Title: Are Small and Medium Scale Produce Farms Inherent Food Safety Risks?

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Abstract: On-farm food safety is treated as the final frontier in addressing source contamination problems of foodborne pathogens in fresh fruits and vegetables. It is a common assumption among food safety experts in the United States (U.S.) that small and medium scale growers pose inherently greater risk because they are viewed as least likely to implement Good Agricultural Practices (GAPs) or attend continuing education programs. Farm scale is an aspect of food safety that is apparent to many yet overlooked by large-scale farmers, produce industry advocates, and regulators who have collectively created the current food safety system of standards and metrics. In this paper, responses to a survey of fresh produce growers about on-farm food safety are examined across farm scales using factor analysis and ANOVA. The findings demonstrate that, with few exceptions, U.S. Midwestern produce growers of all scales report similar levels of knowledge for pathogens, pre-harvest and post-harvest contamination sources, and management practices to prevent contamination. These findings challenge assumptions and generalizations and redirect the food safety conversation away from “knowledge deficit” models and toward the development of food safety standards, metrics, and certification processes that remove structural barriers to implementing on-farm food safety protocols for all scales of fresh produce production.

1 Introduction

Fresh produce food safety is an issue that is currently framed in the United States as both a problem of naturally occurring contamination sources being introduced into the food system by way of farms lacking adequate prevention practices (Stuart 2010), and as a knowledge deficit among smaller scale farmers who industry experts perceive lack the knowledge and resources to prevent or contain contamination events on their farm. Consequently, current approaches are guided by these perceptions that emphasize scale in problem attribution, such as the lack of knowledge or resources among smaller growers, but overlook differences found among scales throughout the chain-of-custody. This oversight has given rise to prescribed solutions one-size-fits-all rather than scale-appropriate solutions (Parker et al. 2012a).

Indeed, scale is often misused as a heuristic of risk that essentializes good and bad farming practices, and as a factor contributing to the risks of microbial contamination with various actors emphasizing increasing risk toward one end of the scale continuum or the other. Yet, while scale is operationalized as an indicator of risk per se, it is largely overlooked in the empirical identification of risks. Critical social science experts point to food safety risks from larger farming systems that may be too complex to manage (DeLind and Howard 2008, Stuart 2008). Conversely, industry and food science experts often assign high levels of risk to smaller scale farms because of perceived knowledge and resource deficiencies (Viswanathan 2012). Rather than focus on risk factors related to different scales of farming, this latter frame is influenced by the assumption that larger-scale farms, convinced of the effectiveness of their food safety programs consisting of third party audits and large-scale processing apparatuses, have adequately addressed contamination sources while smaller farms lack the resources to do so. An

outcome of this has been the development of a plethora of new rules and prescribed educational programs devised to address the alleged shortcomings of growers and deal with natural hazards.

As a result, there is a critical need for analysis using a conceptual framework and empirical evidence that tests these claims so that we can move beyond assumptions. This paper examines farm size, or scale as an overlooked but critical analytical topic in the food safety standard development. In order to move beyond a discourse centered on identifying and targeting the riskiest farm scale, we test the hypothesis that there is little difference in knowledge and perceptions of food safety among growers at different scales of production.

In the following sections we discuss the current context of food safety and public concern, industry and government response, and the literature informing this research. Then we present the methodology utilized for data collection and analysis of a cross-scale survey measuring awareness and concern for food safety risks among fresh produce growers in the U.S. Midwest states of Indiana, Kentucky, Michigan, and Ohio. Specific areas of concern included pathogens, sources of on-farm contamination, effectiveness of prevention practices, and barriers to adopting prevention practices. After a discussion of the findings we conclude with an argument that food safety risks are specific to the structure of each farm as shaped by goals, farm scale, and types of farming systems. This emphasis on risk-based approaches is desirable because it shifts our efforts away from hunting for knowledge deficits among produce growers that may identify how to convince farmers to do things that may be of little benefit to them and that offer little reduction in produce safety risks. This shift can reduce the unintended harm to produce operators from poorly developed policy by addressing perceptions of risk among growers and aligning recommendations and standards with real risks. Creating a food safety system that takes these factors into account will move us away from generalizing risk across

farm scales and toward developing regulation that emphasizes risk-based decision-making and standards with scale-appropriate practices.

1.1 Background and Problem

The number of detected incidents of food borne illness has risen in the last decade to an annual estimate of 9.8 million illnesses, over 55,000 hospitalizations, and 1351 deaths (Scallan et al. 2011). Fresh produce contributes significantly to these incidents (Center for Science in the Public Interest 2008). The 2006 nationwide *E. coli* outbreak from pre-washed, ready-to-eat bagged spinach represents a tipping point prompting consumers, consumer advocacy groups (CAGs), government, and industry actors to respond. Indeed, the response was swift with the development of recommended practices that were disseminated by industry groups, marketing organizations, and Extension services to growers in efforts to prevent microbial contamination and provide assurances of safe produce to wholesale, retail, and direct buyers. In the wake of response to this and other outbreaks, industry advocates who included United Fresh and Western Growers, believing that larger-scale growers and processors possessed adequate resources to address produce safety issues, persuaded policy-makers to focus their efforts on smaller, non-exempt¹ growers with a belief that all growers should be doing the same things. New standards were developed with input from large-scale interests that resulted in many prescribed practices that were inappropriate for smaller scales (Hardesty and Kusunose 2009). Among the new standards were the landmark California Leafy Green Marketing Agreement (CLGMA), multiple private industry standards, third-party audits, and super metrics (private standards designed to enhance market competitiveness by expanding criteria or adding extra, often unverified, criteria). Smaller growers and their interest groups have been frank in sharing their belief that the FDA's draft rules will lead to the demise of small farms. Underpinning these beliefs, researchers found

produce safety practices increased time and money costs among smaller growers (see Hardesty and Kusunose 2009 for examples in California, Becot et al. 2013 for examples in Vermont). Others point to the development of barriers to small and medium scale grower participation in larger markets (DeLind and Howard 2008).

As large incidents of foodborne illnesses continue, grower skepticism of the effectiveness of food safety programs has grown, which is likely to translate into hesitation among growers to adopt new standards or practices. Nonetheless, influential food safety experts have become prominent voices in asserting the key to a safer food system is increased regulation at the farm level (Vergano 2006, Weise 2006). This is notwithstanding that approximately seventeen-percent of produce-related food-borne illnesses have been attributed to farms; the remaining incidents are attributed to processors and consumer practices in the home (Gagliardi et al. 2003). Industry discourse has been shaped by experts who implied or openly proclaimed that smaller scale growers are a concern:

It's not the big guys that worry me at night, but the medium guys, who don't understand all the risks... the big companies understand this better and have effective sanitation programs in place, but small and medium players often do not understand that it's a big vulnerability.

--Dr. David Acheson, Food and Import Safety, Leavitt Partners, formerly with the USDA and later the US FDA (Viswanathan 2013)

[I]n most cases, such small farmers don't have food safety systems in place... The large firms will be diligent and fund it appropriately, however, a large portion of the food industry is constituted by smaller, less well-funded players.

--Steve Niedelman, King and Spaulding, LLP (Viswanathan 2013)

On smaller farms, people can walk straight in from the farm into the facility, bringing in pathogens on their clothing/ shoes etc.

--Jeff Bloom, The Dairy Practices Council (Viswanathan 2013)

Small farms often lack the resources and know-how to comply with industry food safety standards... Buyers need to *manage* local farmers at the local level to provide the necessary level of oversight.

--Michael Jantschke, Director of Food Safety, PRO*ACT (Jantschke 2012, emphasis added)

Most foodborne illnesses don't get noticed because not enough people get sick to alert officials that an outbreak is underway. Undetected outbreaks are more likely with "local" products delivered in small quantities and sold in a small area.

-- Robert Brackett, senior vice president of the Grocery Manufacturers Association (Powell 2008)

[S]mall producers are also less likely than big ones to have had food-safety audits.

--Matt Regusci, PrimusLabs.com (Powell 2008)

Farmers' markets are great, I don't have an issue with them; One day they are going to kill some people though.

--Galen Weston, Executive Chair, Loblaw Companies Ltd., Canada's largest food distributor (Weston 2012).

Concerns over *E. coli* contamination incidents at some Northwest US Chiopotle restaurants has prompted concern about the safety of their locally procured produce with an emphasis on scale (Karst 2015). Adding to these misperceptions, a recent New York Times article (Bellemare 2016) shared results of a study correlating an increase in both the incidents and cases of foodborne illnesses with the number of farmers markets in those states over three different time periods. The speciousness of the interpretation that these increases are related is only casually acknowledged at the conclusion of the article. Even among researchers on this project, it was believed that "smaller, limited resource farmers who sold vegetables commercially were likely to be at the highest risk for producing contaminated products" (*proposal funding this study*).

Despite these anecdotes, best guesses, and expert opinion, there has been little empirical evidence supporting a connection between small and medium scale farming with increased incidents of microbial food contamination or a broader lack of prevention knowledge specific to these scales. As food safety science experts Suslow et al. (2003) suggests, "The potential for contamination does not appear to depend on the size of the operation", but there are risk factors

that are common across all scales of produce growing. Some have found evidence of food safety knowledge “deficits” among small scale New York produce growers limited to three management practices: recording manure applications, composting processes to ensure pathogen kills, and sanitation of wash water practices. Others (Cohen et al. 2005) found that there was a need for improvement in water testing, record keeping, and sanitizing containers and food contact surfaces among New England growers who had overall high adoption rates of many other produce safety practices; Farm scale was not evaluated in that study. In a recent study exclusively focusing on small and mid-sized farms (Harrison et al. 2013), researchers found a small percentage of growers in Georgia, Virginia, and South Carolina needed improvement on manure application timing, irrigation and wash water source testing, with some having limited restroom and handwashing facility access. DeLind and Howard (2008) and Stuart (2008), conversely, each draw on documented outbreaks of foodborne illness to support their concerns that experts and policy-makers are erroneously focusing on the wrong end of the production scale when most incidents are associated with larger-scale production systems and distribution networks. While a single voice does not determine policy or develop regulations, and the context or strength of these statements can be argued, these statements and other like them shape the larger discourse on the subject influencing the approach to risk identification and development of solutions.

2 Literature

Farm structure and scale theories are used to frame this study using a modified mental models and analysis of risk based decision-making research methodology. Farm structure concepts describe implicit relationships among land, labor, and capital, which are interrelated with management practices and decision-making activities that include crop selection, farm size,

marketing strategies, and equipment purchases. Produce growers' perceptions and beliefs (i.e. their mental models) shape and are shaped by this structure, influencing their agendas through multiple interrelated factors, which, taken together are important to understanding their food safety decision-making.

2.1 Scale

Farm scale is a well-documented influence on the adoption of innovations including conservation practices, adoption of difficult or complex technologies, and other land use decision-making (Salamon et al. 1998, Ilbery and Bowler 1998, Burton and Walford 2005). In addition to acreage, farm income is an important measure of farm scale (Lund and Price 1998).

In the context of production and management strategies, the tendency is for smaller farms to be more diversified while larger farms are specialized; each require different distribution and marketing channels (USDA AMS 2009). Qualitative companion studies established that perceptions of food safety risks are coupled to specific farm scales and marketing practices since they are influenced by structural features such as farm size, crop type, and marketing and distribution channels. These features influence core farm food safety problem areas: worker language and cultural differences, health and hygiene, handling practices, irrigation and wash waters quality, and equipment and facility sanitation (Parker et al. 2012a). Additionally, marketing strategies vary by scale with larger farms marketing to wholesalers and retailers while smaller and medium-sized growers tend toward direct marketing channels such as farm stands and farmers' markets and, increasingly, midscale value chains (Lyson et al. 2008, Stevenson et al. 2011). These patterns are influenced by market entry barriers to wholesalers and retail chains such as quantity requirements (Diamond et al. 2009) and marketing agreements like the CLGMA (Hardesty and Kusunose 2009).

While farm scale shapes the relationships among land-labor-capital, the goals and values of farmers are important influences on management decisions (Born and Purcell 2006). While some small and medium scale farms may be incorporated, the agri-family system found in many smaller farms (Bennett 1982) is very different from agribusiness models. These differences include the ratio of dependent to non-dependent household members that effects labor availability, and income needs are shaped by the individual needs of household members.

Regardless of scale, barriers to adopting food safety practices extend beyond time and money constraints. Very often they include knowledge of appropriate practices, awareness of food safety issues, and a lack of trust for regulatory agencies (Yapp and Fairman 2006). Experts have argued that one-size-fits-all approaches cannot resolve the nuances that arise from specific food safety concerns (Rangarajan et al. 2002; Cohen et al. 2001). DeLind and Howard (2008) assert that a one-size-fits-all approach will result in the expansion of large-scale centric farm policies that will exacerbate problems by creating additional barriers for smaller growers who generally are not sources for these problems (DeLind and Howard 2008). This uncertainty leads to farmer reluctance to comply with voluntary standards that are perceived to show a lack of support for small and medium-scale enterprises (Gerstenfeld and Roberts 2000).

2.2 Mental Models and Analysis of Risk Based Decision-Making

Mental models research explores the perceptions and beliefs about a domain of knowledge that people reference for interpreting situations and events, and that influence expectations, decision-making, and the array of possible responses. Knowing this information provides in-depth understandings on the complex thinking of a representative sample of individuals through a five-phase process described in the Methods section. The research process can utilize a variety of qualitative and quantitative techniques to assess and understand these

models (Jones et al. 2011). A mental models framework is an effective and proven approach to understanding decision-making and developing risk communication strategies (Llewellyn et al. 2005), and to engage farmers to better understand their embodied beliefs used in decisions-making. Scientists and researchers have engaged farmers in this way to understand conventional and organic weed management problems (see Wilson et al. 2008, Jabbour et al. 2013, respectively), and food safety issues (Parker et al. 2012b).

In many ways, the differences between real and misperceived risks matter, and while some consequences may be different, both shape behavior and influence outcomes on a farm. For many growers, risk alludes to the “uncertainty” associated with an event or process, but is also attributed to the potential loss resulting from variability or negative outcomes of an event or process (Marston 2011:190).

There are many approaches to analyzing risk based decision-making. For the purpose of this study, risk management decision-making and communication are a process of identifying perceptions of risks associated with a specific domain (i.e. fresh produce food safety), perceptions of sources of risk, perceptions of the elements of risk held by actors engaged in the domain (e.g. farmers, food safety experts, scientists, policy-makers, and regulators), and the decision-making and appropriate responses to risk. Using risk judgement and decision-making as an approach to a complex problem like food safety identifies risks based on specific characteristics and circumstances of the events and processes involved, informs solutions based on the degree of severity of potential outcomes, and may include a cost-benefit analysis or other metric or combination of metrics (Fischhoff et al. 1997, Morgan et al. 2002, Finnoff et al. 2006).

3 Methods

The approach adopted for this study used a five-phase design that breaks from more traditional uses of the methodology that aim to assess perceptions and beliefs of a lay population for comparison with an expert group to identify gaps in knowledge among the lay group (see Morgan et al. 2002). In this modified approach, both expert and lay participants are viewed as having knowledge that is shaped by perceptions and beliefs that provide value for conceptualizing the research problem. This modification shifts our emphasis from a singular focus of what produce growers do not know to a greater understanding of factors influencing both groups of people, experts and growers, making the phases of research reflexive rather than elite driven or linear.

Prior studies conducted by our research group highlighted expert and produce grower decision-making in phase-one and phase-two, respectively. Phase-one synthesized information collected during expert interviews² to develop a model of their perceptions and beliefs of the influences shaping expectations of outcomes and decision-making, which was used to frame phase-two interviews³. This data both captured a verbal review of current knowledge and state of the art understandings of on-farm food safety. This permitted a synthesis of information to occur that helped to identify the correct questions in subsequent phases. In phase-two, interviews with farmers examined knowledge of produce growers to identify areas of overlap and difference between expert and non-expert groups. This provided a cross-check between expert and grower perceptions that highlight key areas to measure in phase-three, presented in this study that quantified the findings of the first two phases and more broadly tested the measures of produce grower decision-making. The final two phases of the larger project were shaped by these findings to develop audience specific, risk-based messages (phase-four) that used adult education

models and evaluated them for effectiveness in influencing adoption of optimal food safety practices (phase-five).

3.1 Survey Design

Interviews with 19 food safety experts and 32 produce growers were conducted between 2007 and 2008 to provide in-depth data on perceptions, attitudes, and beliefs regarding sources of contamination, prevention practices and barriers to adopting prevention practices they identified as important and verified as valid during the interviews. These interviews informed a mail survey that was conducted using Dillman’s Tailored Design Method (Dillman 2000) from December 2008 to March 2009. The survey consisted of the following four recruitment and survey contacts: a pre-survey notification, a survey questionnaire, a reminder postcard, and a second survey mailing. The participant mailing list was created using a random sample of produce growers derived from a mailing list purchased from the Farm Journal, a publication of Farm Journal Media, Inc., of Park Ridge, IL. Farm Journal is the flagship trade magazine that includes readers with mostly conventional fruit and vegetable operations, among other farmer groups, and includes content on crop production and technology, agriculture policy, and issues of concern for farm families. The list was developed using sampling criteria focused on subscribers across farm scales who self-identified as vegetable or fruit growers that resulted in 804 contacts from Indiana, Kentucky, Michigan, and Ohio. Of these, 76% of the records had adequate information to include in our survey mailing. Using USDA definitions of farm size, representation of farm scales was included across large, medium, and small-scale conventional produce growers⁴. Compared to USDA 2012 Census of Agriculture data for produce farms in the four state region, the large farm category is overrepresented (Table 1).

Table 1. Sample Size, Response, and Demographics.

3.2 Measurement

Produce growers were asked to respond to several categories of questions of which four are reported in this paper. Questions assessing grower perceptions of GAP specific prevention practices emphasized farm problem areas of water quality, facility and equipment sanitation, and employee health and hygiene. These were adapted to the survey sections assessing grower perceptions: the relative risk from various contamination pathogens, pre-harvest and post-harvest contamination sources, and the effectiveness of various contamination prevention management practices. A final section assessed perceived economic feasibility of prevention practices. Each was identified as risks or solutions by a panel of food safety experts. Table 2A and 2B presents the categories, subject areas, and examples of question topics.

Table 2A. Variable Descriptions: Contamination Sources, Prevention Practices, and Barriers to Adoption of Practices.

Table 2B. Variable Descriptions: Level of Preparedness, Information Preferences, and Demographics.

3.3 Data Analysis

We used a three-staged analysis to test our hypothesis. In first stage we analyzed the farm scale variable for correlations with other variables to examine each potential relationship to the farm scale variable. In the second stage, we conducted three exploratory Factor Analyses (eFA) to reduce the number of discrete and similar variables to factors for use in an ANOVA. In the third stage, Analysis of Variance (ANOVA) was conducted to examine the variance in factor scores among the farm scale categories. Each stage incorporates insights from the 51 expert and grower interviews to assist in interpretation of the findings.

4 Results and Discussion

4.1 Farm Scale Correlations

The findings provide support for the hypothesis that few differences in food safety knowledge and awareness exist among growers across farm scales, and demonstrate that farmers across all scales had some produce safety misperceptions. Of the 116 variables in our study, just ten percent of them showed evidence of a scale relationship. There were correlations between Farm Scale and the following:

- three of thirty-one Pre-Harvest Contamination variables
- three of the thirty-one Post-Harvest Contamination variables
- three of twenty-eight Prevention Practices variables had significant correlations with farm scale
- three of the twenty-six variables in the Perceived Economic Feasibility of Prevention Practices category

The evidence confirms the belief that many growers in this study have some knowledge but all could benefit from receiving salient produce safety information. These data are presented in Table 3.

Table 3. Produce Safety Sources, Practices and Barriers Correlated with Farm Scale.

The small number of significant correlations indicates a degree of parallel understanding of produce safety risks across farm scales with slightly greater understanding demonstrated among smaller scale farmers (there were eight negative and four positive correlations). A small increase in the perception of risks from pesticide applications, chemical fertilizers, and wildlife feces as pre-harvest sources of contamination was seen among smaller scales. A similar pattern

emerged among the same growers for post-harvest sources of pesticide mix-water, road dust, and storage containers. Smaller scale growers had positive perceptions of treating well water as a prevention practice more than larger growers, while larger growers were more likely to perceive banning raw manure use and keeping livestock out of produce fields. In this research, the perceptions of risk related to familiar practices are minimized by the farmers who rely on them the most.

The perceptions of economic feasibility were significantly correlated with scale for three practices. Treating wash water and banning raw manure were viewed by larger growers as more economically feasible. These findings may relate to existing use of wash water treatment and the preference for chemical fertility sources over compost or manure. Controlling weeds was seen as less feasible by larger farms, likely due to time and labor costs associated with implementing this on larger farms.

4.2 Exploratory Factor Analysis of Attitudes and Perceptions of GAPs

Three exploratory factor analyses models (eFAs) were created to probe for relationships within the variable categories Pre- and Post-harvest Contamination Sources, Prevention Practices, and Feasibility of Prevention Practices, with the goal of reducing the number of similar variables. Each analysis produced statistically significant factors or dimensions with high Cronbach's alpha coefficients indicating their reliability for use in an Analysis of Variance (ANOVA) among farm scales.

Each exploratory analysis illuminated commonalities among variables within each variable category with eigenvalues greater than one. The eFAs used were maximum likelihood using varimax rotation and standard Pearson's r correlations. Factors were created for each variable category in Table 2A and factor labels were assigned based on the commonalities we

found among the variables contributing to each factor and our substantive knowledge of produce safety and this Amish community. For example, Factor 1 was labeled “Field Risks Sources” because of the affinity among variables relating to the spatial location where the presence of a phenomena or activity characterized by a variable would be found or took place (Pesticide Application, Plant Disease, Weed Infestation, Insect Infestation etc.).

In the eFA of Pre- and Post-harvest contamination sources eight factors with eigenvalues greater than one were created that explain a cumulative total of 70% of the variance. Two of factors, Field Risk Sources and Worker Sources, explain 33% and 10% of the variance, respectively. Of the six contamination source variables correlated with farm size in the previous section, two appear in the Field Risk factor, and one in the Equipment Sources factor. These are identified by bold italics in Table 4.

Table 4. Eight Pre- and Post-Harvest Factors Produced by Exploratory Factor Analysis.

The variables in the Prevention Practices category created 6 factors explaining a cumulative 67% of variation. The factors correspond to the farm problem areas identified by food safety experts cited earlier. In the Prevention Practices eFA, more than half the explained variance is in the Water Quality factor that explained 35%. This is followed by the Workers factor explaining just over 9%, and the Livestock Control factor explaining over 7%. One farm scale correlated variable is in the Water Quality factor, two others are in the Livestock Control factor; these are identified by bold italics in Table 5.

Table 5. Six Prevention Practices Factors Produced by Exploratory Factor Analysis.

Seven factors were created in the eFA of the Economic Feasibility variables explaining a cumulative 70% of the variation. Worker Barriers accounted for half the explained variance in

the Perceived Economic Feasibility of Prevention Practices with Treatment and Testing Barriers explaining 9%, Pest Control Barriers explaining 7%, and Manure Management Barriers explaining 5%. The latter three factors each contain one of the three variables that were correlated with farm scale and are identified by bold italics in Table 6.

Table 6. Seven Economic Feasibility Factors Produced by Exploratory Factor Analysis.

4.3 Analysis of Variance

The final analysis in this study is an Analysis of Variance of the farm scale variable by each of the factors from the explanatory Factor Analyses. The ANOVA model resulted in three of the twenty-one factors being statistically significant. The results of this analysis are presented in Table 7.

Table 7. ANOVA of Factors by Farm Scale with Multiple Comparisons of Means.

The ANOVA results show that the small and medium scale growers in this study were more perceptive of pre- and post-harvest Field Risks to produce safety than were large scale growers. There is a significant difference in means between large and small scale growers, highlighting the latter group's greater awareness of contamination from Field Risks (pesticide application, plant disease, weed and insect infestation, pesticide mix water, condensation on produce, and dust drifting into fields in from nearby roads).

Large and medium scale growers perceived fewer barriers to adopting preventative practices in the Facility and Equipment Sanitation factor (proper equipment sanitation, proper restrooms and hand washing station availability, and proper sewage disposal). The significant mean difference between large and small scale growers may support the claim that large scale growers have greater access to resources for capital intense solutions. Alternatively, this could be

influenced by growers believing that the development process for making produce safety rules lacks legitimacy and their skepticism regarding for whom the rules are appropriate. This is likely to be the situation since smaller growers use different growing practices and direct market most of their produce. From interviews, we know that smaller scale growers perceived the new food safety rules will promote a single-scale, large farm bias with capital intensive solutions.

The irrigation and compost factor that includes drip irrigation, no overhead irrigation, and use of composted manure was a greater barrier to adoption by large scale growers. The significant mean difference between large and small scale growers is supported by knowledge that larger scale growers reported greater use of surface water for irrigation and practiced more overhead irrigation. This would pose a greater barrier to their adoption of some irrigation and surface water recommendations.

In the ANOVA, two of the three statistically significant factors were Economic Feasibility factors, which are interpreted as structural barriers. Small scale farms had larger significant mean differences than large scale farms in the Field Risk factor of contamination sources and Irrigation and Compost factor of economic feasibility. Conversely, larger scale farms had a greater mean difference than their small scale counterparts with Facility and Equipment Sanitation factor of economic feasibility.

5 Conclusions

This research has focused on growers perceptions of produce contamination sources and prevention practices as they vary by farm scale. Our previous work has shown there is a great deal of confusion among produce growers regarding GAPs, FSMA and FDA rules, and their implementation. This study aims to provide information that can help to clarify some of this

confusion in a US Midwestern context so that policy-makers, Extension, and other outreach professionals can better address them.

An approach to developing produce safety standards that is sensitive to the risks posed by specific farm structures (farm size, produce type, production practices, marketing type) is a critical yet overlooked component of the discourse on food safety. The findings in this study lend support for ensuring educational programming and information on management practices is available for all farm scales that includes scale-specific content. Further, our interpretation supports the awareness that education alone will not make the food system safer because there are barriers to prevention that include underestimation of the risks of several potential sources of contamination, underestimation of the effectiveness of prevention practices, and perception of economic feasibility of those practices.

Grower perceptions of the economic feasibility of specific practices were mixed. It is likely that the small number of variables correlated with farm scale indicates that the problem is not the lack of awareness of the general concepts of GAPs among specific scales, but rather growers at all farm scales need information that is salient to their operations. These findings and the scale-related variance from the ANOVA point to common threads in the discussion of barriers for small and medium-scales growers that are shaped by perceptions reported in interviews, which include:

- Inflexibility of a standard that does not adapt to local farming conditions.
- Lack of support for their scale of operation.
- Favoritism towards large scale growers in the creation of standards and practices for regulation and market development.

- Negative perceptions of policy and rule development that may stem from a lack of perceived legitimacy in FSMA rules, confusion regarding GAP and new FDA rules, and perceptions of blame and responsibility for foodborne illnesses being misdirected at farmers.

The findings in this study point to a growing need for information that is salient to growers, which include attention to the appropriate farm scale for both equipment and practices to be adopted. The barriers in treating wash water and avoiding the use of raw manure in fields is likely related to misperceptions among policy makers about the practical applications of a proposed standard across farms, and perceptions among growers about the costs in time and money to implement these practices. A salient finding in this research is the number of growers at all scales who do not recognize the various pre- and post-harvest sources of contamination and do not perceive recommended prevention practices to be effective. The variance in significant factor scores between large and small-scale growers in this study highlight differences in perceptions of risk and prevention that can assist outreach professionals in enhancing their programming, and guide policy makers in developing standards for produce safety consisting of benchmarks and measures that apply to all growers *and* metrics of recommended practices that are applicable to specific farm scales. This finding reinforces a need for improved messaging about GAPs and the benefits of GAP training. This will facilitate our understanding of why barriers exist to the adoption of prevention practices. The FDA has acknowledged during public hearings (Produce Safety Project 2010) that they understand the need for FSMA measures to be risk-based and scale-appropriate, and responding to the National Sustainable Agriculture Coalition's (NSAC) comments on the draft rules by changing several contested provisions

regarding water quality testing, irrigation, and compost use. The FDA and the Produce Safety Alliance, who is charged with developing the specific standards and practices, have, however, delayed the release of specific rules and curriculum for practices that meet these criteria, which is an opportunity for these findings to assist this process.

Finally, while there are few differences in knowledge or barriers across grower scales, those that were identified show potential areas to focus outreach and research efforts for addressing fresh produce food safety: irrigation and compost for larger growers, and facility and equipment sanitation for smaller growers. All growers can benefit from robust GAPs training and resources that address the barriers to adoption that exist within and across scales. This can be accomplished by tailoring efforts to small growers by identifying and then verifying effective, scale-appropriate sanitation practices that may already be in use by some, and irrigation and water treatment solutions for larger scale growers. These practices are likely to exist among growers at varying scales but will require further investigation to identify them.

Instead of emphasizing universal prevention practice standards, further on-farm research should evaluate the structural barriers to on farm adoption of produce safety measures and develop recommendations that are accompanied by scale and marketing based metrics. In addition, analyses of fresh produce aggregation and distribution systems for risks and understanding the optimal scales to reduce those risk is warranted. Consumer health and safety must be the foremost goal in developing standards while ensuring that these solutions make a real difference in protecting consumers and not creating additional barriers to farmers for the sake of short-term market assurances. This process of standard development can begin by questioning our assumptions about on-farm food safety, where the best food safety controls can

be implemented in a commodity chain, the messages that are used, and the practices that are promoted before concluding that the audience of growers is knowledge deficient.

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Notes.

¹ The provisions of the Tester Amendment to the Food Safety Modernization Act of 2011 exempts produce farms with less than \$500,000 in gross annual sales, grow only exempt-produce, direct market their produce.

² These included 19 representative farmers, scientists, policy makers, and educators.

³ The term model is derived from the research methodology, Mental Models, and is used to show relationships between variables based on influences. A similar approach is used in multivariate analysis where the output of a statistical procedure is referred to as a model.

⁴ Scales follow USDA ERS definitions for farm sizes: large farms have gross incomes over \$500,000, medium farms are \$100,000 to \$499,000, and small farms are less than \$100,000.

Table

Tables.

Sample Size N	Responses	Useable Surveys	Useable Surveys by Farm Scale			Age	Male	Education	
	Count (%)	Count (%)	Small	Medium	Large	Mode	%	High School (%)	College (%)
575	164 (28.5)	159 (27.7)	60 (37%)	53 (34%)	46 (29%)	51-65	94.4	42.5	57.5
			USDA Census of Agriculture 2012 %						
			(88%)	(4%)	(8%)				

Table 1. Sample Size, Response, and Demographics.

Question Category	Relevant Question Subject Areas	Question Topics			
Contamination Sources	<p>Options were part of a question battery of 62* practices with 5-point Likert scales:</p> <p>Strongly Agree, Somewhat Agree, Neither Agree nor Disagree, Somewhat Disagree, Disagree.</p> <p>The battery focused on this question:</p> <p><i>“To what extent do you agree or disagree that the following can be a source of pre- or post-harvest contamination?”</i></p> <p>*Variables with loading of greater than 0.500 in the Factor Analysis are shown here.</p>	Pre-Harvest		Post-Harvest	
		Pesticide Application Plant Disease Weed Infestation Insect Infestation Worker Hygiene Planting Machinery Raw Manure Composted Manure Livestock Proximity	Rain Seed Transplants Chemical Fertilizers Farm Animal Feces Wildlife Feces Irrigation Water Surface Water Criminal Acts	Pesticide Mix Water Wash Water Hand Harvesting Worker Hygiene Plant Disease Condensation Insect Infestation Road Dust Harvest Machinery Transportation Equipment	Storage Containers Livestock Proximity Animal Feces Criminal Acts
Prevention Practices	<p>Options were part of a question battery of 28 practices with 5-point Likert scales:</p> <p>Very Important, Somewhat Important, Indifferent, Somewhat Unimportant, Not Important</p> <p>The battery focused on this question:</p> <p><i>“To what extent do you consider the following management practices to be important in the prevention of food contamination?”</i></p>	Minimizing Irrigation Contact with Produce Testing Irrigation Water Treating Surface Water Treating Well Water Treating Wash Water Conducting Employee Produce Safety Training Conducting Handwashing Training Providing Restrooms and Wash Station Access Proper Sewage Disposal Posting “Employee Handwashing” Reminders Accessible Standard Operating Procedures Banning Raw Manure Use Livestock Out of Produce Fields Animal Barriers Around Fields		Neighborhood Participation Documenting Standard Operating Procedures Testing Produce Before Leaving Farm Testing Wash Water Proper Equipment Sanitation Using Government Inspections Using Management Inspections 3 rd Party Auditor Inspections Control Plant Diseases Controlling Insects Controlling Weeds Proper Raw Manure Timing Proper Compost Manure Timing Controlling Visitor Access to Fields	
Barriers to Adoption	<p>Options were part of a question battery of 26 practices with 5-point Likert scales:</p> <p>Strongly Agree, Somewhat Agree, Neither Agree nor Disagree, Somewhat Disagree, Disagree.</p> <p>The battery focused on this question:</p> <p><i>“To what extent do you agree or disagree that the following on-farm management practices are economically feasible options to prevent food contamination?”</i></p>	Employee Hygiene Training Employee Handwashing Training Posting Handwashing Signs Translating SOPS to another Language Accessible Standard Operating Procedures Testing Irrigation Water Treating Irrigation Water Testing Produce Testing Wash Water Treating Wash Water Controlling Plant Disease Controlling Insects Control Weeds		Ban Raw Manure Use Testing Compost Installing Animal Barriers Around Fields Proper Equipment Sanitation Providing Restrooms and Hand Wash Stations Proper Sewage Disposal No Use of Chemical Fertilizers Use Government Inspections Use Management Inspections Use 3 rd Party Auditor Inspections Use of Drip Irrigation No Use of Overhead Irrigation Use Composted Manure	

Table 2A. Variable Descriptions: Contamination Sources, Prevention Practices, and Barriers to Adoption of Practices.

Question Category	Relevant Question Subject Areas	Question Topics
Level of Preparedness	<p>Level of Preparedness for Dealing with an On-farm Outbreak</p> <p>5-point Likert Scales addressing the following questions:</p>	<p><i>"To what extent do you believe that your farm is prepared to deal with produce contamination if it were to occur?"</i></p> <p><i>"To what extent do you believe that your employees are knowledgeable in food safety hazards?"</i></p> <p><i>"What would be the impact of a food safety contamination event occurring on your farm?"</i></p>
Information Preferences	Information Channel preferences for the following: Farming, Produce Safety, and Dealing with an Immediate Outbreak. 4 Lists addressing the following:	<p>Preferences for information sources (industry, experience and testimonial, scientific)</p> <p>Preferences for information channels (Extension, friends and family, print media, seminars, consultants)</p> <p>Differences between preferences based on general versus produce safety information seeking</p> <p>Current produce safety information needs</p>
Farm Background	Description of farm size, type, produce grown, number of workers	<i>"Please tell me about your farming operation including farm history, size, land access, produce grown, and number of workers."</i>
Perceptions and Attitudes of Good Agricultural Practices (GAPs)	<p>Familiarity with GAPs</p> <p>Use of GAPs</p> <p>Effectiveness of GAPs</p>	<p>1 Agreement Likert Scale – Are you familiar with Good Agricultural Practices (GAPs)?</p> <p>1 Use Likert Scale – To what extent does your farm practice GAPs?</p> <p>1 Agreement Likert Scale – Following GAPs reduced the risk of produce contamination?</p>
Farm information and respondent demographics	<p>Age: <20 years, 21-35 years, 36-50 years, 51-65 year, 66-80 years, >80 years</p> <p>Sex: Dichotomous Female/Male Option</p> <p>Education: Categories: 8th Grade or less, High School, College, Graduate</p> <p>Farm Scale: 2007 Gross Sales using USDA income-based farm size: <\$250,000 = Small; \$250,000 to \$500,000 = Medium; >\$500,000 = Large</p>	

Table 2B. Variable Descriptions: Level of Preparedness, Information Preferences, and Demographics.

Variable	Question Category	Percent Agreement			Kendall's τ -c	Sig.
		Large Scale	Medium Scale	Small Scale		
Wildlife Feces	Pre-Harvest	73.3	81.1	98.5	-0.146	0.027
Chemical Fertilizers	Pre-Harvest	15.4	38.5	46.1	-0.151	0.038
Pesticide Application	Pre-Harvest	21.9	33.3	44.8	-0.229	0.001
Storage Containers	Post-Harvest	78.3	76.9	87.9	-0.148	0.023
Road Dust from Passing Cars	Post-Harvest	23.9	29.6	46.5	-0.209	0.002
Water for Pesticide Mixing	Post-Harvest	19.5	35.1	45.4	-0.227	0.002
Livestock Out of Produce Fields	Prevention Practices	76.1	83.0	67.9	0.150	0.044
Banning Raw Manure Use	Prevention Practices	34.0	36.3	29.7	0.185	0.012
Treating Well Water	Prevention Practices	18.9	35.8	45.3	-0.184	0.012
Banning Raw Manure Use	Economic Feasibility	37.5	36.1	26.4	0.289	0.000
Treating Wash Water	Economic Feasibility	31.1	39.4	29.3	0.314	0.000
Controlling Weeds	Economic Feasibility	50.0	67.0	74.1	-0.157	0.026

Table 3. Produce Safety Sources, Practices and Barriers Correlated with Farm Scale.

Loading Order	Factor Name	Factor Description	Variables		EV	% VAR	Cronbach's alpha
Factor 1	Field Risk Sources	Risks associated with field activities.	Pre-harvest Pesticide Application Pre-harvest Plant Disease Pre-harvest Weed Infestation Pre-harvest Insect Infestation <i>Post-harvest Pesticide Mix Water</i>	Post-harvest Plant Disease Post-harvest Condensation on Produce Post-harvest Insect Infestation <i>Post-harvest Road Dust</i>	11.35	33.4	0.908
Factor 2	Worker Sources	Contamination sources related to workers activity	Pre-harvest Worker Hygiene Post-harvest Wash Water	Post-harvest Hand Harvesting Post-harvest Worker Hygiene	3.37	9.90	0.811
Factor 3	Equipment Sources	Farm equipment that is in contact with produce and contamination sources	Pre-Harvest Farm Machinery Post-harvest Harvest Machinery	Post-harvest Transport Equipment <i>Post-harvest Produce Storage Containers</i>	2.16	6.36	0.801
Factor 4	Manure Sources	Manure source and use, and domestic animal concerns	Pre-harvest Raw Manure Use Pre-harvest Compost Manure Use	Pre-harvest Livestock Proximity Post-harvest Livestock Proximity	1.80	5.30	0.803
Factor 5	Input Sources	Specific field inputs	Pre-harvest Rain Pre-harvest Seed	Pre-harvest Transplants Pre-harvest Chemical Fertilizer Use	1.51	4.43	0.722
Factor 6	Wildlife Sources	Wild animal feces and access to fields	Pre-harvest Domestic Animal Feces Contact Pre-harvest Wildlife Feces Contact	Post-harvest Domestic Animal Feces Contact	1.31	3.85	0.735
Factor 7	Water Sources	Water sources for irrigation and washing of produce	Pre-harvest Irrigation Water	Pre-harvest Surface Water	1.25	3.68	0.827
Factor 8	Criminal Sources	Intentional acts of contamination	Pre-harvest Criminal Acts	Post-harvest Criminal Acts	1.03	3.02	0.919

Table 4. Eight Pre- and Post-Harvest Factors Produced by Exploratory Factor Analysis.

Loading Order	Factor Name	Factor Description	Variables		EV	% VAR	Cronbach's alpha
Factor 1	Water Quality	Activities related to water quality	Minimizing Irrigation Contact with Produce Testing Irrigation Water Treating Surface Water	<i>Treating Well Water</i> Treating Wash Water	9.84	35.14	0.869
Factor 2	Workers	Activities specific to worker training and hygiene	Conducting Employee Produce Safety Training Conducting Handwashing Training Providing Restrooms and Wash Station Access	Proper Sewage Disposal Posting "Employee Handwashing" Reminders Accessible Standard Operating Procedures	2.54	9.08	0.869
Factor 3	Livestock Control	Controlling animal sources of contamination	<i>Banning Raw Manure on Fields</i> <i>Having No Fields Near Livestock</i> Animal Barriers Around Fields	Neighborhood Participation Documenting Standard Operating Procedures	20.3	7.25	0.848
Factor 4	Post-harvest Best Practices	Use of best practices and auditing tools	Testing Produce Before Leaving Farm Testing Wash Water Proper Equipment Sanitation	Using Government Inspections Using Management Inspections 3 rd Party Auditor Inspections	1.69	6.04	0.809
Factor 5	Pest and Disease Management	Implementing pest controls	Control Plant Diseases Controlling Insects	Controlling Weeds	1.35	4.82	0.920
Factor 6	Manure Management	Implementing proper manure protocols	Proper Raw Manure Timing	Proper Compost Manure Timing	1.23	4.41	0.852

Table 5. Six Prevention Practices Factors Produced by Exploratory Factor Analysis.

Loading Order	Factor Name	Factor Description	Variables		EV	% VAR	Cronbach's alpha
Factor 1	Worker Barriers	Barriers related to worker characteristics including training and culture	Employee Hygiene Training Employee Handwashing Training Posting Handwashing Signs	Translating SOPs to another Language Accessible Standard Operating Procedures	9.49	35.15	0.937
Factor 2	Water Quality Barriers	Water quality testing and treating costs	Testing Irrigation Water Treating Irrigation Water Testing Produce	Testing Wash Water Treating Wash Water	2.43	9.00	0.824
Factor 3	Pest Control Barriers	Barriers to implementing pest controls	Controlling Plant Disease Controlling Insects	Control Weeds	2.08	7.72	0.901
Factor 4	Manure Management Barriers	Barriers to implementing proper manure protocols	Ban Raw Manure Use Testing Compost	Installing Animal Barriers Around Fields	1.46	5.40	0.726
Factor 5	Facility and Equipment Sanitation Barriers	Barriers to maintaining clean equipment and facilities	Proper Equipment Sanitation Providing Restrooms and Hand Wash Stations	Proper Sewage Disposal	1.26	4.68	0.678
Factor 6	Inspection and Audit Barriers	Barriers from best practice certification and auditing	No Use of Chemical Fertilizers Use Government Inspections	Use Management Inspections Use 3 rd Party Auditor Inspections	1.18	4.37	0.729
Factor 7	Irrigation and Composting Barriers	Barriers to implementing proper irrigation and compost for produce	Use of Drip Irrigation No Use of Overhead Irrigation	Use Composted Manure	1.15	4.24	0.600

Table 6. Seven Economic Feasibility Factors Produced by Exploratory Factor Analysis.

ANOVA and Multiple Comparisons

Dependent Variable						Tukey HSD					95% Confidence Interval	
						(I) Farm Scales	(J) Farm Scales	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
Field Risks	Between Groups	2	3.067	3.163	0.045	1 (small)	2 (medium)	0.10457989	.19697704	.856	-.3621124	.5712721
	Groups						3 (large)	*0.50229774	.20841550	.045	.0085047	.9960908
	Within	138	0.970			2	1	-0.10457989	.19697704	.856	-.5712721	.3621124
	Groups						3	0.39771785	.20654545	.135	-.0916446	.8870803
	Total	140				3	1	*-0.50229774	.20841550	.045	-.9960908	-.0085047
							2	-0.39771785	.20654545	.135	-.8870803	.0916446
Facility & Equipment Sanitation	Between Groups	2	4.228	4.449	0.013	1 (small)	2 (medium)	-0.45888431	.19848656	.058	-.9292669	.0114982
	Groups						3 (large)	*-0.55514872	.20361090	.020	-1.0376752	-.0726223
	Within	135	0.950			2	1	0.45888431	.19848656	.058	-.0114982	.9292669
	Groups						3	-0.09626441	.21047678	.891	-.5950620	.4025331
	Total	137				3	1	*0.55514872	.20361090	.020	.0726223	1.0376752
							2	0.09626441	.21047678	.891	-.4025331	.5950620
Irrigation & Compost	Between Groups	2	3.736	3.889	0.023	1 (small)	2 (medium)	0.24878761	.19957631	.428	-.2241775	.7217527
	Groups						3 (large)	*0.57092727	.20472879	.017	.0857516	1.0561030
	Within	135	0.961			2	1	-0.24878761	.19957631	.428	-.7217527	.2241775
	Groups						3	0.32213966	.21163237	.284	-.1793964	.8236758
	Total	137				3	1	*-0.57092727	.20472879	.017	-1.0561030	-.0857516
							2	-0.32213966	.21163237	.284	-.8236758	.1793964

*Statistically significant at >.05

Table 7. ANOVA of Factors by Farm Scale with Multiple Comparisons of Means.