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A Qualitative Analysis of Power Take-Off Driveline Shields: Barriers and Motivators to Shield Use for New York State Farmers

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ABSTRACT. *Machinery entanglements are one of the top three causes of death in farming. Education on the risks of unshielded power take-off (PTO) equipment does not appear to significantly alter farmers willingness to replace missing or broken shielding. Different assessments conducted in various regions of the U.S. indicate that as many as one-third*

to one-half of PTOs are inadequately shielded. Qualitative research was conducted with New York farmers to identify the factors that influence the decision to replace damaged or missing PTO driveline shields. Interview topics included: knowledge of entanglement risks, decisions regarding safety in general, decisions relating to PTO driveline shielding specifically, and the barriers and motivators to replacing missing or broken PTO driveline shields. Interviews with 38 farmers revealed the following themes: (1) farmers are fully aware of PTO entanglement risk, (2) insufficient time and money are primary barriers to purchasing or replacing damaged or missing PTO driveline shields, (3) PTO driveline shield designs are problematic and have led to negative experiences with shielding, and (4) risk acceptance and alternate work strategies are preferred alternatives to replacing shields. Our findings indicate that more innovative approaches will be required to make PTO driveline shield use a viable and attractive choice for farmers. New shield designs that address the practical barriers farmers face, as well as the provision of logistical and financial assistance for shield replacement, may alter the decision environment sufficiently to make replacing PTO driveline shielding a more attractive option for farmers.

Keywords. Driveline shield, Machinery entanglement, Power take-off, PTO, Qualitative research, Risk perception, Safety.

Farming is one of the most dangerous occupations in the U.S., as evidenced by its high incidence of both fatal and non-fatal injuries. In 2010, agriculture had the highest rate of fatal injury (26.9/100,000 workers), nearly ten times the rate for all industries combined (3.5/100,000). It also led all sectors in the rate of non-fatal injury (4.8/100 workers) compared to a national rate of 3.8/100 (NSC, 2012). In the northeastern U.S., power take-off (PTO) equipment injuries are responsible for a significant proportion of these fatalities and injuries, even though PTO shields, which greatly reduce the risk of entanglement, are commercially available (Carrabba, 2008, 2009). PTO injuries are the largest subset of rotating shaft entanglement injuries and are reported in various studies to involve an amputation in 28% to 43% of cases (Beer and Field, 2005; Wilkinson and Field, 1988). Such events occur disproportionately on small diversified farms (Beer and Field, 2005), which are becoming increasingly prevalent in the northeast, according to USDA data (Laumer, 2009).

Despite the obvious risks posed by unshielded PTO drivelines, several investigations examining the presence of PTO shielding have confirmed that PTO shields are frequently damaged or missing (Freeman et al., 2003; Murphy et al., 1998; West and May, 1998). Agricultural health and safety studies of various farm safety practices have revealed that knowledge of risks does not always translate to safer practices (Dee Elkind, 1993). In relation to PTO shielding, Hagel et al. (2008) found that farms enrolled in a rigorous safety training program for more than eight years had more unguarded grain augers than farms that were not enrolled. Further studies by Hartling et al. (2004), Mazur et al. (2005), and Reed et al. (2001) confirmed that educational interventions do not necessarily lead to an increase in PTO shielding. These studies suggest that knowledge of entanglement risk will not likely increase the replacement of missing or broken PTO shielding. The purpose of this research was to explore the apparent gap between PTO knowledge and safety practices by conducting in-depth interviews with New York dairy and livestock farmers on their PTO driveline shielding experiences and practices.

Materials and Methods

Study participants were recruited from small dairy and livestock farms in New York, due to the high proportion of PTO-related injuries and the prevalence of PTO-driven equipment on these farms. A small dairy operation was defined as having less than 200 head of dairy stock, while a small livestock farm was defined as having beef cattle, goats, pigs, sheep, or chickens of approximately the same scale. Research participants were identified through web searches and referrals from other farmers. Members of the agricultural service provider community, such as extension agents, FarmNet employees, Farm Bureau members, and tractor dealerships, were also used as methods of referral.

Potential respondents were contacted by telephone and given a short description of the New York Center for Agricultural Medicine and Health / Northeast Center for Agricultural and Occupational Health (NYCAMH/NEC), as well as a brief description of the study. Principal operators were invited to participate based on their knowledge of farm activities and operations; however, additional family members were welcomed to participate if they appeared interested. All participants in the study received a $20 gift card.

Protection of Rights of Study Participants

The study was approved by the Bassett Healthcare Network Institutional Review Board. Prior to each interview, subjects were briefed on the purpose of the research and their rights as research participants. Permission was also requested for audiotaping interviews. Informed consent was provided by all respondents (farmers and family members).

Data Collection

Interviews were conducted using a semi-structured interview guide that was designed to elicit discussion on work tasks, farm priorities, views about safety, perceived risk of entanglement, and motivators and barriers to installing driveline shields on unprotected rotating machinery shafts. Although the complete PTO shielding system includes tractor master shields, driveline shields, and implement shields, the focus of our research was restricted to behaviors related to the replacement of PTO driveline shielding (henceforth referred to as PTO shielding) in order to simplify the discussions. This was made explicitly clear to the participants at the beginning of each of the interviews conducted. As the interviews progressed, the moderator s guide was revised in order to explore core categories, the boundaries of these categories, and important ideas raised in previous interviews, as well as to understand the relationships between core categories.

All interviews were audiotaped to ensure data accuracy. Transcription was conducted promptly so that data collection and analysis could occur in an iterative fashion, i.e., themes, ideas, or patterns that emerged in one interview could be explored in subsequent interviews until new themes or concepts ceased to emerge and saturation was reached.

Data Analysis

Interviews were analyzed by two of the authors (J. Sorensen and R. Weil) using grounded theory analytical methods (Glaser, 2001; Dew, 2007), as the purpose of the study was not just to describe farmers lived experiences with risk and safety but also to develop a theory regarding how risk is negotiated and how safety decisions are made. Grounded theory permits researchers to conceptualize the data gathered in interviews in order to identify core categories and overarching themes that occur throughout the interviews and determine how these factors fit together to describe behavior.

To facilitate the analytical process, Open Code software was used (Open Code, 2007). Open Code facilitates the analysis of qualitative research by permitting researchers to develop and organize codes and categories for transcribed data. Following each interview, the audiotapes were transcribed and key information was coded line by line. The codes were grouped into larger categories that captured the primary ideas expressed in the code groupings. The categories were reviewed and used to create core categories, which were then revised into themes that captured prominent ideas and the relationships between those ideas. Throughout the analysis, the researchers moved back and forth from transcripts to categories in order to refine, discard, generate, or extend questions, hypotheses, or conclusions. This proceeded until the researchers developed a description of the factors that most closely defined the safety/risk decision-making process. In this article, direct statements from farmers are included to provide examples of how particular themes were discussed. Statements referring to PTO shielding are specific to driveline shields and not other components of the PTO shielding system.

Study Participants

Twenty-two interviews were conducted with a total of 38 participants. Spouses participated in 13 interviews, and an adult son participated in one interview. Table 1 lists the participant characteristics.

Table 1. Study participant overview.

Category	Dairy	Livestock[a]	Total Individuals
Principal male operators	6	3	9
Principal female operators	1	1	2
Husband and wife team	9	4	26
Farm son	1	0	1
Total individuals	17	8	38

[a] Livestock= beef, sheep, pigs, and chickens.

Results

The focus of our inquiry was to develop a more in-depth understanding of the factors that influence a farmer□s decision to replace missing or damaged driveline shields and to identify opportunities for encouraging farmers to engage in this important safety behavior. Based on analysis of the participant interviews, two prominent themes appear to be highly relevant in the decision to replace missing or damaged PTO shielding. These themes are: □the decision environment favors risk□ and □previous experiences reinforce risk.□ In addition to these themes, we identified a third key theme that related to □considerations for altering the PTO shielding decision environment,□ which provides helpful recommendations for future PTO shielding interventions.

Theme 1: The Decision Environment Favors Risk

Limited Time and Money Make It Difficult to Work Safely

The nature of small family farms in New York State has been steadily changing, and the stress of this was evident in the interviews. Farmers described having one or both spouses working full-time or part-time off the farm in order to increase income and secure health insurance. Farmers also indicated that children are increasingly leaving the farm to attend college or pursue other employment opportunities. It can be difficult for farmers to afford to hire experienced, reliable help and farmers felt there was increasing pressure for existing farms to get larger. This is often a difficult decision in light of increasing operating costs and low returns for the products they are marketing. Anecdotally, the interviews indicated that the highest priority for most of the farmers was simply survival.

These realities translate into a daily struggle to balance the myriad demands and challenges inherent in the work environment. These challenges include racing against the weather, dealing with equipment, ensuring that animals are both well and well taken care of, building adequate supplies of feed, managing crops, maintaining electrical systems, working with chemicals, adjusting to seasonal changes in workload, addressing supply fluctuations, opening markets for products, dealing with subsidies, handling debt, balancing off-farm jobs, addressing family needs, and dealing with labor concerns. As one farmer described, □*There□s an awful lot of stress on a farm, mental stress I call it. You drive by a farm and it looks peaceful. As soon as you open the doors on the barn or the buildings and you look inside, you see all the things involved.*□ Farmers described the nature of farming as both predictable and unpredictable. Some tasks could be planned for and controlled, while other unplanned challenges arise that demand an ability to be adaptive and resourceful.

Within this complex environment, farmers are faced with balancing limited resources with myriad tasks and priorities. As one farmer said, □*You do what you can with the time and the money that you have. It□s not an easy business. Safety□s not high on the list when you have a limited amount of money. It would be great in a perfect world if everybody had new machinery with all the safety cutoffs and shielding, but that□s just not the case.*□

As a result, getting the job done is often viewed as more relevant than shielding. From the farmers perspective, *Sometimes we just go and do it. You have to get it done. Sometimes you don t think about safety if you re working under a lot of pressure or stress. Sometimes you don t think about the safety things. Your mind says you have to do this, but you might overlook things. Or I have to get it done by a certain time, so you hurry.* As one farmer succinctly expressed it, *It s tough to tie your shoes while you re walking.*

As demonstrated in these interview excerpts, ensuring that PTO shielding is present and functioning is low on the list of priorities for farmers. In other words, if the choice is to use their time to get the hay in, fix a crucial piece of equipment, or purchase better feed for their cows versus spending time and money on replacing missing or broken shields, the shields are likely to lose. In fact, farmers went so far as to refer to PTO shielding as a luxury. As stated by one farmer, *If the shield is there, that is super, but that s a real luxury at the end of the day. If it s not and I can still run [it], I need to run [it], and that s the same here as it is anywhere. If you re not making enough money to maintain your equipment, if you re not making enough money to pay yourself first and then secondly to maintain equipment, those are the first things that aren t going to get fixed.*

Theme 2: Previous Experiences Reinforce Risk

Negative Shielding Experiences Make Risk a More Appealing Option

PTO-driven equipment is a ubiquitous presence on U.S. farms, and farmers have a long history of experiences that relate to the maintenance and shielding of PTO drivelines. Unfortunately, most of the experiences that the farmers described in relation to PTO shielding appear to be negative. While every farmer acknowledged the risk of unshielded PTOs, they also described, at length, the numerous ways that shields create obstacles to getting their work done efficiently.

This list of shielding issues appeared to be very consistent from farmer to farmer, and it differed little between livestock or dairy operations. Barriers to workflow clustered into three basic categories: shields impede maintenance and equipment use, shields have poor durability, and replacing missing or broken shields is difficult.

Shields Impede Maintenance and Equipment Use. To survive economically, farmers felt that working efficiently and streamlining tasks were absolute necessities. However, necessary tasks, such as greasing driveline components, take much longer with shields in place. Farmers stated they often have to remove the shields to facilitate maintenance. As described by one farmer, *If you have to take it off to grease it, sometimes it doesn t get replaced. It s easier to just leave it off than put it back on because you know you re going to have to grease it again in a couple of days, so why bother putting it back on.* In addition to repairs and maintenance, farmers said they are typically hooking and unhooking machinery throughout the day. The shield can be cumbersome, add weight, and make it harder to hook up machinery. As one farmer said, *Some of them are pretty hard to attach to the tractor. It s easier without them [shields]. Take that damn thing off of there because I can t hook this thing up.*

Shields Have Poor Durability. Farmers also spoke about the frustrating lack of shield durability and felt that replacing shielding was an exercise in futility since the shield inevitably breaks. According to the farmers, the cost of PTO shielding can range from $50 to $750 per shield. This cost is multiplied by the fact that farmers often own multiple pieces of PTO equipment that require shielding (sometimes as many as 25 to 30 machines or more). Farmers described the shields jamming, buckling, freezing, and eventually falling apart. One farmer stated, □*If you go over a knob, it□ll pull apart. I□ve seen them get stuck, and then□it goes □kluck□ and□you can□t fix it so they tear it off.*□

In discussions regarding shield durability, farmers indicated that the life of the shield is largely related to the type of equipment to which the driveline is attached. Heavily used equipment, such as manure spreaders or self-unloading wagons, were even more likely to break than other PTO-driven equipment. The farmer describing this challenge stated, □*I□think the manure spreader from my knowledge is one of the worst to keep a shield on.*□ From the farmers□ point of view, if the shield interferes with work and is likely to break, why make the effort to replace it? As one farmer summed up his frustration with replacing a shield that cost him $750, □*The new one I put on Friday is damaged!*□

Replacing Missing or Broken Shields is Difficult. When asked about the process of replacing shields, farmers often discussed the difficulty of finding the correct replacement parts. As pointed out by the farmers, manufacturers design shields that meet the requirements of the specific types of equipment that they manufacture. Since new equipment with new designs is offered regularly, the shield designs often change as well. Thus, shielding older equipment offers a particular challenge, as equipment dealers do not often keep older parts in stock. This is a chronic problem for small farmers, who typically can only afford older, cheaper equipment. Finding the right parts for older equipment becomes a very time-consuming process, often requiring the farmer to call used parts suppliers, junkyards, or aftermarket websites.

The frustrating experience of ordering a replacement shield was aptly described by one farmer, who stated, □*There□s no universal pieces. I don□t know how many pieces of equipment we have with a PTO shaft on it, but a lot, and every single one of them is different, and we have old John Deere tractors and even with John Deere every single one of them is different. So it□s not an issue of one manufacturer or another, it□s just every one of their shafts are different. You cannot wait. I can□t keep one in stock because there are too many of them, and they□re expensive. We have a lot of covers that are damaged. I would say all of them are damaged.*□

Although farmers said that replacing missing or damaged shields is a particularly complicated enterprise, even new equipment presents shielding problems. Although new equipment is sold with shields in place, farmers indicated that the new shields are prone to breakage and replacement issues. According to the farmers, dealerships are often far away and are not able to stock the many varieties of PTO shields. This fact was illustrated by the farmer who said, □*[T]rying to take [them] to an equipment dealer is hard because they are all so far away, and it□s very expensive for them to come get [them].*□ As a result, tracking down the correct parts for each different PTO driveline requires more time and effort than farmers felt they could reasonably dedicate to the process.

Repeatedly Surviving Risk Exposure Normalizes Risk. As farmers described, risk appears to be inherent within the farm environment. Every day, farmers engage in dangerous tasks and are exposed to risk. Eventually, risky behaviors become an accepted, or □normal,□ part of the job. As one farmer said, □*It□s a hazardous occupation, so there□s going to be a lot of that stuff that happens.*□ The farmers were clear that something could go wrong at any given time. As one farmer described the predicament, □*We do dangerous stuff around the farm all the time. A lot of what we do is dangerous to a certain extent. Somebody□s got to do it. If the elevator is jammed up, somebody□s got to go up there and un-jam it. We do dangerous things.*□ When negative outcomes are consistently averted in these risk encounters, farmers indicated that eventually they become habituated to the risk. A farmer described this common sentiment, □*You do get complacent when you do the same thing every day. You didn□t get hurt, you do it again.*□ However, while they acknowledged taking risks as part of their routine, they were also well aware that normalizing risk could allow them to slide into complacency or laxness. Farmers described trying to balance the need to be sufficiently inured to risk to get the job done while still being attentive enough to avoid injury. In the best of circumstances, they feel they have the ability to do their work safely, but in many instances, they feel that risk is the only viable option.

Theme 3: Considerations for Altering the PTO Shielding Decision Environment

Favored Alternative Safety Strategies

As indicated by the previously described themes, the farmers□ history of negative experiences with shield designs and their consistent lack of time and money create a decision environment in which risk is often viewed as a more efficient modality. Anything that interferes with getting the job done, or that costs more time and money, has definite impacts on the livelihood of the farmer. These factors push the farmers to feel that the better choice is to remove shielding and use common sense, best practices, and experience as a protective approach.

In addition to replacing missing or damaged driveline shields, several other best practices are included in the safety literature. These include not wearing loose clothing when working around drivelines, not stepping over the driveline, and securing long hair. Farmers sometimes follow these practices instead of maintaining the shielding, viewing them as a prudent compromise between efficiency and safety. For example, when discussing their personal safety rules, farmers listed the following: □*I don□t get off the tractor with the power take-off running,*□ □*I don□t wear loose clothing,*□ □*I try to be careful,*□ and □*I□don□t step over a running PTO shaft.*□ These best practices allow the farmer to feel good about working safely and do not require considerable investments of time or money.

However, the farmers were also well aware that these good habits or best practices are an incomplete solution. They acknowledged that they could slip or make a mistake when hurrying. They also admitted that even these precautions are skipped if they are especially tired, hurried, or if a task seems to warrant something more dangerous, like

stepping over a running PTO driveline. They described and acknowledged that accidents could happen in a split second.

Safety Motivators

In addition to discussing various barriers to PTO driveline shielding, the interviews also revealed various beliefs or environmental influences that could reinforce or promote decisions to replace missing or broken shielding. These motivators included a culture of safety on the farm, close calls with PTO injury and exposure to stories about PTO injuries, and a desire to protect others from injury.

Safety Culture. The culture of safety on each farm appeared to influence each farmer□s approach to PTO shielding. Farmers who described using more safety practices and shielding also indicated that they had grown up in an environment that was very strict about working safely. They described family members, school, or 4-H clubs as being particularly influential. As one farmer described, □*My father and grandfather taught us. I□just don□t take any chances with it. I will not get off the tractor if the power take-off is running. That□s just the way we were brought up around it. I will not do it.*□ □*I went through 4-H safety trainings. This machinery is unforgiving, and if something happens there are consequences.*□ □*It is simply not worth the risk for what little bit you□re going to gain in time by not repairing it. If me or my brother were to get hurt like that, what do you do then?*□ As farmers commented on other farms, one stated, □*I don□t see generational differences, I see quality differences. The lower-quality farms tend to be the ones where they□re not focused on all the details, and those are the ones that there□s more issues safety-wise.*□

Personal Stories. Close calls, personal injury, or stories of others being injured or killed were clear motivators for improved shielding and safety practices. Farmers described improving their safety after hearing about the injury or death of another farmer. However, most participants elaborated that such incidents had a largely short-term impact that eroded over time.

Protection of Others. As farmers described their own personal rationalizations for taking risks, they also stated that risk exposures for spouses, children, or employees were not acceptable. A common sentiment was, □*I think in general that more people are concerned about other people on the farm equipment.*□ The desire to protect young children, in particular, was often cited as a motivator to increase shielding on equipment. As one farmer described, □*My son [is] getting more involved in farming. That□s really the main reason, because I□d be afraid that I didn□t educate him enough and I want the safety features there to protect him.*□ In describing unshielded equipment on their farms, the farmers often followed this with the caveat, □*I□m the only one who uses that equipment.*□

The Safety/Risk Decision-Making Process

In summary, interviews with farmers regarding the decision to replace missing or damaged driveline shielding reveal that time, money, past experiences, work pressures, and dangers to others all play a prominent role. However, when taken together, many of

these factors boil down to the following simple cost-benefit consideration: □What is the price I pay for working safely versus what is the price I pay for taking risks?□

In light of these realities, efforts to educate farmers on the risks of working around unshielded PTOs are not likely to be effective, given the current safety/risk decision environment. To create effective behavior change and encourage better shielding practices, efforts need to focus on altering the decision environment. To be specific, safety interventions should seek to alter the decision environment to favor the replacement of missing or damaged PTO shielding instead of taking risks.

To do this, several key factors must be addressed. These include: making the replacement of shields less expensive, making replacement shields simpler to order and install, improving shielding designs, and focusing promotions on the reality of hazards while highlighting the benefits that count.

Strengths and Limitations

The results of this study may be somewhat limited by the emphasis on small diary and livestock farms in a single state, where older equipment is typically used. Therefore, it is possible that PTO shielding considerations are different for populations not represented in this study. Due to time and funding constraints, this study was unable to delve further into gender differences in risk perception. This likely warrants further exploration and could limit the applicability of these results to women□s views on shielding, as only two female principal operators were interviewed. Differences in gender perspectives regarding PTO risks was not a focus of our questions, but during the interviews, the female participants spoke of avoiding work with PTOs or of encouraging their male partners to improve shielding on the farm.

Discussion

PTO injuries represent a significant hardship, both personal and economic, to the U.S. agricultural community. In New York State, data collected by Sorensen et al. (unpublished data, 2013.) indicate that up to 43% of PTO drivelines have missing or damaged shielding. Traditional educational approaches designed to make farmers more aware of entanglement risks have not significantly altered behavior (Hartling et al., 2004; Mazur et al., 2005; Reed et al., 2001). Furthermore, alternative explanations for the low prevalence of PTO shielding are sparse in the literature. This study attempts to address this knowledge gap by identifying how influential decision-making factors work together to favor or not favor the replacement of missing or damaged PTO shielding.

Our findings regarding the impact of workload, stress, and finances on safety decisions are mirrored by other studies on farm safety/risk practices. Pratt et al. (1992) demonstrated a strong association between stress, workload, and occupational injury. In their study, farm workers working more than 60 hours per week and tilling more than 30□acres were almost three times as likely to be injured as those who were working less. Kidd et al. (1996) recommended reducing the number of roles performed exclusively by one farmer as an important injury prevention strategy. They found that decisions to adopt

safety measures were based largely on their impact on productivity rather than the personal health or well-being of the farmer. In addition to these studies, Carpenter et al. (2002) identified cost as an influential factor in the decision to wear or not wear personal protective equipment, such as hard hats, safety glasses, masks, etc. Similar associations were found in a study of ROPS prevalence, in which smaller farms with low sales, small acreage, and no hired labor were much less likely to install ROPS than larger, more profitable farms with hired labor (Myers, 2010). Hagel et al. (2013) identified associations between higher levels of □economic worry□ and the absence of safety shields on grain augers.

In our study, farmers also described bad experiences with PTO shields, centering around difficulty with maintenance, the fragility of shield components (especially during the winter on heavily used equipment), the lack of universal designs, and the difficulty of routine maintenance with the shield in place. Similar findings were noted by Freeman et al. (2003), who found that half of survey respondents reported removing intake shields to service or clean an auger within a two-year period. Issues with PTO designs were also noted in a report issued by the Australian government (Athanasiov et al., 2006), which stated: □until a PTO shaft is designed in such a way that it will not operate unless the shield is in place□PTO shields will continue to be removed and not replaced.□

The normalization of risk described by the farmers in our study has also been identified in other studies of farmers□ risk and safety experiences. A qualitative study of farmers□ safety attitudes in Canada revealed similar risk habituation: □without personally experiencing ill effects of particular exposures, farmers tended to minimize their risk□ (Green, 1999). That study also indicated that farmers who had been previously injured tended to adopt safer farming practices. The farmers in that study also adopted rules and practices, other than shielding PTOs, to mitigate risk. Those findings are echoed in our study as well as a study by Freeman et al. (2003), which found that farmers are willing to accept unsafe practices, such as leaving a PTO shaft unshielded, as long as they take precautions while doing so. Importantly, this study and previous studies (Green, 1999; Kidd et al., 1996; Sorensen et al., 2008) confirm that a farmer□s confidence in avoiding personal injury did not extend to others, including family members and other workers. Consequently, some interviewees stated that they □were the only ones□ who used unshielded equipment in an effort to protect wives, children, and hired laborers from this hazard.

Conclusions

This study provides an in-depth understanding of the decision-making process related to replacing missing or broken PTO driveline shielding based on interviews conducted with a sample of small dairy and livestock farmers in central New York State. The responses in this study show that while farmers value safety, the cost of safety must compete with the harsh realities of economic survival. To encourage the replacement of substandard driveline shielding, new shields need to be developed that cost farmers less time and money. In addition, future interventions must convince farmers that previous issues with shield designs have been successfully resolved. Researchers at NYCAMH/NEC are currently working on incorporating this information into the development of a PTO

shielding program that addresses the barriers and motivators to shielding identified by farmers.

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