unique code to start the survey. We collected 96 responses, a response rate of 19%.

2.1 Survey Question Design

The survey includes four main sections. The first and fourth sections gather general information about farm characteristics and respondent demographics. For example, respondents provided information about the scale and scope of the farm operation, the nature of the management process, e.g., whether the respondent makes nutrient management decisions unilaterally or with a management team, the experience level and education of the respondent, and what if any external advice influences management choices. The middle two sections focus on the specific nutrient management practices used on specific fields. The middle sections also measure subjective beliefs about crop production and weather uncertainty.

Discussions with farmers during focus group interviews revealed potentially important differences in nutrient management strategies across fields of varying quality. We therefore designed our survey to assure coverage of varying land qualities. Survey sections two and three repeat the same set of field-specific questions but for different fields. Respondents were first asked, in section 2, to answer questions as they apply to their *Best Producing field*. In the third survey section respondents, via a randomization process, were asked question as they pertain to either an *Average Performing Field* or a *Typically Under-Performing Field*. Conditioning responses on specific fields of varying quality served two purposes. We believe that asking the farmer to think about a particular field reduced ambiguity, e.g., the survey asked about specific management actions on a particular field rather than general management approaches. Second, the randomization between average and under-performing fields provides variation crucial for identification of differences in management across field quality types, and to identify and quantify heterogeneity in respondents' subjective beliefs about uncertainty as it pertains to fields of varying quality and productivity. Inducing variation in field quality through the randomization mechanism is an important innovation of our survey instrument.

Our survey was administered online using Qualtrics software (an overview is available [here](#)). Among the Qualtrics' useful features is the ability to condition questions on a specific response to an earlier question and use branching features to customize question based on their relevance. For example, farmers who indicated their farm produced livestock were shown questions specific to their livestock production operations; these questions did not appear to respondents who indicated their farms specialized in crop production. Elicitation of the subjective distribution of random outcomes provides an example of the advantages of question customization features of the Qualtrics technology. Following a series of lead-up questions about management practices respondents were asked to report expected production, in bushels per acre. The value the respondent reported was saved and recalled for questions later in the survey.

Among the variables recorded in sections two and three are field characteristics and production practices, including the county in which the field is located, total acres, Corn Suitability Rating (CSR), proportion of the field that is Highly Erodible Land (HEL), the crop rotation, tillage practices, and nutrient testing. CSR is an index used to measure a field's potential for corn productivity.³ Highly Erodible Land (HEL) indexes susceptibility to soil erosion and can play an important role in management. Rotation patterns also matter to nutrient decisions, particularly

³For a detailed discussion of CSR, refer to *Corn Suitability Ratings An Index to Soil Productivity*, PM1168, August 2009, Iowa State University Extension Publication

nitrogen for corn production. Corn is a nitrogen-intensive crop whereas soybeans are a legume that fixes nitrogen in soil. Soybeans in rotation with corn are used to manage soil fertility and reduce the need for added nitrogen. We asked respondents to report their crop in the current year and previous two years (i.e. 2014 through 2012) thus allowing us to identify the specific rotation used. Tillage practices indicate the intensity of the production system and nutrient testing may reduce uncertainty about the soil nutrient profile, thus impacting beliefs (Babcock (1992)).

Farm management encompasses a number of interrelated and potentially complicated decisions. Nutrient management decisions, as with most farm management decisions, are made under uncertainty over prices, weather, and other factors. Our goal is to understand how farmers perceive uncertainty and how the various sources and extent of uncertainty influence management actions. An important objective of our survey is the measure farmers' subjective beliefs about the nutrient management problem, particularly the decisions regarding nitrogen application on managed fields.⁴ We next discuss the questioning strategy underlying belief elicitation.

We asked farmers to rate the fertility of their field using a 5 point adequacy scale, believing this reflects the respondents' own subjective assessment of how productivity potential that drives management choices. Focus group meetings indicated that it is difficult to precisely estimate the nitrogen concentration in soil. Soil testing provides precise measurement of nitrogen concentration. However, not all farmers conduct soil tests and test results can vary within a field and across time. As a follow-up to the fertility adequacy questions, respondents reported their best estimate of how much nitrogen they felt was required to achieve their expected yield target. Respondents were then asked indicate how confident they were in their beliefs about nitrogen requirements. Confidence was assessed, for example, by asking respondents to select whether the true soil nitrogen concentration was within 5%, 10%, 20% and 50% of their estimate.

The nutrients available for plant uptake vary substantially with soil type, weather conditions and the plant growth. This introduces non-uniformity in the availability of nutrients, which also depends on the timing of nitrogen application. Respondents were asked to select specific months in which commercial nitrogen and manure application occurred or were planned. Corresponding to each selected month of nitrogen application, respondents were asked to report the quantity of nitrogen in pounds per acre that was applied or is planned for application, the N-P-K ratio, and the method of application.

2.2 Measuring expectations: Yield and rainfall

One goal of our survey is to elicit subjective beliefs about randomness in crop production. A series of questions were posed to measure the location and shape of a subjective yield distribution. We approached this questioning by asking the respondent to report the *Expected Yield* on the managed field under consideration. The response to this question was then used to frame additional questions about expected yield randomness. The approach is to construct four threshold values from the subjective yield distribution support. Two thresholds on either side of the Expected Yield response were generated: 75% and 90% and 110% and 125% of the reported expected yield value. Hereafter,

⁴Our emphasis on nitrogen application decisions is further motivated by its importance in reducing nitrogen runoff and improving water quality in agriculture.

we refer to these thresholds as T1, T2, T3 and T4. It should be noted that T1-T4 are customized to the *Expected Yield* response and generated automatically by the Qualtrics software. By scaling the thresholds in this way, each respondent is asked about yield thresholds on customized subjective distribution support centered on their expected yield.

The respondent was asked to report probabilities that their realized yield will fall within particular intervals. Probabilities were elicited using the *Chances out of 100* format. Figure 1 provides a screen shot of the actual questions.

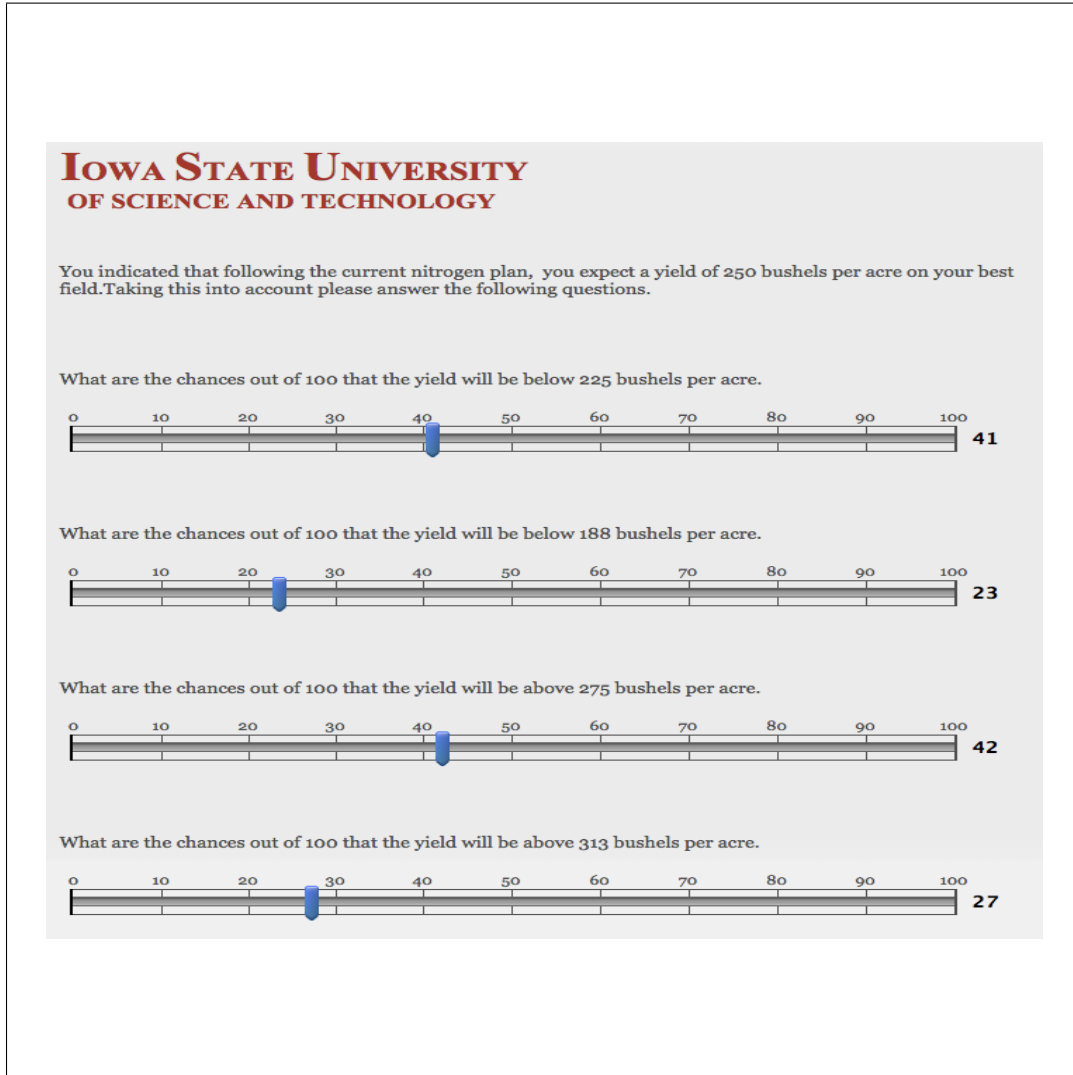


Figure 1: Survey Page for Eliciting Subjective Probabilities

The sequence in which this and similar “chances” questions were presented and the use of a sliding scale for reporting chances are important features of the survey design. The first question posed is “What are the chances out of 100 that the yield will be below T2 bushels per acre.” The respondent used a computer mouse to slide a pointer across a 0-100 scale to enter their answer. Any value between 0 and 100 (inclusive) was permitted. The second question posed is “What are the chances out of 100 that the yield will be below T1 bushels per acre.” The response was entered using the

computer mouse and the same sliding scale.

The Qualtrics software was used to check consistency of a producer's responses, in particular to assure reported values are consistent with the axioms of probability. If a respondent's answer violated the axiom, a warning message displayed. For example, the chances out of 100 that the realized yield is less than T1 cannot exceed the chances out of 100 that it is less than T2. If an entered response violated any of the axioms, a message appeared on the computer screen explaining the error and asked the respondent to review their responses and enter a new chances response. If the new response still violated the axiom of probability, the respondent was allowed to proceed to the next question. We permitted the respondent to move on with additional questions even with a response that was inconsistent believing that a single error message may help guide consistency while multiple error messages could discourage respondents from completing the survey.

Focus group discussion indicated that rainfall in July is an important determinant of crop growth. Farmers' subjective beliefs about rainfall distributions were elicited using a similar *chances out of 100* format, though unlike in the expected yield probability elicitation described above, we anchored threshold rainfall levels on the mean observed rainfall levels in central Iowa. Respondents were told the mean July rainfall in central Iowa is 4.3 inches. These *chances out of 100* questions used thresholds of 0.5, 2.0, 6.5, 8.5 inches per month.

The survey focus then turned to the relationship between nitrogen and yield. Respondents were reminded about the nitrogen applications plans they revealed earlier in the survey (programming in Qualtrics permitted us to recall prior answers from the respondents). The respondent was asked to report expected yield (in bu./acre) if 115%, 130%, 85% and 75% of their most recent nitrogen application was instead applied. They were also asked to report expected yields conditional on the their planned nitrogen application but under alternative July rainfall scenarios: rainfall levels of 6.5 inches, 8.5 inches, 2 inches and 0.5 inches for the month of July.

3 Descriptive Statistics

Of the 96 survey responses, 72 were fully completed, 24 contained some missing information, of which 19 were less than 50% complete. These 19 incomplete surveys were deemed unreliable and dropped from the analysis that follows. Our data contain the 77 fully or mostly complete responses to questions: 72 complete and 5 incomplete on respondents' *Best producing fields*, 34 responses for *Average performing fields*, and 38 responses for *Under performing fields*. We next summarize the responses and highlight the important findings and opportunities for additional work on this issue.

3.1 Land ownership and farmer demographics

Table 1 provides a summary of the respondents' demographics. *Land farmed* is defined as the aggregate of farmland that is owned, leased, or under alternative tenancy arrangement. Respondents' answers ranged from 43 to 11,000 acres, indicating considerable variation in the size of respondents'

	N	Mean	Median	Std. Dev.	Min.	Max.
Land farmed (acres)	77	693.8	412	1,308	43	11,000
Owned farmland (%)	77	56.26	69	41.42	0	100
Leased farmland (%)	77	40.18	26	41.1	0	100
Time spent farming (%)	71	56.61	55	28.88	3	100
Age (years)	71	58.23	60	14.85	25	91
Experience (years)	71	33.77	36	15.7	1	70

Table 1: Demographics and Land Ownership.

farming operations. Among the 77 respondents who answered questions on farm size, 13% report they do not own any land and 39% report they do not farm on leased land, i.e., they own all of the land they farm. We note also the range of respondents' age and experience farming.

Respondents were asked to report their educational attainment. Of the 71 responses to this question, 41 (57.75%) indicated a high school education, 24 (33.80%) indicated they had earned an undergraduate degree and 6 (8.45%) reported completing graduate education (a M.S. or Ph.D. degree). Among farmers who hold an undergraduate degree or higher, 43.3% report that they share nutrient management decision making responsibilities with one or more business partners. 31.7% of respondents with a high school education share decision making responsibility with others.



Figure 2: Time spent farming versus size of operation.

Midwest U.S. farmers often work at multiple jobs. Figure 2 plots the labor hours allocated to farming as a percentage of total labor hours worked (on the vertical axes) against the size of the farm operation (on the horizontal axes). The simple correlation between the labor dedicated to farming and farm size is 0.491 (p-value < 0.000).⁵

Figure 3 plots labor hours devoted to farming (vertical axes) against farmer age (horizontal axes). Respondents below 50 years of age are shown in blue and respondents above 50 years in age are

⁵We have excluded the farm size greater than 2000 acres to make the figure presentable.

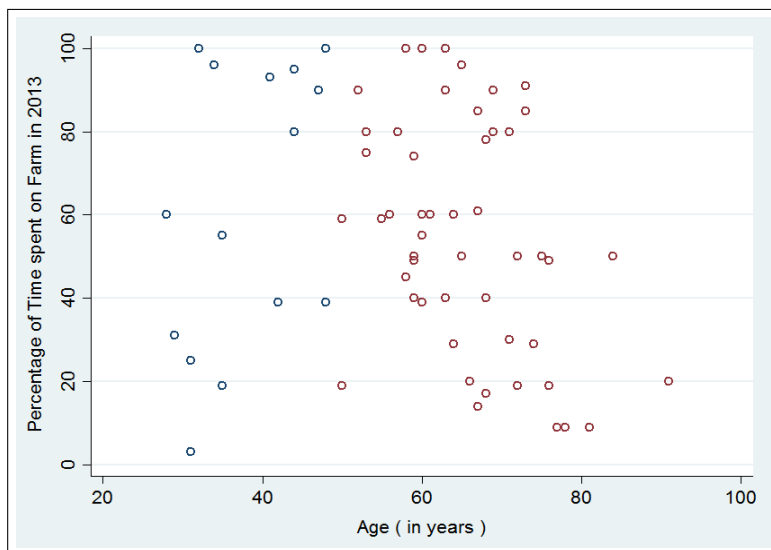


Figure 3: Time spent farming versus farmer age

shown in red. The simple correlation between the labor time spent farming with farmer’s age is -0.368 (p-value 0.008) for farmers 50 years of age or older and 0.4301 (p-value 0.109) for farmers younger than 50 years. The overall correlation is -0.196 (p-value 0.115).

3.2 Management practices

Shared decision making			
	N	Yes (%)	No (%)
	77	36.36	63.64
Source of advice			
	N	Yes (%)	No (%)
ISU Extension	66	21.21	78.79
Agronomist at Farming Co-op	66	92.42	7.58
Agronomist at Professional Consulting Firm	66	9.09	90.91
Other Farmers	66	19.7	80.3
Advice regarding			
	N	Yes (%)	No (%)
Best Producing field	72	52.78	47.22
Average Performing field	34	55.88	44.12
Under Performing field	38	52.63	47.37

Table 2: Nutrient management decisions and advice. **Shared decision making** denotes the percentage of respondents who shared responsibility with others for the nutrient management decisions. **Source of advice** denotes the percentage of respondents who reported they received advice from the four sources indicated. **Advice regarding** denotes the percentage of respondents who received advice pertaining to the three field types indicated.

	N	%
I followed the advice exactly	13	32.50
Based on the advice, I made big adjustment	8	20.00
Based on the advice, I made small adjustment	18	45.00
I did not follow the advice at all	1	2.50
Total	40	100

Table 3: Impact of Nitrogen Management Advice. Table reports response to question on whether received advice was followed.

Table 2 reports the respondents’ sources for nutrient management advice and the field types for which it is sought. The main source of nutrient management advice is from a professional agronomist at the cooperative: 92.4% reported receiving nutrient management advice from this source. The proclivity to seek advice from the cooperative agronomists is not surprising considering the survey respondents in our sample are producer members of the cooperative. One-third of respondents sought nutrient management advice from more than one source. Among the 72 respondents who responded to advice-source questions, 55.6% received field-specific nitrogen management advice on at least one of their fields, and 51.39% of respondents received nitrogen management advice for at least two of the fields they manage.

In informal discussions with agronomists at the cooperative and also Iowa State University, agronomists shared with us that producers may be following older recommendations and ‘rules of thumb’ for nitrogen that are no longer used, and despite their efforts to change those recommendations, producers still use them. In table 3 we report the producers’ responses to how they use the advice from the sources they reported on in table 2. Forty of the respondents answered this question, and of those, about one-third said they followed the advice exactly, and nearly all of the remaining respondents said they used the advise to adjust their plans.

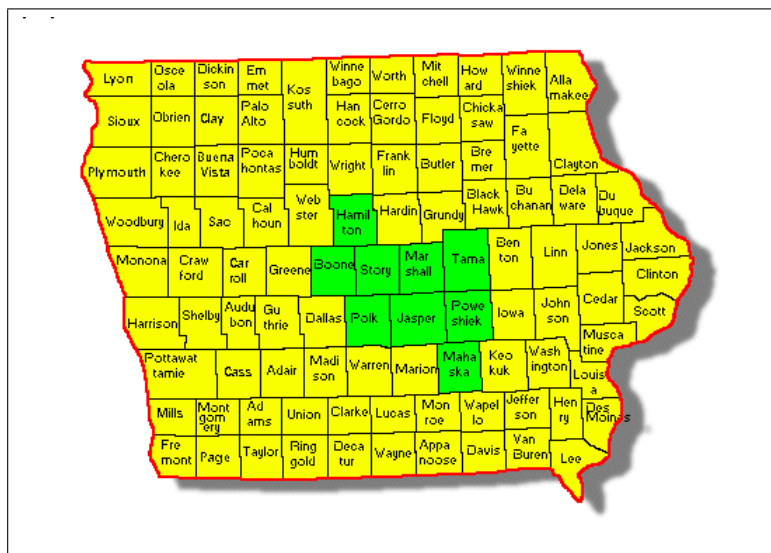


Figure 4: Survey respondents geographical location

Figure 4 illustrates the Iowa counties in which the respondents’ fields are located. Sampled fields are concentrated in Jasper county (41.46%) and Story county (24.68%). The remaining fields (33.77%)

are located in Boone, Hamilton, Mahaska, Marshall, Polk, Poweshiek and Tama counties.

Field Size (acres)						
Field type	N	Mean	Median	Std. Dev.	Min.	Max.
Best producing	77	85.84	77	65.27	9	350
Average performing	34	85.56	70	58.31	10	300
Under performing	38	49	40	33.50	5	160
CSR rating						
Field type	N	Mean	Median	Std. Dev.	Min.	Max.
Best producing	70	82.8	84.5	7.68	60	95
Average performing	32	74.41	73.5	5.91	65	85
Under performing	35	62.14	60	15.62	30	90
Highly erodible land (% of total acres)						
Field type	N	Mean	Median	Std. Dev.	Min.	Max.
Best producing	77	20.23	0	33.81	0	100
Average performing	34	45.55	23.81	45.49	0	100
Under performing	38	53.06	61.25	45.31	0	100
Estimate of nitrogen required (in lbs./acre)						
Field type	N	Mean	Median	Std. Dev.	Min.	Max.
Best producing	76	167.84	162.5	71.11	0	500
Average performing	34	133.82	150	98.94	0	530
Under performing	38	135.34	150	73.56	0	300

Table 4: Field characteristics.

Table 4 reports summary statistics for field size, soil quality, as measured by the proportion of highly erodible land (HEL), and soil nitrogen requirements.

Sample mean CSR rating on the best producing, average performing, and under performing fields is 82.8, 74.41, and 62.14, respectively. HEL shows a similar pattern with the mean and median HEL on best producing fields at 20.23% and 0%, respectively. The mean and median percentage values on average performing fields increase to 45.55% and 23.8%, respectively. The mean and median values for HEL on under performing fields is 53.1% and 61.6%, respectively.

The percentage of HEL land is negatively correlated with field CSR. The correlation coefficient between field CSR and the percentage of HEL land is -0.287 (p-value 0.016) for best producing field, -0.200 (p-value 0.273) for average performing field and -0.676 (p-value < 0.000) for under performing field. This negative correlation is more pronounced on under-performing fields.

Respondents were asked to report nitrogen requirements on their fields, given the yields that they expected. Respondents then were asked a follow up question that asked how confident they were about their field's nitrogen requirements. Respondents chose between pre-specified confidence intervals intended to provide the most accurate description of subjective confidence. Options included a 95% level of confidence, a 90% level of confidence, and so on (options of 80% and 50% confidence

Field type:	Best producing	Average performing	Under performing
95% confident	20 (27.40%)	7 (24.14%)	9 (28.13%)
90% confident	18 (24.66)	4 (13.79)	7 (21.88)
80% confident	14 (19.18)	8 (27.59)	9 (28.13)
50% confident	18 (24.66)	9 (31.03)	5 (15.63)
Not sure	3 (4.11)	1 (3.45)	2 (6.25)
Total	73	29	32

Table 5: Farmers’ Confidence Regarding Nitrogen Requirements. Table reports respondents confidence regarding nitrogen requirements on managed fields.

intervals were included).⁶ Finally, respondents were allowed a *Not Sure* option to reflect the case of little or no confidence in beliefs about the fields’ nitrogen requirements. Table 5 summarizes the responses to this question.

3.3 Subjective yield and rainfall expectations

Field type	N	Mean	Median	Std. Dev.	Min.	Max.
Best producing	68	202.06	200	21.20	150	250
Average performing	26	181.32	185	16.96	140	220
Under performing	29	172.32	175	19.71	125	210

Table 6: Summary Statistics: Expected Corn Yield (bu./acre).

Table 6 provides summary statistics about expected corn yields in bushels per acre by field type. The sample mean and median values for expected yields vary across field types as expected. Recall that the survey instrument allowed the respondent to select a field that they manage based only on the criteria, that is “best producing”. It is no surprise that expected yields are highest on fields identified by respondents as “best producing” than on the other two field types.

Figure 5 plots the quantity of nitrogen applied (measured as cumulative sum of the monthly nitrogen applications the respondent reported) against the elicited subjective expected corn yields. The correlation between elicited expected corn yield and nitrogen applied for the *Best producing fields* is 0.355 (p-value 0.003). The positive correlation suggests that farmers who apply more nitrogen expect higher yields on their *Best producing fields*.

Figure 6 plots field CSR (horizontal axes) against subjective expected yield. The correlation between CSR and expected yield for *Best producing fields* is 0.313 (p-value 0.009).

⁶The interval options provided upper and lower values for the lbs./acre of nitrogen associated with each percentage-based confidence interval.

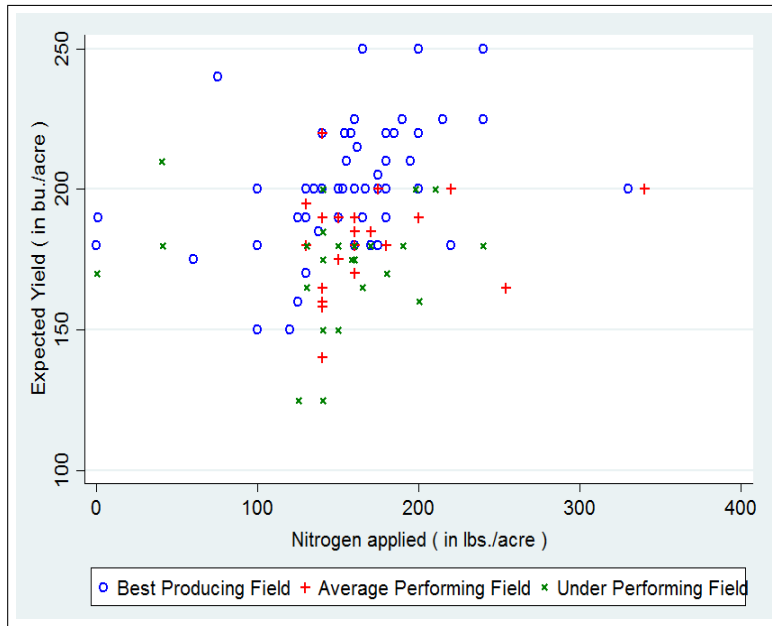


Figure 5: Nitrogen Application and Expected Yield

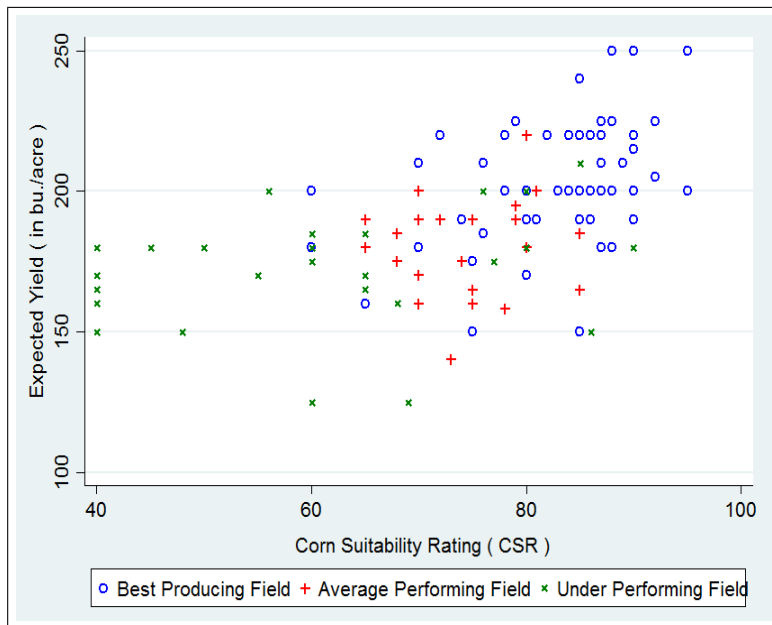


Figure 6: Corn Suitability Ratings (CSR) and Expected Yield. Blue circle represent the response for *Best producing fields*, red plus indicates *Average performing fields* and, *Under performing fields* are indicated by green cross.

Subjective yield distributions

The producers' responses allowed us to capture a total of 121 subjective corn yield distributions using the SPIES approach. Among the 68 "best producing" field yield distribution measurements, we found 3 violations of monotonicity of cumulative probability. Of the 53 under-performing field

measurements, we found 1 violation of monotonicity of cumulative probability. It should be noted that these violations occurred despite being prompted by the survey software of the problem.

A second axiom of probability checked is whether the probabilities of corn yield realizations sum to one. Note that unlike the monotonicity axiom, no warning message was provided to respondents if elicited probabilities, more precisely *chances out of 100* violated the axiom. Among the 68 best producing field measurements 5 did not satisfy the adding up axiom. Among the 53 average- or under-performing measurements 2 violated the adding up axiom.

The SPIES approach was used to measure 73 subjective rainfall distributions for the *Best producing fields*. Violations of probability axioms were more prevalent than with yield distribution measurements. 64 of the 73 cases satisfies the monotonicity of cumulative probability axiom. Among the 9 violations, 6 placed very high values (as high as 96 chances out of 100) on drought conditions as indicated by rainfall totals less than 0.5 inches. The remaining 3 violations appear to be cases of epistemic uncertainty. A check of the adding up axiom indicated 29 violations.

4 Discussion and Suggestions for Future Survey Designs

This section discusses what we learned from the pilot survey design and implementation including shortcomings, and contemplates how future survey-based research in similar agricultural settings might be conducted.

Response rate

Although, an approximate response rate of 19% is reasonable, it was below than the response rate we expected. We believe our relatively low response rate is explained by the timing of the survey and also the lack of follow-up to encourage greater participation. Survey invitations were sent and responses collected in June. In Iowa, planting is nearly complete at this time but additional field work like spraying keeps producers very busy, and this can be a busy time for producers with livestock as well. We believe this contributed significantly to the response rate. Further, the late survey necessarily means the responses capture more information about what actually happened instead of what was planned and anticipated. We believe the ideal time for this survey and our goals is perhaps February or early March when nutrient management decisions are formulated and much uncertainty still exists about weather and planting conditions.

Potential Ambiguity in Questions

Producers were asked to report about the crop growing in 2014. A few respondents reported that the current crop was soybeans, yet, their reported yields were almost certainly for corn on the identified field. We believe prior questions in the survey caused this. The questions prior to

the expected yield question were related to nitrogen usage on the field, and we now assume that respondents were thinking about a prior year in which the field was planted to corn since nitrogen application is not relevant to soybean. This effectively makes their responses hypothetical ones. This ambiguity needs to be addressed in future iterations of this survey.

N-P-K ratio is very standard labeling of fertilizer composition that summarizes the proportion of Nitrogen, Phosphorus and Potassium. Focus group meetings indicated the N-P-K rating convention is familiar and well-understood by farmers. An example was provided in the survey. In spite of this, we find several farmers who have reported numbers inconsistent with percentages. It is likely that they have reported quantities rather than percentages. This should be clarified in future studies.

There is a negligible proportion of farmers in the sample who used manure. We included questions pertaining to manure as suggested in the focus group. Because of the lower prevalence of livestock production in Central Iowa than, for example, North Western or Western Iowa, our population of producers are perhaps less likely to use manure and depend more on commercial nitrogen.

We assume that the expected yield elicited from respondents is the mean of the expected yield distribution. However, this is not guaranteed, nor is it guaranteed that a producer reported, for the relevant questions, a mean in all questions rather than some other measure of central tendency, like median. We might assume that if the respondent reports a mean (and not median) for one of the fields, they are highly likely to report on the mean for the other field, too. We use the cumulative probability response to check this. If the respondent elicited a chance greater than or equal to 50 that either the expected yield will be less than 90% of Expected Yield threshold or greater than 110% of Expected Yield threshold or both, it is certain that they have not reported a median. If a median was elicited as expected yield, less than or greater than cumulative probability around expected yield could not have been greater than or equal to 50. 43% of the farmers who grow corn on at least one of the fields, have reported a value that corresponds to mean. For the rest we still do not know and have assumed that the reported Expected yield is the mean.

There was a programming error in the cumulative probability of rainfall for the *Average* or *Under Performing Field*. Hence, we do not report their rainfall probability. Moreover, since county locations of both the fields are same for most of the respondents, we do not expect disparate rainfall beliefs in the two fields. We see that the inconsistent responses in the rainfall probability is relatively higher. One of the reasons could be the external anchoring aspect of it in spite of the fact that the actual July rainfall for 2014 was indeed 4.5 inches, which is close to the average July rainfall of 4.3 inches. We also realize that the chances of rainfall as low as 2 inches is a drought situation which is not very common. But since farmers have encountered severe drought in 2012, high chances of a drought could be a representation bias⁷. Similarly, a situation of rainfall as low as 0.5 inches or below has never occurred before and can be objectively considered to have a probability of 0. But we see that most of the respondents have placed positive weight on this event. This is an anchoring bias⁸ where respondents believe that if they have been asked to state the probability of occurrence of an event, then there must be positive chances of occurrence of the event.

⁷Refer to Tversky and Kahneman (1974) for representation bias

⁸Refer to Tversky and Kahneman (1974) for anchoring bias

Anchoring effects

In elicitation of the subjective probabilities, we learned that self-anchoring as in the expected yields is a better way to elicit responses as it reduces representative bias and anchoring bias which was observed in the elicitation of subjective rainfall probabilities. It also came to our notice during the survey that the rainfall probability elicitation for the second field was jumbled due to a programming error, as respondents were asked to report less than subjective probabilities for 6.5 and 8.5 inches of rainfall instead of greater than probability. Since this was the last of probability elicitation, many respondents have assumed it was an error and reported what we intended to ask but many responded to the words framed in the question. Although this was undesirable, it did not reflect our study significantly as we had it correctly framed for the first field. Since for most farmers two fields have been in the same county, subjective weather beliefs for first field are representative for second field too (unless farmers are biased in their beliefs about weather across fields). Nonetheless, this unintended misplacement of words have provided us a hint that randomization of questions across respondents for the different thresholds of yield or rainfall might make the responses robust minimizing its dependence on format used.

5 Conclusion

This paper presents an overview of a pilot study of U.S. midwest farmers decision making that was conducted in Iowa in 2014. We provide a rationale for the methods used. We report summary statistics for some survey findings and discuss shortcomings of the pilot study and lessons learned for future research on subjective belief measurement in agriculture. The pilot study survey instrument is reported in an appendix.

The main conclusion we draw is that survey methods that employ direct subjective belief measurement appear to be a viable approach for studying decision making processes and belief formation in uncertain production environments.

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6 Appendix: The Survey Instrument

Please enter your access code on the top left hand side of the survey invitation letter you received from [XXX Cooperative](#).

Please re-enter the access code and confirm

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Introduction

Thank you for agreeing to participate in our survey. The goal of this project is to learn more about the decision processes used by producers when choosing how, when, and how much fertilizer to apply to their fields. The data we collect will be used for this purpose alone.

Any results we report will be sufficiently aggregated to mask individual responses. Your personal responses and your identity will be kept strictly confidential. You can view the Confidentiality Form [Here](#).

The survey should take at most 25-30 minutes to complete. Upon completion, we will send you a formal signed confidentiality agreement that describes the safeguards that will be used to protect your data and a \$50 check. If you are interested, we will also share a copy of our study results when they are ready for distribution.

Participating in this survey is an opportunity to help advance research in the broad area of decision making under uncertainty. Your participation will provide new insights into the decision processes of farmers. Please think carefully about each response you provide and remember that the only wrong answer to a question is one that is disingenuous.

We will begin the survey by asking general questions about your farming business. Questions about fertilizer application decisions on specific fields that you farm will follow.

If you have any questions please contact a project leader:

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General Information I

We would like to know the number of acres on which you are responsible for making nutrient management decisions and, in particular nitrogen application decisions.

Acres that I own personally acres

Acres that I lease from others acres

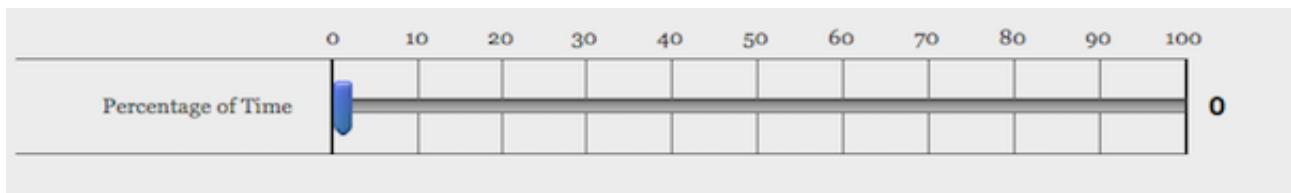
Acres that do not fit the categories above, e.g. absentee landowner acres

Do you share nutrient management decision responsibilities on these acres with other individuals, e.g., a partner who is or is not a family member? If so how many people do you consult?

Yes

No

Please estimate the percentage of your total working hours in 2013 that were spent on activities related to your farm business?



Please specify the count of each kind of animal you have on your farm.

Slaughter or Feeder Cattle

Immature Dairy Cattle

Mature Dairy Cattle

Swine 55 pounds or more

Swine under 55 pounds

Sheep and Lambs

Horses

Turkeys over 7 pounds

Turkeys under 7 pounds

Broiler or layer chickens 3 pounds or more

Broiler or layer chickens under 3 pounds

Do you submit or annually update a Manure Management Plan to the Iowa Department of Natural Resources?

- Yes
- No

Did you buy / sell or are you planning to buy / sell manure in 2014? If you answer yes specify the amount bought or sold.

- Yes I will buy or have bought (in pounds)
- Yes I will sell or have sold (in pounds)
- No

How many distinct fields do you manage? fields

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Fertilizer management

Next we will ask a series of questions about management practices on your best producing field. Please keep this particular field in mind when you answer the following questions.

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[Note: Questions in this section apply to the respondents Best Producing field]

In what county is your best field located?

[Note: Respondent is presented with drop down list of Iowa counties]

What is your best fields corn suitability rating (CSR)?

CSR =

How many of your best fields total acres are classified as highly erodible land (HEL)?

acres

How large is your best field?

acres

How would you rate the fertility on your best field?

- Poor

- Less than adequate
- Adequate
- Better than adequate
- Great

What crop was planted on your best field in the 2012 growing season? (If more than one crop was planted indicate by clicking multiple buttons.)

- Corn
- Soybean
- Other

What crop was planted on your best field in the 2013 growing season? (If more than one crop was planted indicate by clicking multiple buttons.)

- Corn
- Soybean
- Other

What crop(s) did you or will you plant on your best field in 2014? (If more than one crop will be planted indicate by clicking multiple buttons.)

- Corn
- Soybean
- Other

What tillage practice did you use or do you plan to use on your best field during the 2014 growing season?

- Conventional Tillage
- Minimum Tillage
- Mulch Tillage
- No Till
- Conservation Tillage
- Strip Tillage
- High residue

Have you used or are you planning to use a nitrogen test on your best field?

- No
- Yes, I have done or plan to do a soil test
- Yes, I have done or plan to do a plant tissue test

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[*Note: This page appears only if the respondent has chosen “Yes, I have done or plan to do a soil test” and/or “Yes, I have done or plan to do a plant tissue test”*]

In what year and month was the most recent Nitrogen test conducted on your best field?

Year Month

Are you planning additional Nitrogen tests this growing season on your best field?

- No
- Yes, I plan to test for Nitrogen before planting
- Yes, I plan to test for Nitrogen after planting

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We next want you to think about and estimate the Nitrogen content in your your best fields soil today. We realize it may be difficult to know the exact nitrogen concentration. Please make your best estimate.

Based on your best estimate of the current nitrogen concentration on your best field, how many pounds per acre do you think are needed to achieve your expected yield?

pounds per acre

[*Note: Denote the response to this questions as **Z0** lbs./acre*]

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Which of the following statements best describes your confidence in your estimate of your best fields Nitrogen needs?

- I'm confident the field needs more than [**97.5% of Z0**] pounds/acre but less than [**102.5% of Z0**] pounds/acre.

- I'm confident the field needs more than *[95% of Z0]* pounds/acre but less than *[105% of Z0]* pounds/acre.
- I'm confident the field needs more than *[90% of Z0]* pounds/acre but less than *[110% of Z0]* pounds/acre.
- I'm confident the field needs more than *[75% of Z0]* pounds/acre but less than *[125% of Z0]* pounds/acre.
- I'm not sure at all about the fields' Nitrogen needs.

We would now like to ask about Nitrogen applications. Please select the months when commercial nitrogen was/will be applied to your best field.

- September, 2013
- October, 2013
- November, 2013
- December, 2013
- January, 2014
- February, 2014
- March, 2014
- April, 2014
- May, 2014
- June, 2014
- July, 2014
- August, 2014

[*Note: Denote **NM3** as the latest month that nitrogen was applied.*]

Please select the months when manure was/will be applied to your best field.

- September, 2013
- October, 2013
- November, 2013
- December, 2013
- January, 2014
- February, 2014

- March, 2014
- April, 2014
- May, 2014
- June, 2014
- July, 2014
- August, 2014

[Note: Denote **MM1** as the last month that manure was applied.]

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In thinking of your commercial fertilizer use, please indicate the percentages of N/P/K given in the reported guaranteed analysis of the mixed grades or straight materials. For example, a common fertilizer might carry a guaranteed analysis of 10% nitrogen fertilizer, 34% phosphorus, and 0% potassium and be reported as a 10-34-0 mixed grade.

What fertilizer did (will) you apply in [**NM1**] on your best field?

N P K

What fertilizer application method was (will be) used in [**NM1**] on your best field?

- Broadcast
- Anhydrous
- Side banding
- Seed Furrow
- Side dress
- Late side dress
- Others (Please Specify)

How many pounds of nitrogen were applied on your best field in [**NM1**]?

pounds per acre

[Note: Let **QN1** denote lbs./acre applied in month **NM1**.]

What fertilizer did (will) you apply in [**NM2**] on your best field?

N P K

What fertilizer application method was (will be) used in [**NM2**] on your best field?

- Broadcast
- Anhydrous
- Side banding
- Seed Furrow
- Side dress
- Late side dress
- Others (Please Specify)

How many pounds of nitrogen were applied on your best field in [NM2]?
 pounds per acre

[Note: Let QN2 denote lbs./acre of nitrogen applied in month NM2.]

What fertilizer did (will) you apply in [NM3] on your best field?
 N P K

What fertilizer application method was (will be) used in [NM3] on your best field?

- Broadcast
- Anhydrous
- Side banding
- Seed Furrow
- Side dress
- Late side dress
- Others (Please Specify)

How many pounds of nitrogen were applied on your best field in [NM3]?
 pounds per acre

[Note: Let QN3 denote lbs./acre of nitrogen applied in month NM3]

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Did you do a manure Nutrient Content Analysis prior to applying manure on your best field in [MM1]?

- Yes
- No

What type and quantity of manure did you apply on your best field in [MM1]? pounds/acre (gallons/acre if applied in liquid form)

- Beef
- Dairy
- Swine
- Poultry
- Others

Which manure application methods were used on your best field in [MM1]?

- Manure Spreader
- Tanks
- Injectors
- Pumps
- Umbilical system
- Other (please specify)

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Weather and Yield

We would now like to ask questions about the weather conditions and yield you expect in the upcoming 2014 growing season.

Keeping in mind the spring weather conditions , which of the following is closest to the date you have planted or will most likely plant your crop?

- April, 1, 2014
- April, 15, 2014
- May, 1, 2014
- May, 15, 2014

- June, 1, 2014
- June, 15, 2014
- July, 1, 2014
- July, 15, 2014
- Not sure at all about when I will have the crop planted

If planting is completed on the date you expect, during which of the following periods is pollination most likely to occur on your best field?

- May 1 - May, 15, 2014
- May 15, - May 31, 2014
- June 1 - June, 15, 2014
- June 15, - June 31, 2014
- July 1 - July, 15, 2014
- July 15, - July 31, 2014
- August 1 - August, 15, 2014
- August 15, - August 31, 2014
- Not sure at all about the pollination period

If you follow the nitrogen application schedule described earlier, how many bushels do you expect your best field will yield?

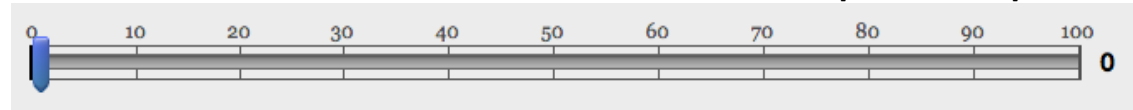
Bushels per acre

[Note: Denote the response to the above question as *[Y1]* Bu./acre.]

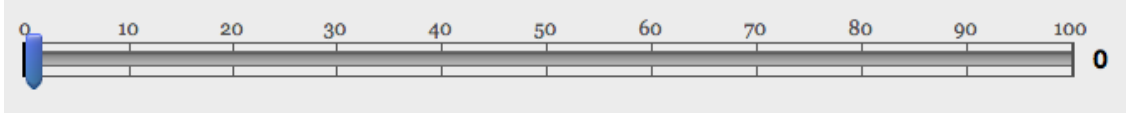
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You indicated that following the current nitrogen plan, you expect a yield of *[Y1]* bushels per acre on your best field. Taking this into account please answer the following questions.

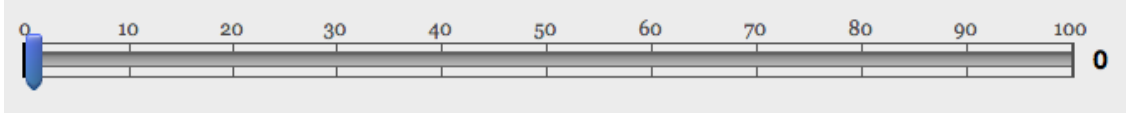
What are the chances out of 100 that the yield will be below *[90% of Y1]* bushels per acre.



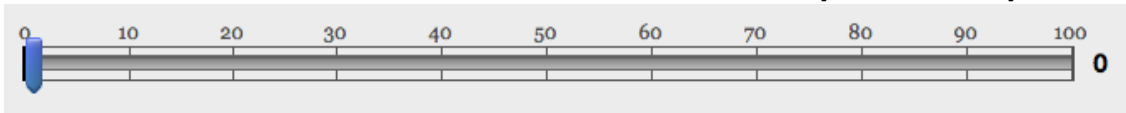
What are the chances out of 100 that the yield will be below [75% of Y1] bushels per acre.



What are the chances out of 100 that the yield will be above [110% of Y1] bushels per acre.



What are the chances out of 100 that the yield will be above [125% of Y1] bushels per acre.



[Note: If the response violates monotonicity of cumulative probability, the following error message appears; “Your response indicates that the chances average yield falls below [75% of Y1] bushels per acre are greater than the chances average yield falls below [90% of Y1] bushels per acre. Please review and confirm your responses to the last two questions, or “Your response indicates that the chances average yield exceeds [110% of Y1] bushels per acre are less than the chances average yield exceeds [125% of Y1] bushels per acre. Please review and confirm your responses to the last two questions”]

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We would now like you to describe how yield might change if you were to apply different amounts of nitrogen fertilizer. You indicated that you plan to apply [QN3] pounds/acre in your [NM3] application.

Suppose instead you applied [115% of QN3] pounds per acre at the [NM3] application. How many bushels per acre would your best field now yield?

Bushels per acre

Suppose instead you applied [130% of QN3] pounds per acre at the [NM3] application. How many bushels per acre would your best field now yield?

Bushels per acre

Suppose instead you applied [85% of QN3] pounds per acre at the [NM3] application. How many bushels per acre would your best field now yield?

Bushels per acre

Suppose instead you applied [75% of QN3] pounds per acre at the [NM3] application. How many bushels per acre would your best field now yield?

Bushels per acre

Weather Conditions and Yield

Data from the National Oceanic and Atmospheric Administration indicates that the historical average rainfall in central Iowa during the month of July is 4.3 inches per month.

Suppose 6.5 inches of rain falls during the month of July. How many bushels per acre would your best field now yield?

Bushels per acre

Suppose 8.5 inches of rain falls during the month of July. How many bushels per acre would your best field now yield?

Bushels per acre

Suppose 2 inches of rain falls during the month of July. How many bushels per acre would your best field now yield?

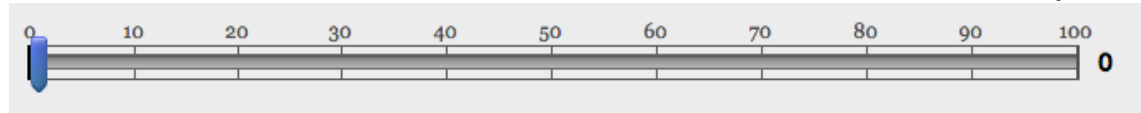
Bushels per acre

Suppose 0.5 inches of rain falls during the month of July. How many bushels per acre would your best field now yield?

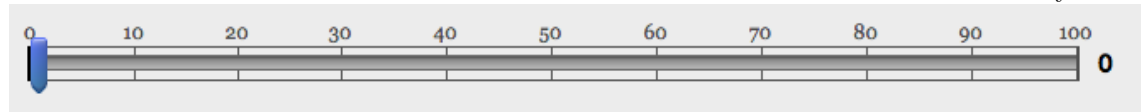
Bushels per acre

We realize that rainfall can be difficult to predict. We would like you to estimate rain that will fall on your best field during July of 2014. Keep in mind that the historical average monthly rainfall in July is 4.3 inches.

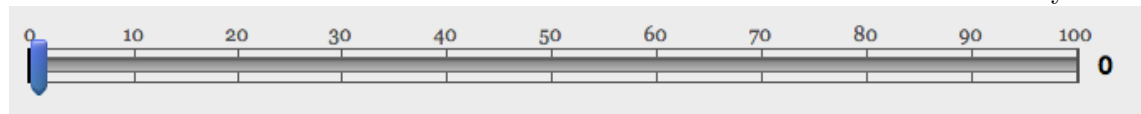
What are the chances out of 100 that 6.5 inches of rainfall or more will fall on your best field?



What are the chances out of 100 that 8.5 inches of rainfall or more will fall on your best field?



What are the chances out of 100 that 2 inches of rainfall or less will fall on your best field?



What are the chances out of 100 that 0.5 inches of rainfall or less will fall on your best field?



[*If the response violates the monotonicity of cumulative probability, the following error message appears; “Your response indicates that the chances average rainfall in July 2014 being more than 8.5 inches is greater than the chances average rainfall in July 2014 being more than 6.5 inches. Please review and confirm your responses to the last two questions” or “Your response indicates that the chances average rainfall in July 2014 being less than 2 inches is lesser than the chances average rainfall in July 2014 being less than 0.5 inches. Please review and confirm your responses to the last two questions”]*

[*Note: This marks the end of section specific to the Best producing field]*

----- Page break -----

[*For each respondent an **average** or **under performing** field was chosen at random for questions pertaining to this section. Let the randomly chosen field be [FTYP]*

Next we will ask a series of questions about management practices on one of your [FTYP] performing fields. Please keep this particular field in mind when you answer the following questions.

⊙ Press Next to Continue

----- Page break -----

[*Note: The questions in this section are directed at the respondent’s [FTYP] performing fields.]*

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We will close with few more general questions.

Have you received Nitrogen management advice from any of the following sources in the past year?

- Iowa State University Extension Services
- Agronomists at my Farming Coop
- Agronomists at a professional consulting firm

Other farmers

Have you ever received a specific Nitrogen management recommendation for your best field?

- Yes
- No

Have you ever received a specific Nitrogen management recommendation for your [*FTYP*] producing field?

- Yes
- No

----- Page break -----

[*Note: The next questions are asked only if the respondent received nitrogen management recommendations for their best or [*FTYP*] performing field or both.]*

How much influence did the advice you received affect the nitrogen management plan that you eventually followed?

- I followed the advice exactly
- Based on the advice, I made big adjustments to my Nitrogen management strategy
- Based on the advice, I made small adjustments to my Nitrogen management strategy
- I did not follow the advice at all

We will conclude our survey with a few questions about yourself and your farming experience.

How old are you?

How long have you been farming?

What is the highest level of schooling that you completed?

- High school
- Four year undergraduate degree
- Graduate degree

Thank you for participating in this study!

Yes, please send me a copy of the study findings !

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